EE 107 Lab 5 (Week 6)

Title: Temperature Sensor Data Conversion and Display

Description: This laboratory session involves constructing a simple circuit to generate a variable analog voltage from a temperature sensor and read it into the Arduino board processor as a digitized signal. Then the input value will be converted to an equivalent temperature value in degrees Celsius and displayed on the Serial Monitor. Completing the tasks require you be familiar with the built-in firmware functions of the Arduino Integrated Development Environment (IDE). See below for details on the task and for the format and content of the required report to be submitted at the beginning of the next laboratory session.

Task Specifics:

1) Create the following sub-directory in your mapped mavdisk drive (or M drive), "M:/My_Private_Files/Lab4". Use this directory for your lab.

2) Construct the circuit as shown in the diagram for this lab.

2) Write a new *.INO which reads in the analog voltage from the sensor, converts it to degrees Celsius with at least 0.1 degrees precision (i.e. you will need to use a 'float' variable type during your conversion) and writes the result every 500 ms to the Serial Monitor. For example, the Serial Monitor should have the following after two seconds assuming the correct temperature is 25.6 degrees Celsius:

```
25.6 degC
25.6 degC
25.6 degC
25.6 degC
```

This should be done in the loop() function so that if you heat or cool the sensor, a change in the displayed temperature will be reflected in the Serial Monitor. Refer to the temperature sensor datasheet to understand the transfer function required within your code.

Report Format and Guidelines:

Your report must include the following at a minimum:

1) A title page containing the experiment number, experiment title, date of lab, due date of report and printed names of the group members.

2) A paper copy of the source code from the Task and a screenshot of your solution working with the Serial Monitor displayed on the screen. Ensure your program includes header and statement comments as described in class.

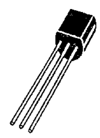
3) A description of your solution to complete the Task including your transfer function.

Your report should be typed, stapled and written with proper grammar and correct spelling. Your report will be graded on readability as well as content.

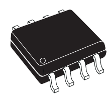
LM135
LM235-LM335,A

PRECISION TEMPERATURE SENSORS

- DIRECTLY CALIBRATED IN ^{o}K
- 1^{o}C INITIAL ACCURACY
- OPERATES FROM 450µA TO 5mA
- LESS THAN 1Ω DYNAMIC IMPEDANCE



Z
TO92
(Plastic Package



D
SO8
(Plastic Micropackage)

DESCRIPTION

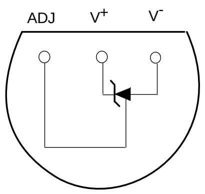
The LM135, LM235, LM335 are precision temperature sensors which can be easily calibrated. They operate as a 2-terminal Zener and the breakdown voltage is directly proportional to the absolute temperature at 10mV/^{o}K. The circuit has a dynamic impedance of less than 1Ω and operates within a range of current from 450µA to 5mA without alteration of its characteristics. Calibrated at +25^{o}C, the LM135, LM235, LM335 have a typical error of less than 1^{o}C over a 100^{o}C temperature range. Unlike other sensors, the LM135, LM235, LM335 have a linear output.

ORDER CODES

Part number	Temperature Range	Package	
		Z	D
LM135	–55^{o}C, +150^{o}C	•	•
LM235	–40^{o}C, +125^{o}C	•	•
LM335,A	–40^{o}C, +100^{o}C	•	•

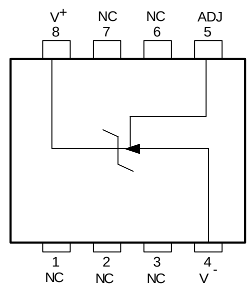
PIN CONNECTIONS

TO92
(Bottom view)



135-01.EPS

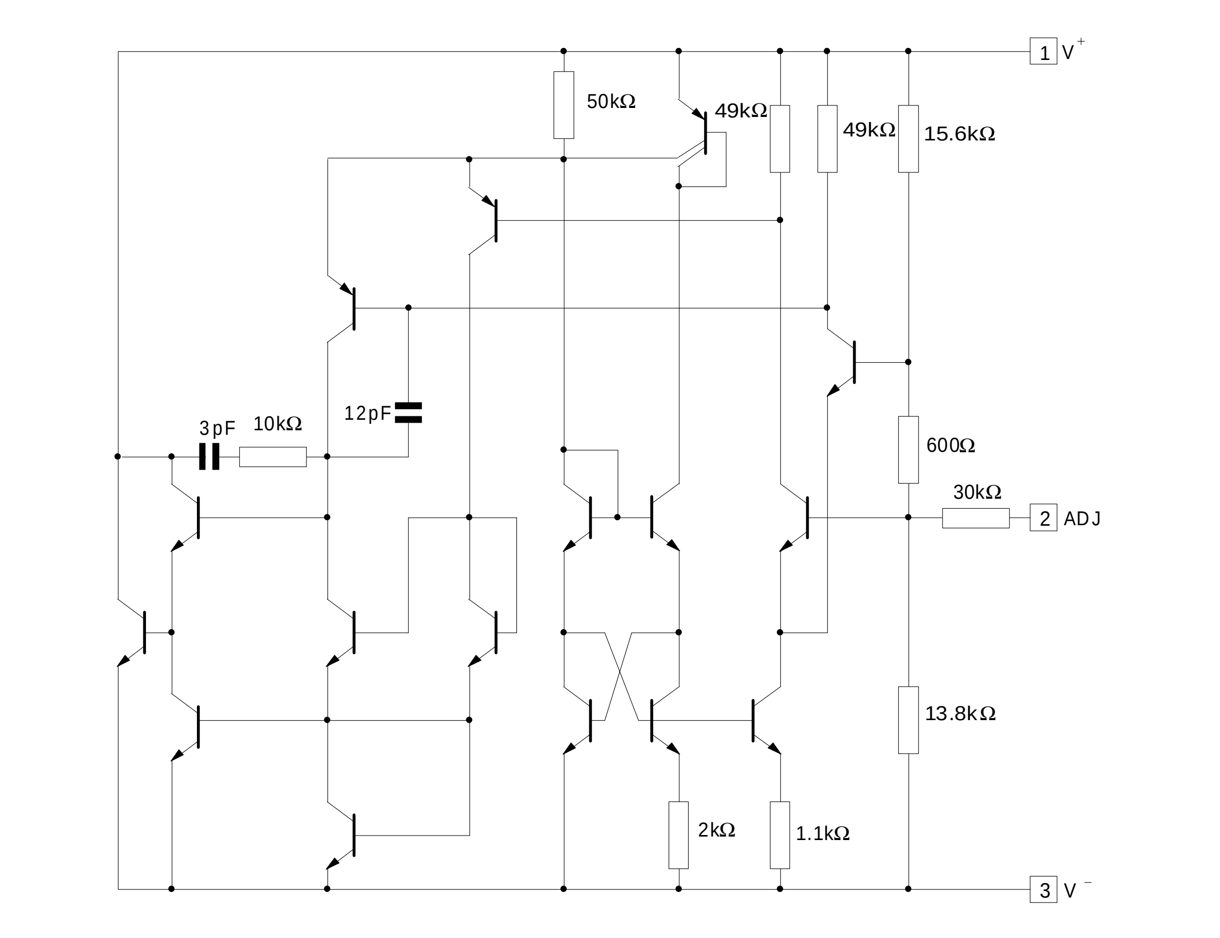
SO8
(Top view)



