

## LM185-2.5/LM285-2.5/LM385-2.5 Micropower Voltage Reference Diode

### General Description

The LM185-2.5/LM285-2.5/LM385-2.5 are micropower 2-terminal band-gap voltage regulator diodes. Operating over a 20  $\mu$ A to 20 mA current range, they feature exceptionally low dynamic impedance and good temperature stability. On-chip trimming is used to provide tight voltage tolerance. Since the LM-185-2.5 band-gap reference uses only transistors and resistors, low noise and good long term stability result.

Careful design of the LM185-2.5 has made the device exceptionally tolerant of capacitive loading, making it easy to use in almost any reference application. The wide dynamic operating range allows its use with widely varying supplies with excellent regulation.

The extremely low power drain of the LM185-2.5 makes it useful for micropower circuitry. This voltage reference can be used to make portable meters, regulators or general purpose analog circuitry with battery life approaching shelf life. Further, the wide operating current allows it to replace older references with a tighter tolerance part. For applications requiring 1.2V see LM185-1.2.

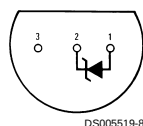
The LM185-2.5 is rated for operation over a  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  temperature range while the LM285-2.5 is rated  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$  and the LM385-2.5  $0^{\circ}\text{C}$  to  $70^{\circ}\text{C}$ . The LM185-2.5/LM285-2.5 are available in a hermetic TO-46 package and the LM285-2.5/LM385-2.5 are also available in a low-cost TO-92 molded package, as well as S.O. and SOT-23. The LM185-2.5 is also available in a hermetic leadless chip carrier package.

### Features

- $\pm 20$  mV ( $\pm 0.8\%$ ) max. initial tolerance (A grade)
- Operating current of 20  $\mu$ A to 20 mA
- $0.6\Omega$  dynamic impedance (A grade)
- Low temperature coefficient
- Low voltage reference — 2.5V
- 1.2V device and adjustable device also available — LM185-1.2 series and LM185 series, respectively

### Connection Diagrams

TO-92  
Plastic Package

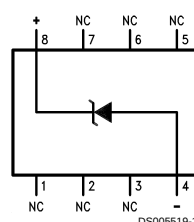


DS0005519-8

Bottom View

Order Number LM285Z-2.5,  
LM285BXZ-2.5, LM285BYZ-2.5  
LM385Z-2.5, LM385AXZ-2.5  
LM385AYZ-2.5, LM385BZ-2.5,  
LM385BXZ-2.5 or LM385BYZ-2.5  
See NS Package Number Z03A

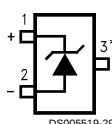
SO Package



DS0005519-11

Order Number LM285M-2.5,  
LM285BXM-2.5, LM285BYM-2.5  
LM385M-2.5, LM385BM-2.5  
LM385BXM-2.5 or LM385BYM-2.5  
See NS Package Number M08A

SOT-23



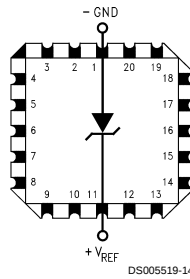
DS0005519-29

\* Pin 3 is attached to the Die Attach Pad (DAP) and should be connected to Pin 2 or left floating.

Order Number LM385M3-2.5  
See NS Package Number MA03B

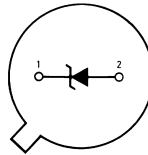
## Connection Diagrams (Continued)

**LCC**  
**Leadless Chip Carrier**



Order Number LM185E-2.5/883  
See NS Package Number E20A

**TO-46**  
**Metal Can Package**



**Bottom View**  
Order Number LM185H-2.5,  
LM185H-2.5/883, LM185BXH-2.5,  
LM185BXH-2.5/883, LM185BYH-2.5,  
LM185BYH2.5/883, LM285H-2.5,  
or LM285BYH-2.5  
See NS Package Number H02A

