



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.



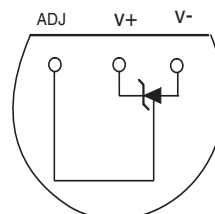
TO-92
(Plastic package)



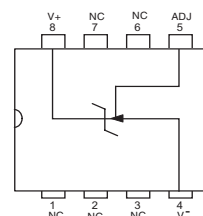
SO-8
(Plastic micropackage)

Pin connections

TO-92
(Bottom view)



SO-8
(Top view)



3 Temperature accuracy

Table 2. Temperature accuracy

| Parameter | LM135 - LM235 - LM335A | | | LM335 | | | Unit |
|--|------------------------|------------|----------|-------|------------|--------|--------------------|
| | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| Operating output voltage $T_{\text{case}} = +25^{\circ}\text{C}$, $I_{\text{R}} = 1\text{mA}$ | 2.95 | 2.98 | 3.01 | 2.92 | 2.98 | 3.04 | V |
| Uncalibrated temperature error ($I_{\text{R}} = 1\text{mA}$) $T_{\text{case}} = +25^{\circ}\text{C}$ $T_{\text{min}} \leq T_{\text{case}} \leq T_{\text{max}}$ | | 1 2 | 3 5 | | 4 5 | 6 9 | $^{\circ}\text{C}$ |
| Temperature error with 25°C calibration $T_{\text{min}} \leq T_{\text{case}} \leq T_{\text{max}}$, $I_{\text{R}} = 1\text{mA}$ LM135 - LM235 LM335 LM335A | | 0.5 0.5 | 1.5 1 | | 1 2 | | $^{\circ}\text{C}$ |
| Calibrated error at extended temperature $T_{\text{case}} = T_{\text{max}}$ (intermittent) | | 2 | | | 2 | | $^{\circ}\text{C}$ |
| Non-linearity ($I_{\text{R}} = 1\text{mA}$) LM135 - LM235 LM335 LM335A | | 0.3 0.3 | 1 1.5 | | 0.3 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 $450\mu\text{A} \leq I_{\text{R}} \leq 5\text{mA}$ at constant temperature | | 2.5 | 10 | | 3 | 14 | mV |
| Dynamic impedance ($I_{\text{R}} = 1\text{mA}$) | | 0.5 | | | 0.6 | | Ω |
| Output voltage temperature drift | | +10 | | | +10 | | mV/ $^{\circ}\text{C}$ |
| Time constant Still air Air 0.5m/s Stirred oil | | 80 10 1 | | | 80 10 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

