

# APL431



## Adjustable Precision Shunt Regulator

### Features

- Precise Reference Voltage to 2.500V
- Guaranteed 0.5%, 1% or 2% Reference Voltage Tolerance
- Sink Current Capability, 1mA to 100mA
- Quick Turn-on
- Adjustable Output Voltage,  $V_O = V_{ref}$  to 20V
- Low Operational Cathode Current, 250 $\mu$ A Typical
- 0.1 $\Omega$  Typical Output Impedance
- SOT-23, SOT-23-5, SOT-89, SO-8, TO-92 and TO-92S Packages

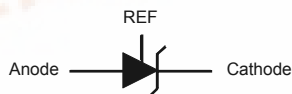
### General Description

The APL431 is a 3-terminal adjustable voltage reference with specified thermal stability over applicable commercial temperature ranges. Output voltage may be set to any value between  $V_{ref}$  (2.5 V) and 20 V with two external resistors (see Figure 2). When used with an photocoupler, the APL431 is an ideal voltage reference in isolated feedback circuits for 2.5V to 12V switching-mode power supplies. This device has a typical output impedance of 0.1 $\Omega$ . Active output circuitry provides a very sharp turn-on characteristic, making the APL431 excellent replacements for zener diodes in many applications, including on-board regulation and adjustable power supplies.

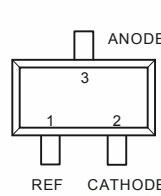
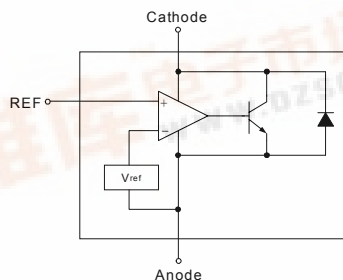
### Applications

- Linear Regulators
- Adjustable Power Supply
- Switching Power Supply

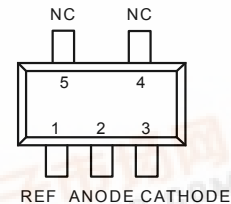
### Symbol



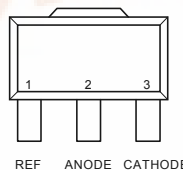
### Functional Diagram



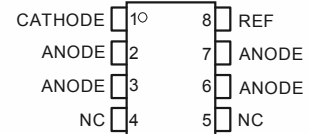
SOT-23 (Top View)



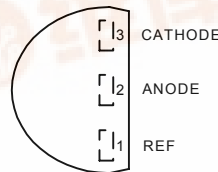
SOT-23-5 (Top View)



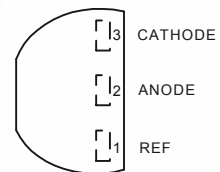
SOT-89 (Top View)



SO-8 (Top View)

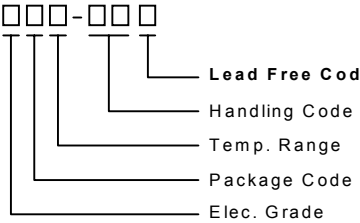


TO-92 (Top View)



TO-92S (Top View)

## Ordering and Marking Information

|   |   |
|---|---|
| <p>APL431    □□□-□□□</p>  <p>Lead Free Code<br/>Handling Code<br/>Temp. Range<br/>Package Code<br/>Elec. Grade</p> | <p>Elec. Grade<br/>A : 0.5% Reference Voltage Tolerance<br/>B : 1% Reference Voltage Tolerance<br/>C : 2% Reference Voltage Tolerance</p> <p>Package Code<br/>A : SOT-23    B : SOT-23-5    D : SOT-89<br/>E : TO-92    I : TO-92S    K : SO-8<br/>Y : Chip Form</p> <p>Temp. Range<br/>C : 0 to 70 °C    I : -40 to 85 °C</p> <p>Handling Code<br/>PB : Plastic Bag    TB : Tape &amp; Box<br/>TR : Tape &amp; Reel</p> <p>Lead Free Code<br/>L : Lead Free Device<br/>Blank : Original Device</p> |
| <p>APL431 A/B :    <span style="border: 1px solid black; padding: 2px;">431</span></p>  | <p>APL431 E/I :    <span style="border: 1px solid black; padding: 2px;">APL<br/>431<br/>XXXXX</span>    XXXXXX - Date Code</p>  |
| <p>APL431 D/K :    <span style="border: 1px solid black; padding: 2px;">APL431<br/>XXXXX</span>    XXXXXX - Date Code</p>   |   |

## Absolute Maximum Ratings

| Symbol        | Parameter   | Rating                 | Unit                   |
|---------------|---|------------------------|------------------------|
| $V_{KA}$      | Cathode voltage   | 20                     | V                      |
| $I_K$         | Continuous cathode current range                        | 100                    | mA                     |
| $I_{REF}$     | Reference current range                                 | 3                      | mA                     |
| $\theta_{JA}$ | Thermal Resistance from Junction to Ambient in Free Air |                        | °C/W                   |
|               | SOT-23  | 416                    |                        |
|               | SOT-23-5  | 357                    |                        |
|               | SOT-89  | 250                    |                        |
|               | TO-92   | 250                    |                        |
|               | SO-8  | 210                    |                        |
| $T_A$         | Ambient temperature range                               | APL431XXC<br>APL431XXI | 0 to 70<br>-40 to 85   |
| $T_j$         | Junction temperature range                              | APL431XXC<br>APL431XXI | 0 to 150<br>-40 to 150 |
| $T_{STG}$     | Storage Temperature Range                               |                        | -65 to 150             |
| $T_{SOL}$     | Lead temperature range, $T_s$ (Soldering, 10sec)        |                        |                        |
|               | Original Device   | 260                    | °C                     |
|               | Lead Free Device  | 300                    |                        |