**Absolute Maximum Ratings** (Notes 1, 2)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

|                                      |                  |
|--------------------------------------|------------------|
| Reverse Current                      | 30 mA            |
| Forward Current                      | 10 mA            |
| Operating Temperature Range (Note 3) |                  |
| LM185-2.5                            | -55°C to + 125°C |
| LM285-2.5                            | -40°C to + 85°C  |
| LM385-2.5                            | 0°C to 70°C      |
| Storage Temperature                  | -55°C to + 150°C |

## Soldering Information

|                         |       |
|-------------------------|-------|
| TO-92 Package (10 sec.) | 260°C |
| TO-46 Package (10 sec.) | 300°C |
| SO and SOT Package      |       |
| Vapor Phase (60 sec.)   | 215°C |
| Infrared (15 sec.)      | 220°C |

See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" for other methods of soldering surface mount devices.

**Electrical Characteristics**

(Note 4)

| Parameter                                     | Conditions                                                                   | Typ                       | LM385A-2.5<br>LM385AX-2.5<br>LM385AY-2.5 |                              | Units<br>(Limits)                    |
|-----------------------------------------------|------------------------------------------------------------------------------|---------------------------|------------------------------------------|------------------------------|--------------------------------------|
|                                               |                                                                              |                           | Tested<br>Limit<br>(Note 5)              | Design<br>Limit<br>(Note 6)  |                                      |
| Reverse Breakdown Voltage                     | $I_R = 100 \mu A$                                                            | 2.500<br><br><b>2.500</b> | 2.480<br>2.520                           | <b>2.470</b><br><b>2.530</b> | V(Min)<br>V(Max)<br>V(Min)<br>V(Max) |
| Minimum Operating Current                     |                                                                              | 12                        | 18                                       | <b>20</b>                    | $\mu A$<br>(Max)                     |
| Reverse Breakdown Voltage Change with Current | $I_{MIN} \leq I_R \leq 1mA$                                                  |                           | 1                                        | <b>1.5</b>                   | mV<br>(Max)                          |
|                                               | $1 mA \leq I_R \leq 20 mA$                                                   |                           | 10                                       | <b>20</b>                    | mV<br>(Max)                          |
| Reverse Dynamic Impedance                     | $I_R = 100 \mu A$ ,<br>$f = 20 Hz$                                           | 0.2                       |                                          | 0.6<br><b>1.5</b>            | $\Omega$                             |
| Wideband Noise (rms)                          | $I_R = 100 \mu A$<br>$10 Hz \leq f \leq 10 kHz$                              | 120                       |                                          |                              | $\mu V$                              |
| Long Term Stability                           | $I_R = 100 \mu A$ ,<br>$T = 1000 Hr$ ,<br>$T_A = 25^\circ C \pm 0.1^\circ C$ | 20                        |                                          |                              | ppm                                  |
| Average Temperature Coefficient (Note 7)      | $I_{MIN} \leq I_R \leq 20 mA$                                                |                           | <b>30</b>                                |                              | ppm/°C                               |
|                                               | X Suffix                                                                     |                           | <b>50</b>                                |                              | (Max)                                |
|                                               | Y Suffix<br>All Others                                                       |                           |                                          | <b>150</b>                   |                                      |