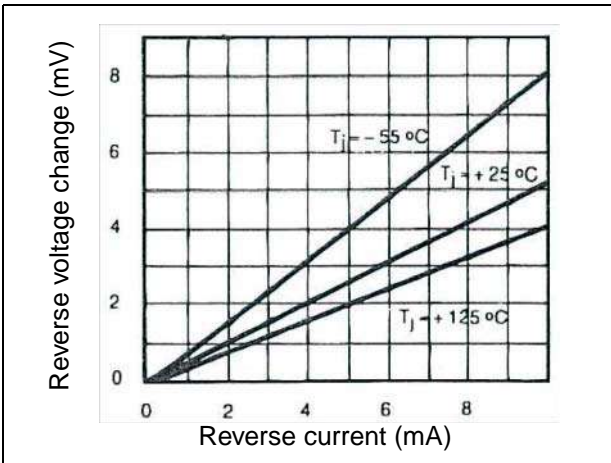


Figure 3. Calibrated error

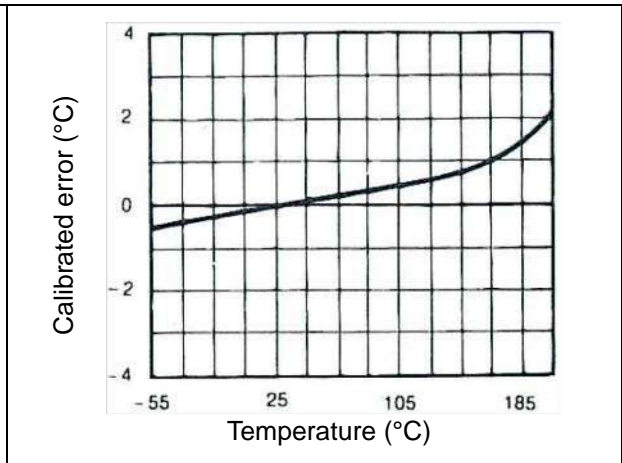


Figure 4. Reverse characteristics

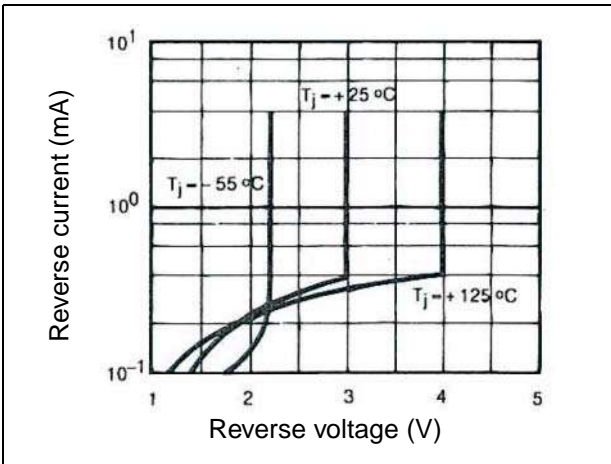


Figure 5. Response time

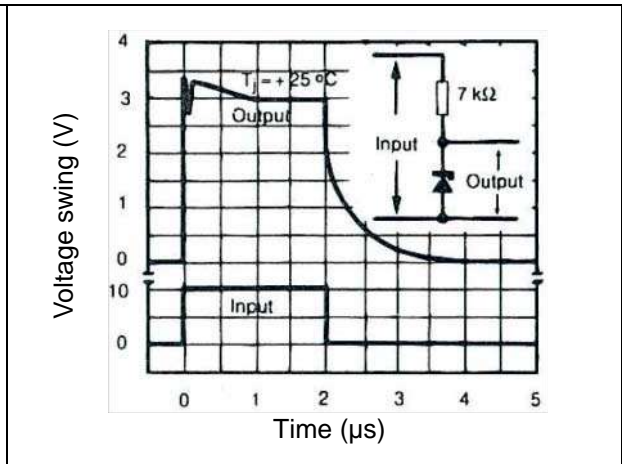


Figure 6. Dynamic impedance

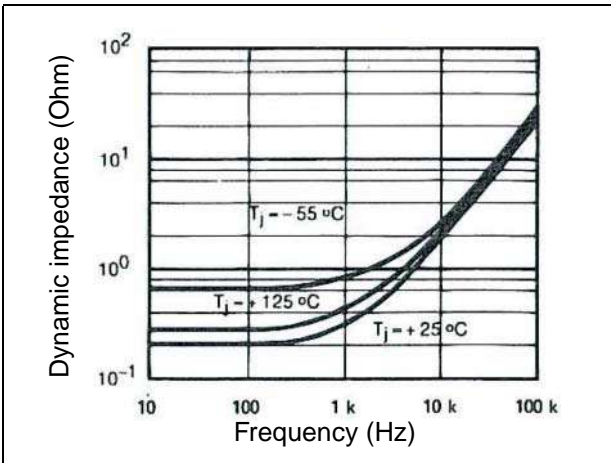


Figure 7. Noise voltage

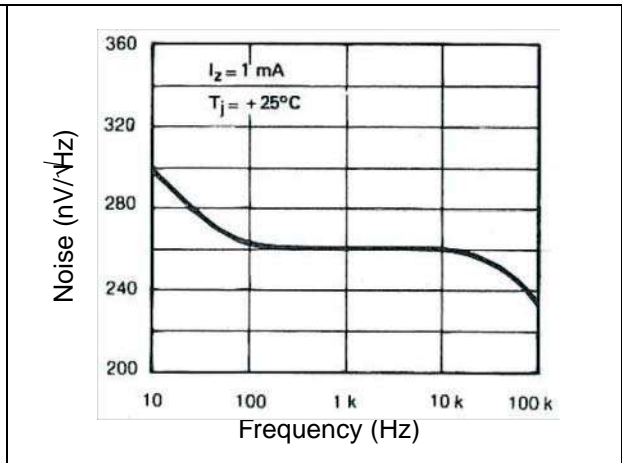


Figure 8. Thermal resistance junction to air

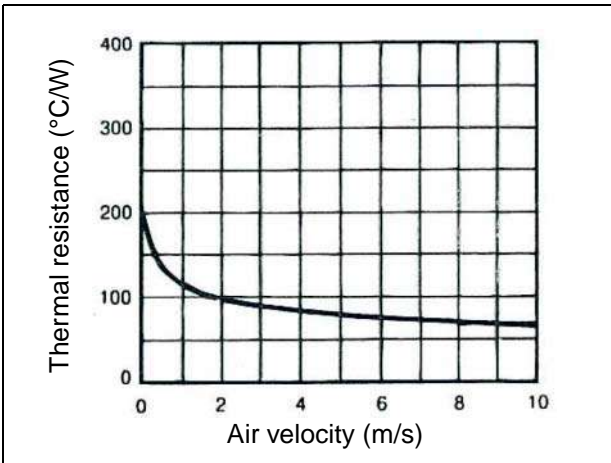


Figure 9. Thermal time constant

