Analog Temperature Sensor – LM335

Single-supply linear-output temperature sensor in bare die form

Rev 1.1
28/04/20

Description

The LM335 precision linear-output temperature sensor is designed for simple calibration and ease of use. Output is derived from an integrated 2-terminal Zener with a breakdown voltage directly proportional to absolute temperature at 10mV/°K. Calibrated at +25°C, the LM335 has an accuracy of 1°C over a wide -40°C to 100°C temperature range. With less than 1Ω dynamic impedance, performance is consistent across a current range of 450µA to 5mA. The device suits use as a general purpose sensor where its small size, low impedance and linear output enables simple circuit integration.

Features:

- Wide temperature range: -40 to +100°C
- 1% typical accuracy at 25°C
- Single-point calibration for high precision
- Operates from 450µA to 5mA
- <1Ω dynamic impedance
- Linear output
- Small size for high integration

Ordering Information

The following part suffixes apply:

- No suffix - MIL-STD-883 /2010B Visual Inspection

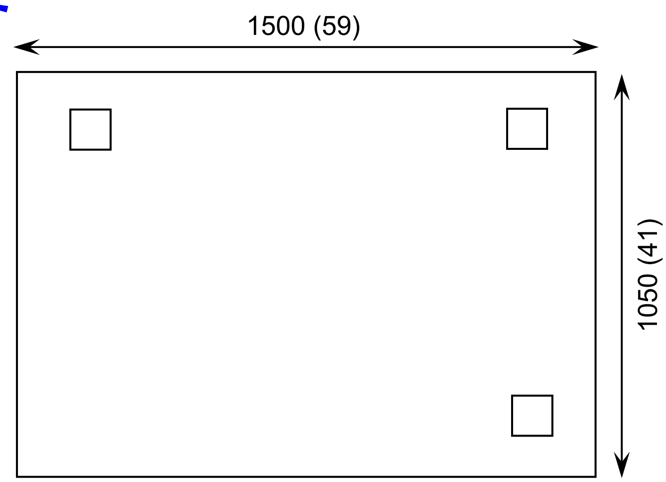
For High Reliability versions of this product please see

LM135 and LM135A

For higher precision commercial grade product please see

LM335A

Die Dimensions in µm (mils)



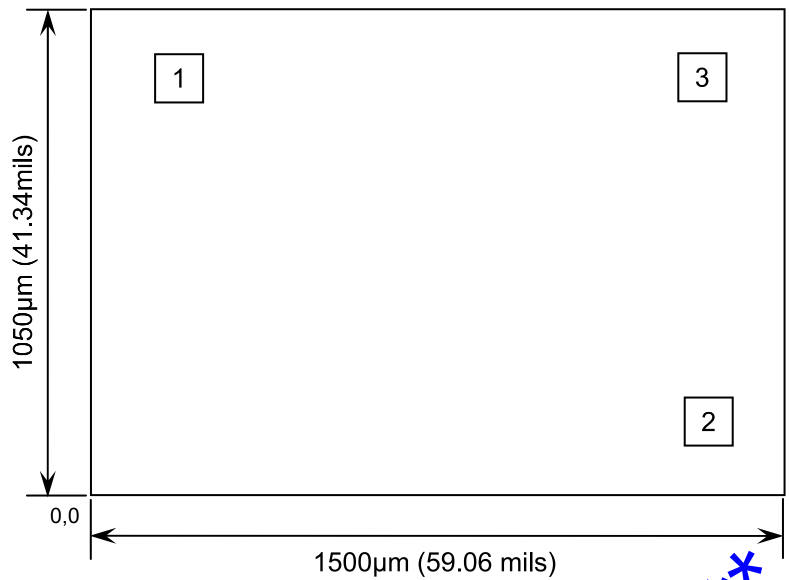
Supply Formats:

- Default – Die in Waffle Pack (400 per tray capacity)
- Sawn Wafer on Tape – On request
- Unsawn Wafer – On request
- Die Thickness <> 350µm(14 Mils) – On request
- Assembled into Hermetic Package – On request