## Electrical Characteristics (Continued)

| Parameter                                     | Conditions                                                                                              | Typ | LM185-2.5<br>LM185BX-2.5<br>LM185BY-2.5<br>LM285-2.5<br>LM285BX-2.5<br>LM285BY-2.5 |                             | LM385B-2.5<br>LM385BX-2.5<br>LM385BY-2.5 |                             | LM385-2.5                   |                             | Units<br>(Limit)               |
|-----------------------------------------------|---------------------------------------------------------------------------------------------------------|-----|------------------------------------------------------------------------------------|-----------------------------|------------------------------------------|-----------------------------|-----------------------------|-----------------------------|--------------------------------|
|                                               |                                                                                                         |     | Tested<br>Limit<br>(Note 5)<br>(Note 8)                                            | Design<br>Limit<br>(Note 6) | Tested<br>Limit<br>(Note 5)              | Design<br>Limit<br>(Note 6) | Tested<br>Limit<br>(Note 5) | Design<br>Limit<br>(Note 6) |                                |
| Reverse Breakdown Voltage                     | $T_A = 25^\circ\text{C}$ ,<br>$20\ \mu\text{A} \leq I_R \leq 20\ \text{mA}$                             | 2.5 | 2.462<br>2.538                                                                     |                             | 2.462<br>2.538                           |                             | 2.425<br>2.575              |                             | V(Min)<br>V(Max)               |
| Minimum Operating Current                     |                                                                                                         | 13  | 20                                                                                 | <b>30</b>                   | 20                                       | <b>30</b>                   | 20                          | <b>30</b>                   | $\mu\text{A}$<br>(Max)         |
| Reverse Breakdown Voltage Change with Current | $20\ \mu\text{A} \leq I_R \leq 1\ \text{mA}$                                                            |     | 1                                                                                  | <b>1.5</b>                  | 2.0                                      | <b>2.5</b>                  | 2.0                         | <b>2.5</b>                  | mV<br>(Max)                    |
|                                               | $1\ \text{mA} \leq I_R \leq 20\ \text{mA}$                                                              |     | 10                                                                                 | <b>20</b>                   | 20                                       | <b>25</b>                   | 20                          | <b>25</b>                   | mV<br>(Max)                    |
| Reverse Dynamic Impedance                     | $I_R = 100\ \mu\text{A}$ ,<br>$f = 20\ \text{Hz}$                                                       | 1   |                                                                                    |                             |                                          |                             |                             |                             | $\Omega$                       |
| Wideband Noise (rms)                          | $I_R = 100\ \mu\text{A}$ ,<br>$10\ \text{Hz} \leq f \leq 10\ \text{kHz}$                                | 120 |                                                                                    |                             |                                          |                             |                             |                             | $\mu\text{V}$                  |
| Long Term Stability                           | $I_R = 100\ \mu\text{A}$ ,<br>$T = 1000\ \text{Hr}$ ,<br>$T_A = 25^\circ\text{C} \pm 0.1^\circ\text{C}$ | 20  |                                                                                    |                             |                                          |                             |                             |                             | ppm                            |
| Average Temperature Coefficient (Note 7)      | $I_R = 100\ \mu\text{A}$                                                                                |     |                                                                                    |                             |                                          |                             |                             |                             |                                |
|                                               | X Suffix                                                                                                |     | <b>30</b>                                                                          |                             | <b>30</b>                                |                             |                             |                             | ppm/ $^\circ\text{C}$          |
|                                               | Y Suffix                                                                                                |     | <b>50</b>                                                                          |                             | <b>50</b>                                |                             |                             |                             | ppm/ $^\circ\text{C}$          |
|                                               | All Others                                                                                              |     |                                                                                    | <b>150</b>                  |                                          | <b>150</b>                  |                             | <b>150</b>                  | ppm/ $^\circ\text{C}$<br>(Max) |

**Note 1:** Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics. The guaranteed specifications apply only for the test conditions listed.

**Note 2:** Refer to RETS185H-2.5 for military specifications.

**Note 3:** For elevated temperature operation,  $T_{J\ \text{MAX}}$  is:

LM185       $150^\circ\text{C}$

LM285       $125^\circ\text{C}$

LM385       $100^\circ\text{C}$

| Thermal Resistance                  | TO-92                                                                      | TO-46                 | SO-8                  | SOT-23                |
|-------------------------------------|----------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|
| $\theta_{ja}$ (Junction to Ambient) | $180^\circ\text{C/W}$ (0.4" Leads)<br>$170^\circ\text{C/W}$ (0.125" Leads) | $440^\circ\text{C/W}$ | $165^\circ\text{C/W}$ | $283^\circ\text{C/W}$ |
| $\theta_{jc}$ (Junction to Case)    | N/A                                                                        | $80^\circ\text{C/W}$  | N/A                   | N/A                   |

**Note 4:** Parameters identified with boldface type apply at temperature extremes. All other numbers apply at  $T_A = T_J = 25^\circ\text{C}$ .

