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.

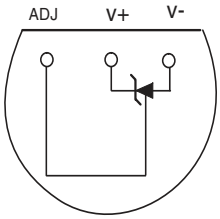
Calibrated at +25°C, the LM135, LM235, and LM335 have a typical error of less than 1°C over a 100°C temperature range. Unlike other sensors, the LM135, LM235, LM335 have a linear output.

TO-92
(Plastic package)

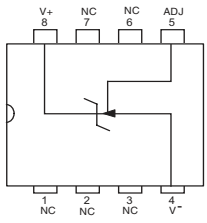
SO-8
(Plastic micropackage)

Pin connections

TO-92
(Bottom view)

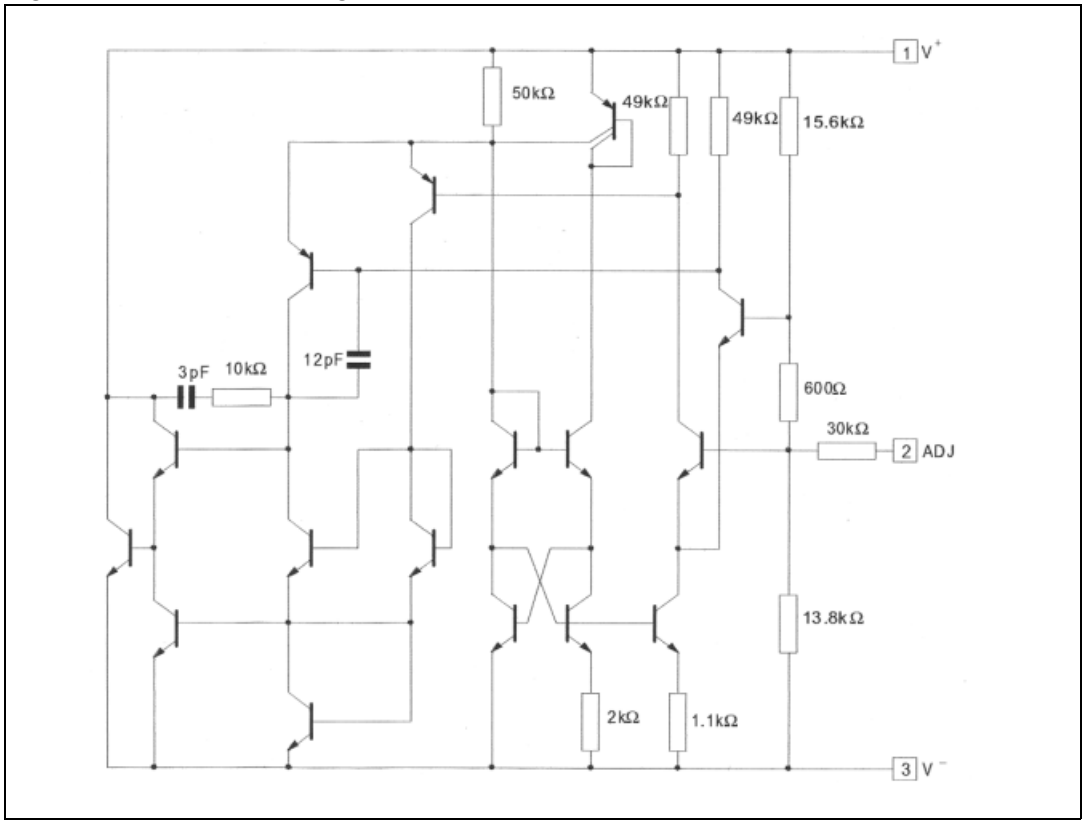


SO-8
(Top view)



1 Schematic diagram

Figure 1. Schematic diagram



2 Absolute maximum ratings

Table 1. Absolute maximum ratings (AMR)

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

1. $T_j \leq 150°C$

3 Temperature accuracy

Table 2. Temperature accuracy

Parameter	LM135 - LM235 - LM335A			LM335			Unit
	Min.	Typ.	Max.	Min.	Typ.	Max.	
Operating output voltage T_{case} = +25°C, I_R = 1mA	2.95	2.98	3.01	2.92	2.98	3.04	V
Uncalibrated temperature error (I_R = 1mA) T_{case} = +25°C $T_{min} \leq T_{case} \leq T_{max}$		 1 2	 3 5		 4 5	 6 9	°C
Temperature error with 25°C calibration $T_{min} \leq T_{case} \leq T_{max}$, I_R = 1mA LM135 - LM235 LM335 LM335A		 0.5 0.5	 1.5 1		 1	 2	°C
Calibrated error at extended temperature $T_{case} = T_{max}$ (intermittent)		2			2		°C
Non-linearity (I_R = 1mA) LM135 - LM235 LM335 LM335A		0.3 0.3	1 1.5		 0.3 	 1.5 	°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 450µA ≤ I_R ≤ 5mA at constant temperature		2.5	10		3	14	mV
Dynamic impedance (I_R = 1mA)		0.5			0.6		Ω
Output voltage temperature drift		+10			+10		mV/°C
Time constant Still air Air 0.5m/s Stirred oil		 80 10 1			 80 10 1		s
Time stability (T_{case} = +125°C)		0.2			0.2		°C/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

