AP431/AP431A

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.
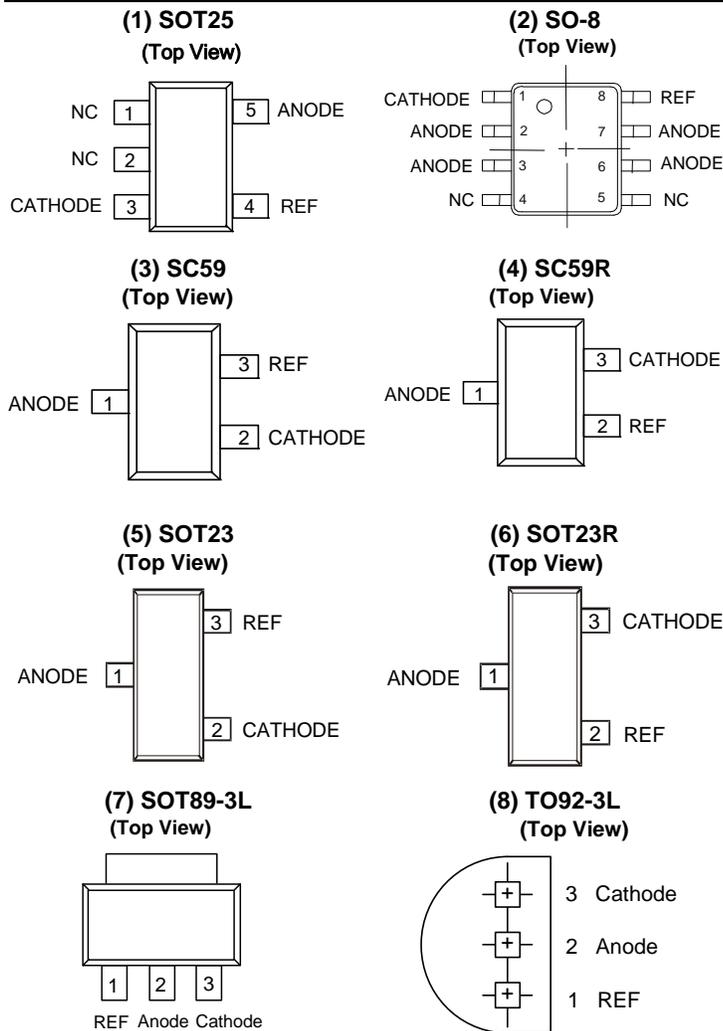
The precise (+/-) 1% Reference voltage tolerance of the AP431/AP431A make it possible in many applications to avoid the use of a variable resistor, consequently saving cost and eliminating drift and reliability problems associated with it.
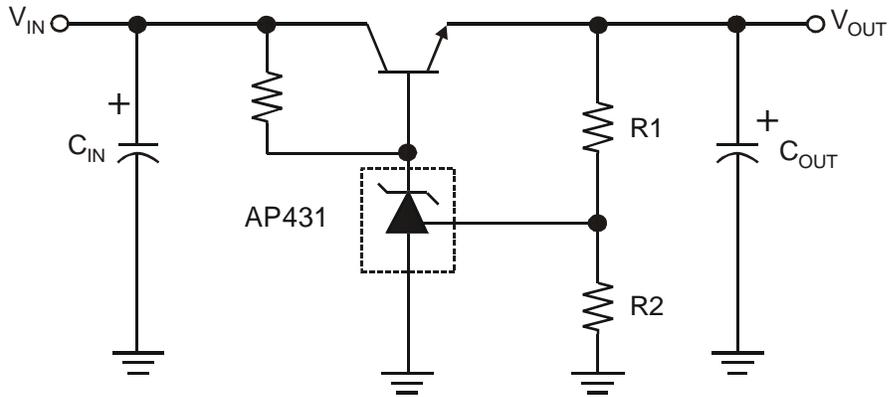
Features

- 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: 30 ppm/°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, SOT89-3L and TO92-3L
- SOT23, SOT23R, SOT25, SC59, SC59R, SO-8, SOT89-3L, TO92-3L: Available in "Green" Molding Compound (No Br, Sb)
- Lead Free Finish/ RoHS Compliant (Note 1)

Notes: 1. EU Directive 2002/95/EC (RoHS). All applicable RoHS exemptions applied. Please visit our website at http://www.diodes.com/products/lead_free.html.
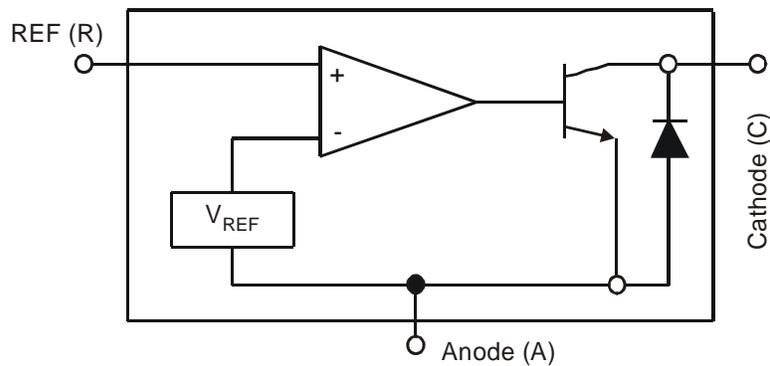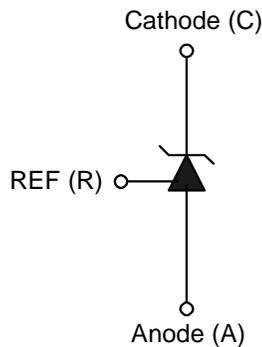
Pin Assignments

(1) SOT25
(Top View)

(2) SO-8
(Top View)

(3) SC59
(Top View)

(4) SC59R
(Top View)

(5) SOT23
(Top View)