135-02.EPS

October 1997

SCHEMATIC DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	LM135	LM235	LM335,A	Unit
 I_R I_F	Current Reverse Forward	 15 10	 15 10	 15 10	mA
T_{oper}	Operating Free-air Temperature Range - (note 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	–65 to +150	–65 to +150	°C

Note : 1. $T_j \leq 150^oC$

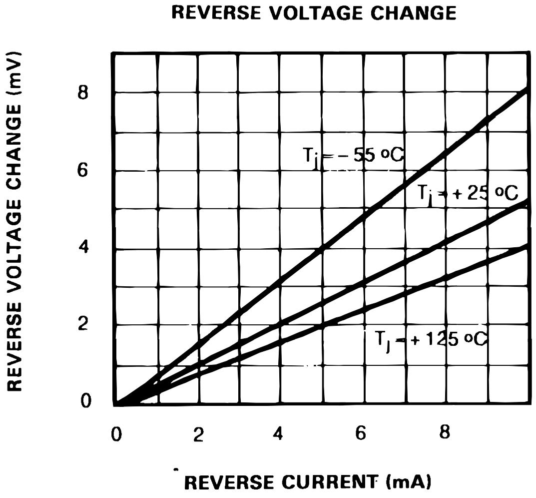
TEMPERATURE ACCURACY

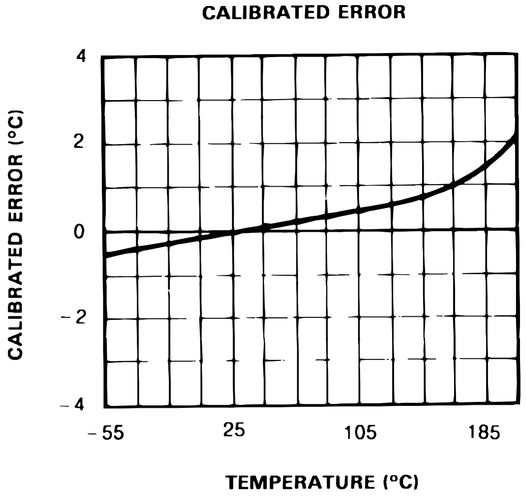
Parameter	LM135 - LM235 LM335A			LM335			Unit
	Min.	Typ.	Max.	Min.	Typ.	Max.	
Operating Output Voltage T_{case} = +25°C, I_R = 1mA	2.95	2.98	3.01	2.92	2.98	3.04	V
Uncalibrated Temperature Error (I_R = 1mA) T_{case} = +25°C $T_{min.} \le T_{case} \le T_{max.}$		1 2	3 5		2 4	6 9	°C
Temperature Error with 25°C Calibration $T_{min.} \le T_{case} \le T_{max.}$, 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

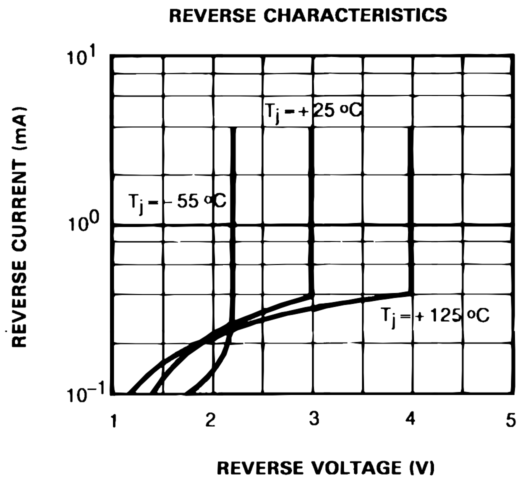
ELECTRICAL CHARACTERISTICS - (note 1)