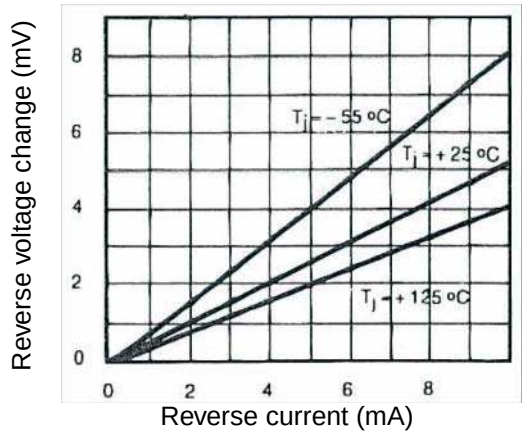


Figure 3. Calibrated error

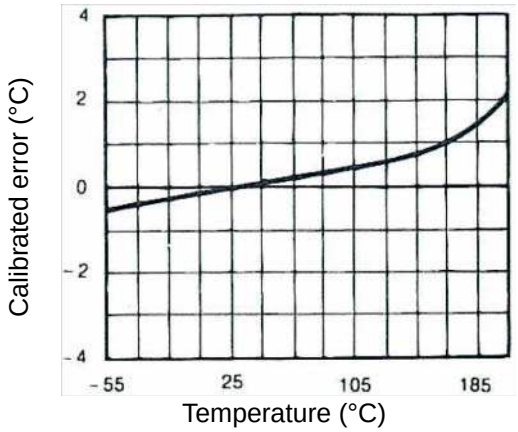


Figure 4. Reverse characteristics

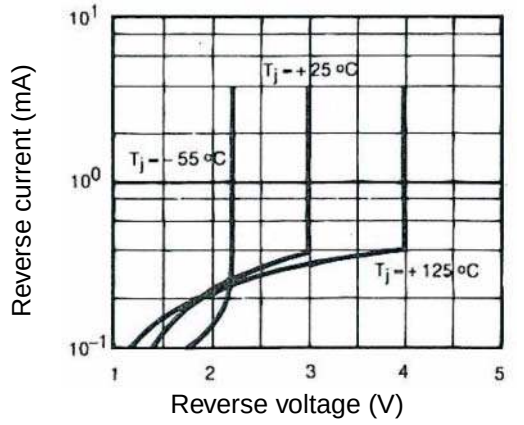


Figure 5. Response time

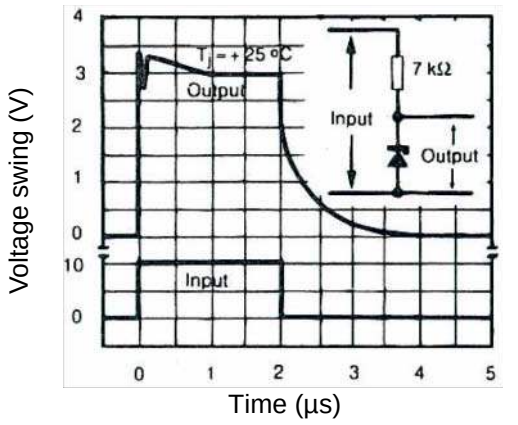


Figure 6. Dynamic impedance

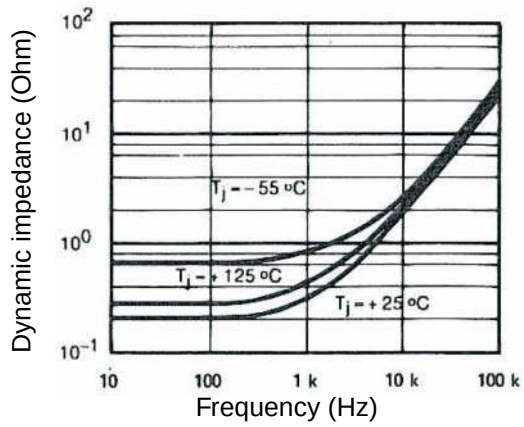


Figure 7. Noise voltage

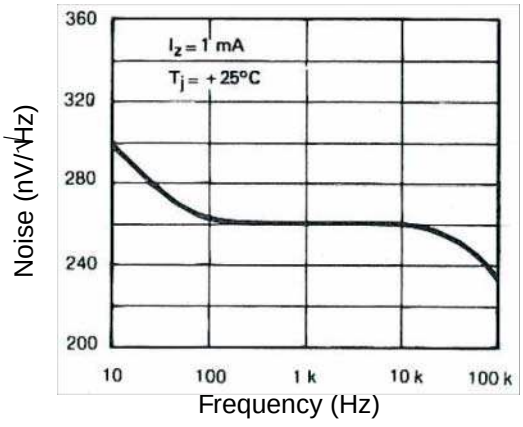


Figure 8. Thermal resistance junction to air

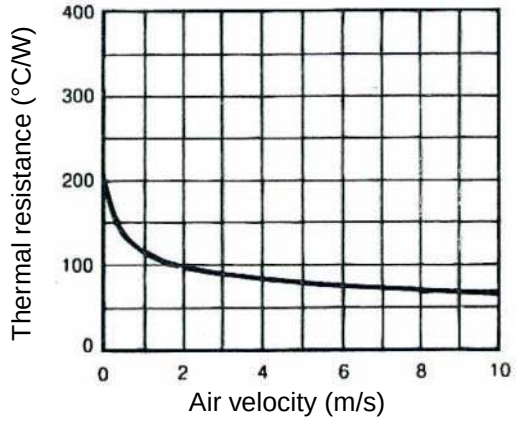


Figure 9. Thermal time constant

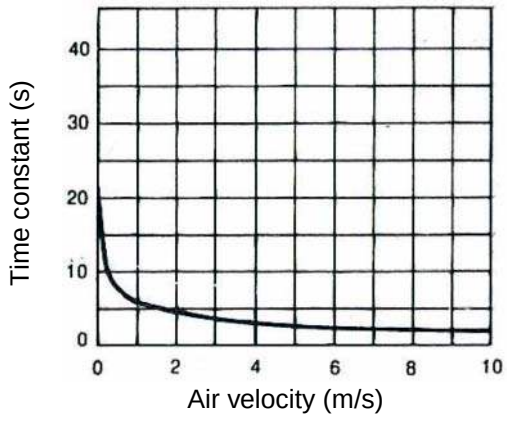


Figure 10. Thermal response in still air