## Electrical Characteristics (Cont.) $T_A = 25^\circ\text{C}$ ( unless otherwise noted)

| Symbol                           | Parameter                                | Test Conditions   | APL431  |       |          | Unit          |   |
|----------------------------------|--|---|---------|-------|----------|---------------|---|
|                                  |  |   | Min.    | Typ.  | Max.     |               |   |
| $V_{REF}$                        | Reference voltage                        | $V_{KA}=V_{REF}, I_K=10\text{mA}^{*1}$  | APL431A | 2.487 | 2.500    | 2.513         | V |
|                                  |  |   | APL431B | 2.475 | 2.500    | 2.525         |   |
|                                  |  |   | APL431C | 2.450 | 2.500    | 2.550         |   |
| $\Delta V_{REF} / T$             | Reference voltage drift over temp. range | $V_{KA}=V_{REF}, I_K=10\text{mA}$<br>$T_A = 0 \text{ to } 70^\circ\text{C}^{*1}$<br>$T_A = -40 \text{ to } 85^\circ\text{C}^{*1}$ |         |       | 20<br>30 | mV            |   |
| $\Delta V_{REF} / \Delta V_{KA}$ | Voltage ratio (open loop gain)           | $I_K=10\text{mA}, V_{KA}=V_{REF} \text{ to } 10\text{V}^{*2}$   |         | -1.5  | -3       | mV/V          |   |
|                                  |  | $I_K=10\text{mA}, V_{KA}=V_{REF} \text{ to } 20\text{V}^{*2}$   |         | -1.2  | -2.5     |               |   |
| $I_{REF}$                        | Reference current                        | $I_K=10\text{mA}, R_1=10\text{k}\Omega, R_2=\text{open}^{*2}$   |         | 1.0   | 3        | $\mu\text{A}$ |   |
| $\Delta I_{REF}/T$               | Reference current drift                  | $I_K=10\text{mA}, R_1=10\text{k}\Omega, R_2=\text{open}, T_A= -40 \text{ to } 85^\circ\text{C}^{*2}$                              |         | 0.3   | 1        | $\mu\text{A}$ |   |
| $I_{K(\text{min})}$              | Min. cathode current                     | $V_{KA}=V_{REF}^{*1}$   |         | 0.25  | 0.5      | mA            |   |
| $I_{K(\text{off})}$              | Off-state cathode current                | $V_{KA}= 20\text{V}, V_{REF}= 0\text{V}^{*3}$   |         | 0.1   | 1        | $\mu\text{A}$ |   |
| $ Z_{KA} $                       | Dynamic impedance                        | $V_{KA}=V_{REF}$<br>$I_K=1\text{mA to } 100\text{mA}, f \leq 1\text{kHz}^{*1}$  |         | 0.1   | 0.4      | $\Omega$      |   |
| $I_K$                            | Cathode current                          | $V_{KA}=V_{REF} + 50\text{mV}^{*2}$   |         |       | 100      | mA            |   |

Notes :   \*1 : use Figure 1  
               \*2 : use Figure 2  
               \*3 : use Figure 3

**Test figures**

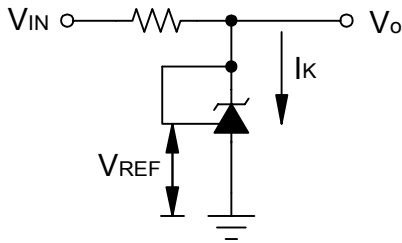


Figure 1. Test Circuit for  $V_{KA} = V_{REF}$ ,  $V_O = V_{KA} = V_{REF}$

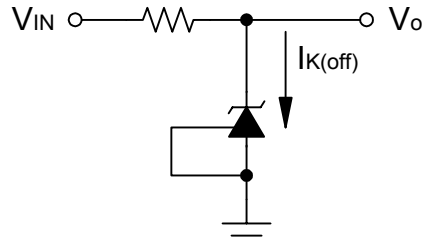


Figure 3. Test Circuit for  $I_{K(off)}$

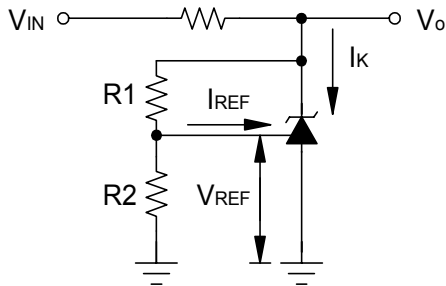
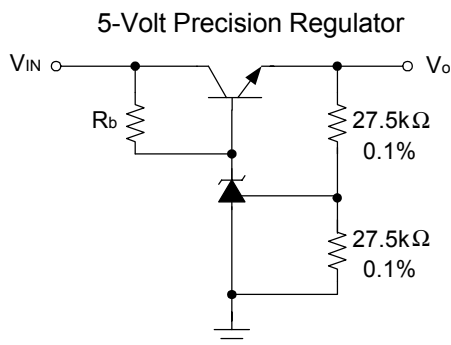


Figure 2. Test Circuit for  $V_{KA} > V_{REF}$   
 $V_O = V_{KA} = V_{REF} \times (1 + R_1/R_2) + I_{REF} \times R_1$

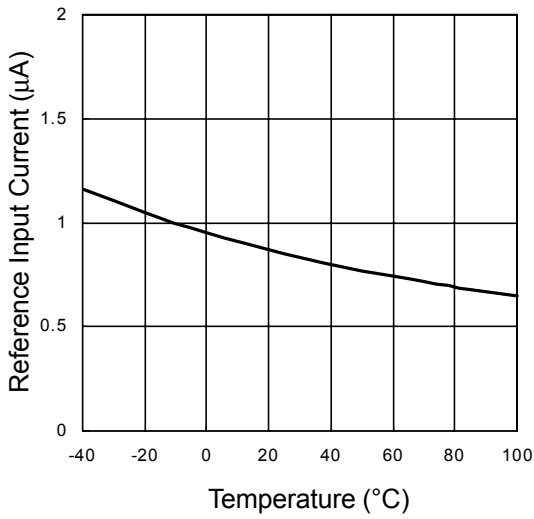
**Application schematic**



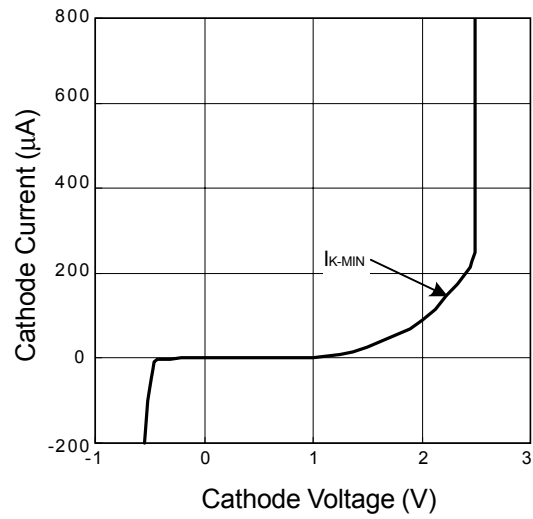
\*  $R_b$  should provide cathode current large than 1mA to maintain APL431 work properly.