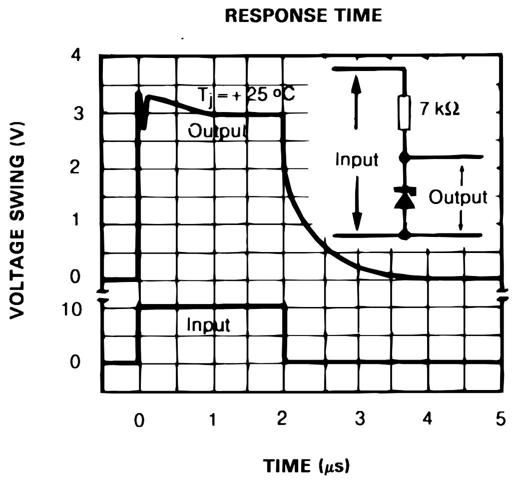
Parameter	LM135 - LM235			LM335,A			Unit
	Min.	Typ.	Max.	Min.	Typ.	Max.	
Operating output voltage change with current 450µA ≤ I_R ≤ 5mA at constant temperature		2.5	10		3	14	mV
Dynamic Impedance (I_R = 1mA)		0.5			0.6		Ω
Output Voltage Temperature Drift		+10			+10		mV/°C
Time Constant Still Air Air 0.5m/s Stirred Oil		80 10 1			80 10 1		s
Time Stability (T_{case} = +125°C)		0.2			0.2		°C/kh

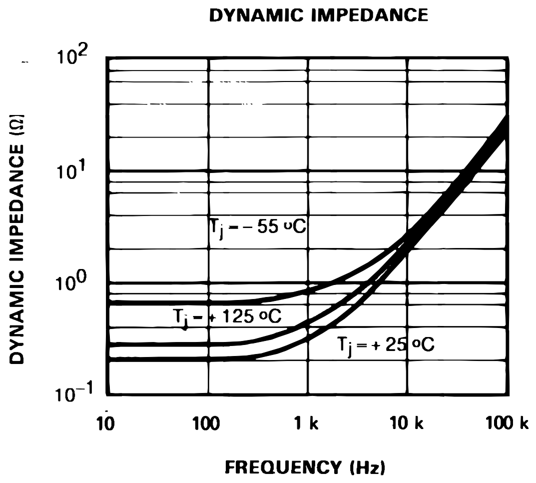
Note : 1. Accuracy measurements are made in a well-stirred oil bath. For other conditions, self heating must be considered.

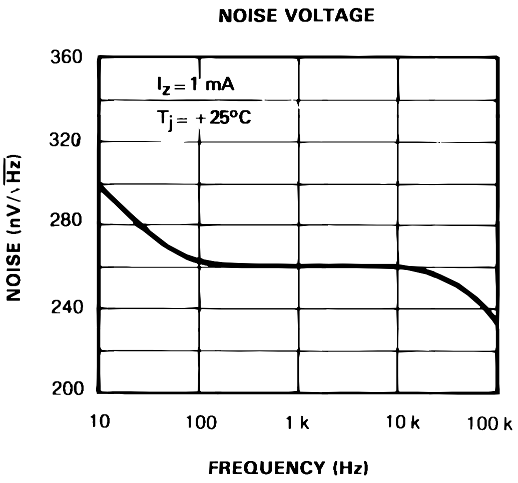

REVERSE VOLTAGE CHANGE
REVERSE VOLTAGE CHANGE (mV)
Tj = – 55 °C
Tj = + 25 °C
Tj = + 125 °C
REVERSE CURRENT (mA)

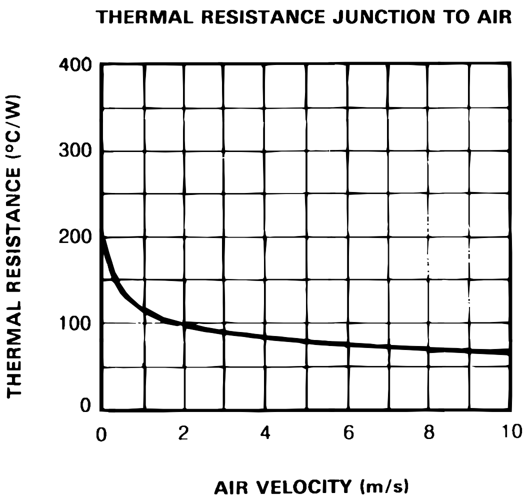

CALIBRATED ERROR
CALIBRATED ERROR (°C)
TEMPERATURE (°C)

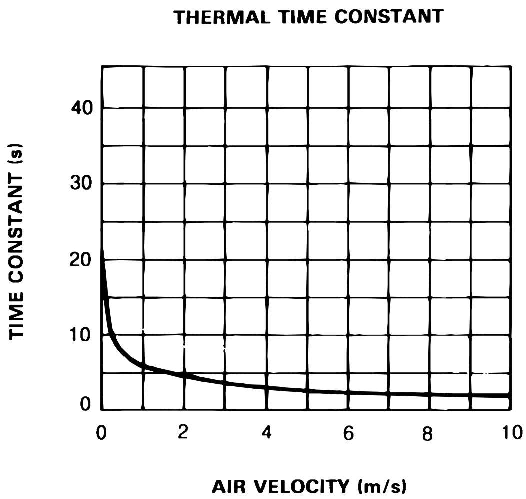

REVERSE CHARACTERISTICS
REVERSE CURRENT (mA)
Tj = + 25 °C
Tj = – 55 °C
Tj = + 125 °C
REVERSE VOLTAGE (V)

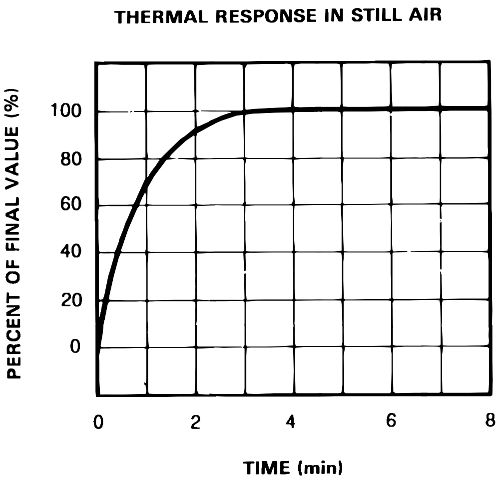

RESPONSE TIME
VOLTAGE SWING (V)
Tj = + 25 °C
Output
Input
7 kΩ
TIME (μs)