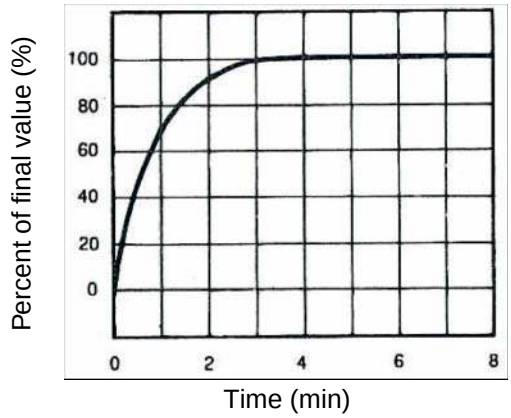


Figure 11. Thermal response in stirred oil bath

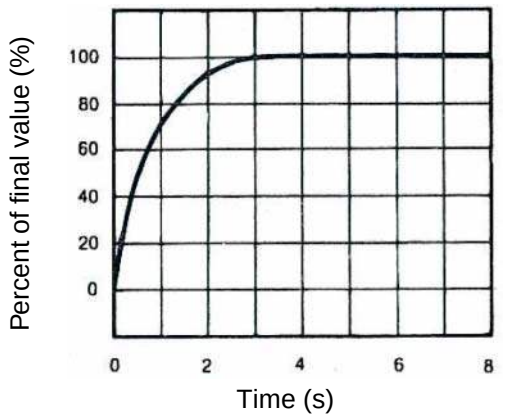
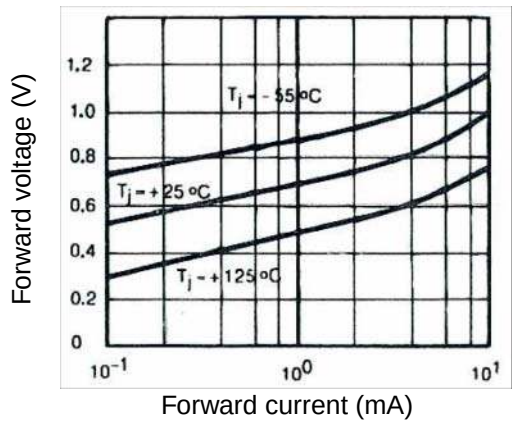


Figure 12. Forward characteristics



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:

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

where T is the unknown temperature and To 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

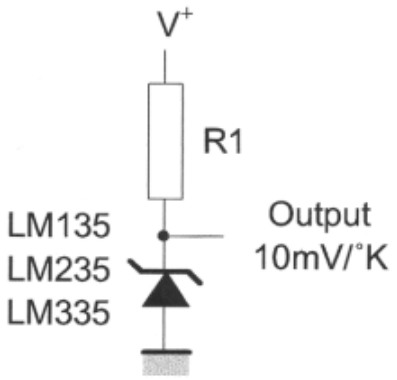


Figure 14. Wide operating supply

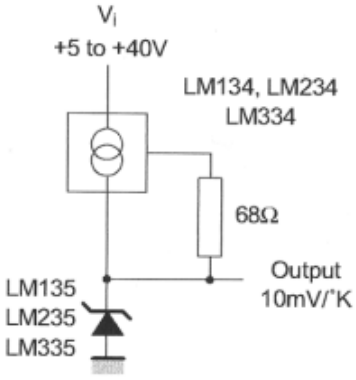
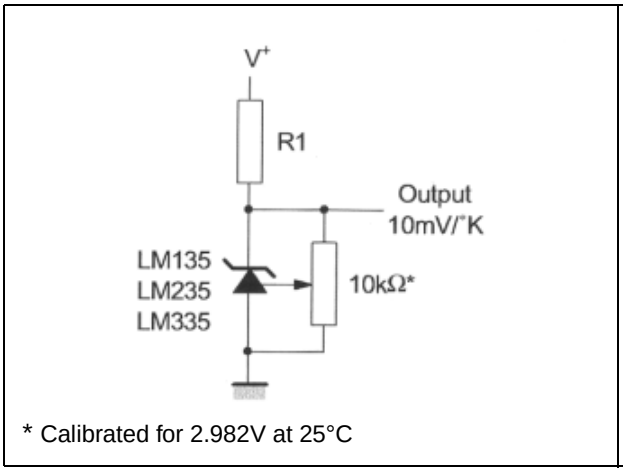