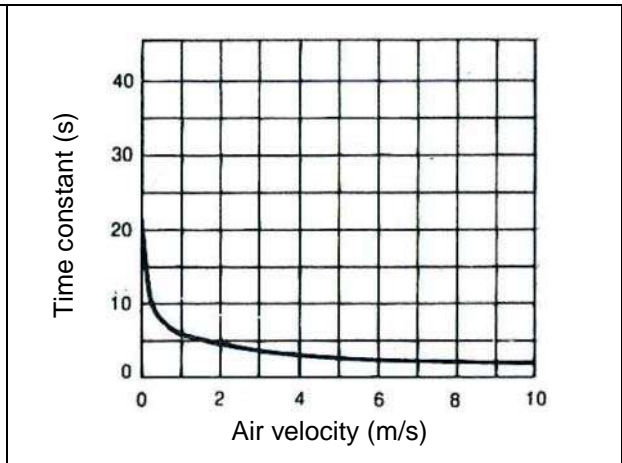


Figure 10. Thermal response in still air

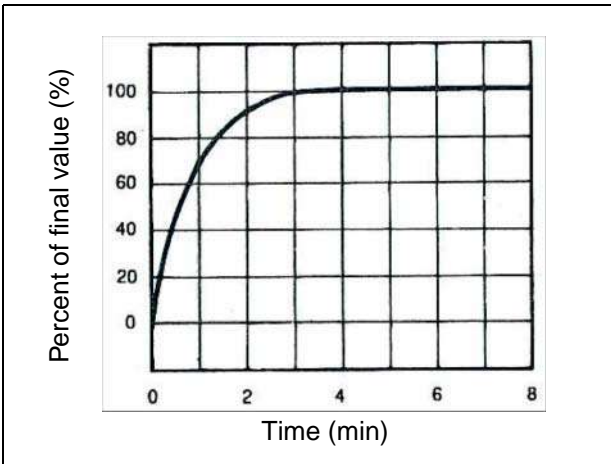


Figure 11. Thermal response in stirred oil bath

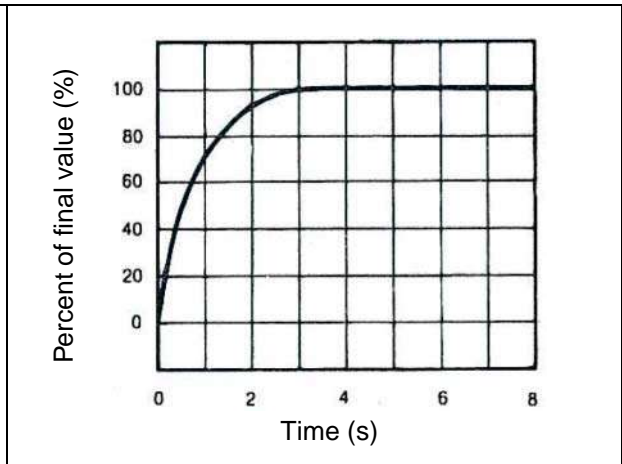
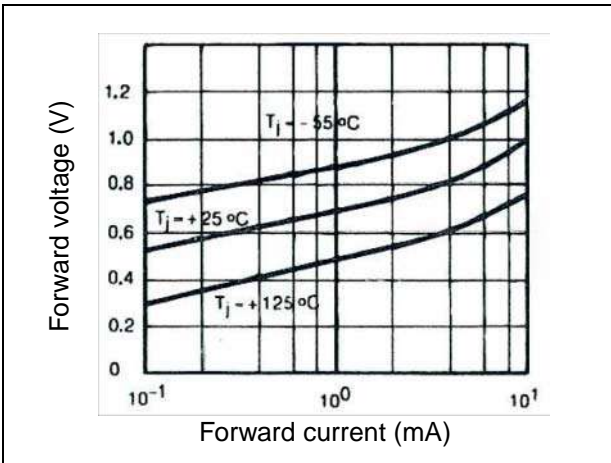


Figure 12. Forward characteristics



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:

$$V_{OT} + VO_{TO} \times \frac{T}{T_0}$$

where T is the unknown temperature and T₀ 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