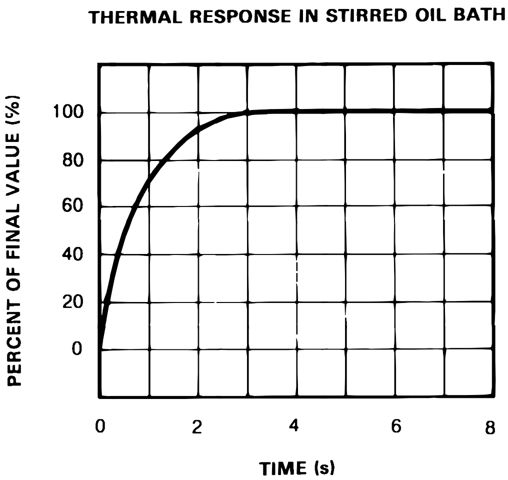

DYNAMIC IMPEDANCE
DYNAMIC IMPEDANCE (Ω)
Tj = – 55 °C
Tj = + 125 °C
Tj = + 25 °C
FREQUENCY (Hz)

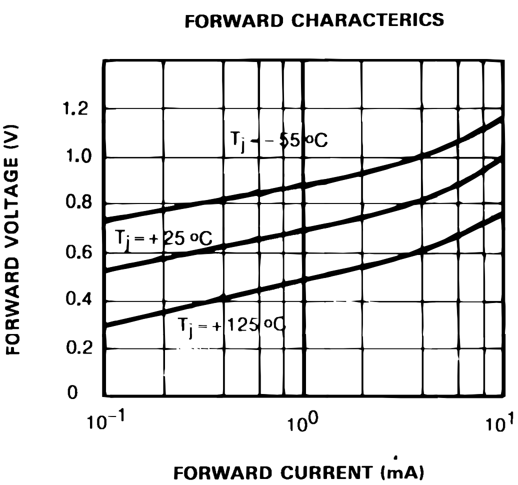

NOISE VOLTAGE
NOISE (nV/√Hz)
Iz = 1 mA
Tj = + 25°C
FREQUENCY (Hz)


THERMAL RESISTANCE JUNCTION TO AIR
THERMAL RESISTANCE (°C/W)
400
300
200
100
0
0 2 4 6 8 10
AIR VELOCITY (m/s)


THERMAL TIME CONSTANT
TIME CONSTANT (s)
40
30
20
10
0
0 2 4 6 8 10
AIR VELOCITY (m/s)


THERMAL RESPONSE IN STILL AIR
PERCENT OF FINAL VALUE (%)
100
80
60
40
20
0
0 2 4 6 8
TIME (min)


THERMAL RESPONSE IN STIRRED OIL BATH
PERCENT OF FINAL VALUE (%)
100
80
60
40
20
0
0 2 4 6 8
TIME (s)


FORWARD CHARACTERICS
FORWARD VOLTAGE (V)
1.2
1.0
0.8
0.6
0.4
0.2
0
Tj = – 55 oC
Tj = + 25 oC
Tj = + 125 oC
10^{-1} 10^{0} 10^{1}
FORWARD CURRENT (mA)

APPLICATION HINTS

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^oK (–273.15^oC). Errors in output voltage versus temperature are only slope. Thus a calibration of the slope at one temperature corrects errors at all temperatures.

The output of the circuit (calibrated or not) can be given by the equation : $V_{OT} = VO_{TO} \times \frac{T}{T_o}$

where T is the unknown temperature and T_O is the reference temperature (in ^oK).

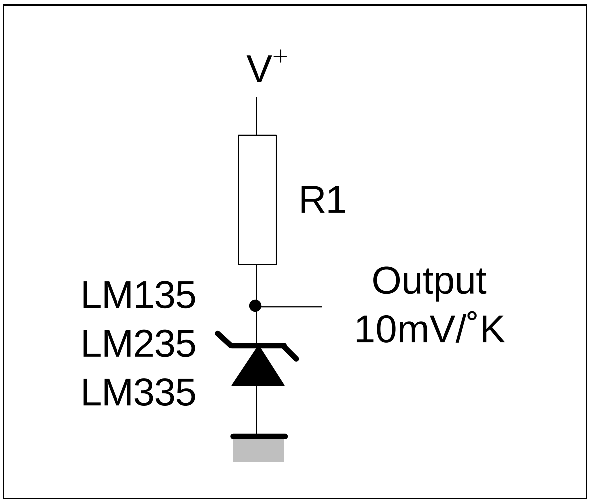
Nominally the output is calibrated at 10mV/^oK.

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, LM335 should operate with a low current, but sufficient to drive the sensor and its calibration circuit to their maximum operating temperature.