## Typical Characteristics

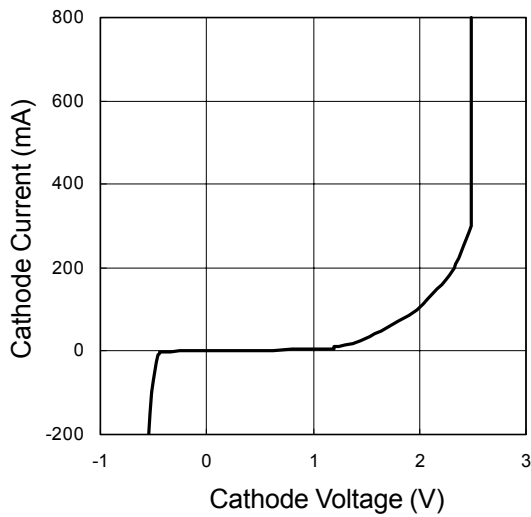
Reference Input Current vs. Temperature



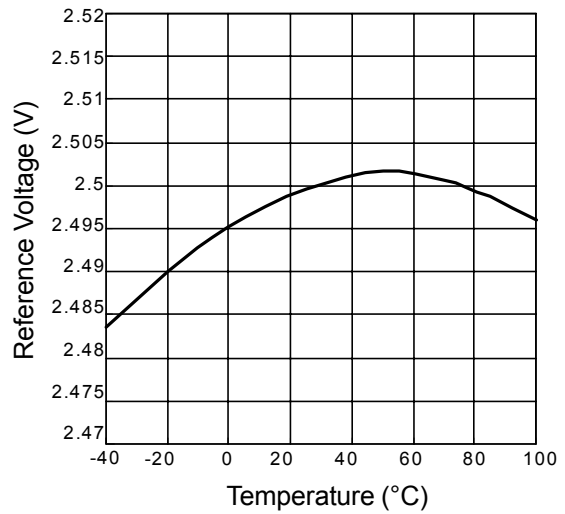
Cathode Current vs. Cathode Voltage



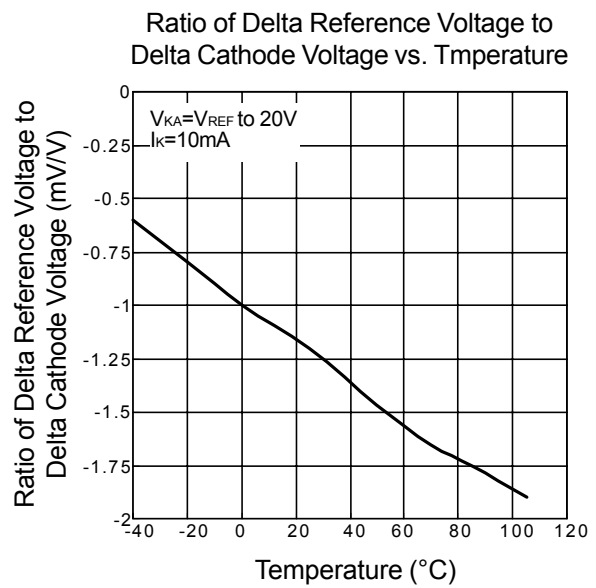
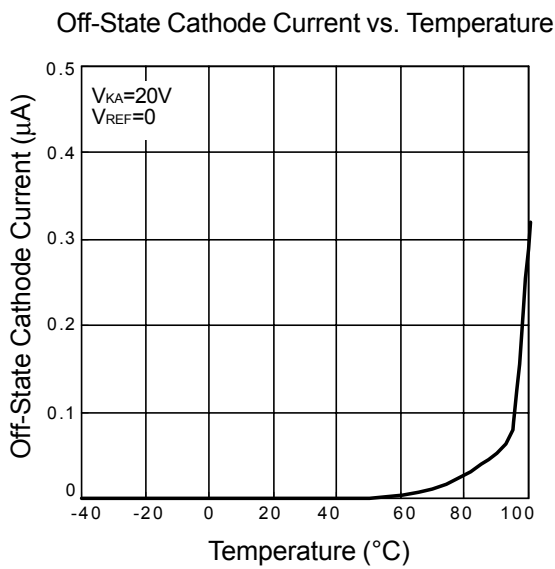
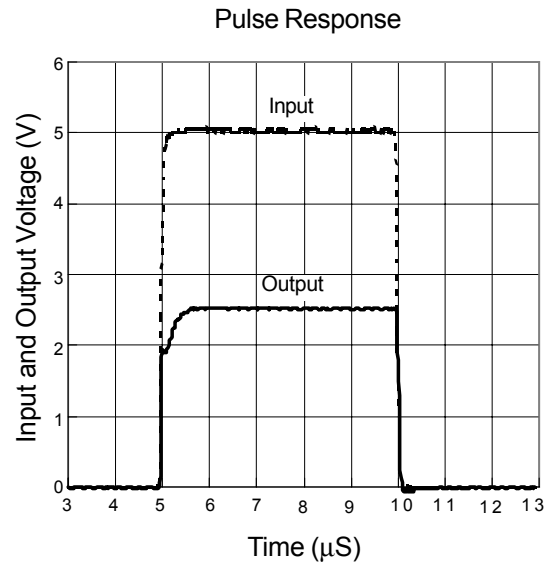
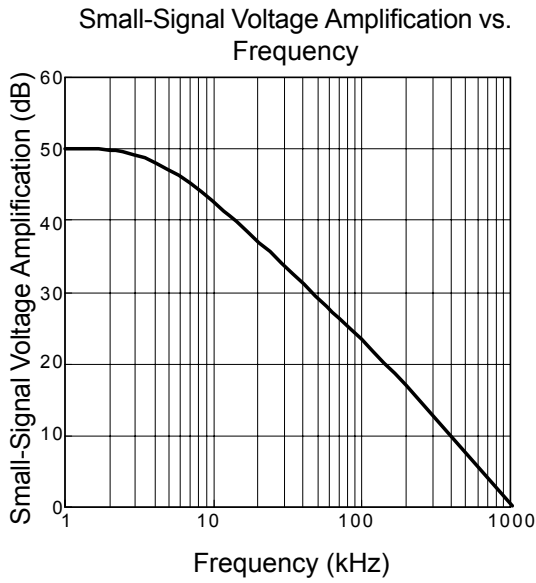
Cathode Current vs. Cathode Voltage