**Note 5:** Guaranteed and 100% production tested.

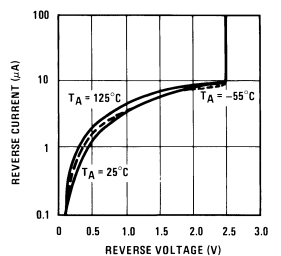
**Note 6:** Guaranteed, but not 100% production tested. These limits are not used to calculate average outgoing quality levels.

**Note 7:** The average temperature coefficient is defined as the maximum deviation of reference voltage at all measured temperatures between the operating  $T_{\text{MAX}}$  and  $T_{\text{MIN}}$ , divided by  $T_{\text{MAX}} - T_{\text{MIN}}$ . The measured temperatures are  $-55^\circ\text{C}$ ,  $-40^\circ\text{C}$ ,  $0^\circ\text{C}$ ,  $25^\circ\text{C}$ ,  $70^\circ\text{C}$ ,  $85^\circ\text{C}$ ,  $125^\circ\text{C}$ .

**Note 8:** A military RETS electrical specification available on request.

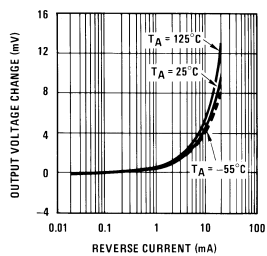
## Typical Performance Characteristics

### Reverse Characteristics



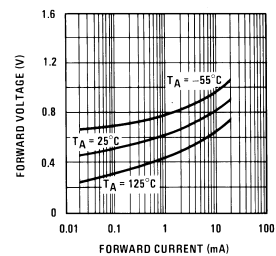
DS005519-15

### Reverse Characteristics



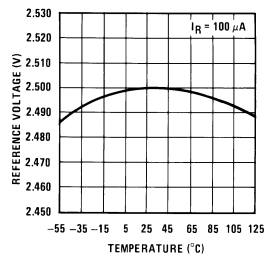
DS005519-16

### Forward Characteristics



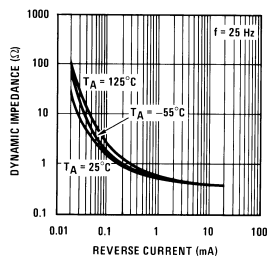
DS005519-17

### Temperature Drift



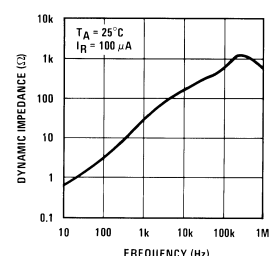
DS005519-18

### Reverse Dynamic Impedance



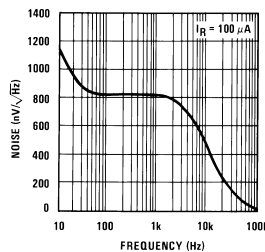
DS005519-19