Figure 15. Calibrated sensor



* Calibrated for 2.982V at 25°C

Figure 16. Average temperature sensing

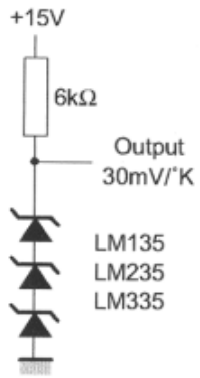


Figure 17. Isolated temperature sensor

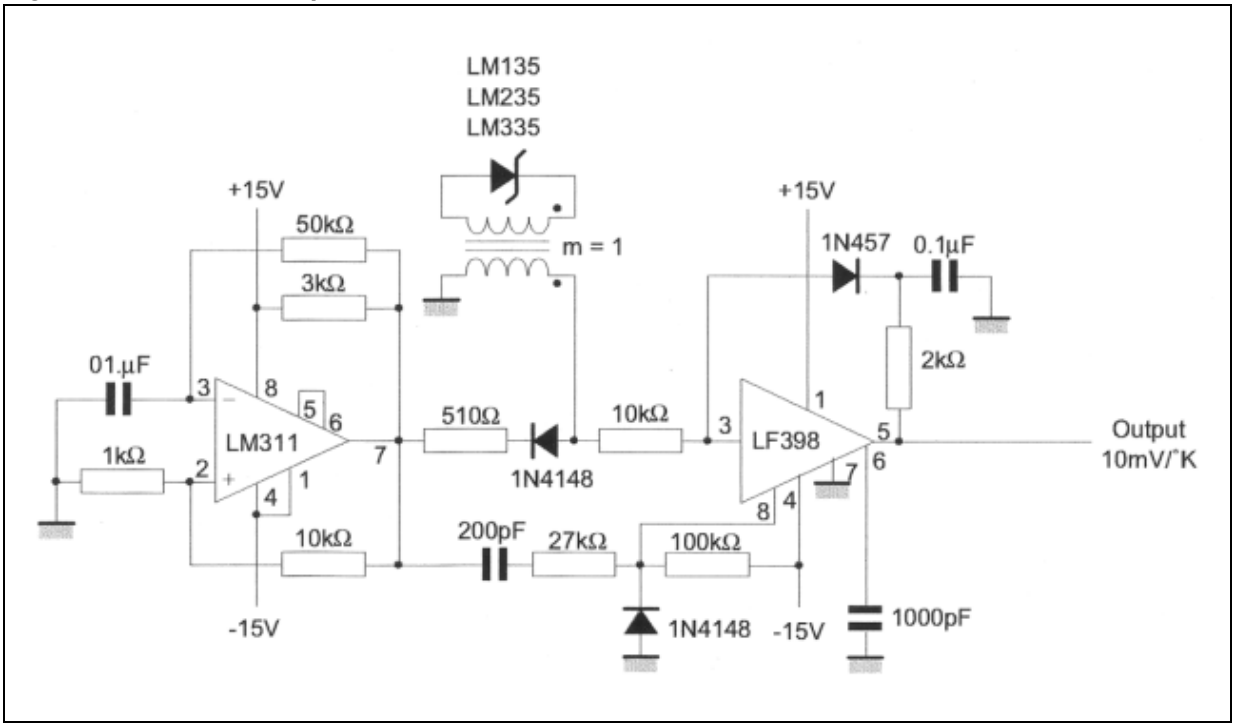


Figure 18. Simple temperature controller

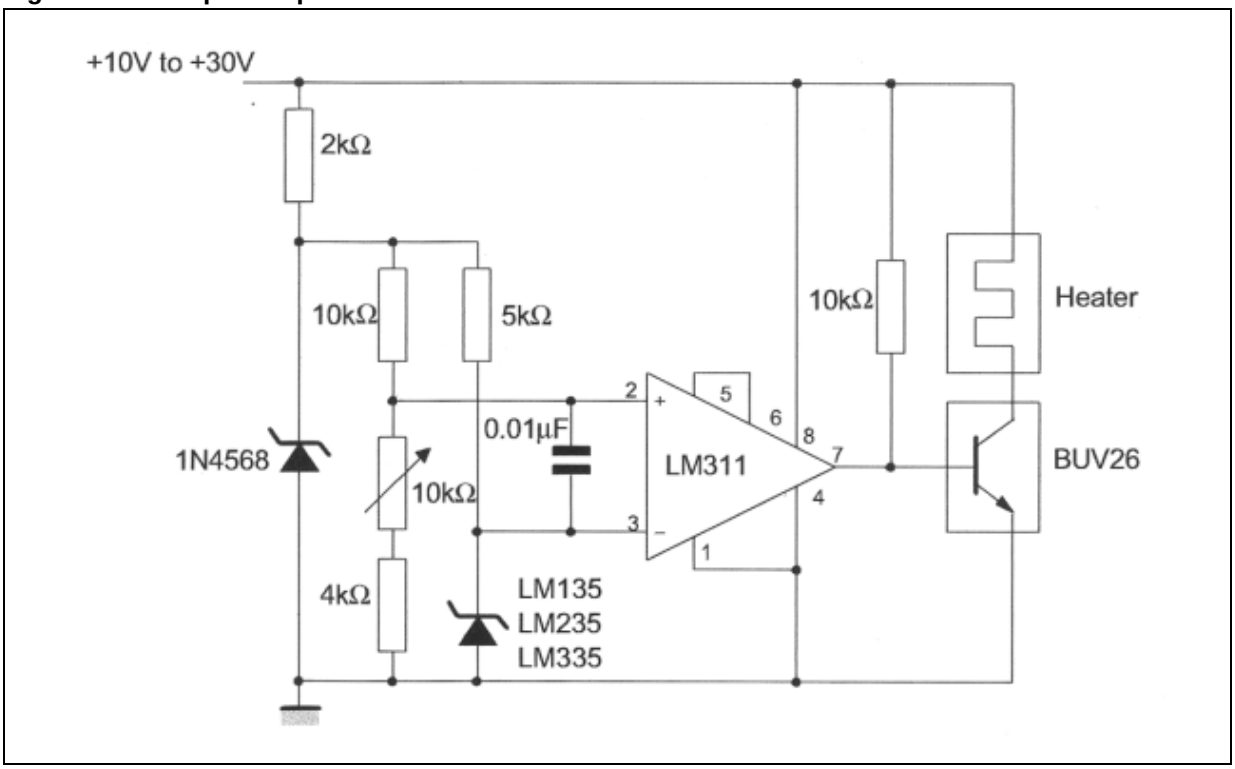


Figure 19. Centigrade thermometer