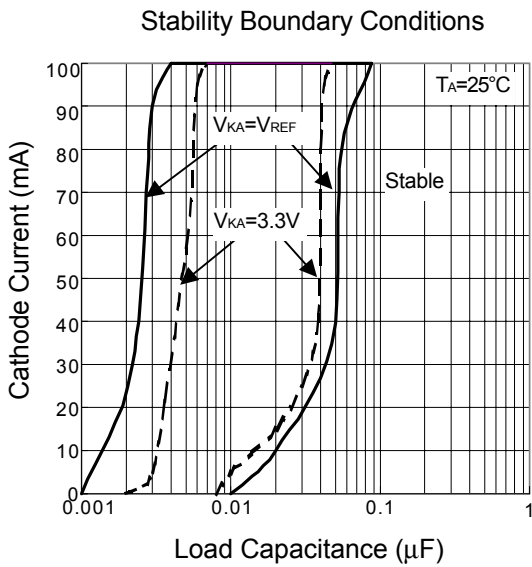
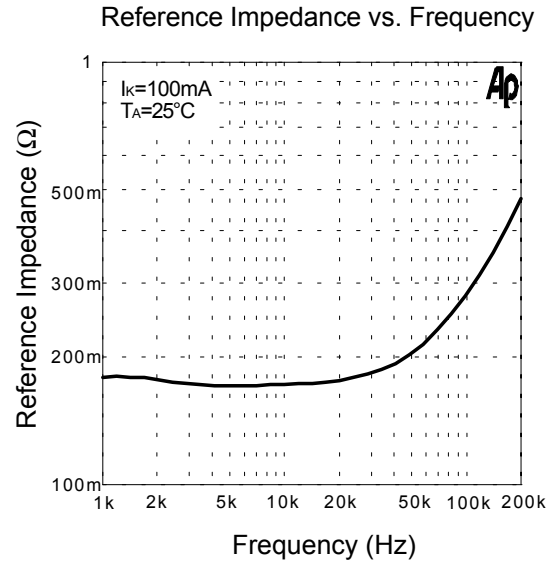
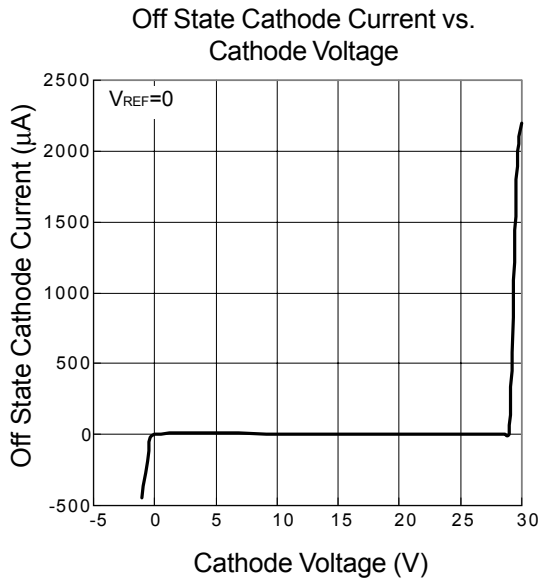
Reference Voltage vs. Temperature



Typical Characteristics (Cont.)

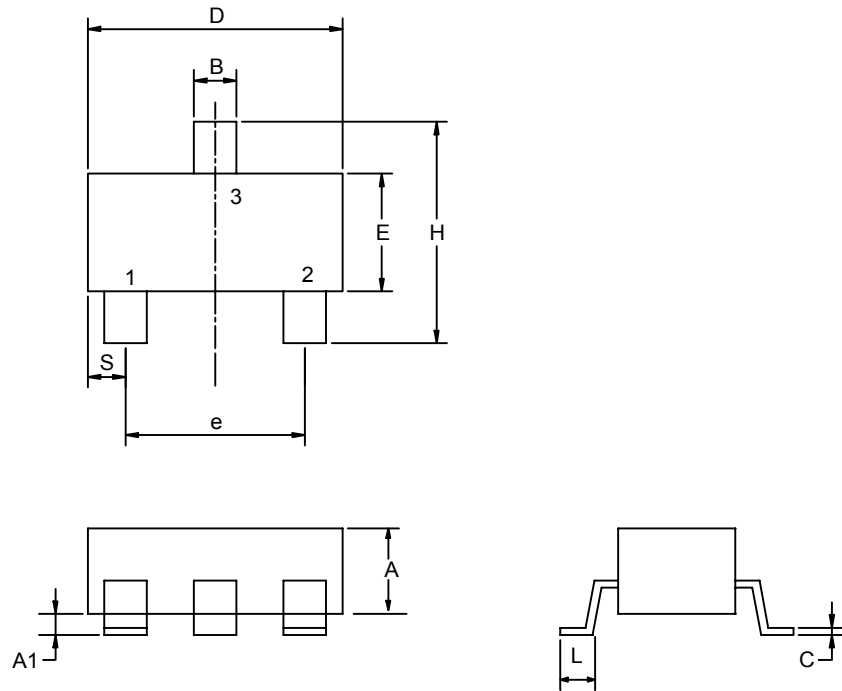


## Typical Characteristics (Cont.)



## Packaging Information

SOT-23

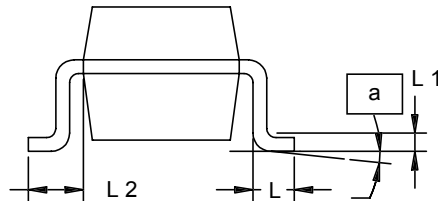
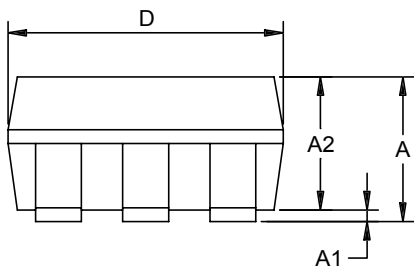
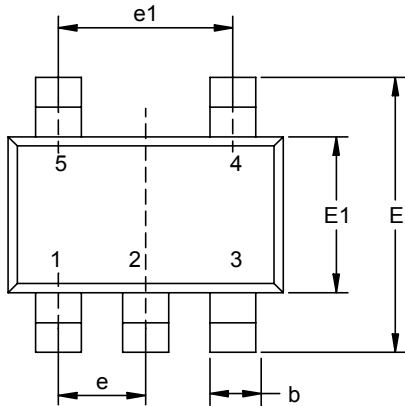