Mechanical Specification

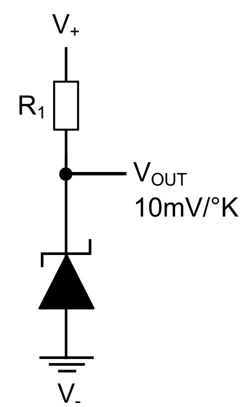
Die Size (Unsawn)	1500 x 1050 59 x 41	µm mils
Minimum Bond Pad Size	104 x 104 4.09 x 4.09	µm mils
Die Thickness	350 (±20) 13.78 (±0.79)	µm mils
Top Metal Composition	Al 1%Si 1.1µm	
Back Metal Composition	N/A – Bare Si	

Pad Layout and Functions



PAD	FUNCTION	COORDINATES (µm)	
		X	Y
1	V+	134	848
2	V-	1281	103
3	ADJ	1268	848
CONNECT CHIP BACK TO V- OR FLOAT			

Simplified Schematic



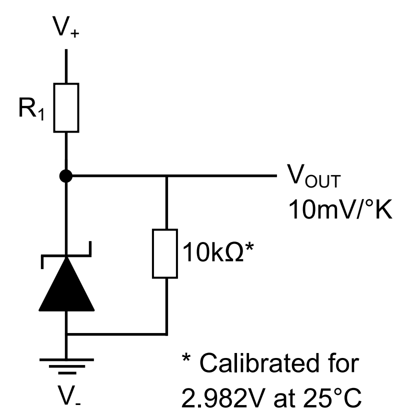
Calibration methodology and schematic

The LM335 response is proportional to 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:

$$V_{OUT_T} + V_{OUT_{T_O}} \times \frac{T}{T_o}$$

Where:

- T is the unknown temperature
- T_O is the reference temperature (in °K).



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

Application Note:

Self-heating can decrease accuracy; LM335 should be operated at low current but sufficient enough to drive the sensor and calibration circuit to the maximum operating temperature. If 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.

Absolute Maximum Ratings[1]

PARAMETER	SYMBOL	VALUE		UNIT
Reverse Current	I_R	15		mA
Forward Current	I_F	10		mA
Operating Temperature	T_{OPER}	Continuous	-40 to +100	°C
Storage Temperature	T_{STG}	-65 to +150		°C

1. Operation above the absolute maximum rating may cause device failure. Operation at the absolute maximum ratings, for extended periods, may reduce device reliability.

Recommended Operating Conditions

PARAMETER		SYMBOL	MIN	MAX	UNITS
Temperature	Continuous	T_A	-40	100	°C
Forward Current		I_F	0.45	5	mA

Temperature Parameters[2] (T_A = 25°C unless otherwise specified)

PARAMETER	SYMBOL	CONDITIONS	LIMITS			UNITS
			MIN	TYP	MAX	
Output Voltage	V_{OUT}	T_J = 25°C, I_R = 1mA	2.92	2.98	3.04	V
Un-calibrated Temperature Error	ΔT_1	T_A = 25°C, I_R = 1mA	-	2	6	°C
	ΔT_2	-40˚C≤ T_A≤ +100˚C, I_R = 1mA	-	4	9	°C
25°C Calibrated Temperature Error	ΔT_3	-40˚C≤ T_A≤ +100˚C, I_R = 1mA	-	1	2	°C
Non-linearity	ΔT_4	-40˚C≤ T_A≤ +100˚C, I_R = 1mA	-	0.3	1.5	°C

Electrical Parameters[2] (T_A = 25°C unless otherwise specified)

PARAMETER	SYMBOL	CONDITIONS	LIMITS			UNITS
			MIN	TYP	MAX	
Output voltage change with current	ΔV_{OUT}	450µA ≤ I_R ≤ 5mA, Constant temperature	-	3	14	mV
Dynamic impedance	ΔR_1	T_J = 25°C, I_R = 1mA	-	0.6	-	Ω
Temperature coefficient of output voltage	TC	T_J = 25°C, I_R = 1mA	-	+10	-	mV/°C
Time constant	τ_T	Still air	-	80	-	s
		Air 0.5m/s	-	10	-	
		Stirred oil	-	1	-	
Time stability	T_{STAB}	T_J = 125°C	-	0.2	-	°C/1000h

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

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Typical Characteristics (T_J = 25°C unless otherwise specified)

