



# LM135-LM235-LM335

## Precision temperature sensors

### Features

- Directly calibrated in °K
- 1°C initial accuracy
- Operates from 450µA to 5mA
- Less than 1Ω dynamic impedance

### Description

The LM135, LM235, LM335 are precision temperature sensors which can be easily calibrated. They operate as a 2-terminal Zener and the breakdown voltage is directly proportional to the absolute temperature at 10mV/°K.

The circuit has a dynamic impedance of less than 1Ω and operates within a range of current from 450µA to 5mA without alteration of its characteristics.

Calibrated at +25°C, the LM135, LM235, and LM335 have a typical error of less than 1°C over a 100°C temperature range. Unlike other sensors, the LM135, LM235, LM335 have a linear output.



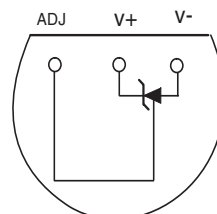
**TO-92**  
(Plastic package)



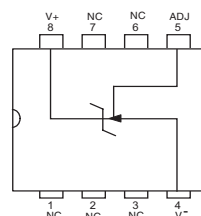
**SO-8**  
(Plastic micropackage)

### Pin connections

**TO-92**  
(Bottom view)

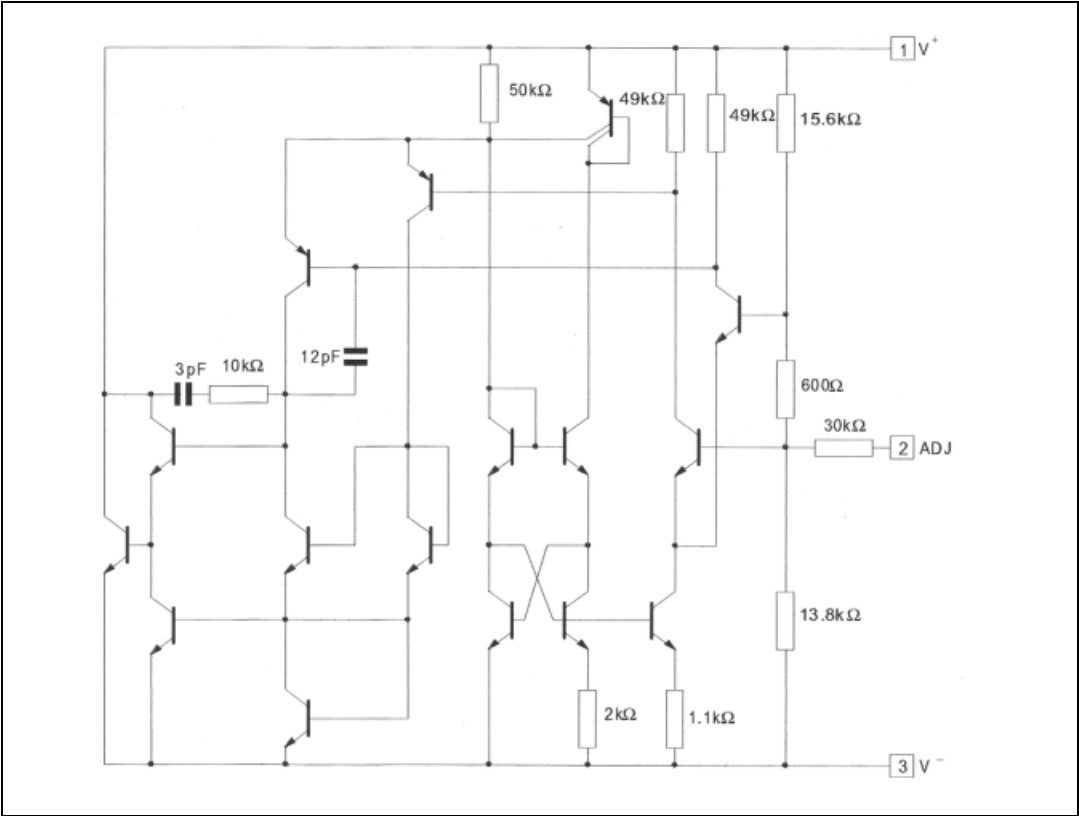


**SO-8**  
(Top view)



1 Schematic diagram

Figure 1. Schematic diagram



2 Absolute maximum ratings

Table 1. Absolute maximum ratings (AMR)

| Symbol         | Parameter                                                                            | LM135                       | LM235                       | LM335-<br>LM335A            | Unit |
|----------------|--------------------------------------------------------------------------------------|-----------------------------|-----------------------------|-----------------------------|------|
| $I_R$<br>$I_F$ | Current<br>Reverse<br>Forward                                                        |                             | 15<br>10                    |                             | mA   |
| $T_{oper}$     | Operating free-air temperature<br>range <sup>(1)</sup><br>Continuous<br>Intermittent | -55 to +150<br>+150 to +200 | -40 to +125<br>+125 to +150 | -40 to +100<br>+100 to +125 | °C   |
| $T_{stg}$      | Storage temperature range                                                            | -65 to +150                 |                             |                             | °C   |

1.  $T_j \leq 150^\circ\text{C}$

### 3 Temperature accuracy

**Table 2. Temperature accuracy**

| Parameter                                                                                                                                                                     | LM135 - LM235 - LM335A |            |          | LM335 |            |        | Unit               |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------|------------|----------|-------|------------|--------|--------------------|
|                                                                                                                                                                               | Min.                   | Typ.       | Max.     | Min.  | Typ.       | Max.   |                    |
| Operating output voltage<br>$T_{\text{case}} = +25^{\circ}\text{C}$ , $I_R = 1\text{mA}$                                                                                      | 2.95                   | 2.98       | 3.01     | 2.92  | 2.98       | 3.04   | V                  |
| Uncalibrated temperature error ( $I_R = 1\text{mA}$ )<br>$T_{\text{case}} = +25^{\circ}\text{C}$<br>$T_{\text{min}} \leq T_{\text{case}} \leq T_{\text{max}}$                 |                        | 1<br>2     | 3<br>5   |       | 4<br>5     | 6<br>9 | $^{\circ}\text{C}$ |
| Temperature error with $25^{\circ}\text{C}$ calibration<br>$T_{\text{min}} \leq T_{\text{case}} \leq T_{\text{max}}$ , $I_R = 1\text{mA}$<br>LM135 - LM235<br>LM335<br>LM335A |                        | 0.5<br>0.5 | 1.5<br>1 |       | 1<br>2     |        | $^{\circ}\text{C}$ |
| Calibrated error at extended temperature<br>$T_{\text{case}} = T_{\text{max}}$ (intermittent)                                                                                 |                        | 2          |          |       | 2          |        | $^{\circ}\text{C}$ |
| Non-linearity ( $I_R = 1\text{mA}$ )<br>LM135 - LM235<br>LM335<br>LM335A                                                                                                      |                        | 0.3<br>0.3 | 1<br>1.5 |       | 0.3<br>1.5 |        | $^{\circ}\text{C}$ |