| Dim | Millimeters |      | Inches    |       |
|-----|-------------|------|-----------|-------|
|     | Min.        | Max. | Min.      | Max.  |
| A   | 1.00        | 1.30 | 0.039     | 0.051 |
| A1  | 0.00        | 0.10 | 0.000     | 0.004 |
| B   | 0.35        | 0.51 | 0.014     | 0.020 |
| C   | 0.10        | 0.25 | 0.004     | 0.010 |
| D   | 2.70        | 3.10 | 0.106     | 0.122 |
| E   | 1.40        | 1.80 | 0.055     | 0.071 |
| e   | 1.90 BSC    |      | 0.075 BSC |       |
| H   | 2.40        | 3.00 | 0.094     | 0.118 |
| L   | 0.37        |      | 0.0015    |       |



**Packaging Information**

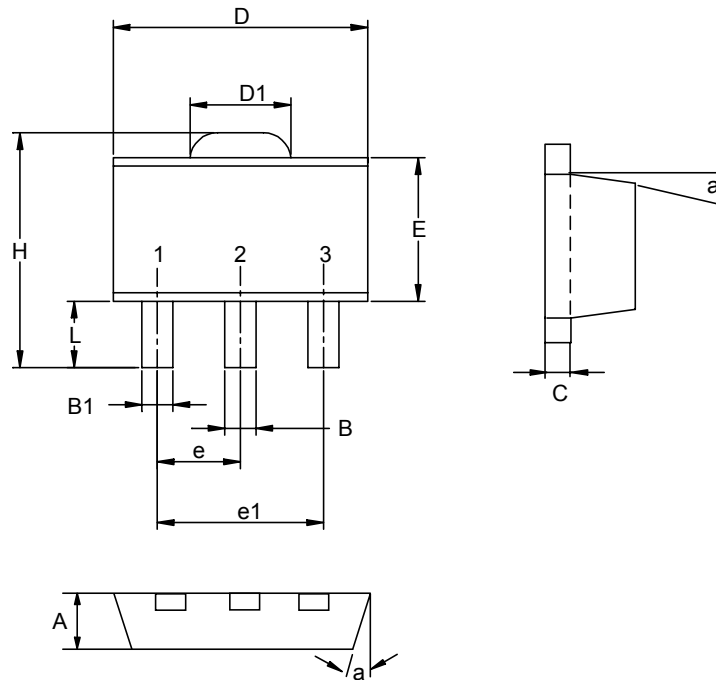
SOT-23-5



| Dim      | Millimeters |      | Inches    |       |
|----------|-------------|------|-----------|-------|
|          | Min.        | Max. | Min.      | Max.  |
| A        | 0.95        | 1.45 | 0.037     | 0.057 |
| A1       | 0.05        | 0.15 | 0.002     | 0.006 |
| A2       | 0.90        | 1.30 | 0.035     | 0.051 |
| D        | 2.8         | 3.00 | 0.110     | 0.118 |
| E        | 2.6         | 3.00 | 0.102     | 0.118 |
| E1       | 1.5         | 1.70 | 0.059     | 0.067 |
| L        | 0.35        | 0.55 | 0.014     | 0.022 |
| L1       | 0.20 BSC    |      | 0.008 BSC |       |
| L2       | 0.5         | 0.7  | 0.020     | 0.028 |
| N        | 5           |      | 5         |       |
| $\alpha$ | 0°          | 10°  | 0°        | 10°   |

## Packaging Information

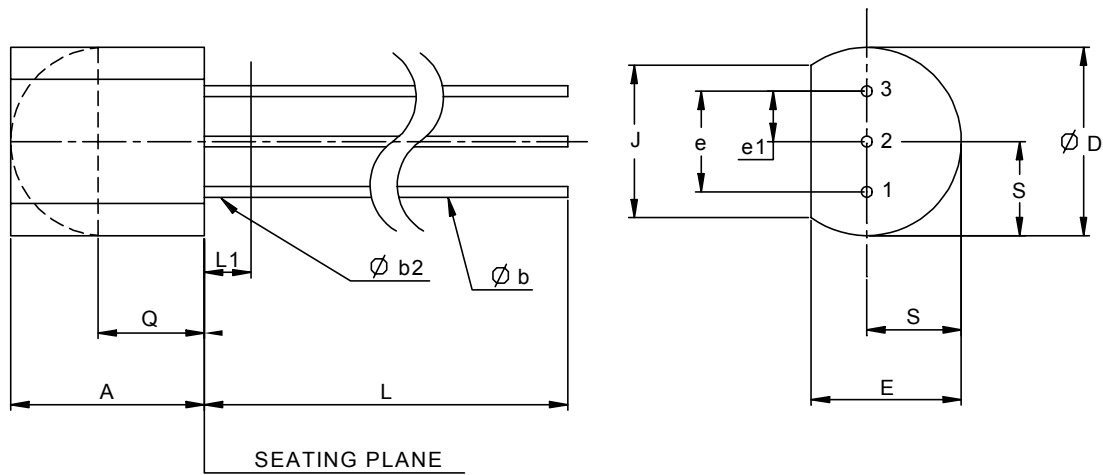
SOT-89



| Dim      | Millimeters |      | Inches    |       |
|----------|-------------|------|-----------|-------|
|          | Min.        | Max. | Min.      | Max.  |
| A        | 1.40        | 1.60 | 0.055     | 0.063 |
| B        | 0.40        | 0.56 | 0.016     | 0.022 |
| B1       | 0.35        | 0.48 | 0.014     | 0.019 |
| C        | 0.35        | 0.44 | 0.014     | 0.017 |
| D        | 4.40        | 4.60 | 0.173     | 0.181 |
| D1       | 1.35        | 1.83 | 0.053     | 0.072 |
| e        | 1.50 BSC    |      | 0.059 BSC |       |
| e1       | 3.00 BSC    |      | 0.118 BSC |       |
| E        | 2.29        | 2.60 | 0.090     | 0.102 |
| H        | 3.75        | 4.25 | 0.148     | 0.167 |
| L        | 0.80        | 1.20 | 0.031     | 0.047 |
| $\alpha$ |             | 10°  |           | 10°   |