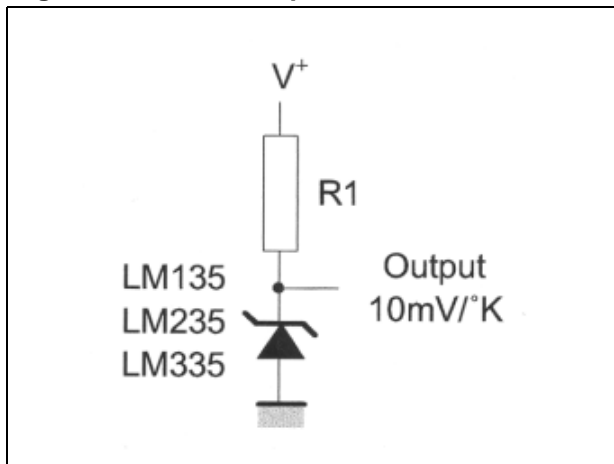


Figure 14. Wide operating supply

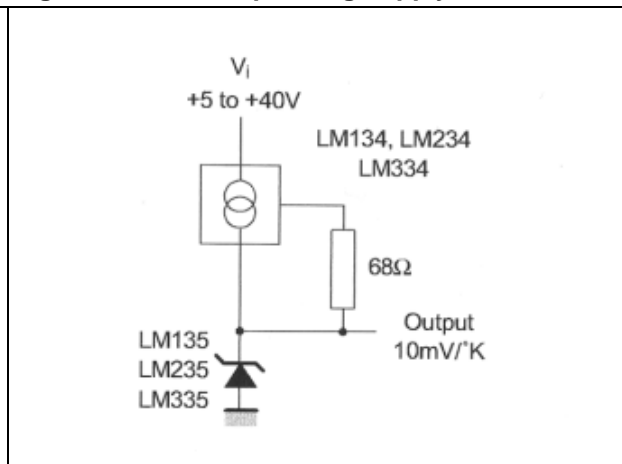


Figure 15. Calibrated sensor

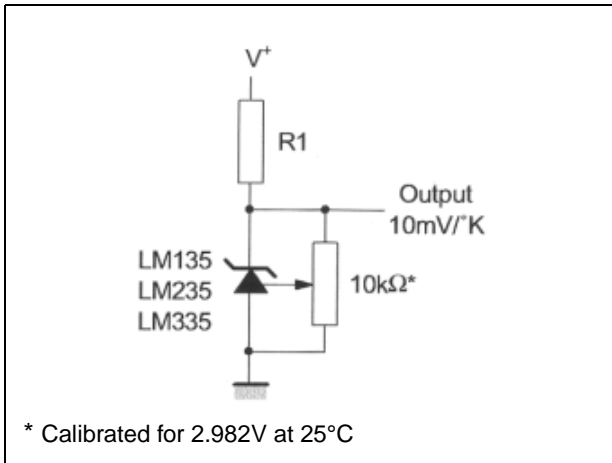


Figure 16. Average temperature sensing

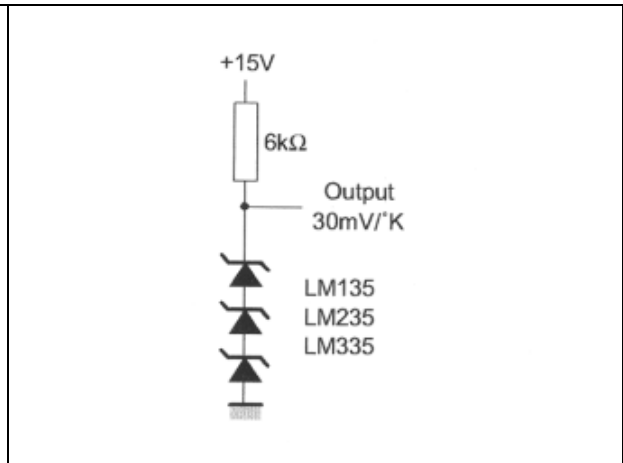


Figure 17. Isolated temperature sensor

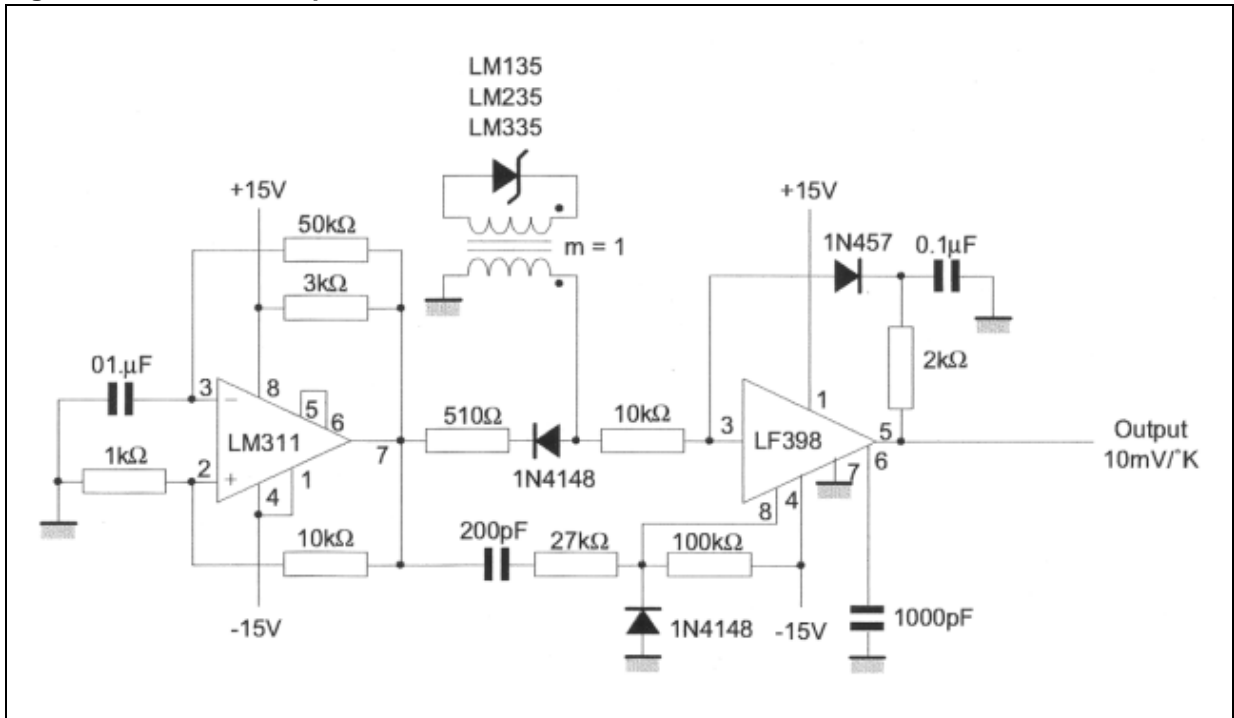