### 4 Electrical characteristics

**Table 3. Electrical characteristics**

| Parameter                                                                                                         | LM135 - LM235 |               |      | LM335-LM335A |               |      | Unit                         |
|-------------------------------------------------------------------------------------------------------------------|---------------|---------------|------|--------------|---------------|------|------------------------------|
|                                                                                                                   | Min.          | Typ.          | Max. | Min.         | Typ.          | Max. |                              |
| Operating output voltage change with current<br>$450\mu\text{A} \leq I_R \leq 5\text{mA}$ at constant temperature |               | 2.5           | 10   |              | 3             | 14   | mV                           |
| Dynamic impedance ( $I_R = 1\text{mA}$ )                                                                          |               | 0.5           |      |              | 0.6           |      | $\Omega$                     |
| Output voltage temperature drift                                                                                  |               | +10           |      |              | +10           |      | mV/ $^{\circ}\text{C}$       |
| Time constant<br>Still air<br>Air 0.5m/s<br>Stirred oil                                                           |               | 80<br>10<br>1 |      |              | 80<br>10<br>1 |      | s                            |
| Time stability ( $T_{\text{case}} = +125^{\circ}\text{C}$ )                                                       |               | 0.2           |      |              | 0.2           |      | $^{\circ}\text{C}/\text{kh}$ |

**Note:** Accuracy measurements are made in a well-stirred oil bath. For other conditions, self-heating must be considered