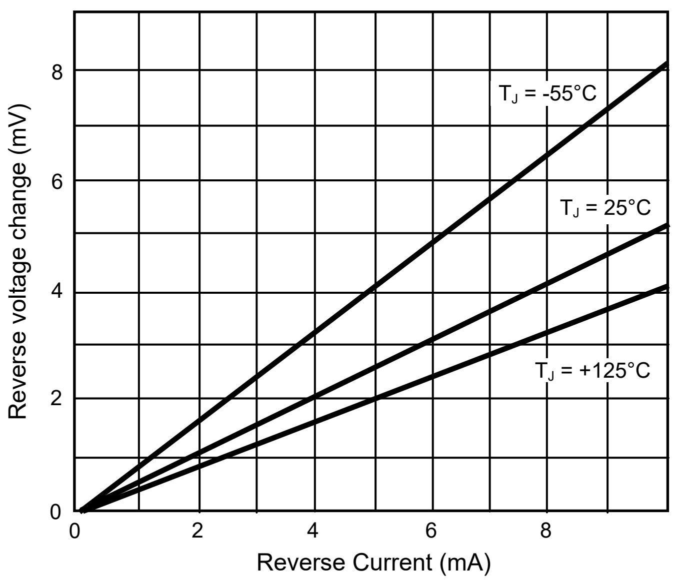

FIGURE 1. Reverse Voltage Change

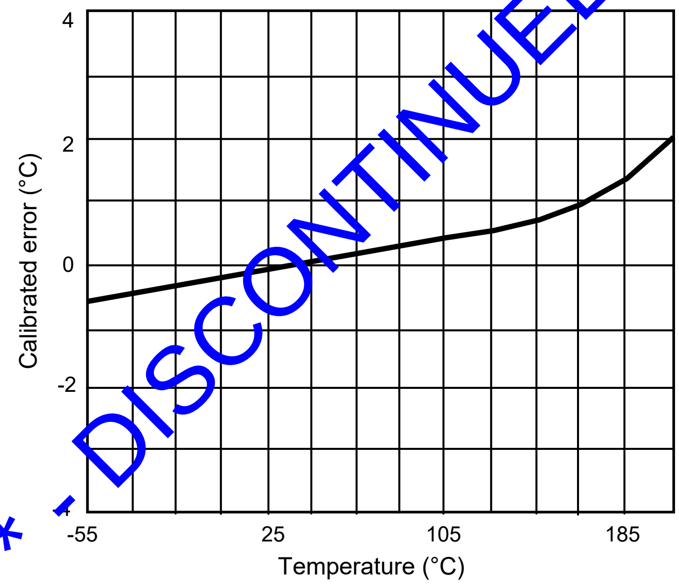

FIGURE 2. Calibrated error

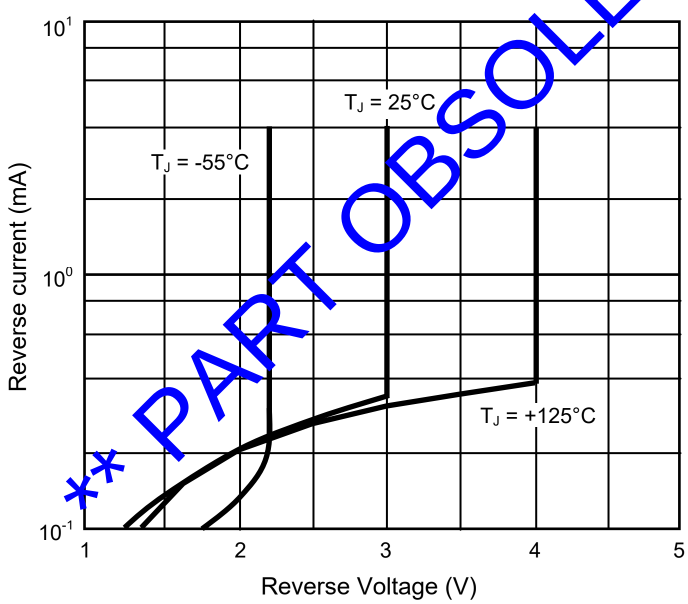

FIGURE 3. Reverse characteristics

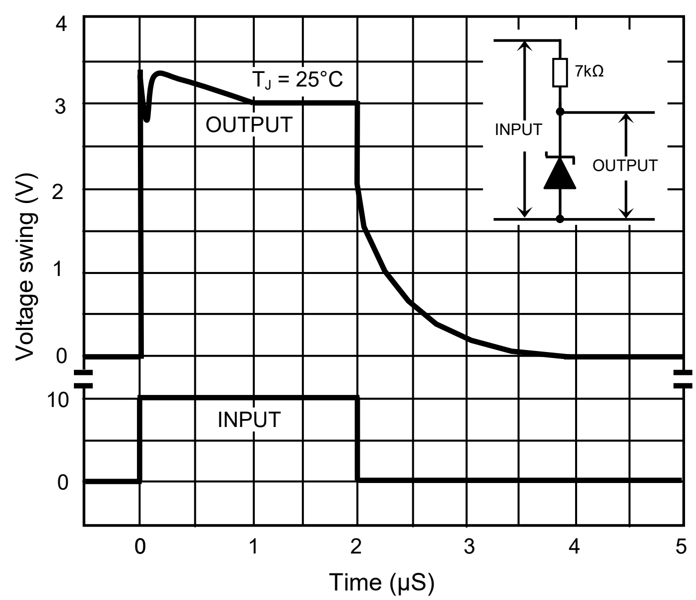

FIGURE 4. Response time

Typical Characteristics (T$_J$ = 25°C unless otherwise specified)