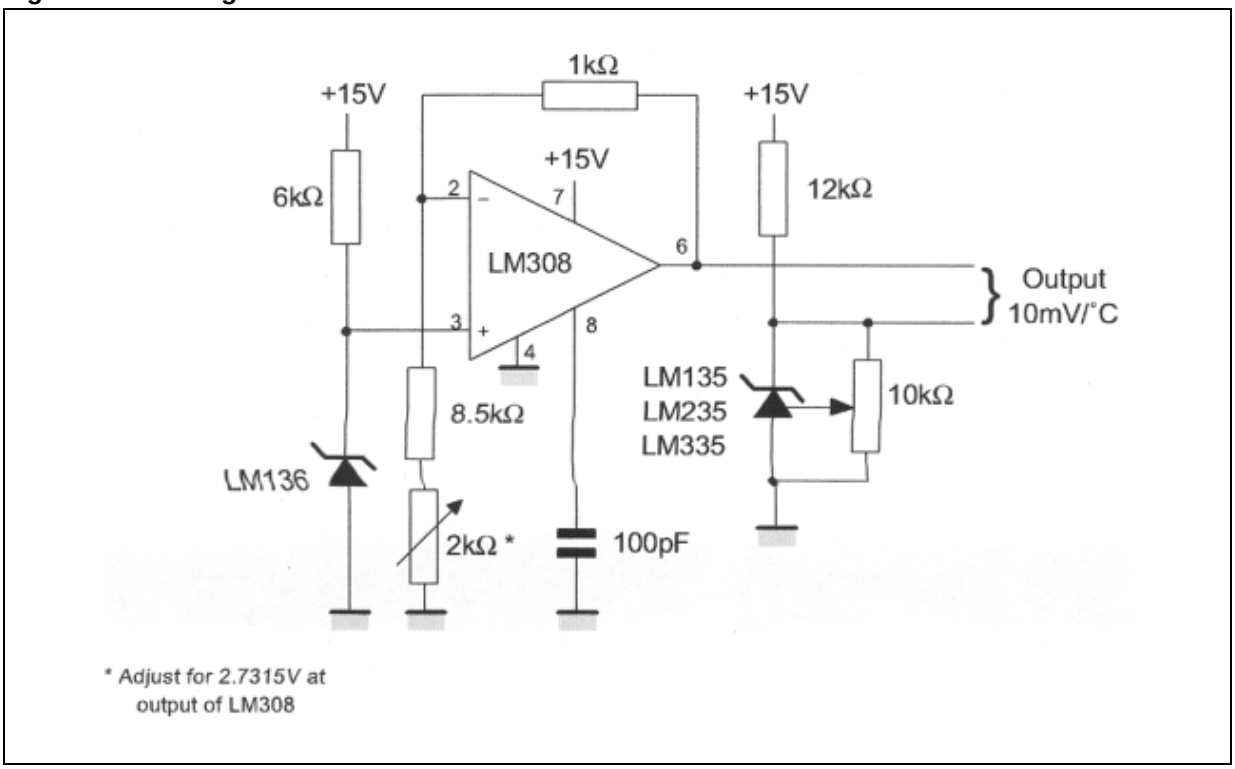


Figure 20. Differential temperature sensor

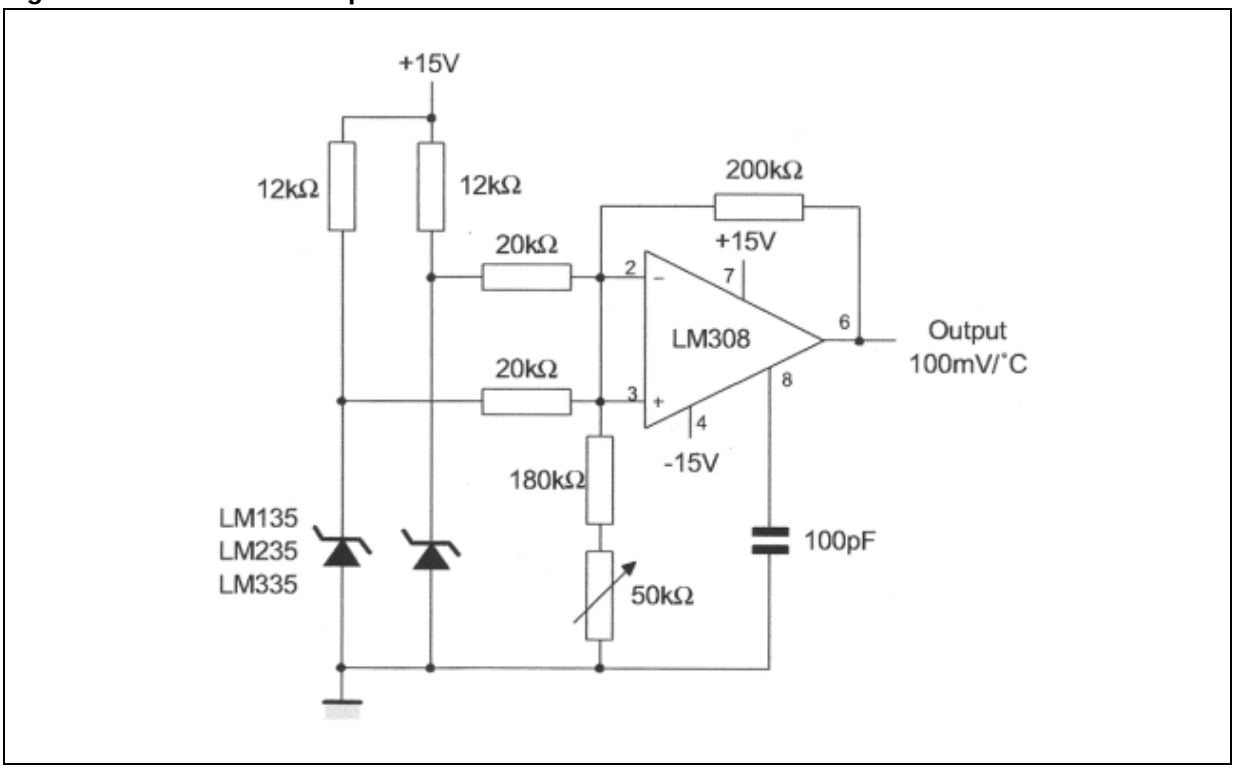
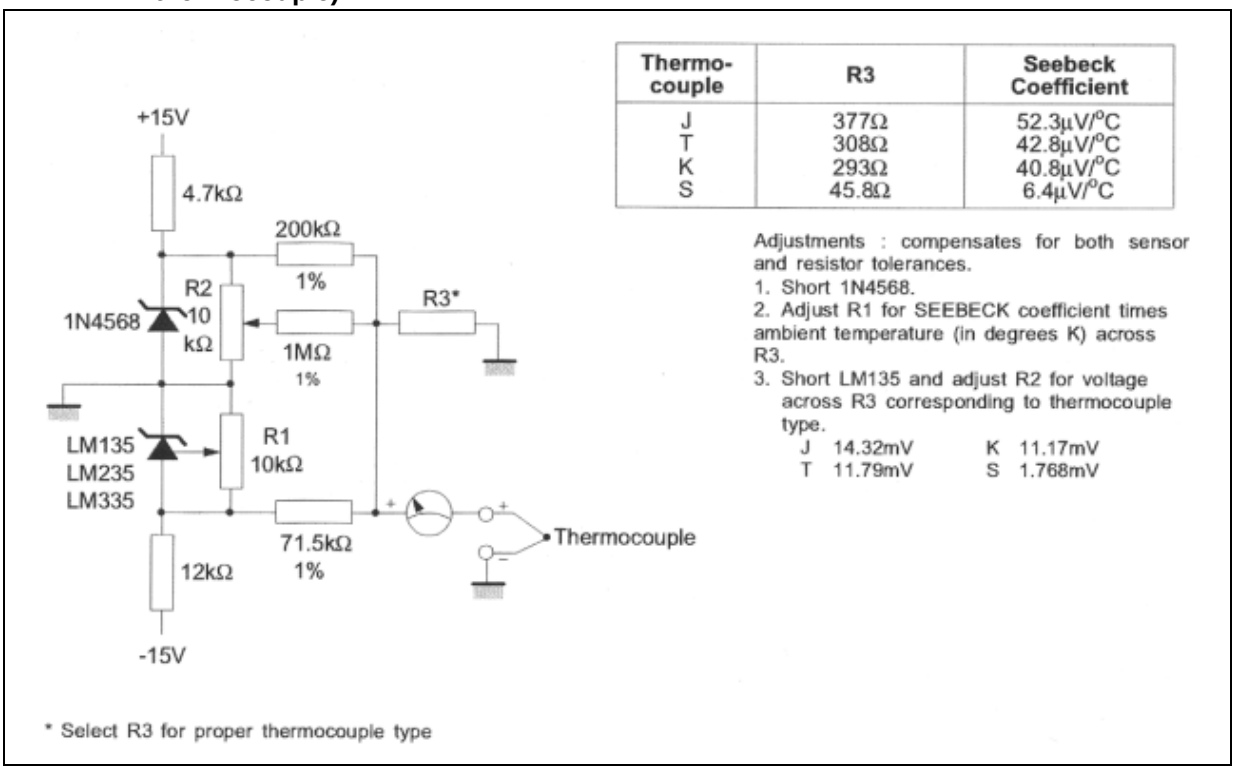