(6) SOT23R
(Top View)

(7) SOT89-3L
(Top View)

REF   Anode   Cathode

(8) TO92-3L
(Top View)

3 Cathode

2 Anode

1 REF

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Typical Application Circuit

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

Precision Regulator

Functional Block Diagram

Symbol

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Absolute Maximum Ratings

Symbol	Parameter		Rating	Unit
Vcv	Cathode Voltage		+36	V
I_{CC}	Continuous Cathode Current		-10 to +250	mA
I_{REF}	Reference Input Current		10	mA
T_{OP}	Operating Temperature		-20 to +85	°C
T_{ST}	Storage Temperature		-65 to +150	°C
P_D	Power Dissipation (Notes 2, 3)	SOT23(R)	400	mW
		SOT25	550	mW
		SC59(R)	400	mW
		SO-8	600	mW
		SOT89-3L	800	mW
		TO92-3L	780	mW

Notes: 2. T_J, max =150°C.
3. Ratings apply to ambient temperature at 25°C.

Electrical Characteristics (T_A = 25°C, Vdd = 3V; unless otherwise specified)

Symbol	Parameter	Test Conditions		Min	Typ.	Max	Unit
V_{REF}	Reference voltage	$V_{KA} = V_{REF}$, I_{KA} = 10mA (Fig.1)	AP431 AP431A	2.470 2.482	2.495	2.520 2.507	V
V_{REF}	Deviation of Reference input voltage over temperature (Note 4)	$V_{KA} = V_{REF}$, I_{KA} = 10mA, Ta = Full range (Fig.1)		—	8.0	20	mV
$\dfrac{\Delta V_{REF}}{\Delta V_{KA}}$	Ratio of the change in Reference voltage to the change in Cathode voltage	I_{KA} = 10mA (Fig. 2)	$V_{KA} = V_{REF}$ to10V	—	-1.4	-2.0	mV/V
			V_{KA} = 10V to 36V	—	-1	-2	mV/V
I_{REF}	Reference input current	R1 = 10KΩ,R2 = ∞ I_{KA}= 10mA (Fig. 2)		—	1.4	3.5	µA
αI_{REF}	Deviation of Reference input current over temperature	R1 = 10KΩ,R2 = ∞ I_{KA} = 10mA Ta = Full range (Fig. 2)		—	0.4	1.2	µA
$I_{KA(MIN)}$	Minimum Cathode current for regulation	$V_{KA} = V_{REF}$ (Fig.1)		—	0.19	0.5	mA
$I_{KA(OFF)}$	Off-state current	V_{KA} = 36V, V_{REF} = 0V (Fig. 3)		—	0.1	1.0	µA
$|Z_{KA}|$	Dynamic output impedance (Note 5)	$V_{KA} = V_{REF}$ $V_{KA} = V_{REF}$ ΔI_{KA} = 0.1mA ~ 15mA Frequency ≤ 1KHz (Fig.1)		—	0.2	0.5	Ω

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Electrical Characteristics (T_A = 25°C, V_{dd} = 3V; unless otherwise specified)
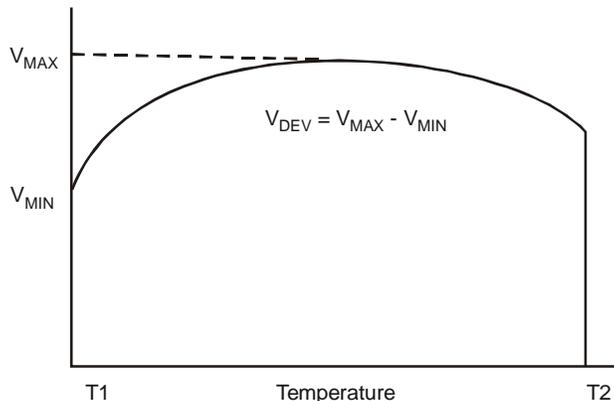
Notes: 4. Deviation of reference input voltage, V_{DEV}, is defined as the maximum variation of the reference over the full temperature range.

The average temperature coefficient of the reference input voltage αV_{REF} is defined as:

$$\left|\alpha V_{REF}\right| = \frac{(\frac{V_{DEV}}{V_{REF}(25°C)}) \cdot 10^6}{T_2 - T_1} \quad\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (ppm/_{°C})$$

Where:
T2 – T1 = full temperature change.
αV_{REF} can be positive or negative depending on whether the slope is positive or negative.

Notes: 5. The dynamic output impedance, R_Z, is defined as:

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

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

$$\left|Z_{KA}{}'\right| = \frac{\Delta v}{\Delta i} \approx \left|Z_{KA}\right| \quad (1 + \frac{R1}{R2})$$

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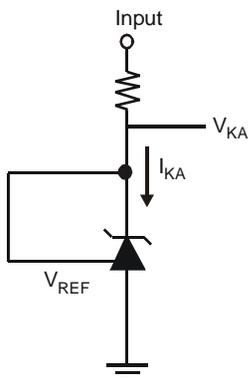
Fig 1. Test Circuit for $V_{KA} = V_{REF}$
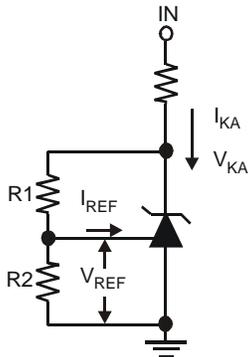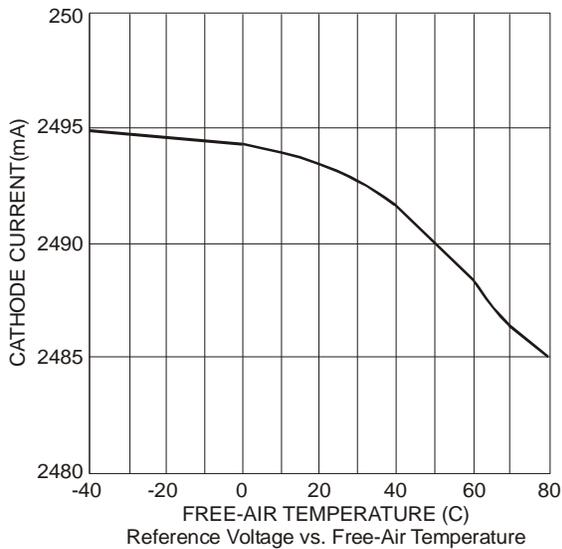