**Packaging Information**

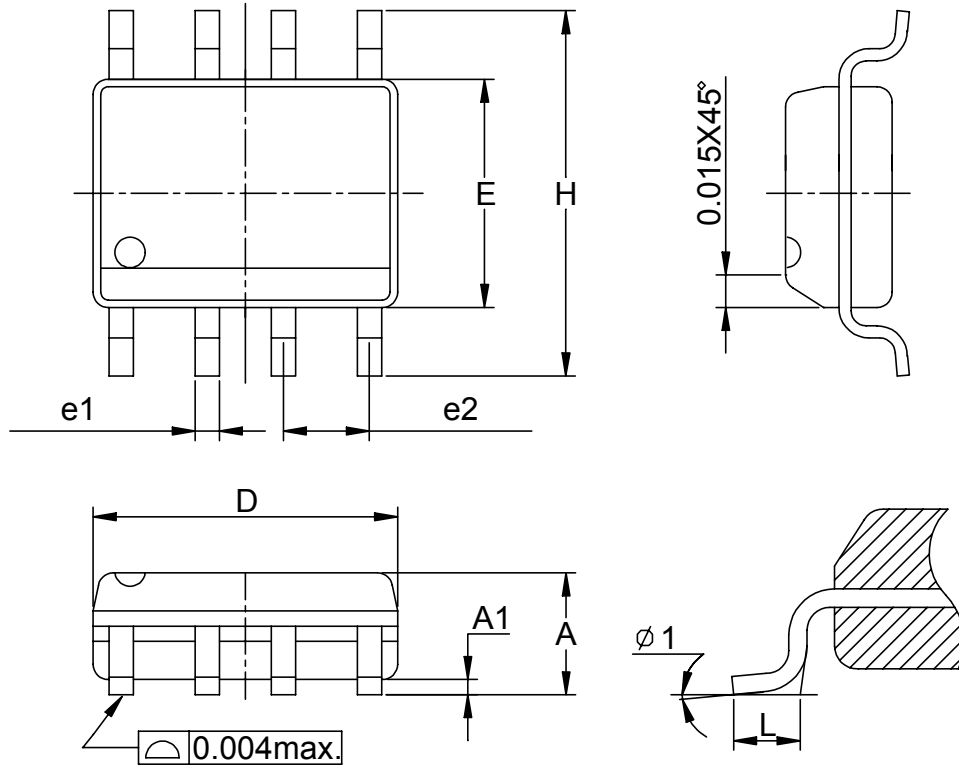
TO-92



| Dim  | Millimeters |       | Inches |       |
|------|-------------|-------|--------|-------|
|      | Min.        | Max.  | Min.   | Max.  |
| A    | 4.318       | 5.334 | 0.170  | 0.210 |
| φ b  | 0.406       | 0.559 | 0.016  | 0.022 |
| φ b2 | 0.406       | 0.559 | 0.016  | 0.022 |
| φ D  | 4.445       | 5.207 | 0.175  | 0.205 |
| E    | 3.175       | 4.191 | 0.125  | 0.165 |
| e    | 2.413       | 2.667 | 0.095  | 0.105 |
| e1   | 1.143       | 1.397 | 0.045  | 0.055 |
| J    | 3.429       |       | 0.135  |       |
| L    | 12.70       |       | 0.500  |       |
| L1   |             | 1.27  |        | 0.050 |
| Q    | 2.921       |       | 0.115  |       |
| S    | 2.032       | 2.667 | 0.080  | 0.105 |

**Packaging Information**

SO-8



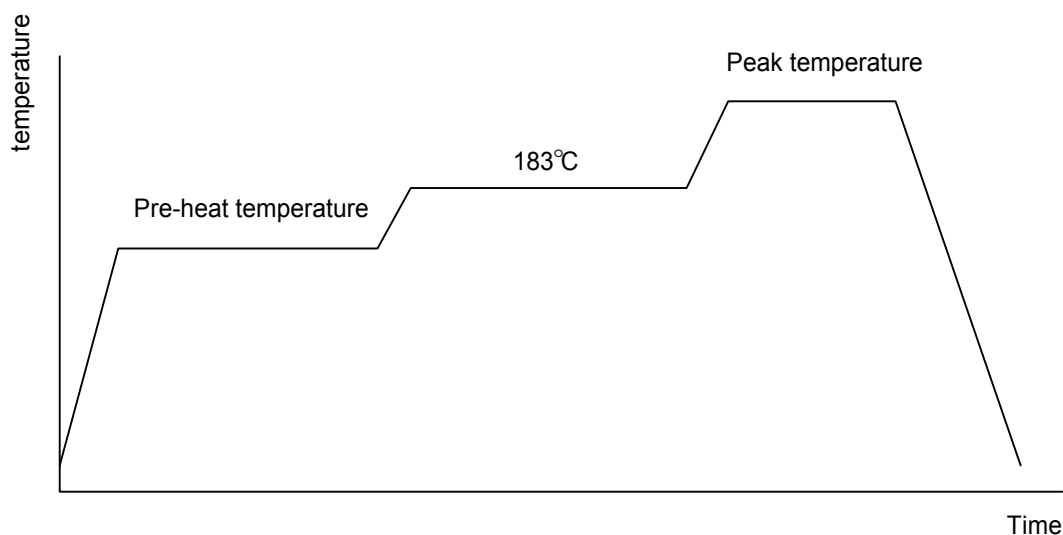
| Dim | Millimeters |      | Inches  |       |
|-----|-------------|------|---------|-------|
|     | Min.        | Max. | Min.    | Max.  |
| A   | 1.35        | 1.75 | 0.053   | 0.069 |
| A1  | 0.10        | 0.25 | 0.004   | 0.010 |
| D   | 4.80        | 5.00 | 0.189   | 0.197 |
| E   | 3.80        | 4.00 | 0.150   | 0.157 |
| H   | 5.80        | 6.20 | 0.228   | 0.244 |
| L   | 0.40        | 1.27 | 0.016   | 0.050 |
| e1  | 0.33        | 0.51 | 0.013   | 0.020 |
| e2  | 1.27BSC     |      | 0.50BSC |       |
| φ 1 | 8°          |      | 8°      |       |