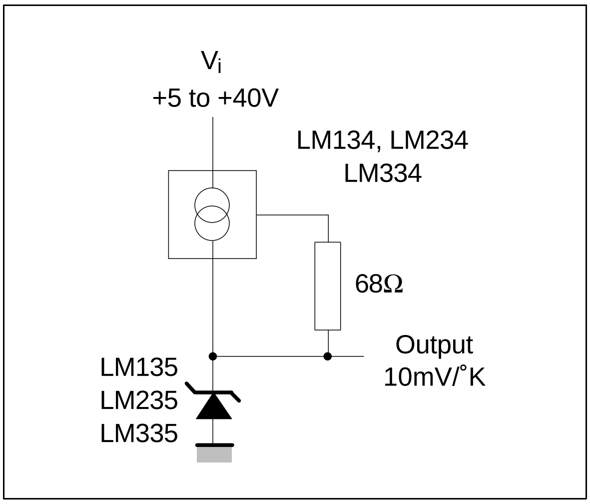
If the sensor is used in surroundings where the thermal resistane is constant, the errors due to self heating can be externally calibrated. This is possible if the circuit is biased with a temperature stable current. Heating will then be proportional to zener voltage and therefore temperature. In this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

TYPICAL APPLICATIONS

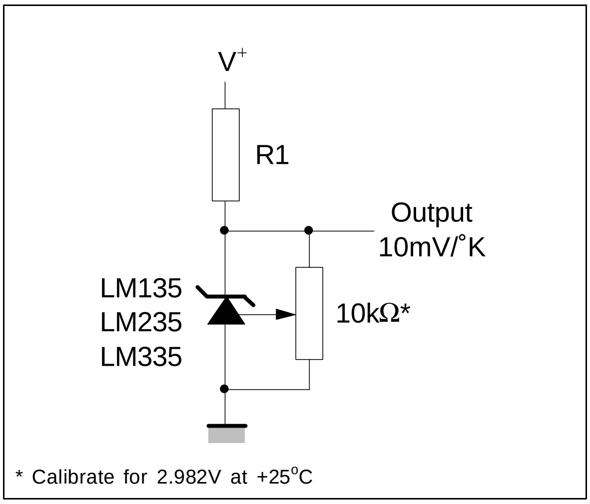
BASIC TEMPERATURE SENSOR



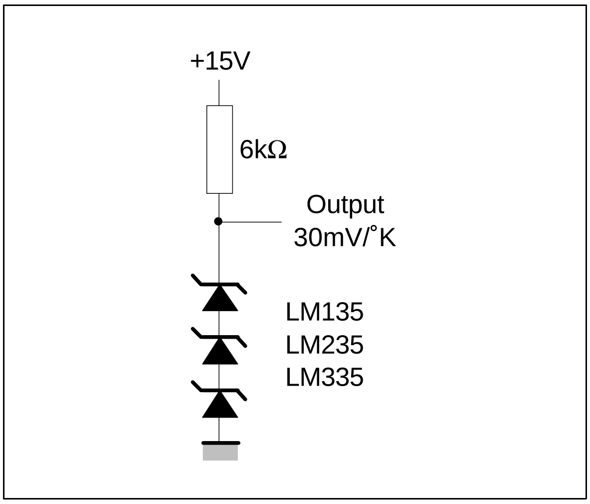
WIDE OPERATING SUPPLY



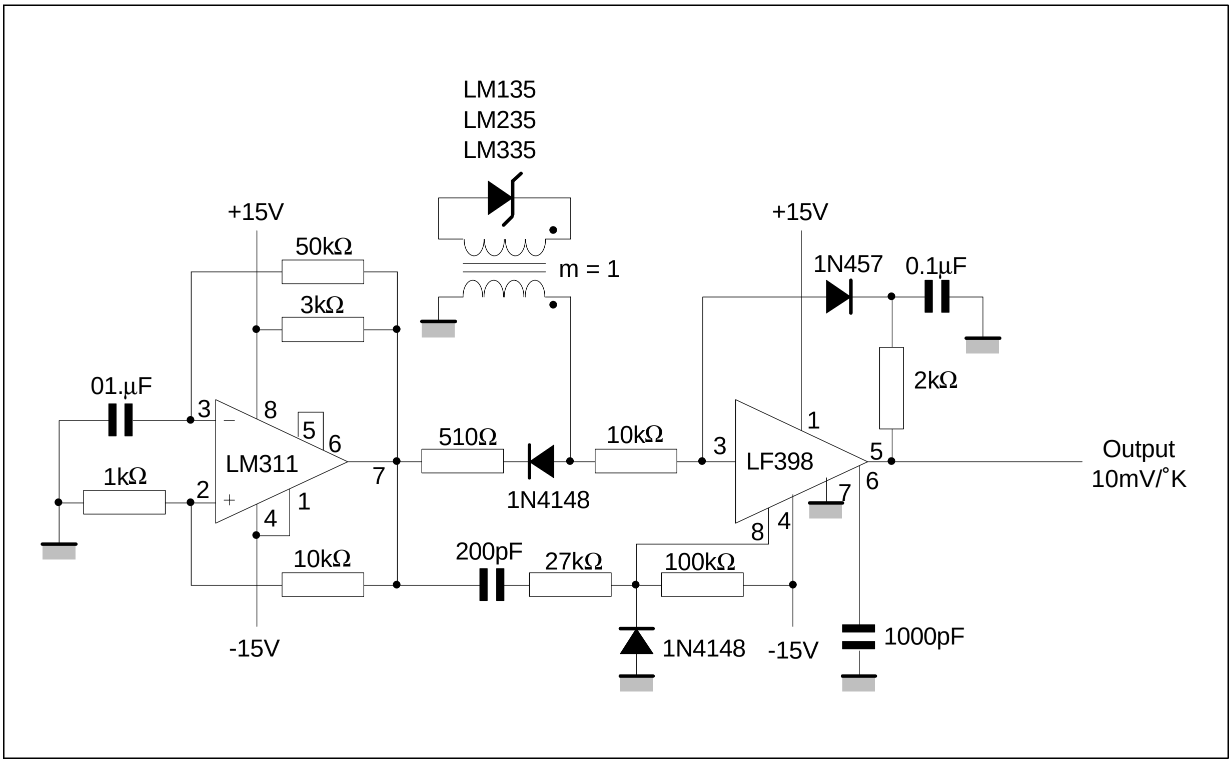
CALIBRATED SENSOR



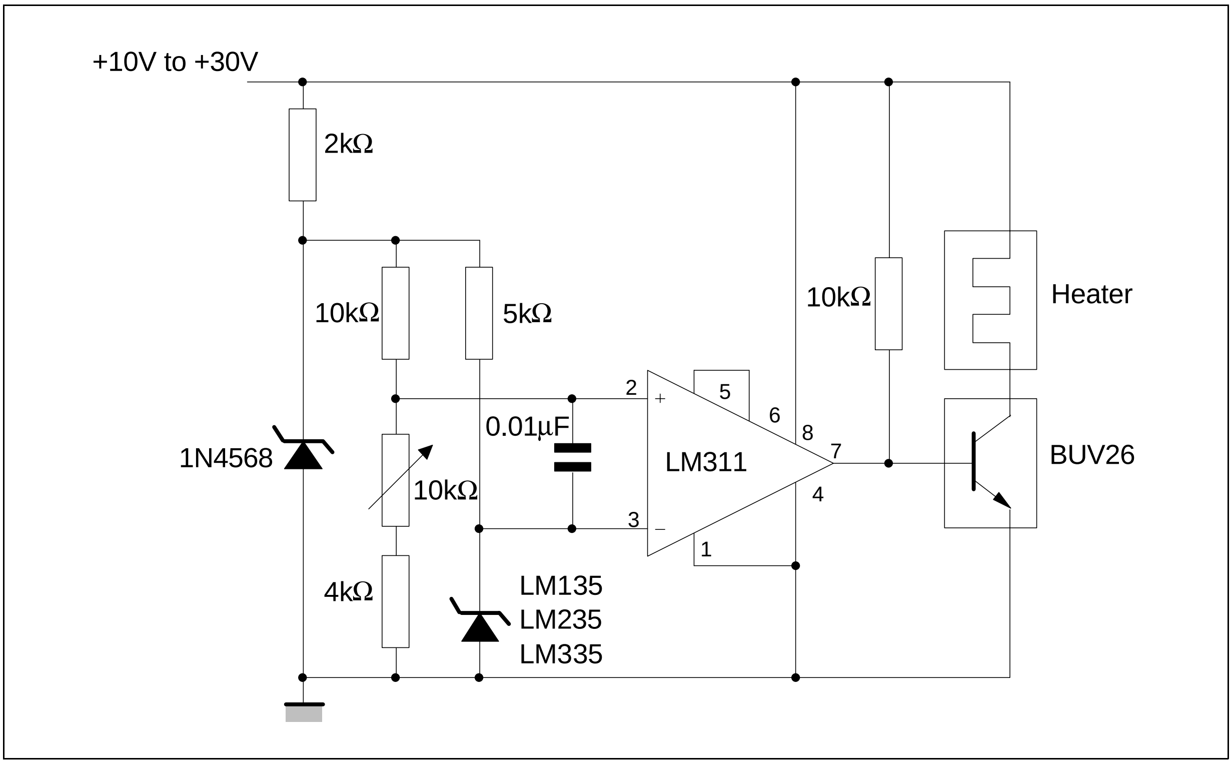
AVERAGE TEMPERATURE SENSING