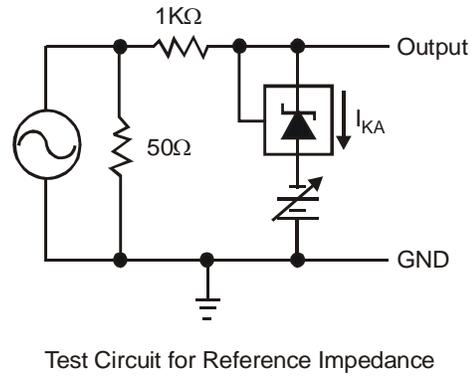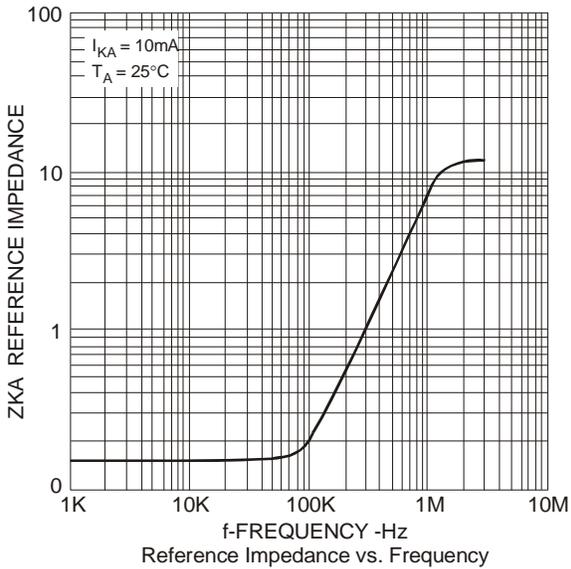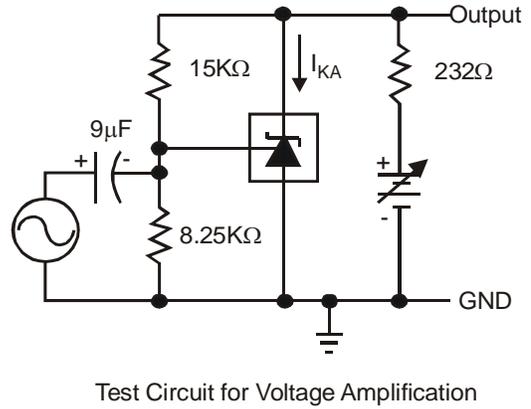Note: $V_{KA} = V_{REF} (1 + R1/R2) + I_{REF} \times R1$
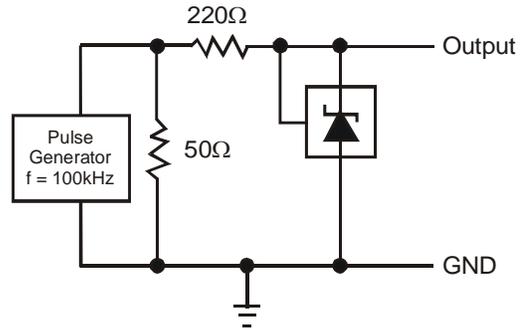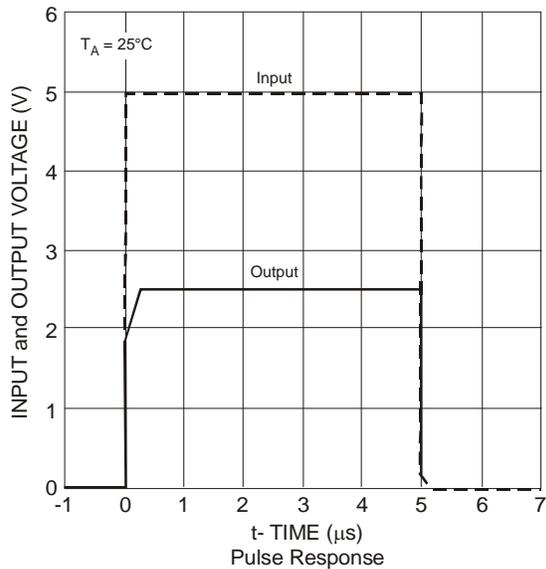
Fig 2. Test Circuit for $V_{KA} > V_{REF}$
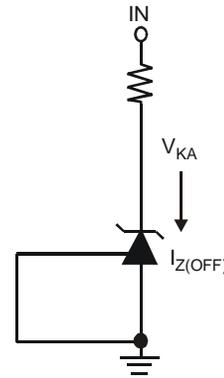
Fig 3. Test Circuit for Off-State Current

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Typical Performance Characteristics

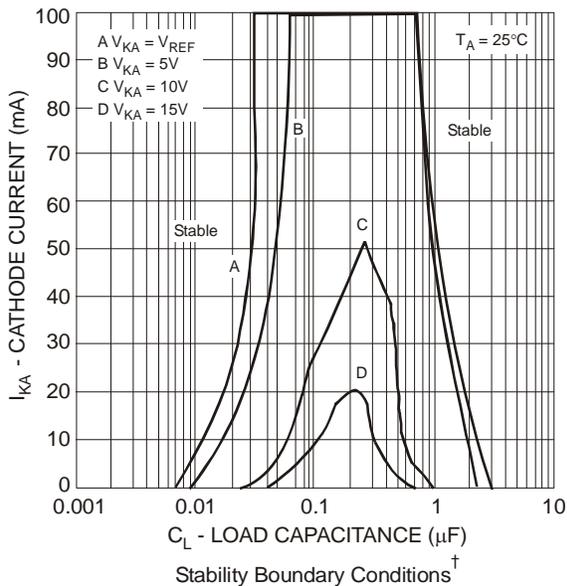Cathode Current vs. Cathode Voltage

Cathode Current (μA) vs. Cathode Voltage

Reference Voltage vs. Free-Air Temperature

Reverence Input Current vs. Free Temperature

Change in Reference Voltage vs. Cathode Voltage

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Typical Performance Characteristics (cont.)