## Physical Specifications

|                    |  |
|--------------------|--|
| Terminal Material  | Solder-Plated Copper (Solder Material : 90/10 or 63/37 SnPb) |
| Lead Solderability | Meets EIA Specification RSI86-91, ANSI/J-STD-002 Category 3. |

## Reflow Condition (IR/Convection or VPR Reflow)

Reference JEDEC Standard J-STD-020A APRIL 1999



## Classification Reflow Profiles

|  | Convection or IR/<br>Convection | VPR                      |
|--|---------------------------------|--------------------------|
| Average ramp-up rate(183°C to Peak)        | 3°C/second max.                 | 10 °C /second max.       |
| Preheat temperature 125 ± 25°C)            | 120 seconds max                 |                          |
| Temperature maintained above 183°C         | 60 – 150 seconds                |                          |
| Time within 5°C of actual peak temperature | 10 –20 seconds                  | 60 seconds               |
| Peak temperature range                     | 220 +5/-0°C or 235 +5/-0°C      | 215-219°C or 235 +5/-0°C |
| Ramp-down rate                             | 6 °C /second max.               | 10 °C /second max.       |
| Time 25°C to peak temperature              | 6 minutes max.                  |                          |

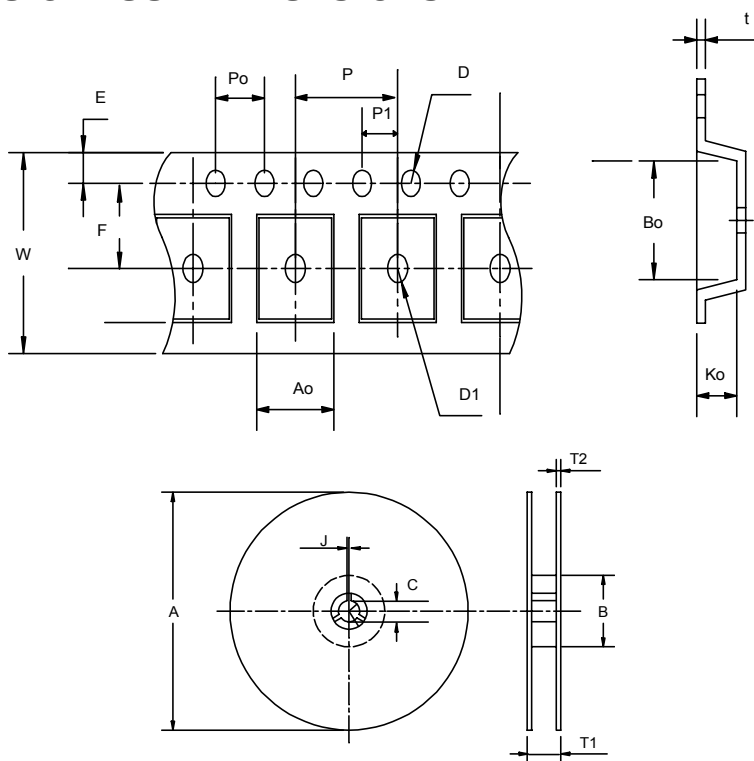
## Package Reflow Conditions

| pkg. thickness ≥ 2.5mm<br>and all bgas | pkg. thickness < 2.5mm and<br>pkg. volume ≥ 350 mm <sup>3</sup> | pkg. thickness < 2.5mm and pkg.<br>volume < 350mm <sup>3</sup> |
|--|---|--|
| Convection 220 +5/-0 °C                |   | Convection 235 +5/-0 °C  |
| VPR 215-219 °C                         |   | VPR 235 +5/-0 °C   |
| IR/Convection 220 +5/-0 °C             |   | IR/Convection 235 +5/-0 °C                                     |

## Reliability test program

| Test item     | Method              | Description                    |
|---------------|---------------------|--------------------------------|
| SOLDERABILITY | MIL-STD-883D-2003   | 245°C , 5 SEC                  |
| HOLT          | MIL-STD-883D-1005.7 | 1000 Hrs Bias @ 125 °C         |
| PCT           | JESD-22-B, A102     | 168 Hrs, 100 % RH , 121°C      |
| TST           | MIL-STD-883D-1011.9 | -65°C ~ 150°C, 200 Cycles      |
| ESD           | MIL-STD-883D-3015.7 | VHBM > 2KV, VMM > 200V         |
| Latch-Up      | JESD 78             | 10ms , I <sub>tr</sub> > 100mA |