Figure 2. Reverse voltage change

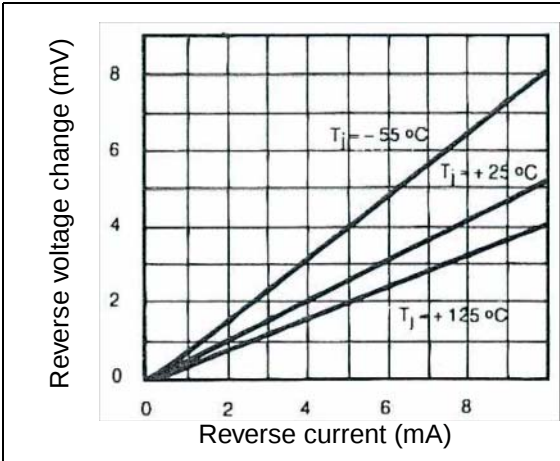


Figure 3. Calibrated error

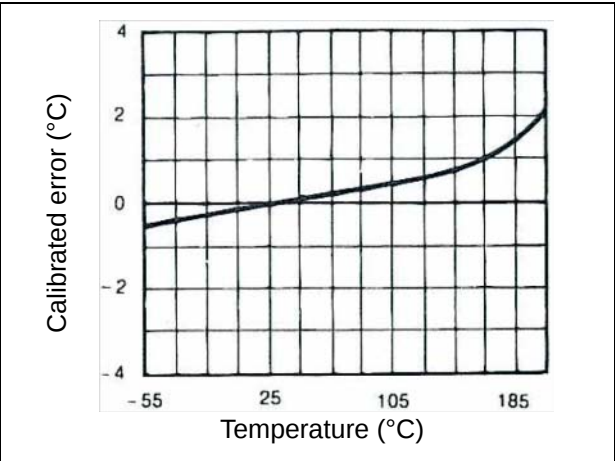


Figure 4. Reverse characteristics

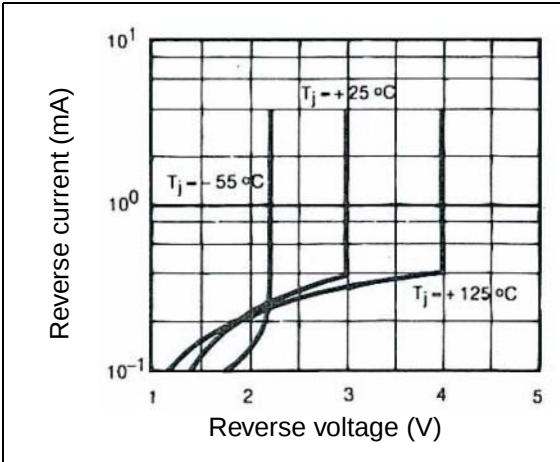


Figure 5. Response time

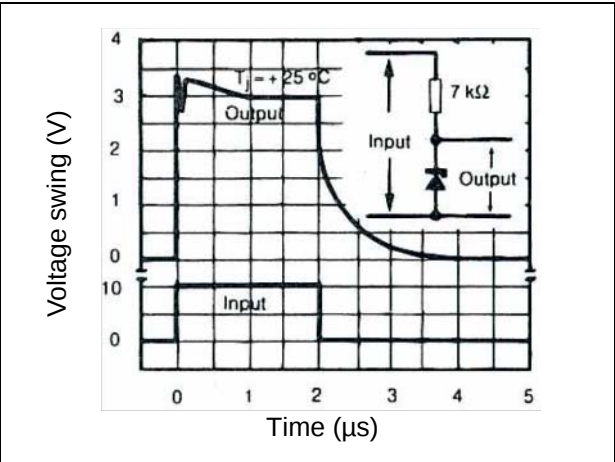


Figure 6. Dynamic impedance

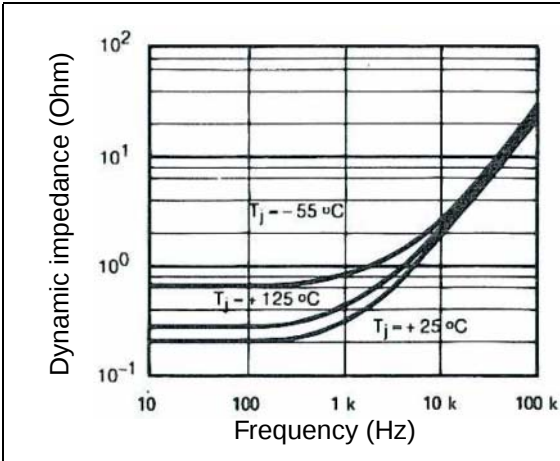


Figure 7. Noise voltage

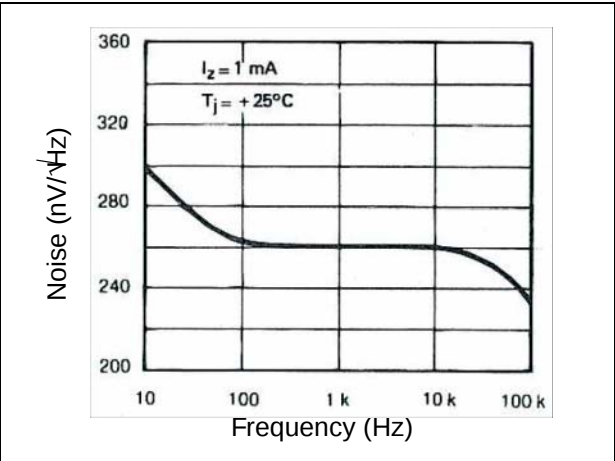


Figure 8. Thermal resistance junction to air

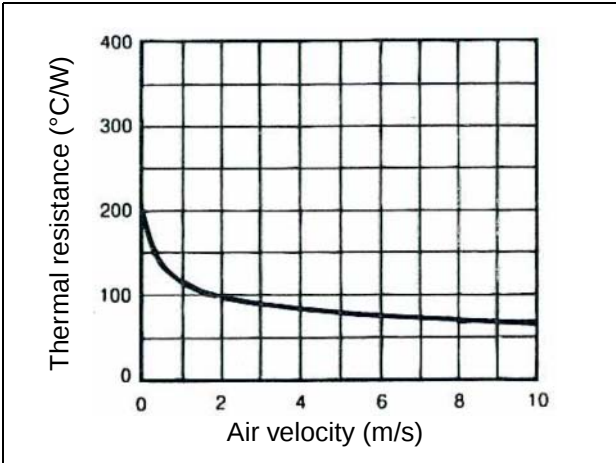


Figure 9. Thermal time constant

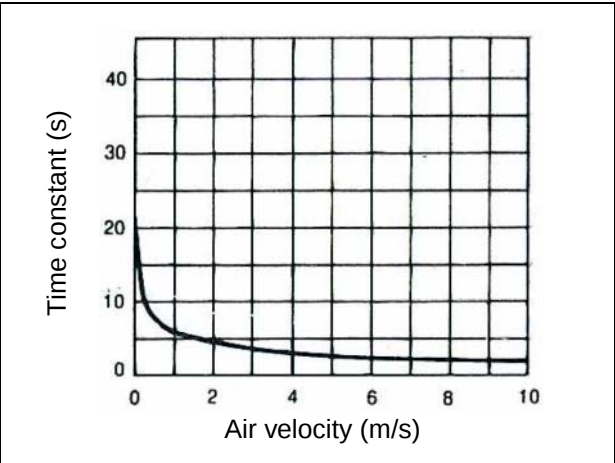


Figure 10. Thermal response in still air

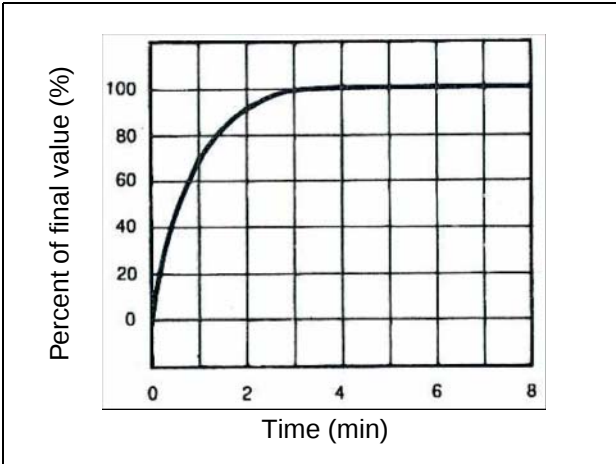


Figure 11. Thermal response in stirred oil bath

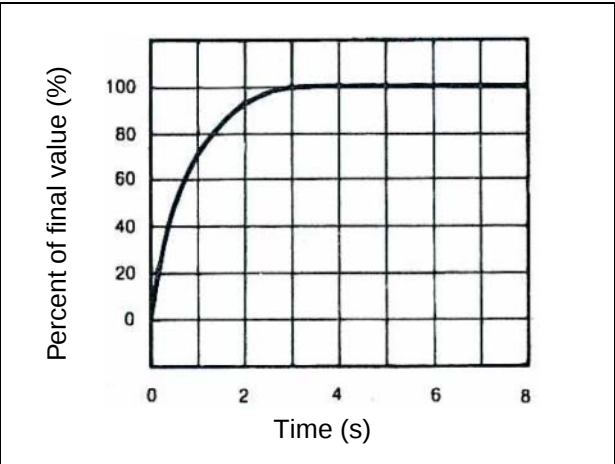
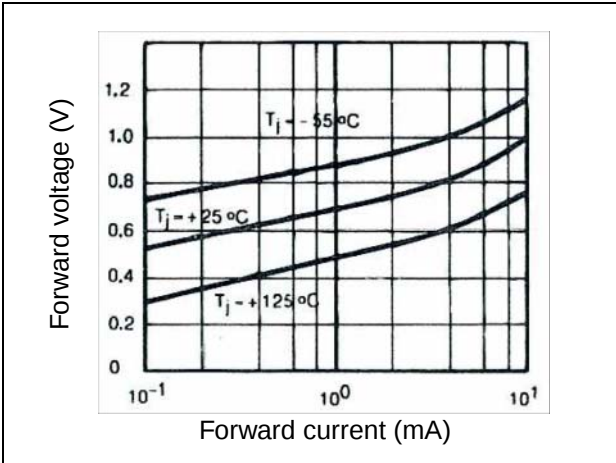


Figure 12. Forward characteristics



## 5 Application information

There is an easy method of calibrating the device for higher accuracies (see [Typical applications](#)).

The single point calibration works because the output of the LM135, LM235, LM335 is proportional to the absolute temperature with the extrapolated output of sensor going to 0V at 0°K (-273.15°C). Errors in output voltage versus temperature are only slope. Thus a calibration of the slope at one temperature corrects errors at all temperatures.

The circuit output (calibrated or not) is given by the equation:

$$V_{OT} + V_{OTO} \times \frac{T}{T_0}$$

where T is the unknown temperature and T<sub>0</sub> is the reference temperature (in °K).

Nominally, the output is calibrated at 10mV/°K.

Precautions should be taken to ensure good sensing accuracy. As in the case of all temperatures sensors, self-heating can decrease accuracy. The LM135, LM235, and LM335 should operate with a low current but sufficient to drive the sensor and its calibration circuit to their maximum operating temperature.

If the sensor is used in surroundings where the thermal resistance is constant, the errors due to self-heating can be externally calibrated. This is possible if the circuit is biased with a temperature stable current. Heating will then be proportional to Zener voltage and therefore temperature. In this way, the error due to self-heating is proportional to the absolute temperature as scale factor errors.