Small-Signal Voltage Amplification vs. Frequency

Test Circuit for Voltage Amplification

Reference Impedance vs. Frequency

Test Circuit for Reference Impedance

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Typical Performance Characteristics (cont.)

Pulse Response

Test Circuit for Pulse Response


Stability Boundary Conditions†

Test Circuit for Curve A

†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_{KA} and I_{KA} conditions with $C_L = 0$. V_{BATT} and C_L were then adjusted to determine the ranges of stability.
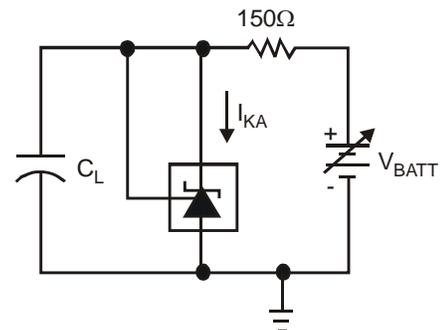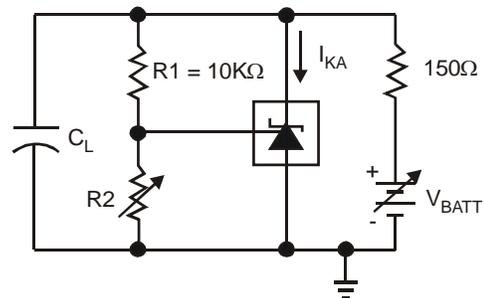
Test Circuit for Curve B, C, and D

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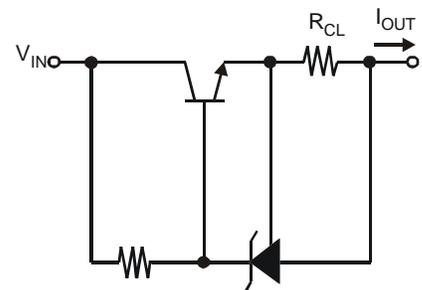
Application Examples
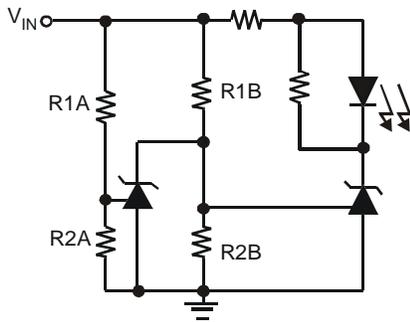
LED on when Low Limit < V_{IN} < High Limit
Low Limit $\approx V_{REF}$ (1 + R1B/R2B)
High Limit $\approx V_{REF}$ (1 + R1A/R2A)
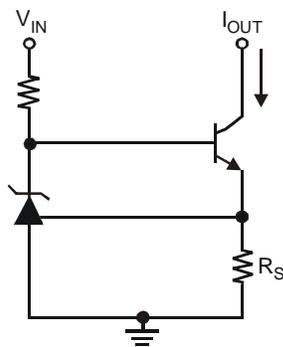
Fig. 4 Voltage Monitor
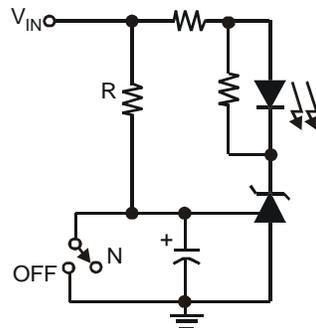
$$Delay = RC \times \ln\left(\frac{V_{IN}}{V_{IN} - V_{REF}}\right)$$
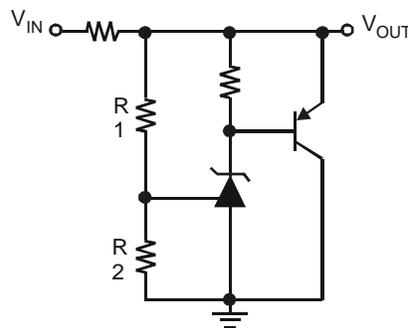
Fig 5. Delay Timer

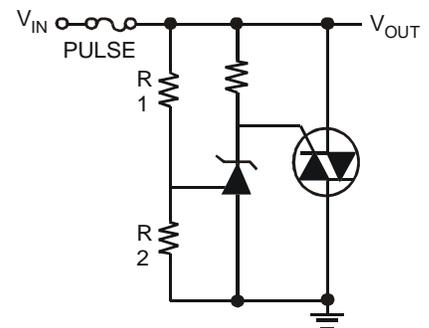$$I_{OUT} = V_{REF} / R_{CL}$$

Fig 6. Current Limiter or Current Source
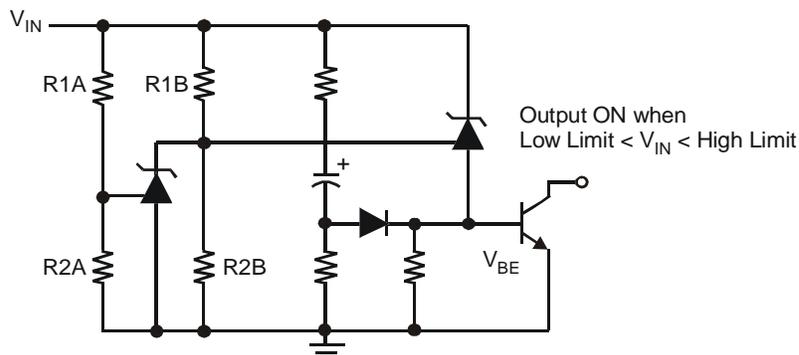
$$I_{OUT} = V_{REF} / R_S$$