### Reverse Dynamic Impedance



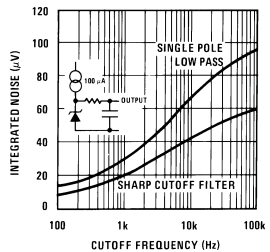
DS005519-20

### Noise Voltage



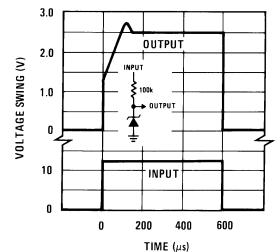
DS005519-21

### Filtered Output Noise



DS005519-22

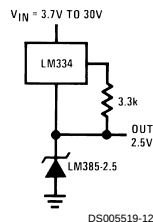
### Response Time



DS005519-23

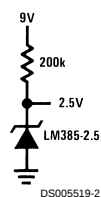
## Applications

### Wide Input Range Reference



DS005519-12

### Micropower Reference from 9V Battery

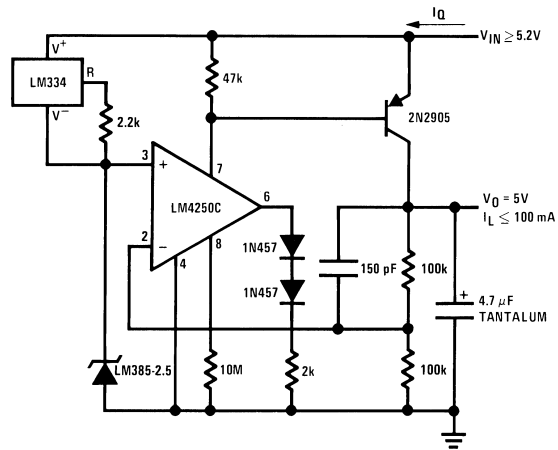


DS005519-2

## LM385-2.5 Applications

## LM385-2.5 Applications (Continued)

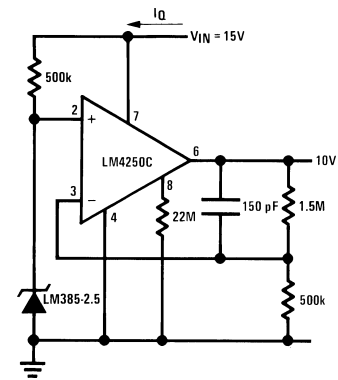
### Micropower 5V Reference (Note 9)



DS005519-9

Note 9:  $I_Q \cong 40 \mu A$

### Micropower 10V Reference (Note 10)

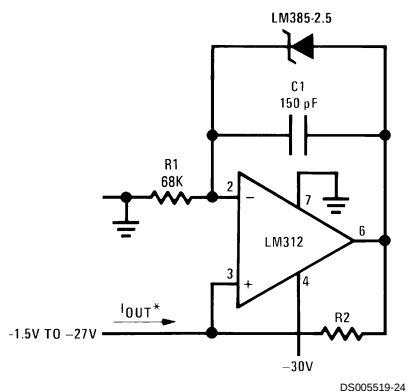


DS005519-10

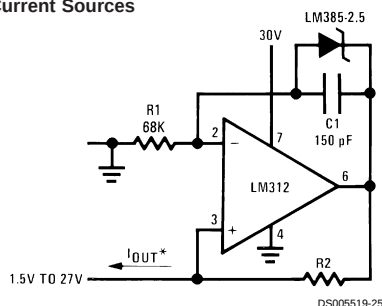
Note 10:  $I_Q \cong 30 \mu A$  standby current

## LM385-2.5 Applications (Continued)

### Precision 1 $\mu\text{A}$ to 1 mA Current Sources

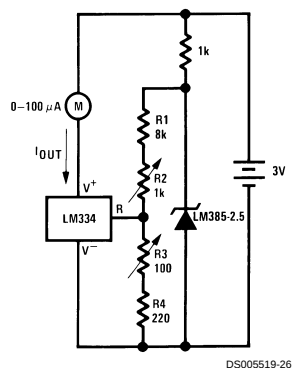


$$I_{OUT} = \frac{2.5V}{R2}$$



### METER THERMOMETERS

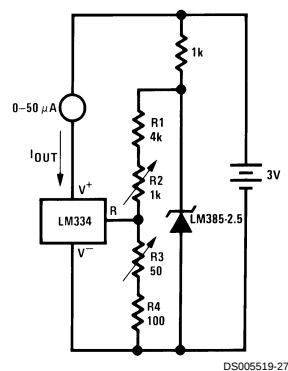
#### 0°C–100°C Thermometer



#### Calibration

1. Short LM385-2.5, adjust R3 for  $I_{OUT} = \text{temp}$  at  $1\mu\text{A}/^\circ\text{K}$
2. Remove short, adjust R2 for correct reading in centigrade