### Typical applications

Figure 13. Basic temperature sensor

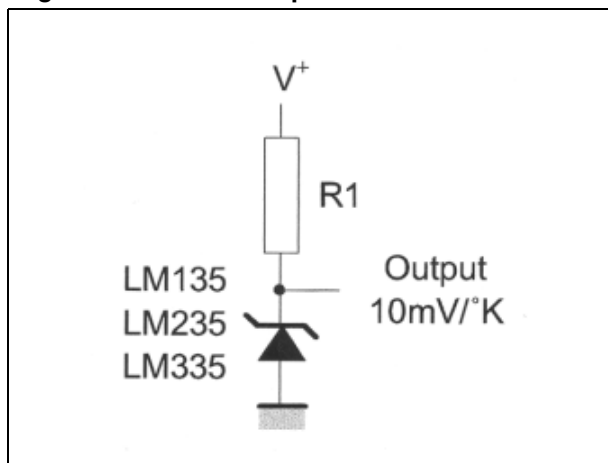


Figure 14. Wide operating supply

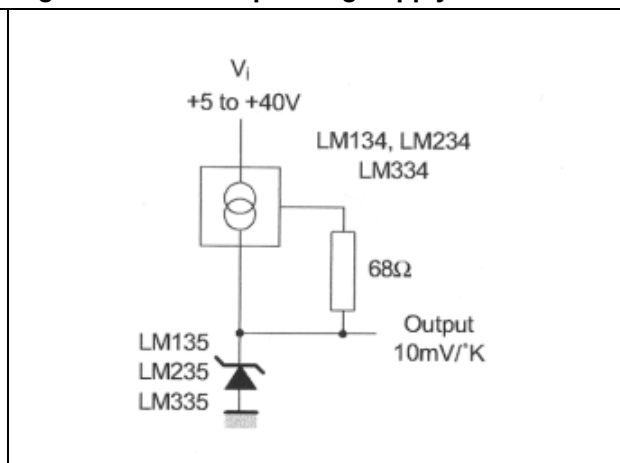


Figure 15. Calibrated sensor

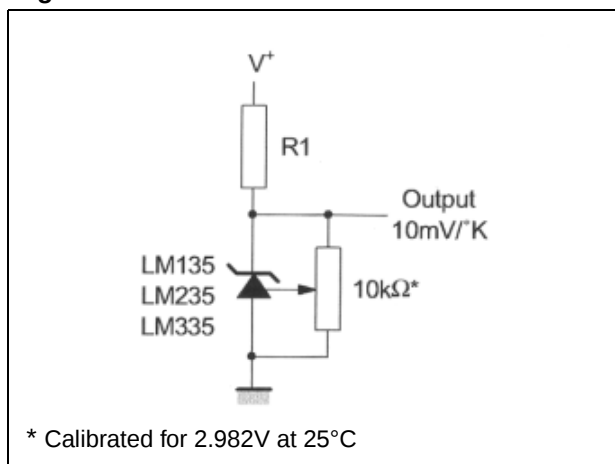


Figure 16. Average temperature sensing

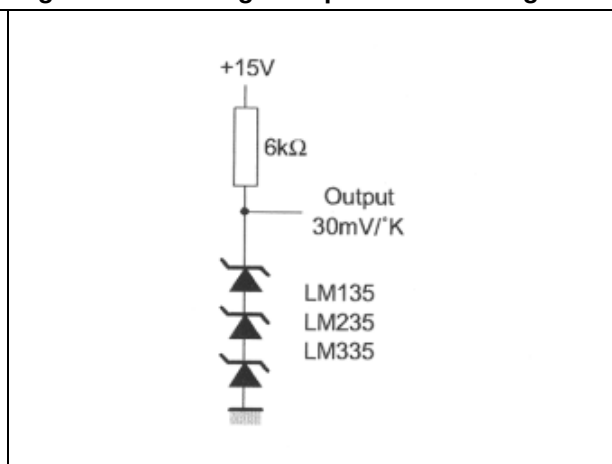


Figure 17. Isolated temperature sensor

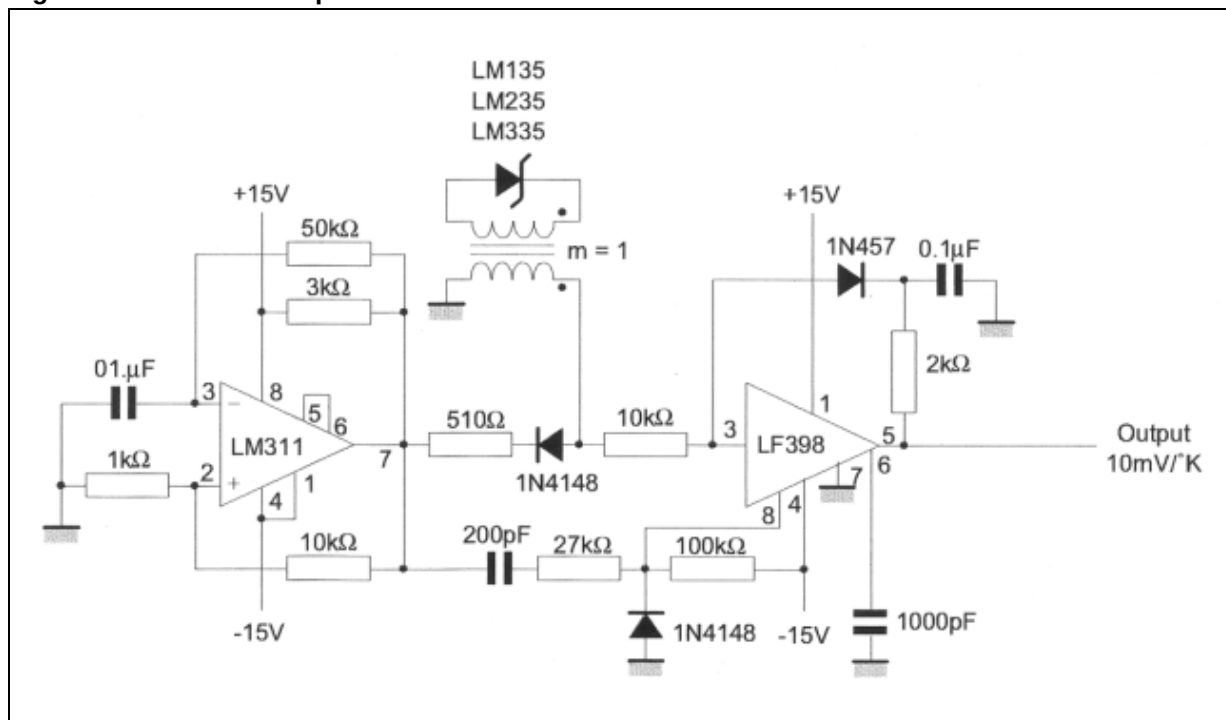