Fig. 7 Constant-Current Sink

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

Fig. 8 Higher-Current Shunt Regulator

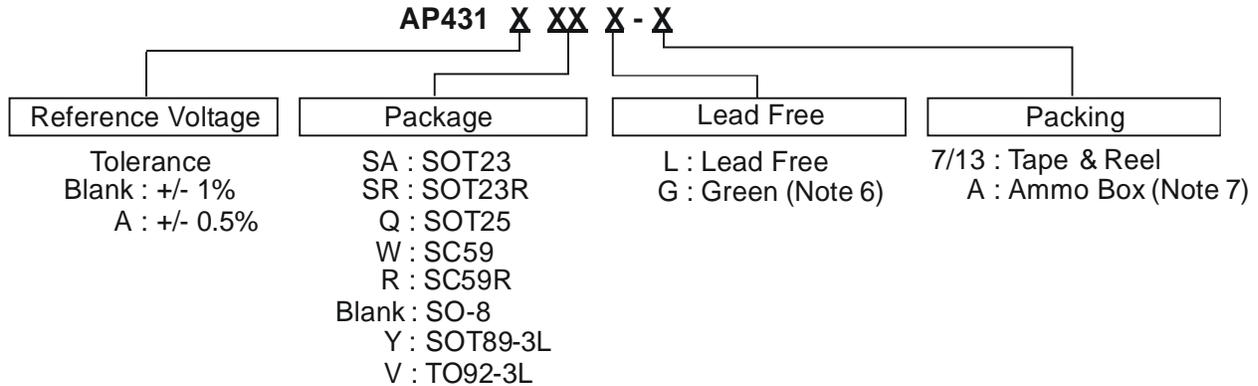$$Limit \approx (1 + R1/R2) \times V_{REF}$$

Fig. 9 Crow Bar

Output ON when
Low Limit < V_{IN} < High Limit

Low Limit $\approx V_{REF}$ (1 + R1B/R2B) + V_{BE}
High Limit $\approx V_{REF}$ (1 + R1A/R2A)

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

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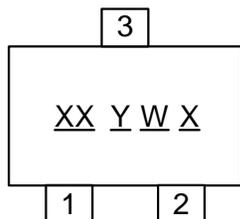Document number: DS31002 Rev. 17 - 2

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Ordering Information

AP431 X XX X - X

Reference Voltage	Package	Lead Free	Packing
Tolerance Blank : +/- 1% A : +/- 0.5%	SA : SOT23 SR : SOT23R Q : SOT25 W : SC59 R : SC59R Blank : SO-8 Y : SOT89-3L V : TO92-3L	L : Lead Free G : Green (Note 6)	7/13 : Tape & Reel A : Ammo Box (Note 7)

	Device (Note 8)	Package Code	Packaging (Note 9)	7"/13 Tape and Reel		Ammo Box	
				Quantity	Part Number Suffix	Quantity	Part Number Suffix
Pb	AP431(A)SAG-7	SA	SOT23	3000/Tape & Reel	-7	NA	NA
Pb	AP431(A)SRG-7	SR	SOT23R	3000/Tape & Reel	-7	NA	NA
Pb	AP431(A)QL-7	Q	SOT25	3000/Tape & Reel	-7	NA	NA
Pb	AP431(A)QG-7	Q	SOT25	3000/Tape & Reel	-7	NA	NA
Pb	AP431(A)WL-7	W	SC59	3000/Tape & Reel	-7	NA	NA
Pb	AP431(A)WG-7	W	SC59	3000/Tape & Reel	-7	NA	NA
Pb	AP431(A)RL-7	R	SC59R	3000/Tape & Reel	-7	NA	NA
Pb	AP431(A)RG-7	R	SC59R	3000/Tape & Reel	-7	NA	NA
Pb	AP431(A)G-13		SO-8	2500/Tape & Reel	-13	NA	NA
Pb	AP431(A)YL-13	Y	SOT89-3L	2500/Tape & Reel	-13	NA	NA
Pb	AP431(A)YG-13	Y	SOT89-3L	2500/Tape & Reel	-13	NA	NA
Pb	AP431(A)VL-A	V	TO92-3L	NA	NA	2000/Box	NA
Pb	AP431(A)VG-A	V	TO92-3L	NA	NA	2000/Box	NA

Notes: 6. SO-8, SOT23 and SOT23R are available in "Green" products only.
       7. Ammo Box is for TO92-3L Spread Lead.
       8. Suffix "A" denotes AP431A device.
       9. Pad layout as shown on Diodes Inc. suggested pad layout document AP02001, which can be found on our website at
          http://www.diodes.com/datasheets/ap02001.pdf.