Figure 18. Simple temperature controller

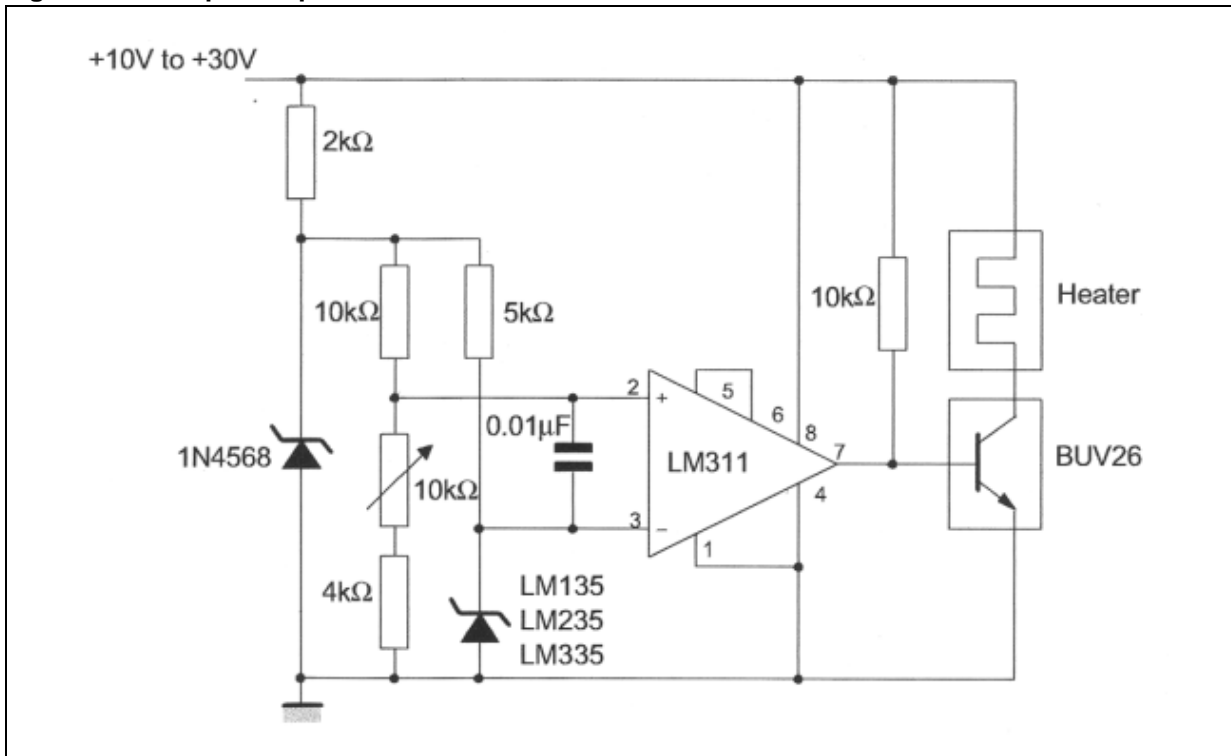


Figure 19. Centigrade thermometer

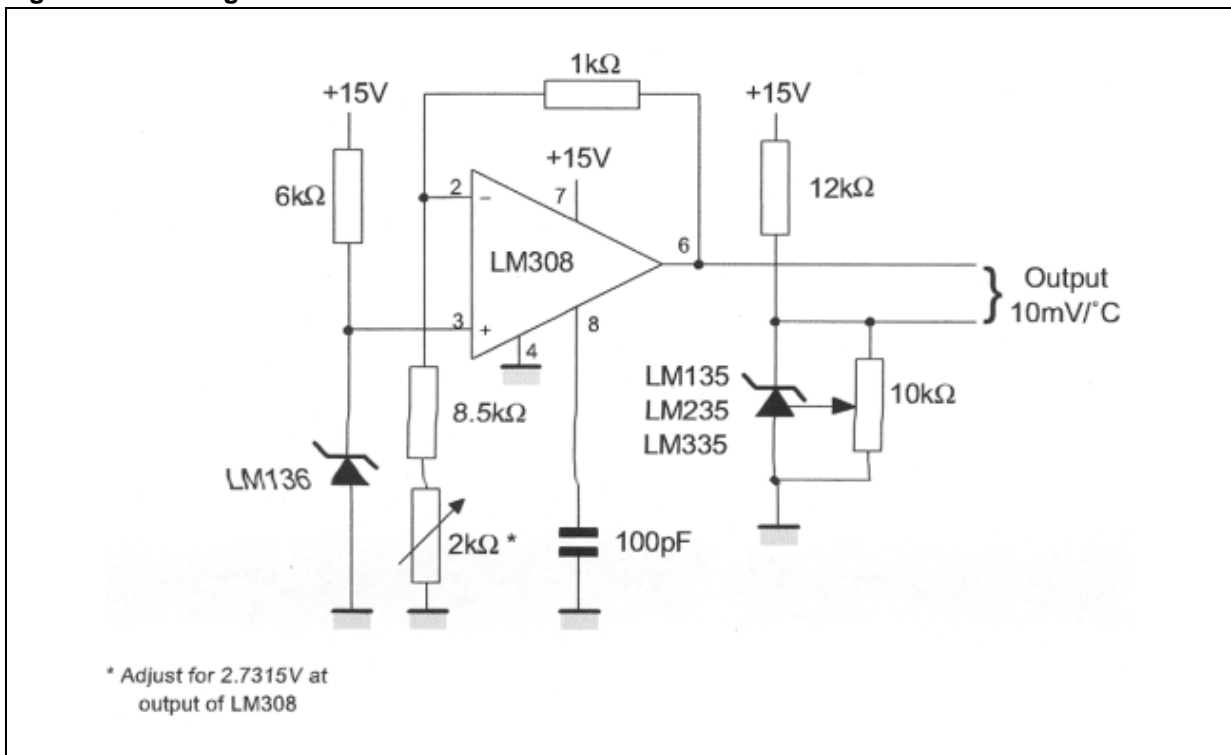


Figure 20. Differential temperature sensor

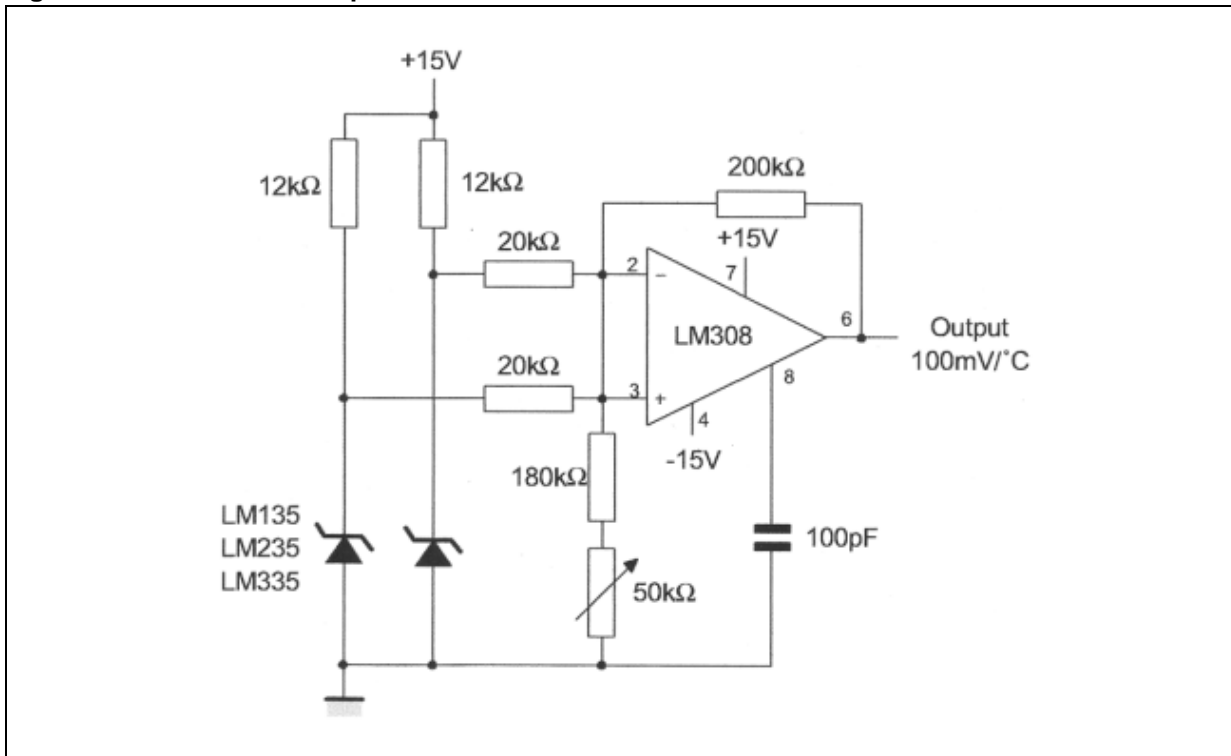


Figure 21. Thermocouple cold junction compensation (compensation for grounded thermocouple)