Figure 18. Simple temperature controller

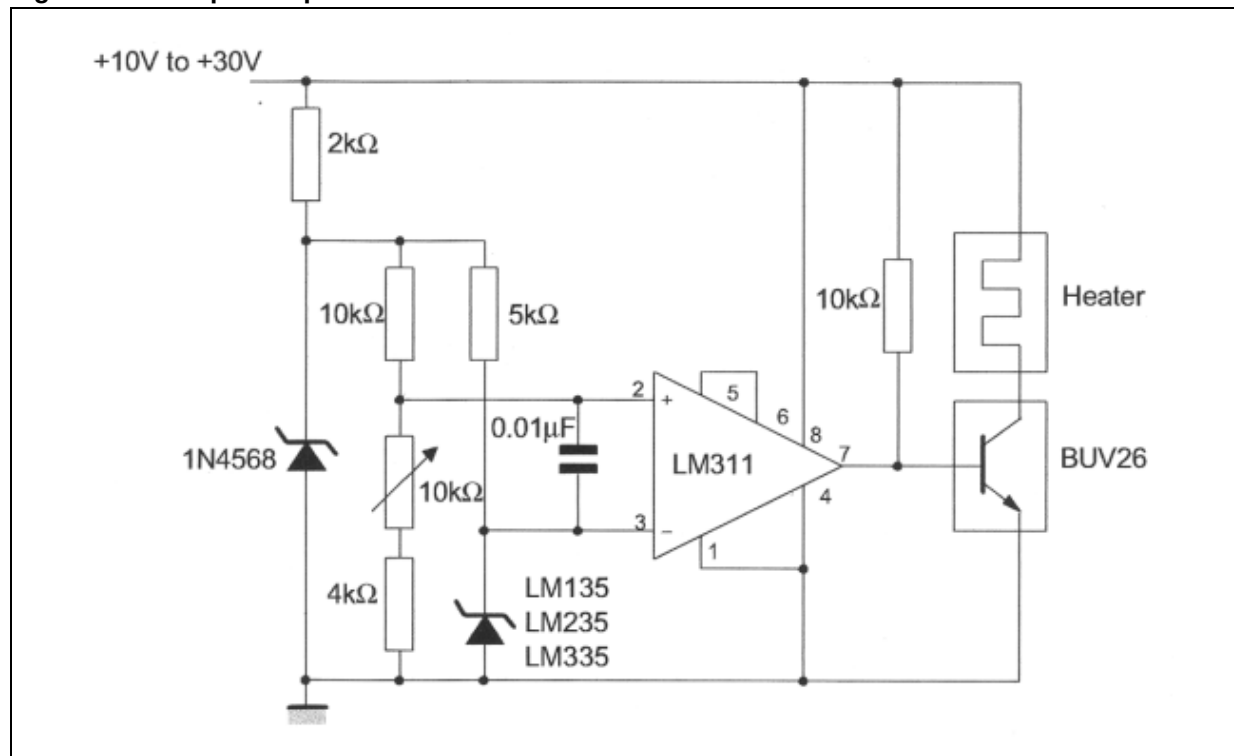


Figure 19. Centigrade thermometer

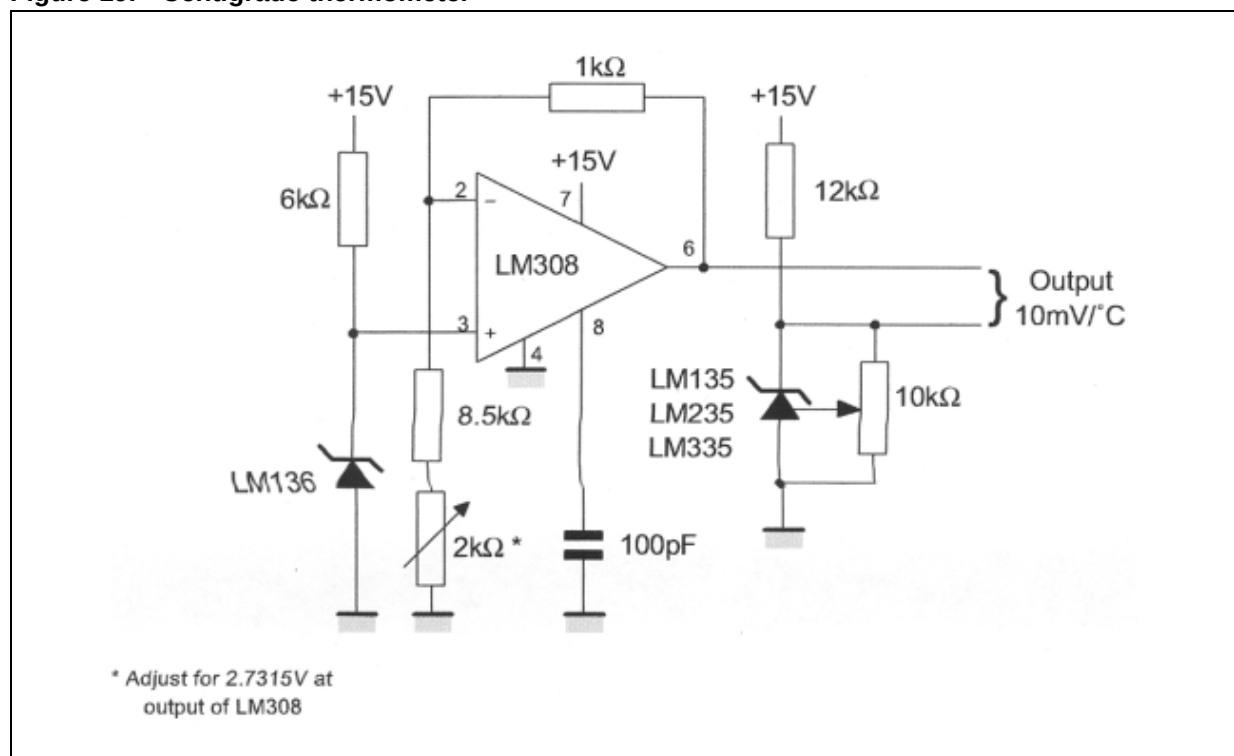


Figure 20. Differential temperature sensor

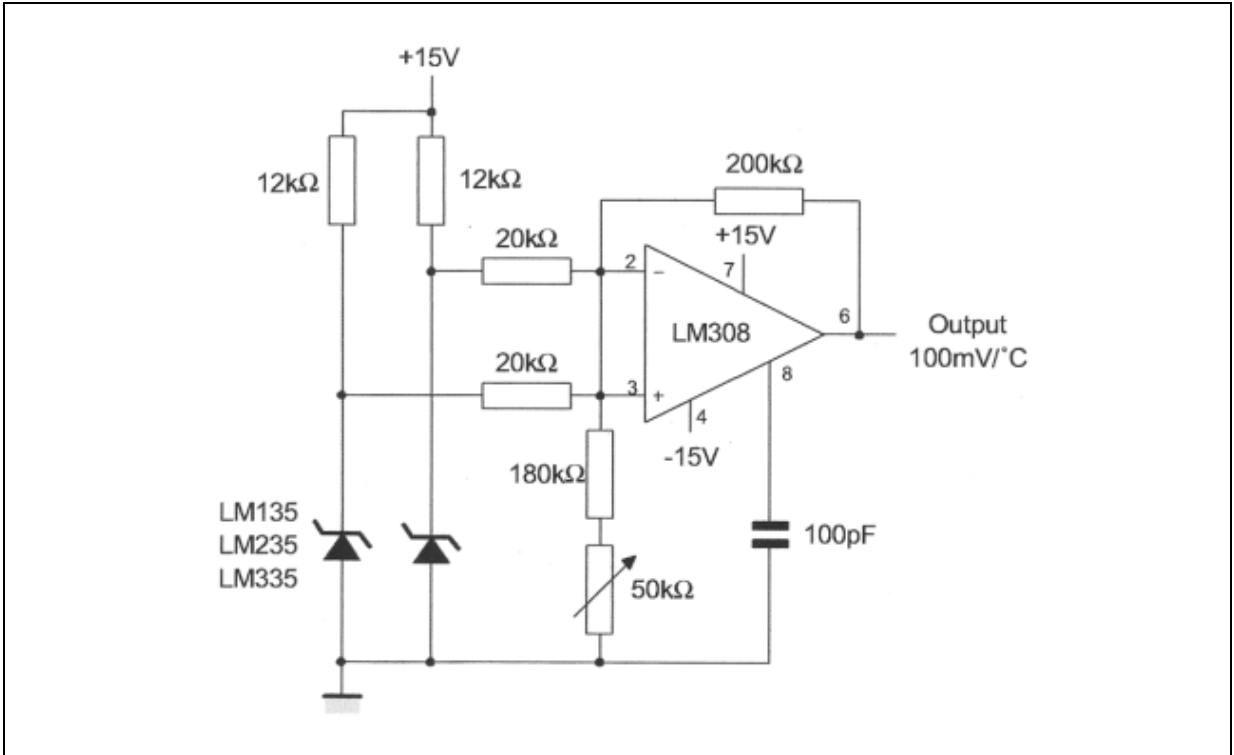


Figure 21. Thermocouple cold junction compensation (compensation for grounded thermocouple)

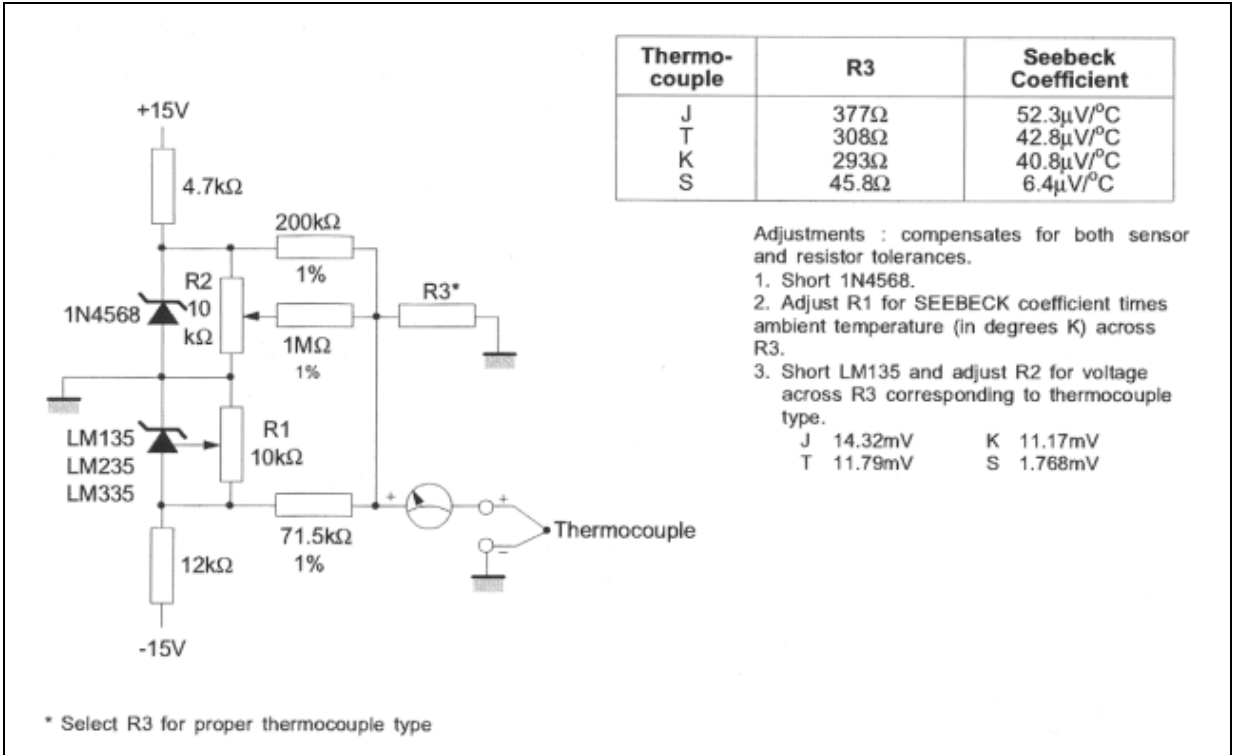
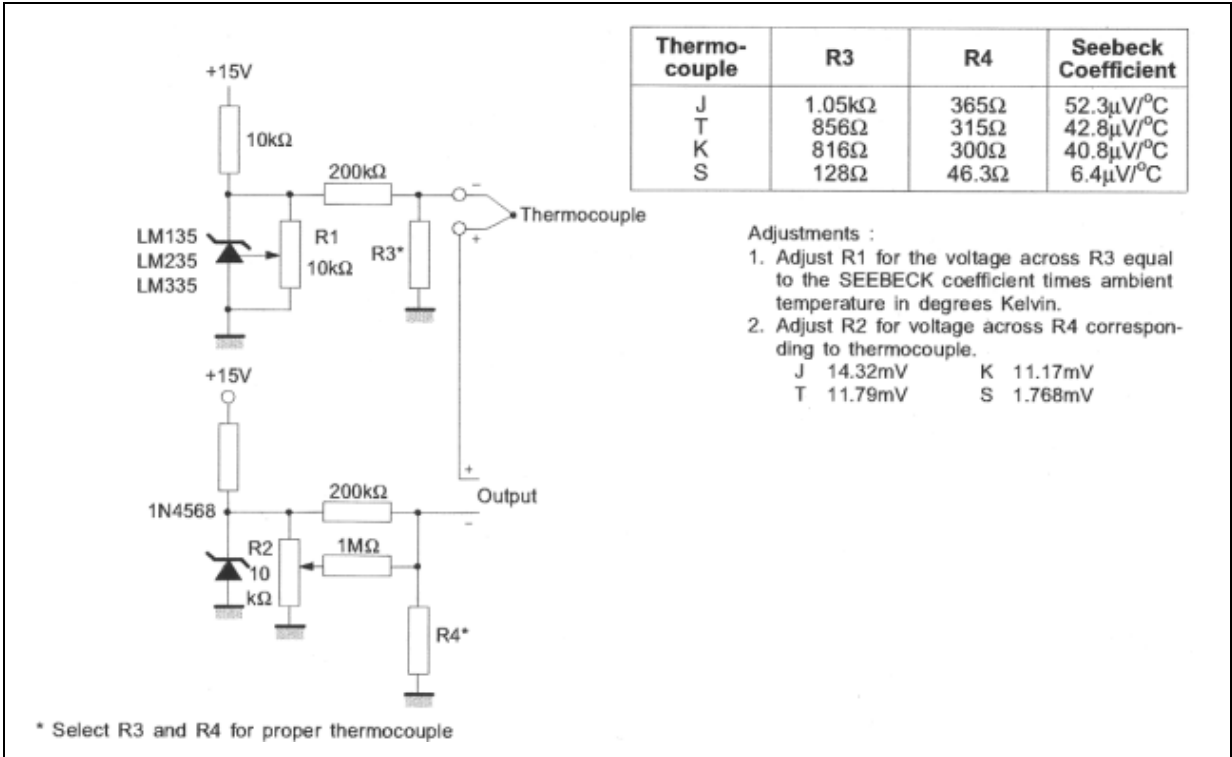


Figure 22. Single power supply cold junction compensation



## 6 Package information

In order to meet environmental requirements, STMicroelectronics offers these devices in ECOPACK® packages. These packages have a lead-free second level interconnect. The category of second level interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label. ECOPACK is an STMicroelectronics trademark. ECOPACK specifications are available at: [www.st.com](http://www.st.com).