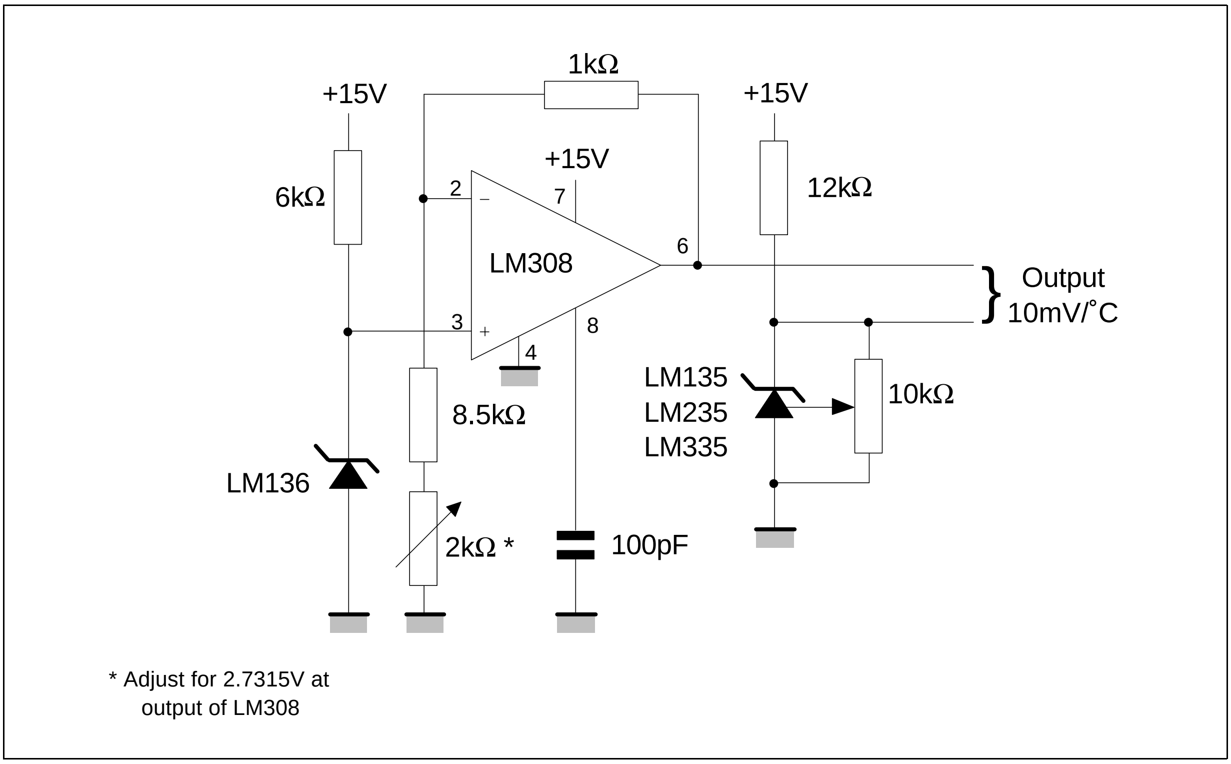
ISOLATED TEMPERATURE SENSOR



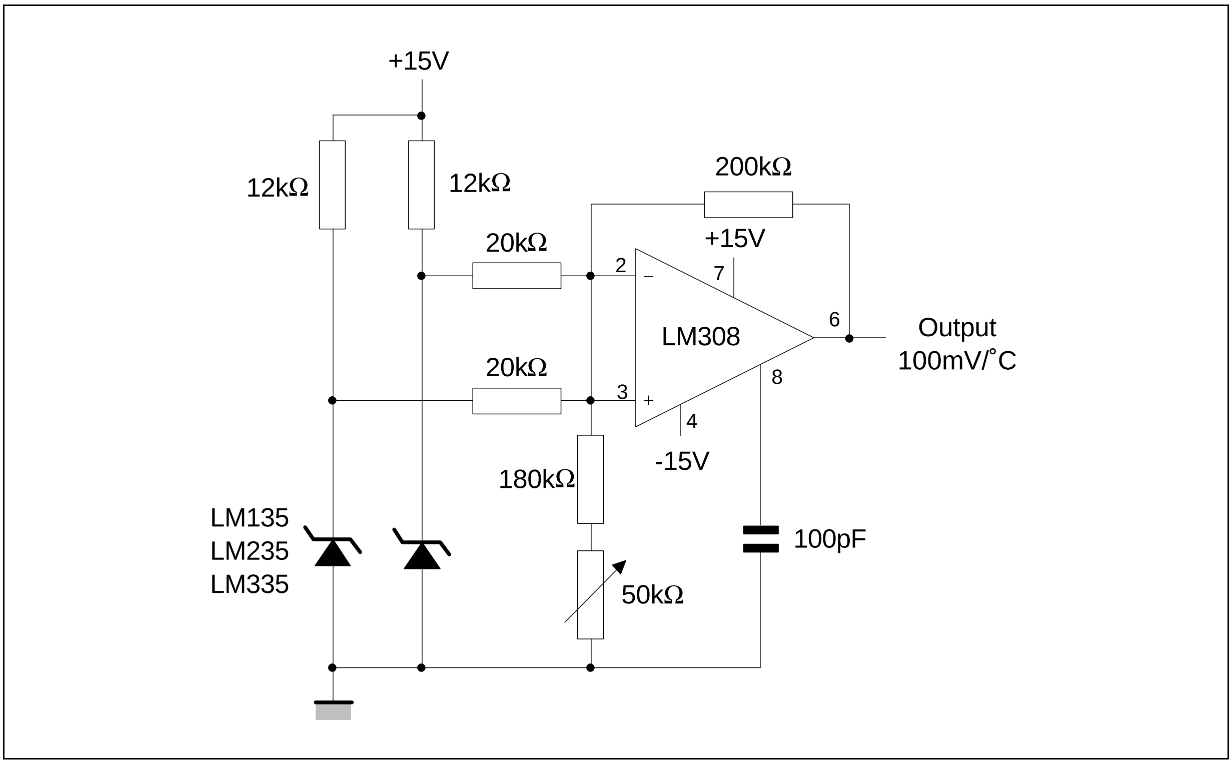
SIMPLE TEMPERATURE CONTROLLER



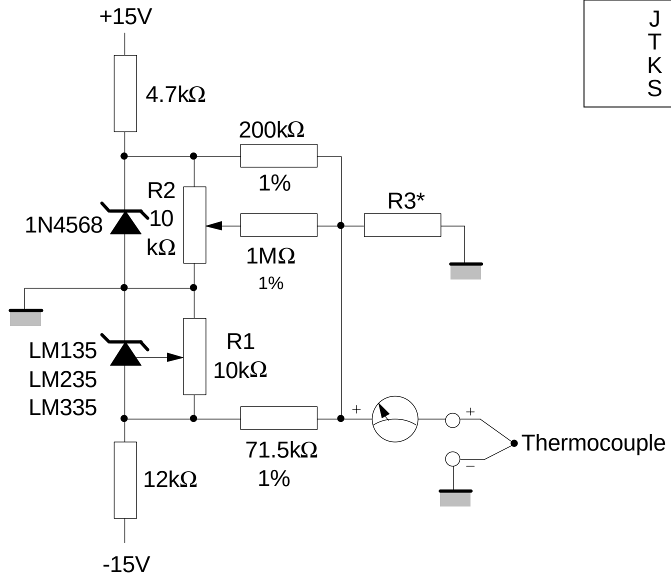
CENTIGRADE THERMOMETER



DIFFERENTIAL TEMPERATURE SENSOR



THERMOCOUPLE COLD JUNCTION COMPENSATION (compensation for grounded thermocouple)