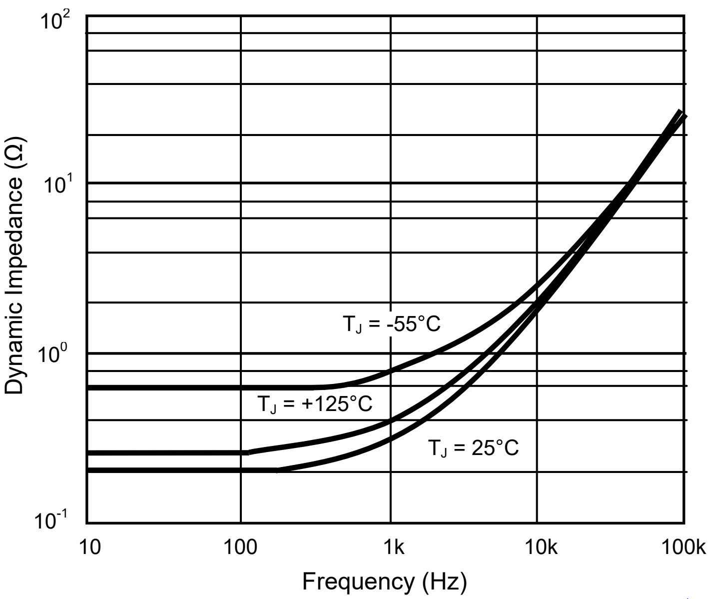

FIGURE 5. Dynamic Impedance

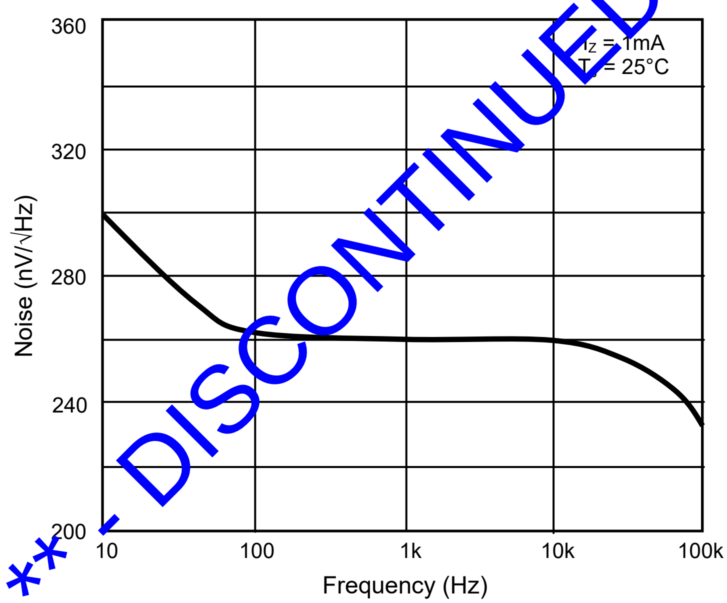

FIGURE 6. Noise voltage

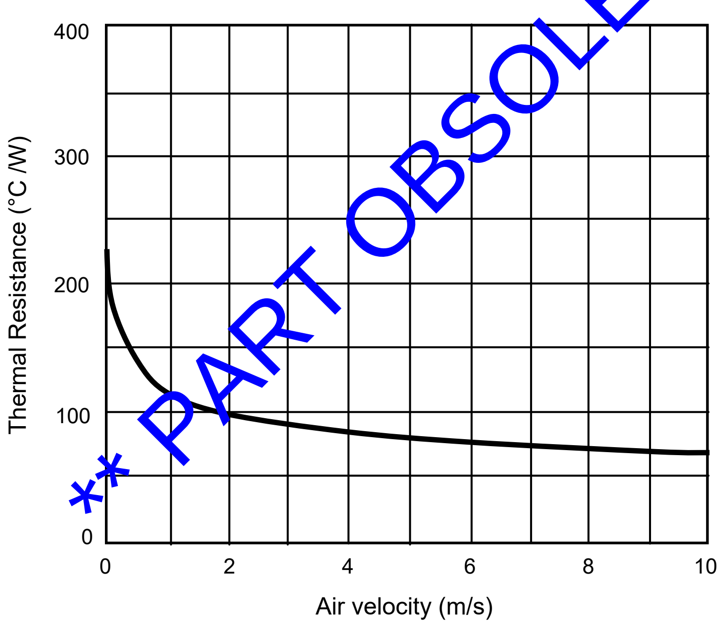

FIGURE 8. Thermal resistance, junction-to-air

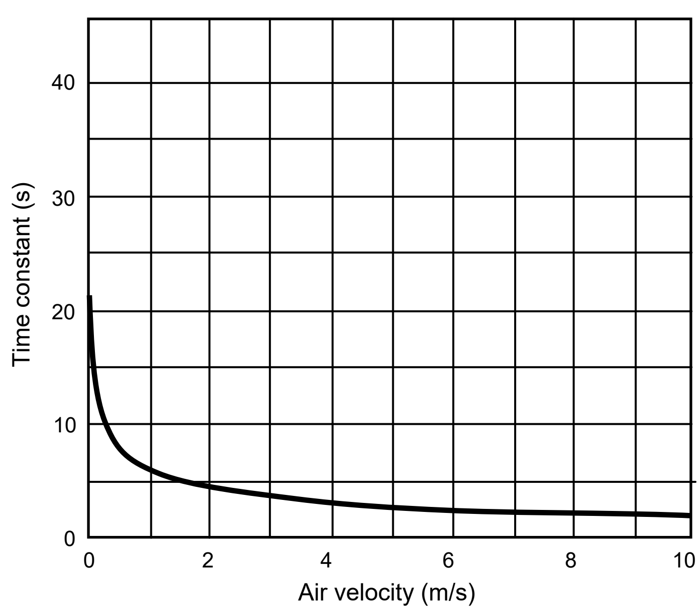

FIGURE 9. Thermal time constant

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Typical Characteristics (T_J = 25°C unless otherwise specified)