### 6.1 TO-92 tape & reel package information

Figure 23. TO-92 tape & reel package mechanical drawing

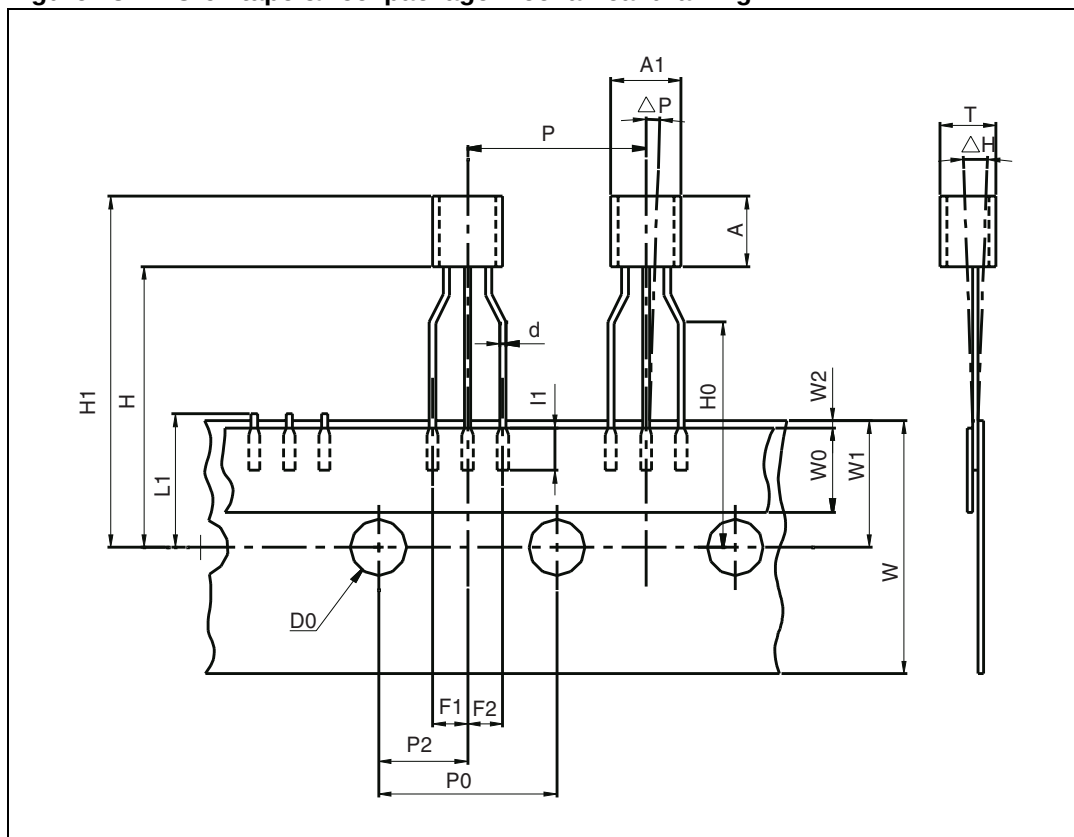


Table 4. TO-92 tape &amp; reel package mechanical data

| Dim.       | Millimeters |      |      | Inches |       |       |
|------------|-------------|------|------|--------|-------|-------|
|            | Min.        | Typ. | Max. | Min.   | Typ.  | Max.  |
| AL         |             |      | 5.0  |        |       | 0.197 |
| A          |             |      | 5.0  |        |       | 0.197 |
| T          |             |      | 4.0  |        |       | 0.157 |
| d          |             | 0.45 |      |        | 0.018 |       |
| l1         | 2.5         |      |      | 0.098  |       |       |
| P          | 11.7        | 12.7 | 13.7 | 0.461  | 0.500 | 0.539 |
| PO         | 12.4        | 12.7 | 13   | 0.488  | 0.500 | 0.512 |
| P2         | 5.95        | 6.35 | 6.75 | 0.234  | 0.250 | 0.266 |
| F1/F2      | 2.4         | 2.5  | 2.8  | 0.094  | 0.098 | 0.110 |
| $\Delta h$ | -1          | 0    | 1    | -0.039 | 0     | 0.039 |
| $\Delta P$ | -1          | 0    | 1    | -0.039 | 0     | 0.039 |
| W          | 17.5        | 18.0 | 19.0 | 0.689  | 0.709 | 0.748 |
| W0         | 5.7         | 6    | 6.3  | 0.224  | 0.236 | 0.248 |
| W1         | 8.5         | 9    | 9.75 | 0.335  | 0.354 | 0.384 |
| W2         |             |      | 0.5  |        |       | 0.020 |
| H          |             |      | 20   |        |       | 0.787 |
| H0         | 15.5        | 16   | 16.5 | 0.610  | 0.630 | 0.650 |
| H1         |             |      | 25   |        |       | 0.984 |
| DO         | 3.8         | 4.0  | 4.2  | 0.150  | 0.157 | 0.165 |
| L1         |             |      | 11   |        |       | 0.433 |