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Marking Information

(1) SC59 and SC59R
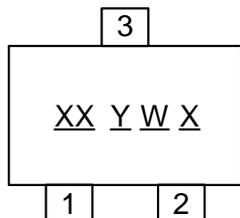
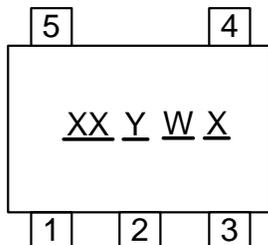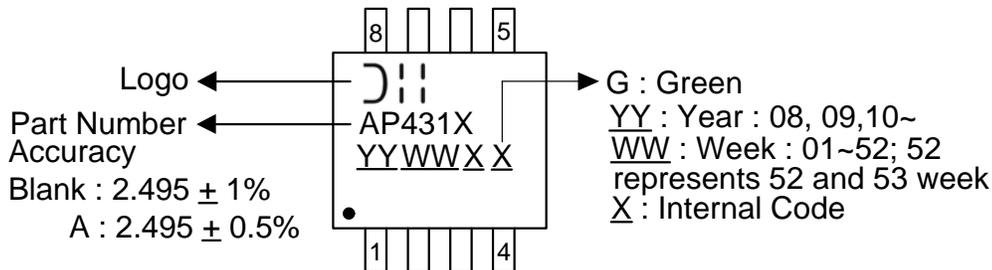**(Top View)**

<u>XX</u> : Identification code
<u>Y</u> : Year 0~9
<u>W</u> : Week : A~Z : 1~26 week;
    a~z : 27~52 week; z represents
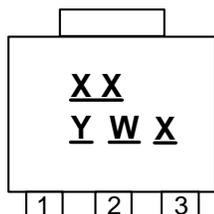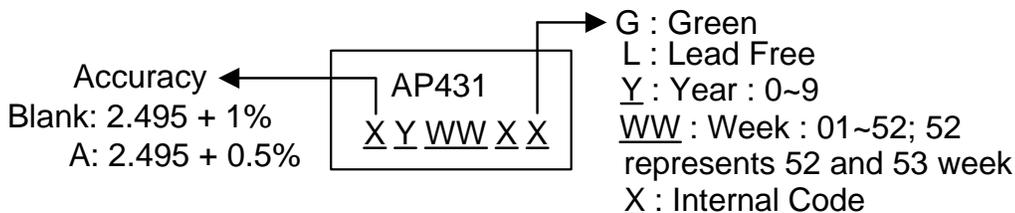   52 and 53 week
<u>X</u> : A~Z : Green
    a~z : Lead Free

Pin layout:
```
        [3]
    XX Y W X
   [1]      [2]
```

(2) SOT23 and SOT23R

(Top View)

<u>XX</u> : Identification code
<u>Y</u> : Year 0~9
<u>W</u> : Week : A~Z : 1~26 week;
    a~z : 27~52 week; z represents
    52 and 53 week
<u>X</u> : A~Z : Green

Pin layout:
```
        [3]
    XX Y W X
   [1]      [2]
```

(3) SOT25

(Top View)

<u>XX</u> : Identification code
<u>Y</u> : Year 0~9
<u>W</u> : Week : A~Z : 1~26 week;
    a~z : 27~52 week; z represents
    52 and 53 week
<u>X</u> : A~Z : Green
    a~z : Lead Free

Pin layout:
```
   [5]        [4]
    XX Y W X
   [1]  [2]  [3]
```

(4) SO-8

(Top View)

Logo ←

Part Number ←
Accuracy
Blank : 2.495 ± 1%
   A : 2.495 ± 0.5%

Marking:
```
   Ɔ¦¦
   AP431X
   YYWWX X
```

→ G : Green
<u>YY</u> : Year : 08, 09,10~
<u>WW</u> : Week : 01~52; 52
represents 52 and 53 week
<u>X</u> : Internal Code

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Marking Information (cont.)

(5) SOT89-3L

(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

(6) TO92-3L

(Top View)

Accuracy
Blank: 2.495 + 1%
A: 2.495 + 0.5%

AP431
X Y WW X X

G : Green
L : Lead Free
Y : Year : 0~9
WW : Week : 01~52; 52
 represents 52 and 53 week
X : Internal Code

Identification Code Table

Device	Package (Note 10)	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	SOT89-3L	A4	YM
AP431AY	SOT89-3L	A5	YM

Notes: 10. For Packaging Details, go to our website at http://www.diodes.com/datasheets/ap02007.pdf.

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Package Outline Dimensions (All Dimensions in mm)

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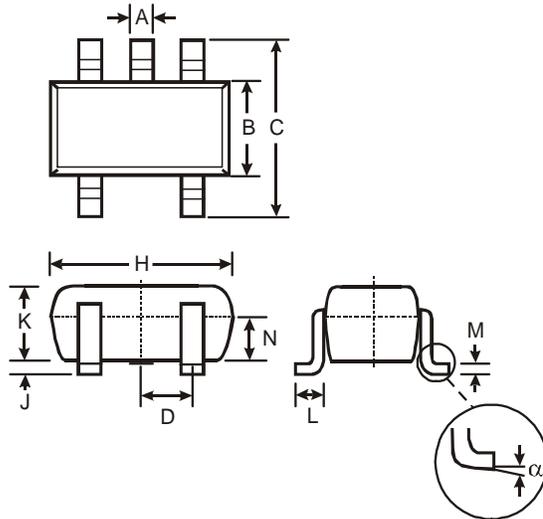
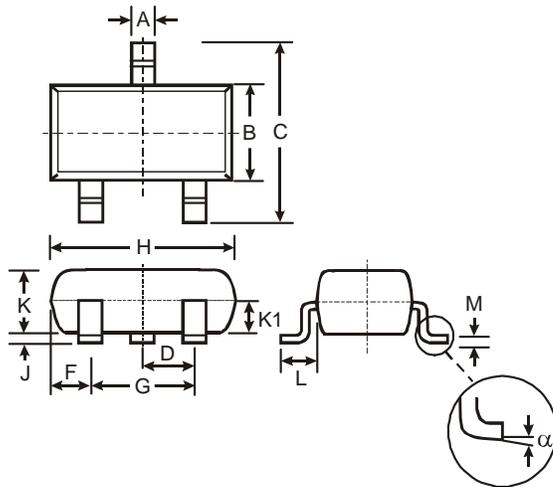| SOT25			
Dim	Min	Max	Typ
A	0.35	0.50	0.38
B	1.50	1.70	1.60
C	2.70	3.00	2.80
D	—	—	0.95
H	2.90	3.10	3.00
J	0.013	0.10	0.05
K	1.00	1.30	1.10
L	0.35	0.55	0.40
M	0.10	0.20	0.15
N	0.70	0.80	0.75
α	0°	8°	—
All Dimensions in mm			