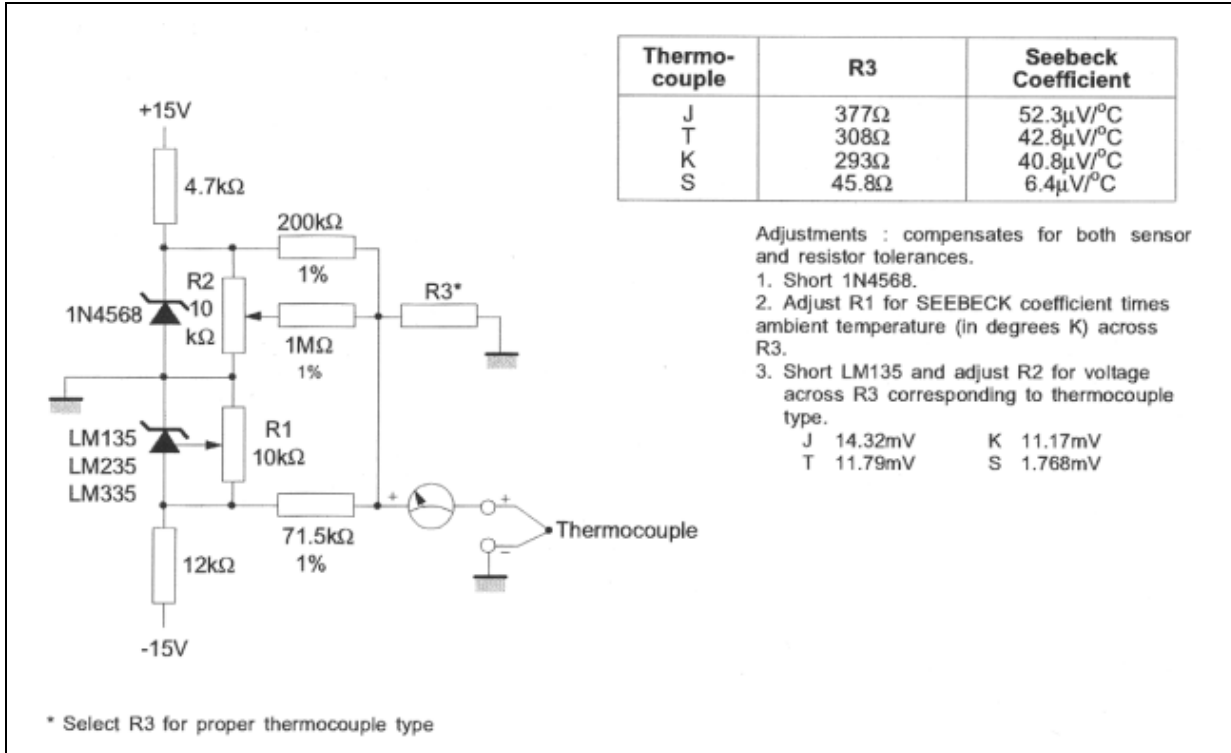
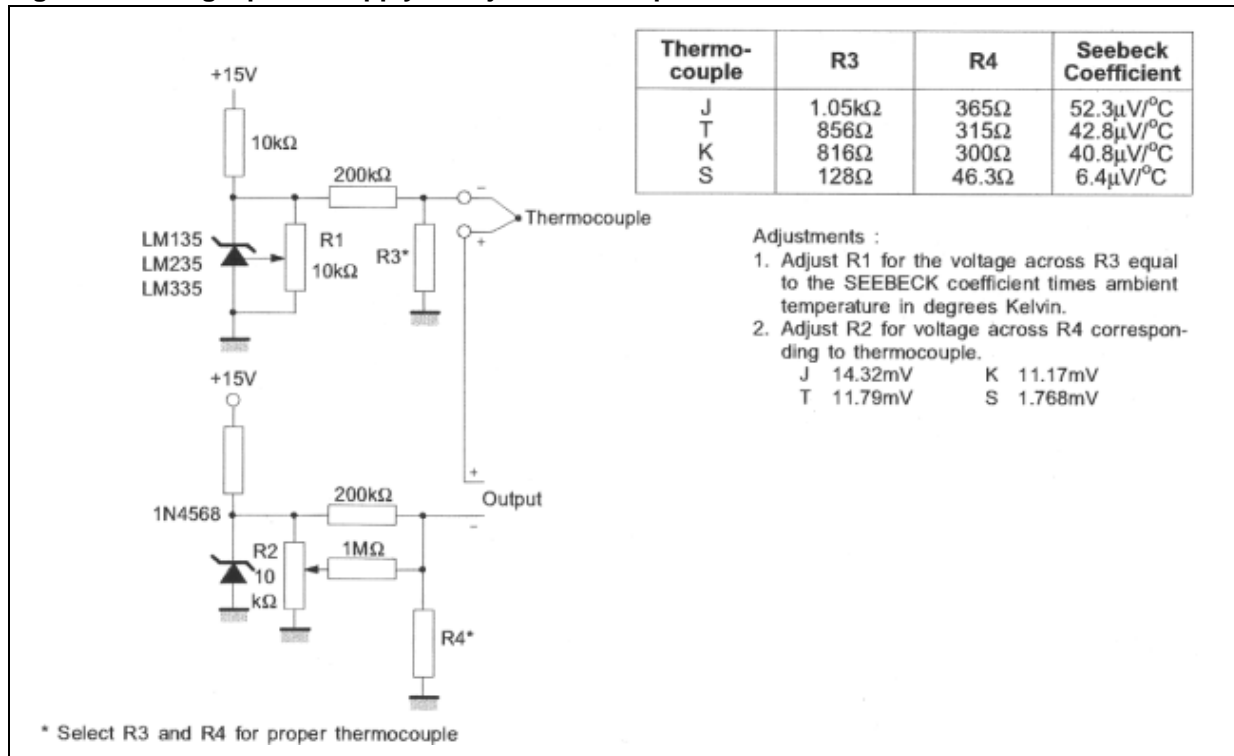


Figure 22. Single power supply cold junction compensation



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.