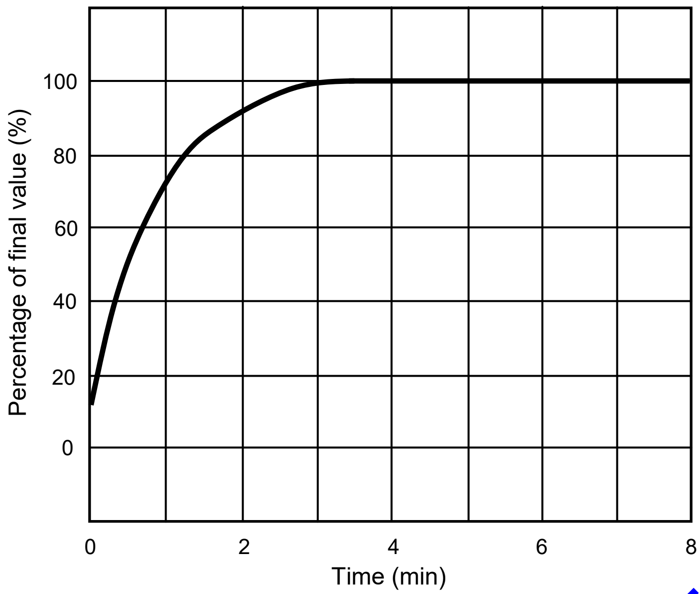

FIGURE 10. Thermal response in still air

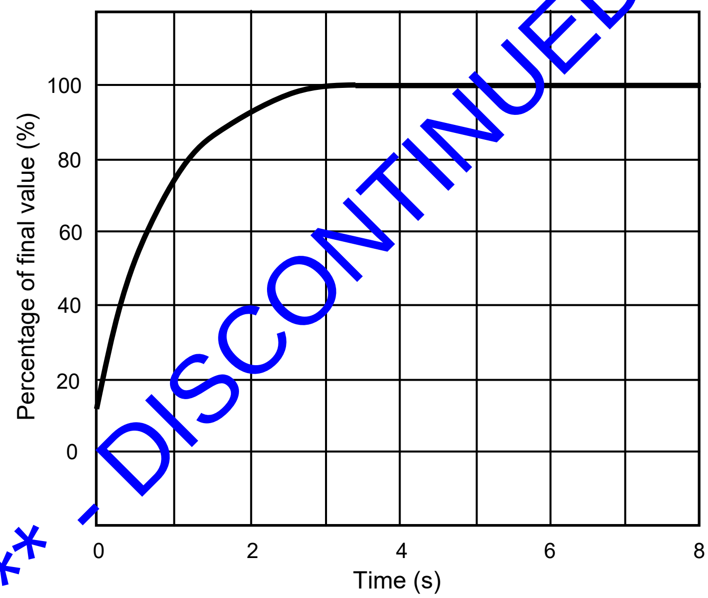

FIGURE 11. Thermal response in stirred-oil bath

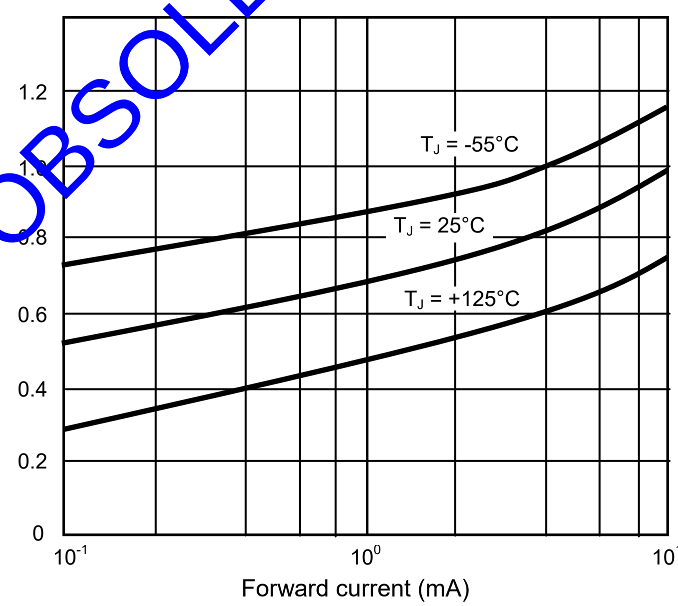

FIGURE 12. Forward characteristics