## 6.2 TO-92 bulk package information

Figure 24. TO-92 bulk package mechanical drawing

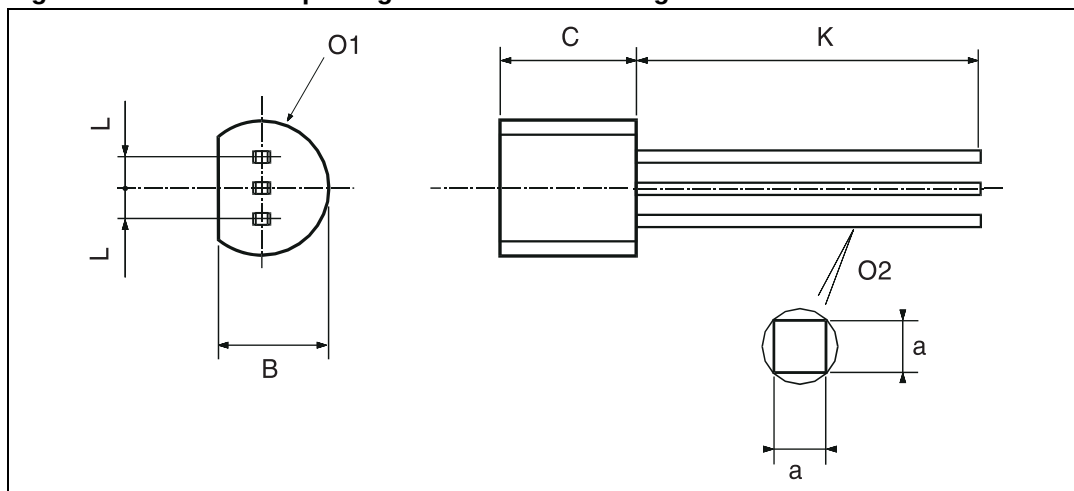


Table 5. TO-92 bulk package mechanical data

| Dim. | Millimeters |      |       | Inches |        |        |
|------|-------------|------|-------|--------|--------|--------|
|      | Min.        | Typ. | Max.  | Min.   | Typ.   | Max.   |
| L    |             | 1.27 |       |        | 0.05   |        |
| B    | 3.2         | 3.7  | 4.2   | 0.126  | 0.1457 | 0.1654 |
| O1   | 4.45        | 5.00 | 5.2   | 0.1752 | 0.1969 | 0.2047 |
| C    | 4.58        | 5.03 | 5.33  | 0.1803 | 0.198  | 0.2098 |
| K    | 12.7        |      |       | 0.5    |        |        |
| O2   | 0.407       | 0.5  | 0.508 | 0.016  | 0.0197 | 0.02   |
| a    | 0.35        |      |       | 0.0138 |        |        |

## 6.3 SO-8 package information

Figure 25. SO-8 package mechanical drawing

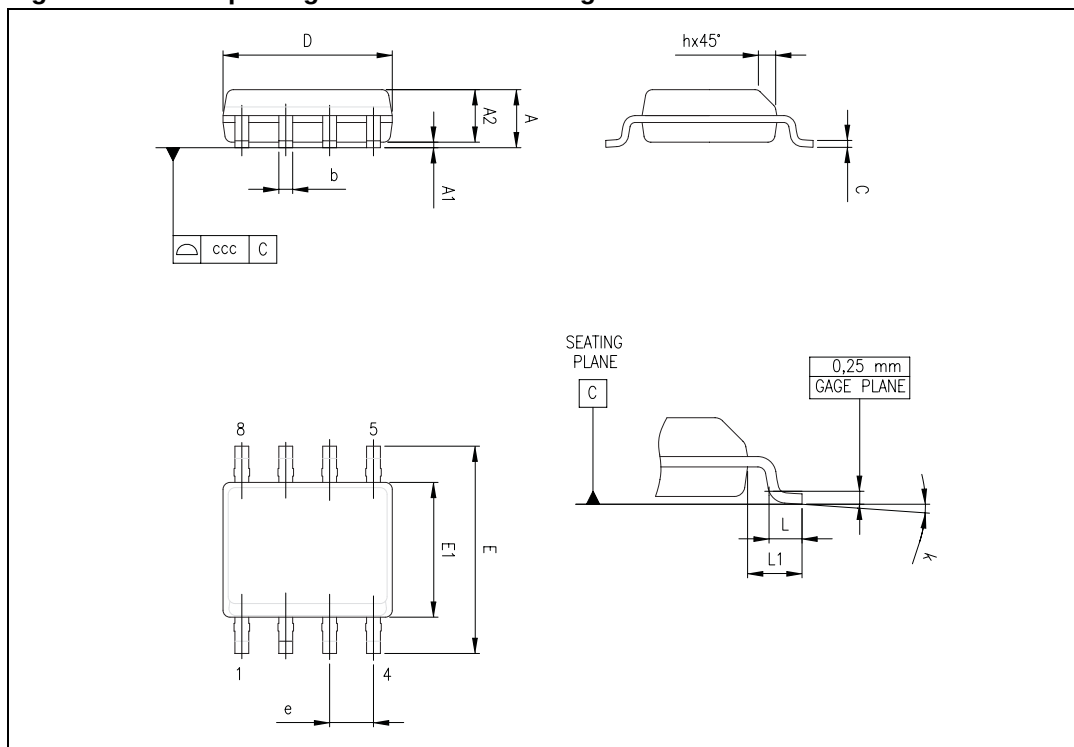


Table 6. SO-8 package mechanical data

| Ref. | Dimensions  |      |      |        |       |       |
|------|-------------|------|------|--------|-------|-------|
|      | Millimeters |      |      | Inches |       |       |
|      | Min.        | Typ. | Max. | Min.   | Typ.  | Max.  |
| A    |             |      | 1.75 |        |       | 0.069 |
| A1   | 0.10        |      | 0.25 | 0.004  |       | 0.010 |
| A2   | 1.25        |      |      | 0.049  |       |       |
| b    | 0.28        |      | 0.48 | 0.011  |       | 0.019 |
| c    | 0.17        |      | 0.23 | 0.007  |       | 0.010 |
| D    | 4.80        | 4.90 | 5.00 | 0.189  | 0.193 | 0.197 |
| H    | 5.80        | 6.00 | 6.20 | 0.228  | 0.236 | 0.244 |
| E1   | 3.80        | 3.90 | 4.00 | 0.150  | 0.154 | 0.157 |
| e    |             | 1.27 |      |        | 0.050 |       |
| h    | 0.25        |      | 0.50 | 0.010  |       | 0.020 |
| L    | 0.40        |      | 1.27 | 0.016  |       | 0.050 |
| k    | 1°          |      | 8°   | 1°     |       | 8°    |
| ccc  |             |      | 0.10 |        |       | 0.004 |

## 7 Ordering information

**Table 7. Order codes**

| Order code          | Temperature range | Package | Packing                | Marking |
|---------------------|-------------------|---------|------------------------|---------|
| LM135Z              | -55°C to +150°C   | TO-92   | Bulk                   | LM135   |
| LM235D<br>LM235DT   | -40°C to +125°C   | SO-8    | Tube or<br>Tape & reel | LM235   |
| LM235Z              | -40°C to +125°C   | TO-92   | Bulk                   | LM235   |
| LM335D<br>LM335DT   | -40°C to +100°C   | SO-8    | Tube or<br>Tape & reel | LM335   |
| LM335AD<br>LM335ADT |                   |         |                        | LM335A  |
| LM335Z              | -40°C to +100°C   | TO-92   | Bulk                   | LM335   |
| LM335AZ<br>LM335AZT |                   |         | Bulk or<br>Tape & reel | LM335A  |

## 8 Revision history

**Table 8. Document revision history**

| Date          | Revision | Changes                                                                                                                                                                                                                                                 |
|---------------|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 6-May-2003    | 1        | Initial release.                                                                                                                                                                                                                                        |
| 13-April-2004 | 2        | Corrected error in pinout diagram for TO-92 package on cover page (it is a bottom view, not a top view).                                                                                                                                                |
| 11-Feb-2007   | 3        | Updated <a href="#">Section 6: Package information</a> and <a href="#">Table 7: Order codes</a> .<br>Corrected typical values for uncalibrated temperature error in <a href="#">Table 2</a> .<br>Improved quality of electrical characteristics curves. |

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