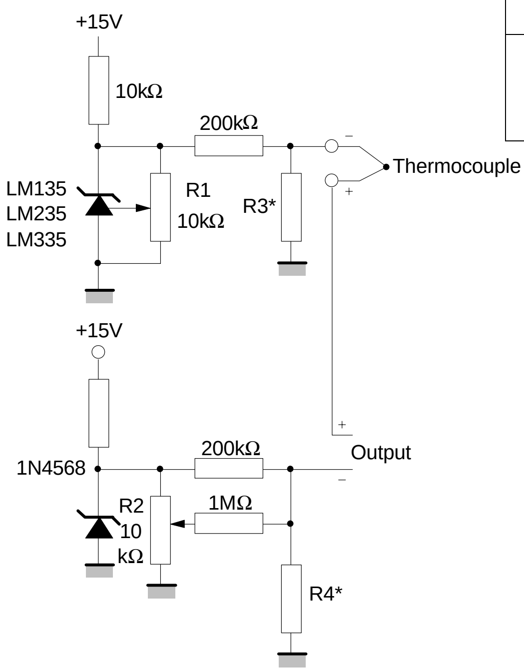
Thermo-couple	R3	Seebeck Coefficient
J	377Ω	52.3µV/°C
T	308Ω	42.8µV/°C
K	293Ω	40.8µV/°C
S	45.8Ω	6.4µV/°C

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

* Select R3 for proper thermocouple type

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

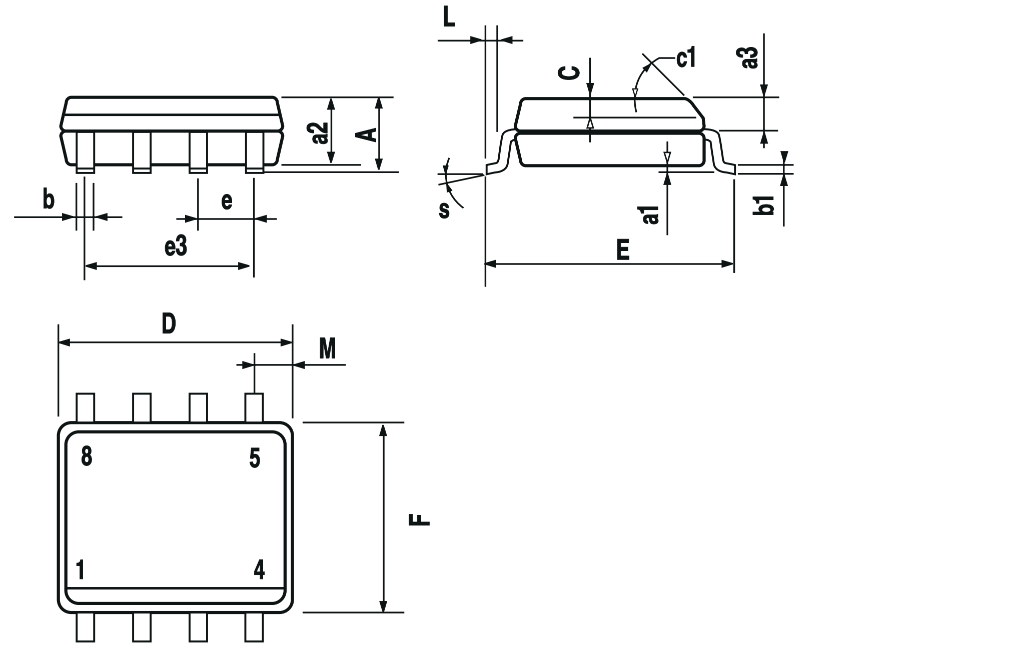
Adjustments :

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 correspon-ding to thermocouple.
   J 14.32mV K 11.17mV
   T 11.79mV S 1.768mV

* Select R3 and R4 for proper thermocouple

PACKAGE MECHANICAL DATA

8 PINS - PLASTIC MICROPACKAGE (SO)

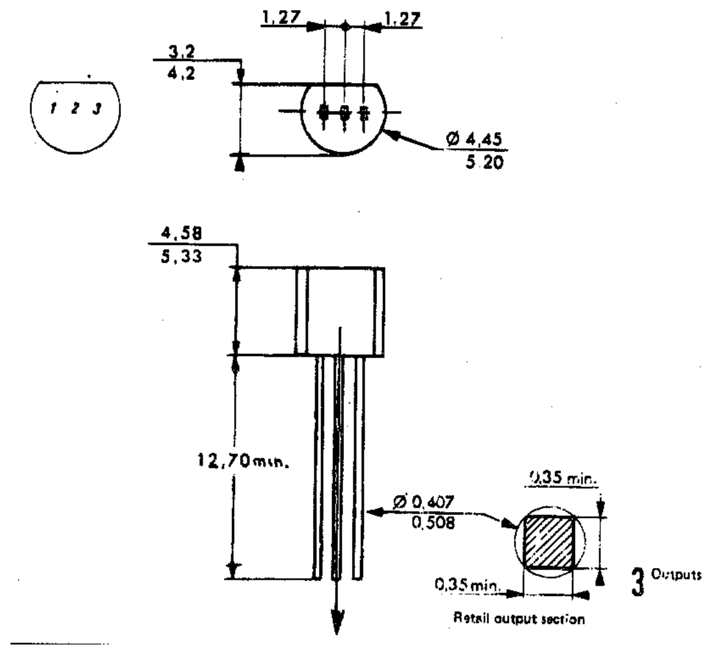


Dimensions	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.069
a1	0.1		0.25	0.004		0.010
a2			1.65			0.065
a3	0.65		0.85	0.026		0.033
b	0.35		0.48	0.014		0.019
b1	0.19		0.25	0.007		0.010
C	0.25		0.5	0.010		0.020
c1	45^o (typ.)					
D	4.8		5.0	0.189		0.197
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		3.81			0.150	
F	3.8		4.0	0.150		0.157
L	0.4		1.27	0.016		0.050
M			0.6			0.024
S	8^o (max.)					

SO8.TBL

PACKAGE MECHANICAL DATA

3 PINS - PLASTIC PACKAGE TO92



PM-TO92.IMG

Dimensions	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		

TO92TBL