(2) Package Type: SC59 and SC59R
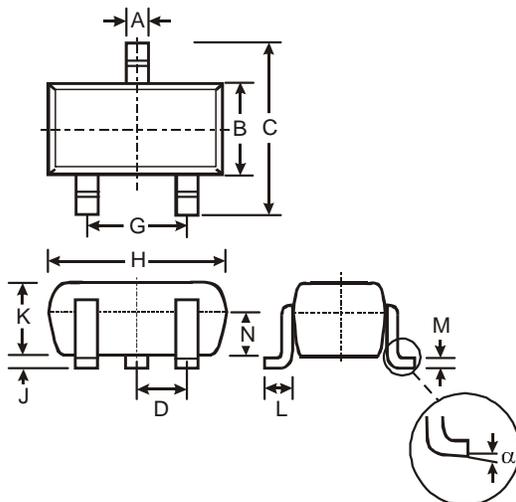
SC59			
Dim	Min	Max	Typ
A	0.35	0.50	0.38
B	1.50	1.70	1.60
C	2.70	3.00	2.80
D	-	-	0.95
G	-	-	1.90
H	2.90	3.10	3.00
J	0.013	0.10	0.05
K	1.00	1.30	1.10
L	0.35	0.55	0.40
M	0.10	0.20	0.15
N	0.70	0.80	0.75
α	0°	8°	-
All Dimensions in mm			

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Package Outline Dimensions (cont.)

(3) Package Types: 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
α	0°	8°	-
All Dimensions in mm			

(4) Package Type: SO-8
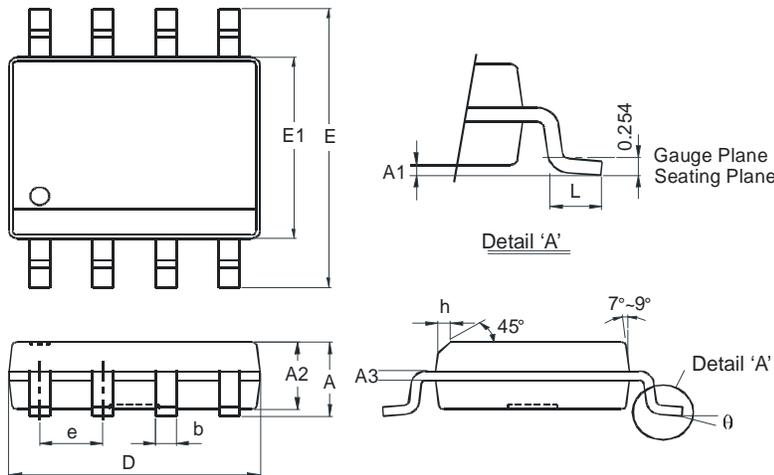
SO-8		
Dim	Min	Max
A	-	1.75
A1	0.10	0.20
A2	1.30	1.50
A3	0.15	0.25
b	0.3	0.5
D	4.85	4.95
E	5.90	6.10
E1	3.85	3.95
e	1.27 Typ	
h	-	0.35
L	0.62	0.82
θ	0°	8°
All Dimensions in mm		

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Package Outline Dimensions (cont.)

(5) Package Type: SOT89-3L
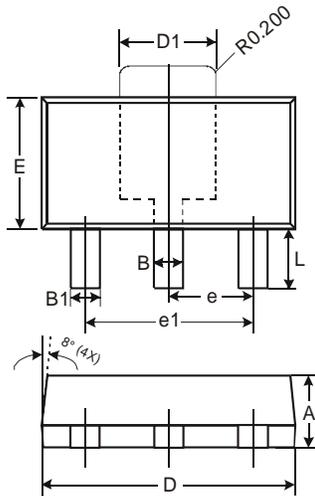
SOT89		
Dim	**Min**	**Max**
A	1.40	1.60
B	0.44	0.62
B1	0.35	0.54
C	0.35	0.43
D	4.40	4.60
D1	1.52	1.83
E	2.29	2.60
e	1.50 Typ	
e1	3.00 Typ	
H	3.94	4.25
L	0.89	1.20
All Dimensions in mm		

(6) Package Type: TO92-3L

LOOSE PRODUCT

TAPED PRODUCT
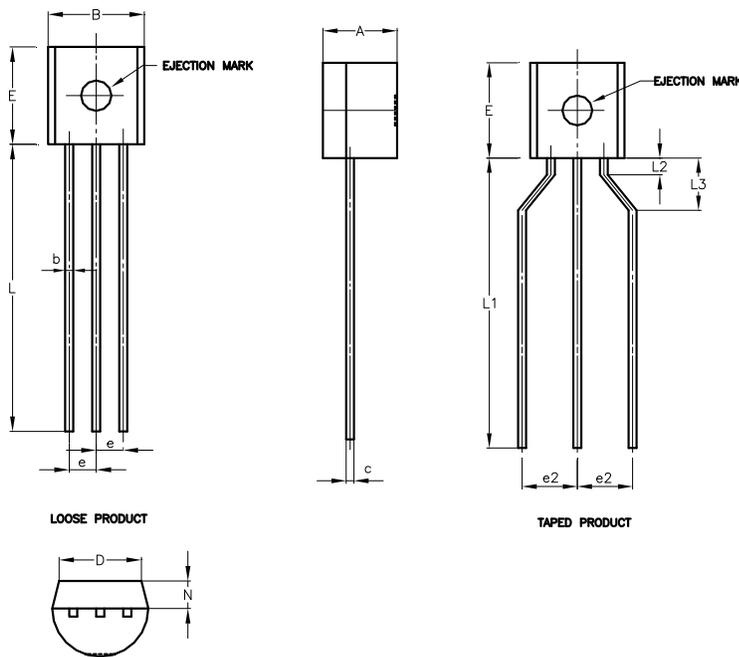
TO92 -3L			
Dim	**Min**	**Max**	**Typ**
A	3.45	3.66	–
B	4.27	4.78	
b	–	–	0.38
c	–	–	0.38
D	–	–	3.87
E	4.32	4.83	–
e	–	–	1.27
e2	2.40	2.90	–
L	12.98	15.00	–
L1	12.80	15.00	–
L2	0.80	–	–
L3	2.00	3.00	–
N	1.22	1.37	–
All Dimensions in mm			