6.1 TO-92 tape & reel package information

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

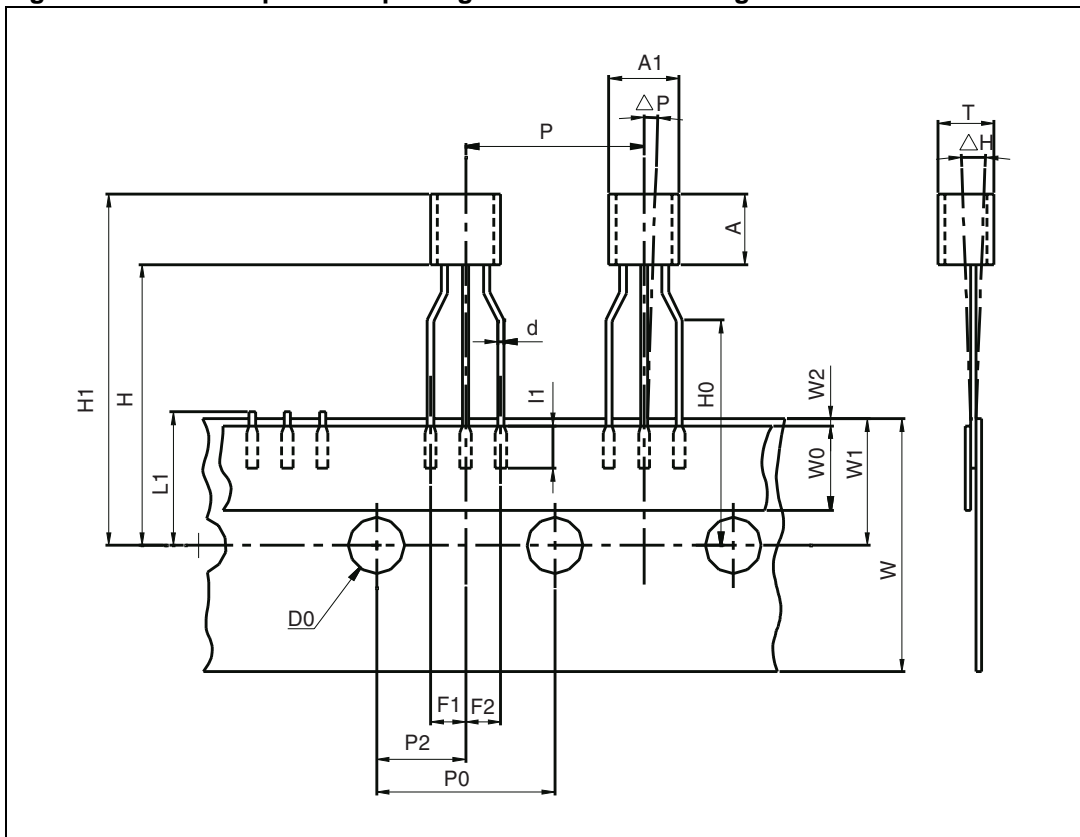


Table 4. TO-92 tape & reel package mechanical data

| 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 |
| Δh | -1 | 0 | 1 | -0.039 | 0 | 0.039 |
| ΔP | -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