## Carrier Tape & Reel Dimensions



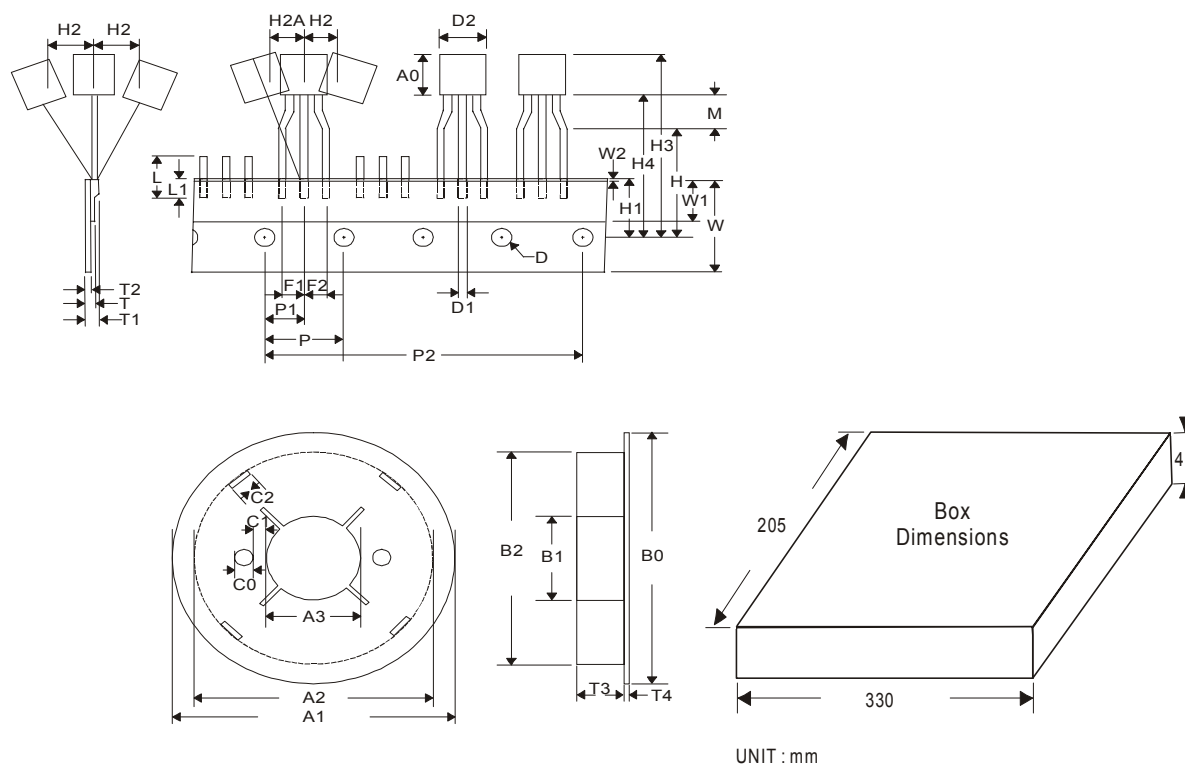
| Application | A          | B         | C              | J          | T1         | T2        | W                | P         | E           |
|-------------|------------|-----------|----------------|------------|------------|-----------|------------------|-----------|-------------|
| SOP-8       | 330 ± 1    | 62 +1.5   | 12.75+<br>0.15 | 2 ± 0.5    | 12.4 ± 0.2 | 2 ± 0.2   | 12 ± 0.3         | 8 ± 0.1   | 1.75 ± 0.1  |
|             | F          | D         | D1             | Po         | P1         | Ao        | Bo               | Ko        | t           |
|             | 5.5 ± 1    | 1.55 +0.1 | 1.55+ 0.25     | 4.0 ± 0.1  | 2.0 ± 0.1  | 6.4 ± 0.1 | 5.2 ± 0.1        | 2.1 ± 0.1 | 0.3 ± 0.013 |
| Application | A          | B         | C              | J          | T1         | T2        | W                | P         | E           |
| SOT-23      | 178 ± 1    | 60 ± 1.0  | 12.0           | 2.5 ± 0.15 | 9.0 ± 0.5  | 1.4       | 8.0+ 0.3<br>-0.3 | 4.0       | 1.75        |
|             | F          | D         | D1             | Po         | P1         | Ao        | Bo               | Ko        | t           |
|             | 3.5 ± 0.05 | 1.5 +0.1  | φ 0.1MIN       | 4.0        | 2.0 ± 0.05 | 3.1       | 3.0              | 1.3       | 0.2 ± 0.03  |

(mm)

| Application | A          | B         | C           | J          | T1        | T2         | W                    | P          | E           |
|-------------|------------|-----------|-------------|------------|-----------|------------|----------------------|------------|-------------|
| SOT-23-5    | 178 ±1     | 72 ± 1.0  | 13.0 + 0.2  | 2.5 ± 0.15 | 8.4 ± 2   | 1.5 ± 0.3  | 8.0 ± 0.3            | 4 ± 0.1    | 1.75 ± 0.1  |
|             | F          | D         | D1          | Po         | P1        | Ao         | Bo                   | Ko         | t           |
|             | 3.5 ± 0.05 | 1.5 ± 0.1 | 1.5 ± 0.1   | 4.0 ± 0.1  | 2.0 ± 0.1 | 3.15 ± 0.1 | 3.2 ± 0.1            | 1.4 ± 0.1  | 0.2 ± 0.033 |
| Application | A          | B         | C           | J          | T1        | T2         | W                    | P          | E           |
| SOT-89      | 178 ±1     | 70 ± 2    | 13.5 ± 0.15 | 3 ± 0.15   | 14 ± 2    | 1.3 ± 0.3  | 12 + 0.3<br>12 - 0.1 | 8 ± 0.1    | 1.75 ± 0.1  |
|             | F          | D         | D1          | Po         | P1        | Ao         | Bo                   | Ko         | t           |
|             | 5.5 ± 0.05 | 1.5 ± 0.1 | 1.5 ± 0.1   | 4.0 ± 0.1  | 2.0 ± 0.1 | 4.8 ± 0.1  | 4.5 ± 0.1            | 1.80 ± 0.1 | 0.3 ± 0.013 |

(mm)

## Carrier Tape & Reel Dimensions



| Application | A0         | A1        | A2          | A3          | B0                 | B1       | B2         | C0         | C1         |
|-------------|------------|-----------|-------------|-------------|--------------------|----------|------------|------------|------------|
| TO-92       | 3.18~12    | 90 ±1     | 76 ±1       | 30 ±1       | 90 ±1              | 31 ±1    | 76 ±1      | 5.8        | 3.8        |
|             | C2         | D         | D1          | D2          | F1=F2              | F1-F2    | M          | H          | H1         |
|             | 7.8        | 4.0 ± 0.2 | 0.36 ~ 0.53 | 9.0 MAX     | 2.5 + 0.2<br>- 0.1 | ± 0.3    | 2.5 ± 0.5  | 16 ± 0.5   | 9 ± 0.5    |
|             | H2         | H2A       | H3          | H4          | H5=H0+M            | L        | L1         | P          | P1         |
|             | 0.5 MAX    | 0.5 MAX   | 27.0 MAX    | 20.0 MAX    | 18.5 ± 0.5         | 11.0 MAX | 2.5 MIN    | 12.7 ± 0.3 | 6.35 ± 0.4 |
|             | P2         | T         | T1          | T2          | T3                 | T4       | W          | W1         | W2         |
|             | 50.8 ± 0.5 | 0.55 MAX  | 1.42 MAX    | 0.36 ~ 0.68 | 15                 | 1.7      | 18.0 ± 0.2 | 6.0 ± 0.2  | ≤ 1        |

(mm)

## Cover Tape Dimensions

| Application | Carrier Width | Cover Tape Width | Devices Per Reel |
|-------------|---------------|------------------|------------------|
| SOP- 8      | 12            | 9.3              | 2500             |
| SOT- 23     | 8             | 5.3              | 3000             |
| SOT- 23-5   | 8             | 5.3              | 3000             |
| SOT- 89     | 12            | 9.3              | 1000             |
| TO-92       | 17.5~19       | 5.0~7.0          | 2000             |

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