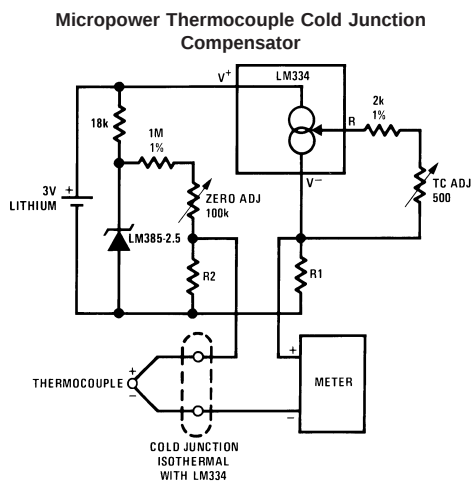
#### 0°F–50°F Thermometer



#### Calibration

1. Short LM385-2.5, adjust R3 for  $I_{OUT} = \text{temp}$  at  $1.8\mu\text{A}/^\circ\text{K}$
2. Remove short, adjust R2 for correct reading in  $^\circ\text{F}$

## LM385-2.5 Applications (Continued)



DS005519-6

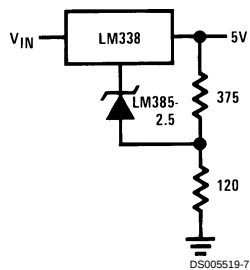
### Adjustment Procedure

1. Adjust TC ADJ pot until voltage across R1 equals Kelvin temperature multiplied by the thermocouple Seebeck coefficient.
2. Adjust zero ADJ pot until voltage across R2 equals the thermocouple Seebeck coefficient multiplied by 273.2.

| Thermocouple<br>Type | Seebeck                                       |              |              | Voltage       | Voltage   |
|----------------------|-----------------------------------------------|--------------|--------------|---------------|-----------|
|                      | Co-                                           | R1           | R2           | Across R1     | Across R2 |
|                      | efficient<br>( $\mu\text{V}/^\circ\text{C}$ ) | ( $\Omega$ ) | ( $\Omega$ ) | @25°C<br>(mV) | (mV)      |
| J                    | 52.3                                          | 523          | 1.24k        | 15.60         | 14.32     |
| T                    | 42.8                                          | 432          | 1k           | 12.77         | 11.78     |
| K                    | 40.8                                          | 412          | 953 $\Omega$ | 12.17         | 11.17     |
| S                    | 6.4                                           | 63.4         | 150 $\Omega$ | 1.908         | 1.766     |