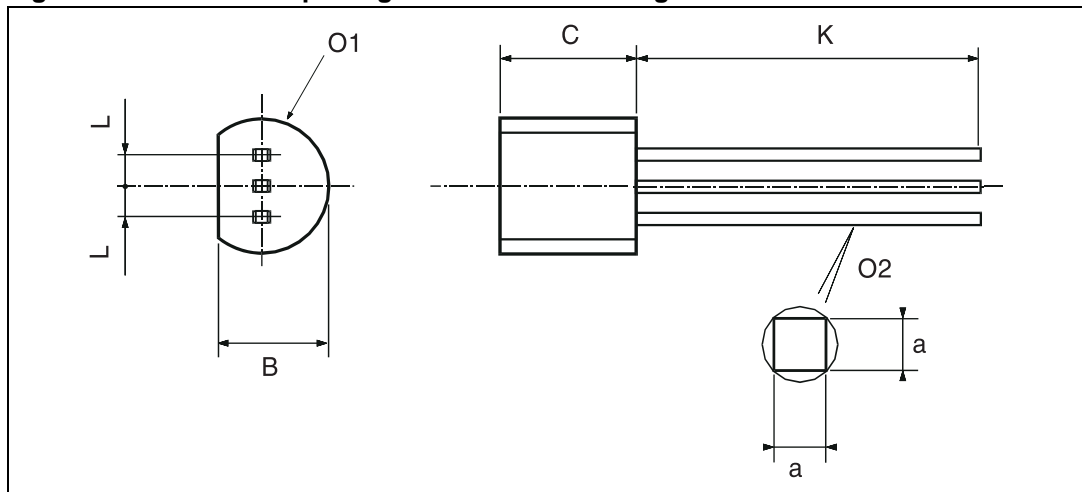


Table 5. TO-92 bulk package mechanical data

| 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

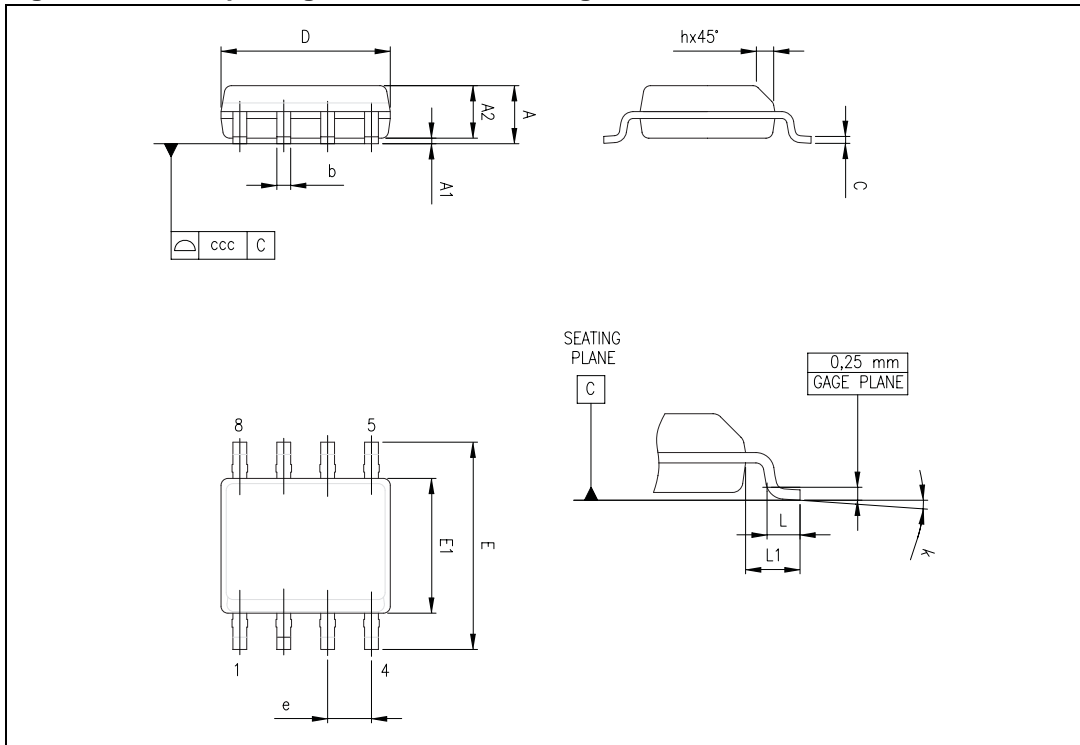


Table 6. SO-8 package mechanical data

| 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 LM235DT | -40°C to +125°C | SO-8 | Tube or Tape & reel | LM235 |
| LM235Z | -40°C to +125°C | TO-92 | Bulk | LM235 |
| LM335D LM335DT | -40°C to +100°C | SO-8 | Tube or Tape & reel | LM335 |
| LM335AD LM335ADT | | | | LM335A |
| LM335Z | -40°C to +100°C | TO-92 | Bulk | LM335 |
| LM335AZ LM335AZT | | | Bulk or 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 Section 6: Package information and Table 7: Order codes . Corrected typical values for uncalibrated temperature error in Table 2 . Improved quality of electrical characteristics curves. |

Please Read Carefully:

Information in this document is provided solely in connection with ST products. STMicroelectronics NV and its subsidiaries ("ST") reserve the right to make changes, corrections, modifications or improvements, to this document, and the products and services described herein at any time, without notice.

All ST products are sold pursuant to ST's terms and conditions of sale.

Purchasers are solely responsible for the choice, selection and use of the ST products and services described herein, and ST assumes no liability whatsoever relating to the choice, selection or use of the ST products and services described herein.

No license, express or implied, by estoppel or otherwise, to any intellectual property rights is granted under this document. If any part of this document refers to any third party products or services it shall not be deemed a license grant by ST for the use of such third party products or services, or any intellectual property contained therein or considered as a warranty covering the use in any manner whatsoever of such third party products or services or any intellectual property contained therein.

UNLESS OTHERWISE SET FORTH IN ST'S TERMS AND CONDITIONS OF SALE ST DISCLAIMS ANY EXPRESS OR IMPLIED WARRANTY WITH RESPECT TO THE USE AND/OR SALE OF ST PRODUCTS INCLUDING WITHOUT LIMITATION IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE (AND THEIR EQUIVALENTS UNDER THE LAWS OF ANY JURISDICTION), OR INFRINGEMENT OF ANY PATENT, COPYRIGHT OR OTHER INTELLECTUAL PROPERTY RIGHT.

UNLESS EXPRESSLY APPROVED IN WRITING BY AN AUTHORIZED ST REPRESENTATIVE, ST PRODUCTS ARE NOT RECOMMENDED, AUTHORIZED OR WARRANTED FOR USE IN MILITARY, AIR CRAFT, SPACE, LIFE SAVING, OR LIFE SUSTAINING APPLICATIONS, NOR IN PRODUCTS OR SYSTEMS WHERE FAILURE OR MALFUNCTION MAY RESULT IN PERSONAL INJURY, DEATH, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE. ST PRODUCTS WHICH ARE NOT SPECIFIED AS "AUTOMOTIVE GRADE" MAY ONLY BE USED IN AUTOMOTIVE APPLICATIONS AT USER'S OWN RISK.

Resale of ST products with provisions different from the statements and/or technical features set forth in this document shall immediately void any warranty granted by ST for the ST product or service described herein and shall not create or extend in any manner whatsoever, any liability of ST.

ST and the ST logo are trademarks or registered trademarks of ST in various countries.

Information in this document supersedes and replaces all information previously supplied.

The ST logo is a registered trademark of STMicroelectronics. All other names are the property of their respective owners.

© 2008 STMicroelectronics - All rights reserved

STMicroelectronics group of companies

Australia - Belgium - Brazil - Canada - China - Czech Republic - Finland - France - Germany - Hong Kong - India - Israel - Italy - Japan - Malaysia - Malta - Morocco - Singapore - Spain - Sweden - Switzerland - United Kingdom - United States of America

www.st.com