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Package Outline Dimensions (cont.)

TO92-3L for Ammo pack

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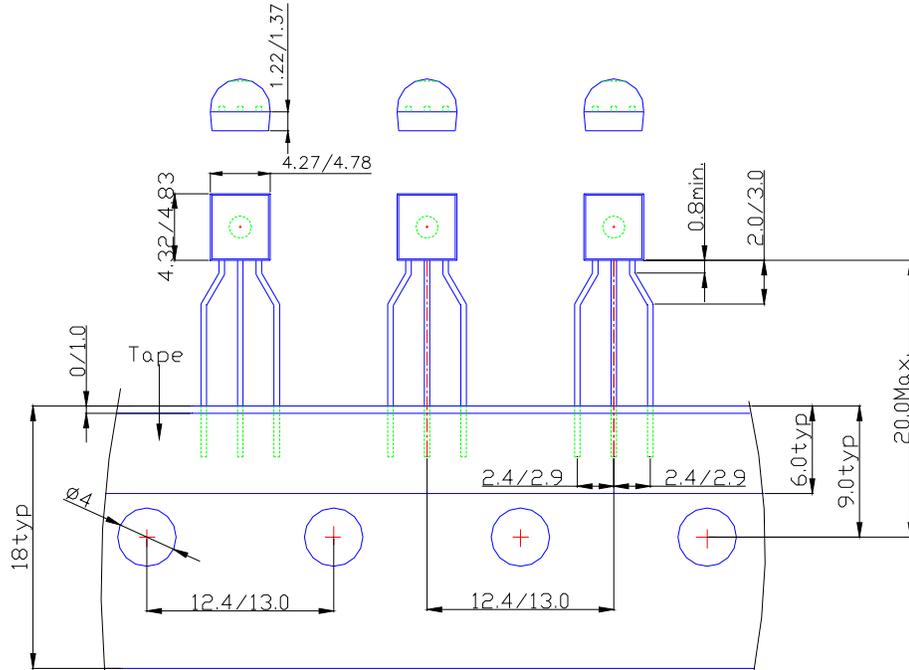
Suggested Pad Layout

(1) SOT25
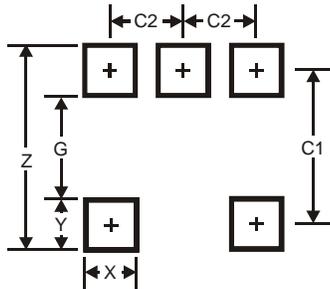
Dimensions	Value (in mm)
Z	3.20
G	1.60
X	0.55
Y	0.80
C1	2.40
C2	0.95

(2) SC59 and SC59R
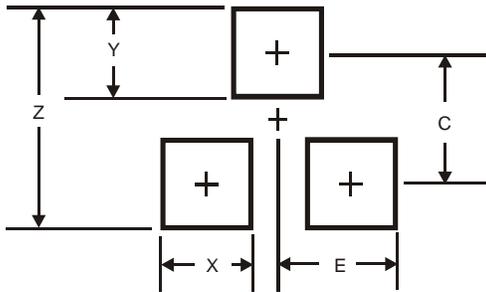
Dimensions	Value (in mm)
Z	3.4
X	0.8
Y	1.0
C	2.4
E	1.35

(3) SOT23 and SOT23R
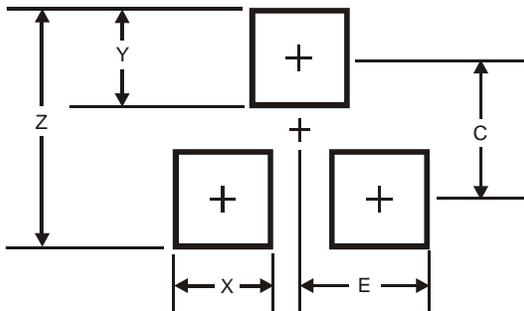
Dimensions	Value (in mm)
Z	2.9
X	0.8
Y	0.9
C	2.0
E	1.35

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Suggested Pad Layout (cont.)

(4) SO-8
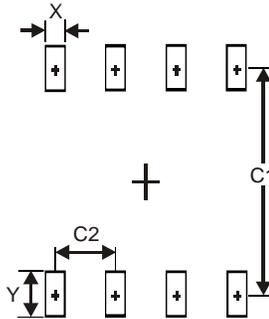
Dimensions	Value (in mm)
X	0.60
Y	1.55
C1	5.4
C2	1.27

(5) SOT89-3L
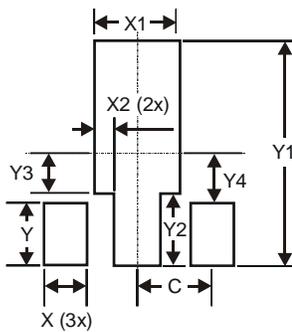
Dimensions	Value (in mm)
X	0.900
X1	1.733
X2	0.416
Y	1.300
Y1	4.600
Y2	1.475
Y3	0.950
Y4	1.125
C	1.500

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