Figure 21. Thermocouple cold junction compensation (compensation for grounded thermocouple)



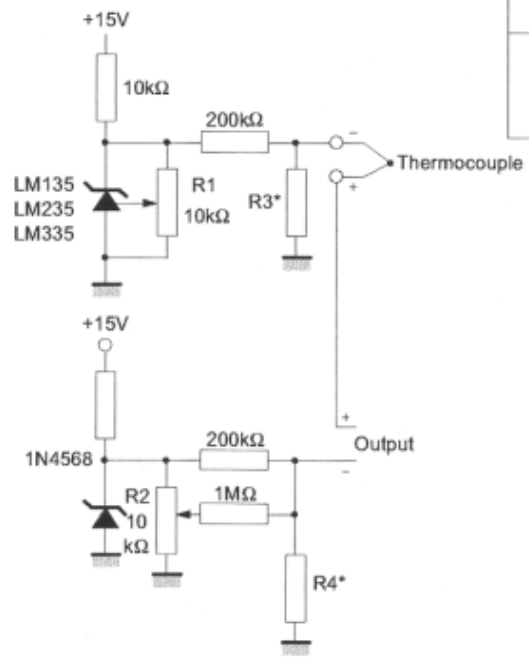
Thermo-couple	R3	Seebeck Coefficient
J	377Ω	52.3µV/°C
T	308Ω	42.8µV/°C
K	293Ω	40.8µV/°C
S	45.8Ω	6.4µV/°C

Adjustments : compensates for both sensor and resistor tolerances.

1. Short 1N4568.
2. Adjust R1 for SEEBECK coefficient times ambient temperature (in degrees K) across R3.
3. Short LM135 and adjust R2 for voltage across R3 corresponding to thermocouple type.

J	14.32mV	K	11.17mV
T	11.79mV	S	1.768mV

Figure 22. Single power supply cold junction compensation



Thermo-couple	R3	R4	Seebeck Coefficient
J	1.05kΩ	365Ω	52.3µV/°C
T	856Ω	315Ω	42.8µV/°C
K	816Ω	300Ω	40.8µV/°C
S	128Ω	46.3Ω	6.4µV/°C

Adjustments :

1. Adjust R1 for the voltage across R3 equal to the SEEBECK coefficient times ambient temperature in degrees Kelvin.
2. Adjust R2 for voltage across R4 corresponding to thermocouple.
   J 14.32mV K 11.17mV
   T 11.79mV S 1.768mV

* Select R3 and R4 for proper thermocouple

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

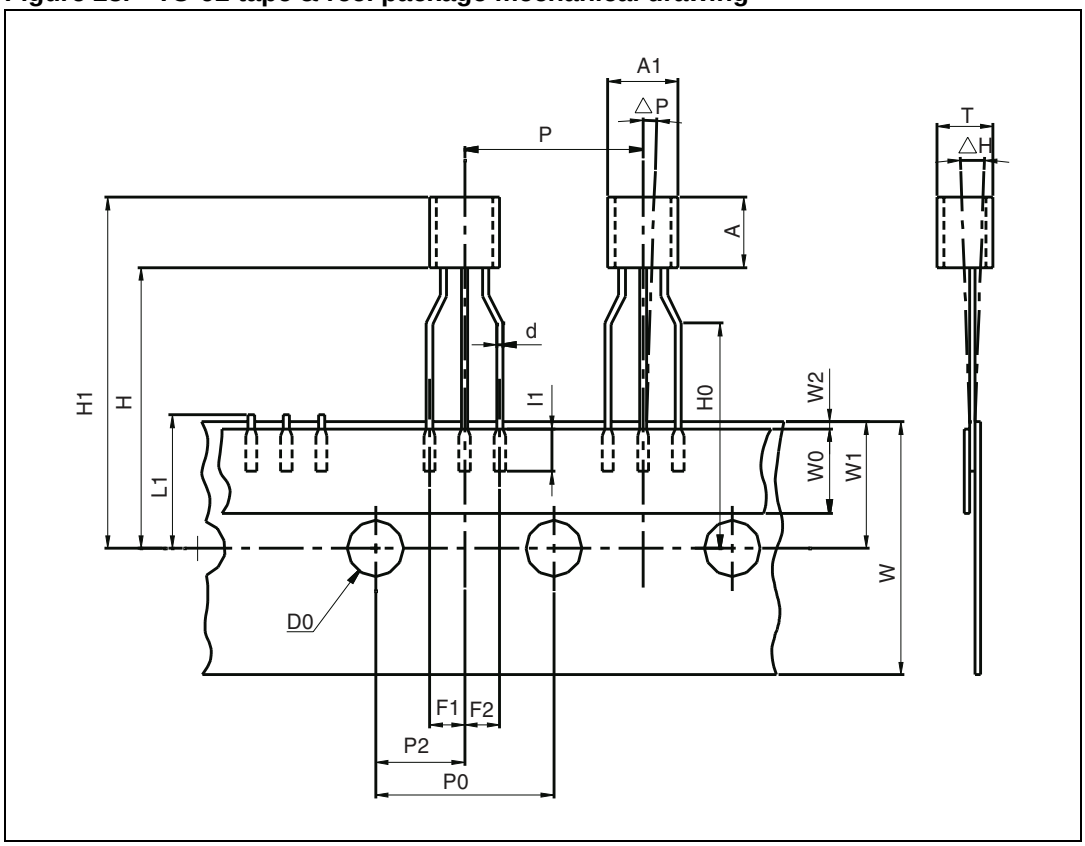


Table 4. TO-92 tape & reel package mechanical data

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	
I1	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