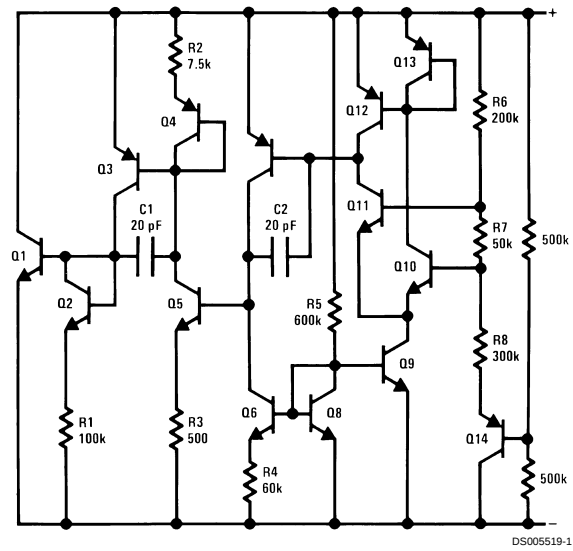
Typical supply current 50  $\mu$ A

### Improving Regulation of Adjustable Regulators



DS005519-7

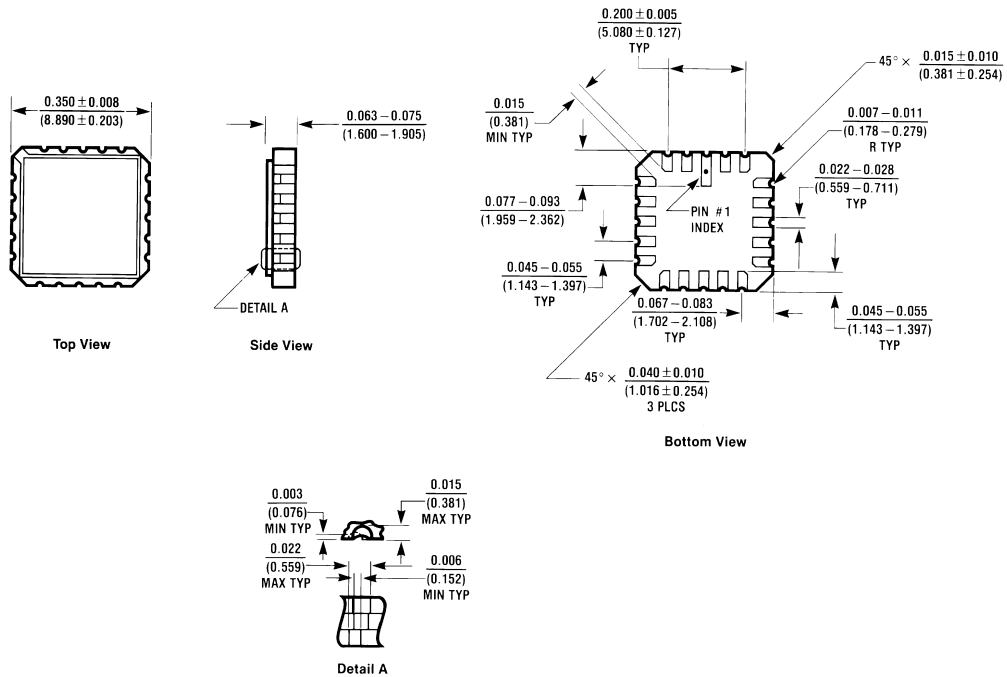
## Schematic Diagram



LM185-2.5/LM285-2.5/LM385-2.5

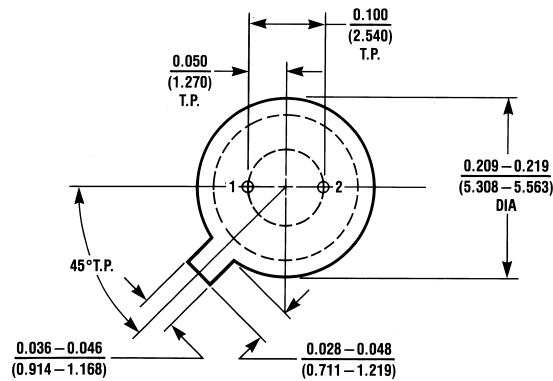
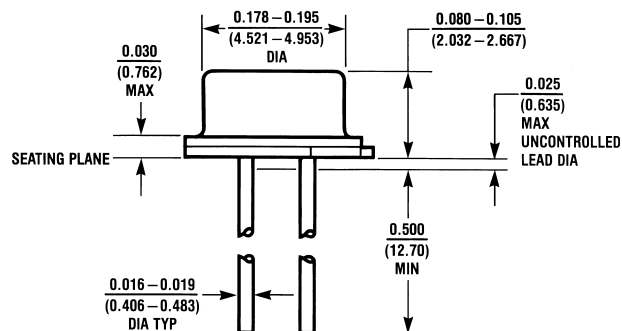
# Physical Dimensions

inches (millimeters) unless otherwise noted



E20A (REV. 01)

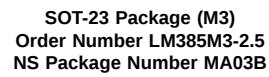
Order Number LM185E-2.5/883  
NS Package Number E20A