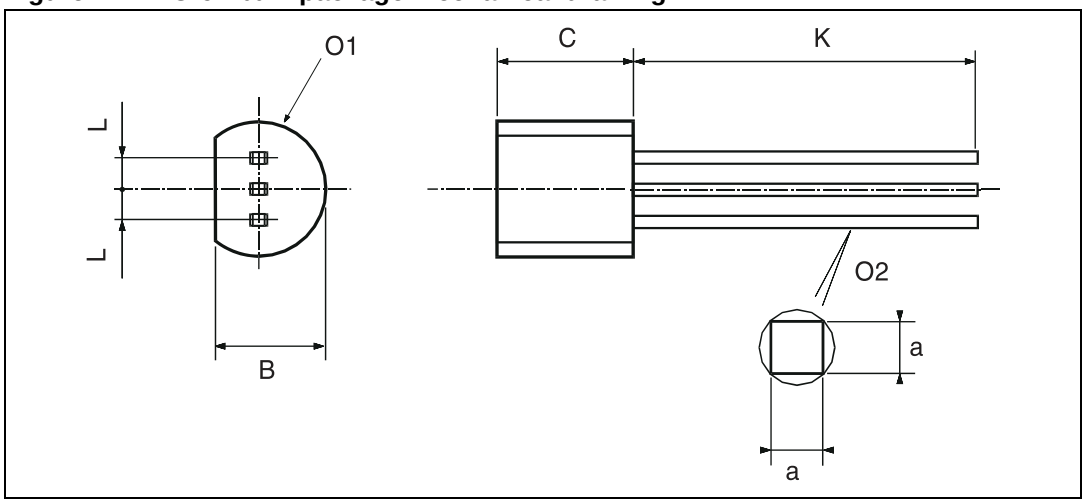


Table 5. TO-92 bulk package mechanical data

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

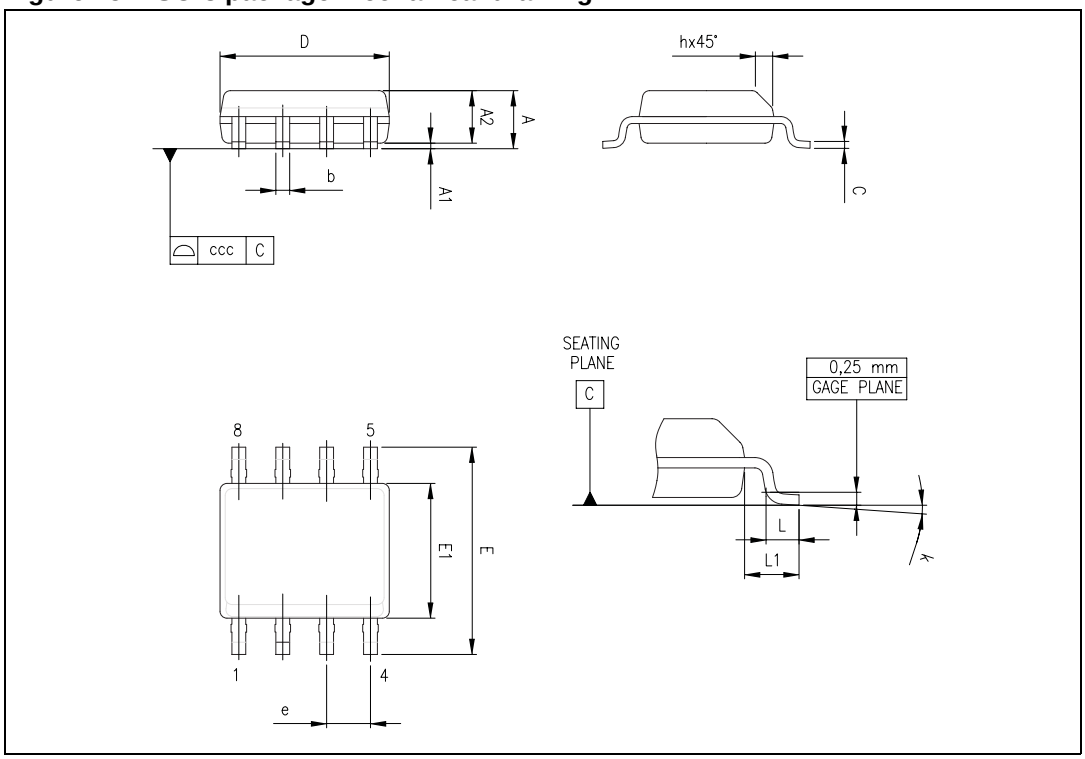


Table 6. SO-8 package mechanical data

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.