**Physical Dimensions** inches (millimeters) unless otherwise noted (Continued)

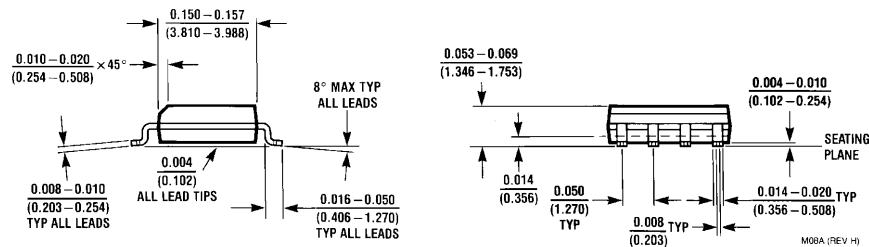
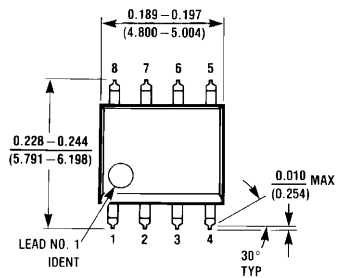
H02A (REV C)

**TO-46 Metal Can Package (H)**

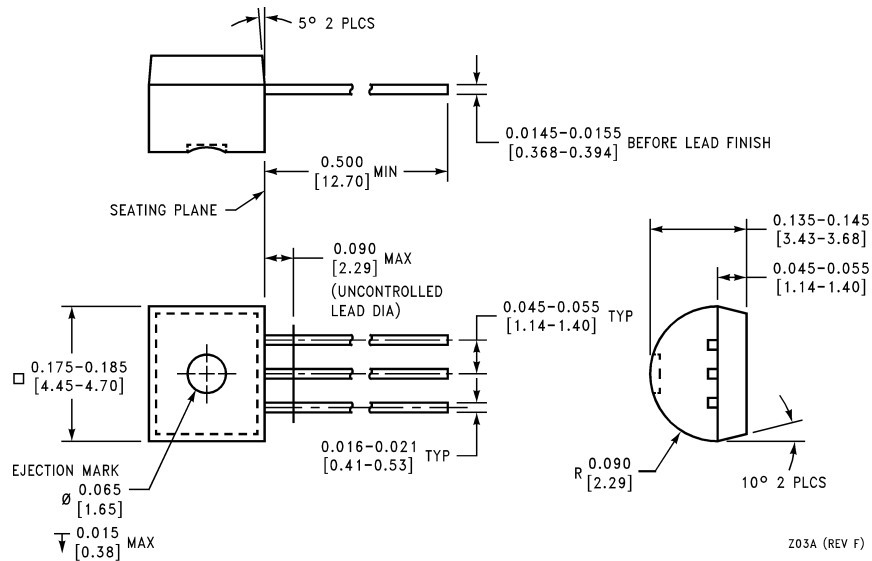
Order Number LM185H-2.5, LM185H-2.5/883, LM185BXH-2.5, LM185BXH-2.5/883,  
LM185BYH-2.5, LM185BYH-2.5/883, LM285H-2.5, or LM285BYH-2.5  
NS Package Number H02A



# Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



Small Outline (SO-8) Package (M)  
 Order Number LM285M-2.5, LM285BXM-2.5, LM285BYM-2.5,  
 LM385M-2.5, LM385BM-2.5, LM385BXM-2.5 or LM385BYM-2.5  
 NS Package Number M08A

**Physical Dimensions** inches (millimeters) unless otherwise noted (Continued)

**TO-92 Plastic Package (Z)**  
**Order Number LM285Z-2.5, LM285BXZ-2.5, LM285BYZ-2.5,**  
**LM385Z-2.5, LM385AXZ-2.5, LM385AYZ-2.5,**  
**LM385BZ-2.5, LM385BXZ-2.5 or LM385BYZ-2.5**  
**NS Package Number Z03A**

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2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



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