Typical Applications

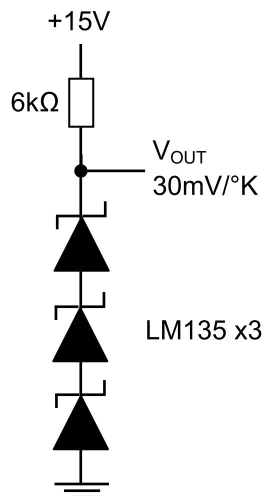

FIGURE 13.

Average Temperature Sensing

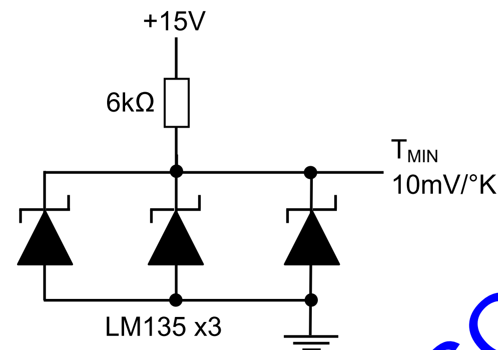

FIGURE 14.

Minimum Temperature Sensing

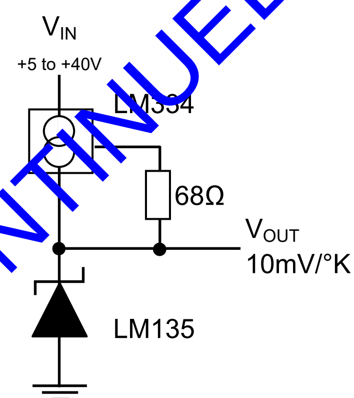

FIGURE 15.

Wide operating supply

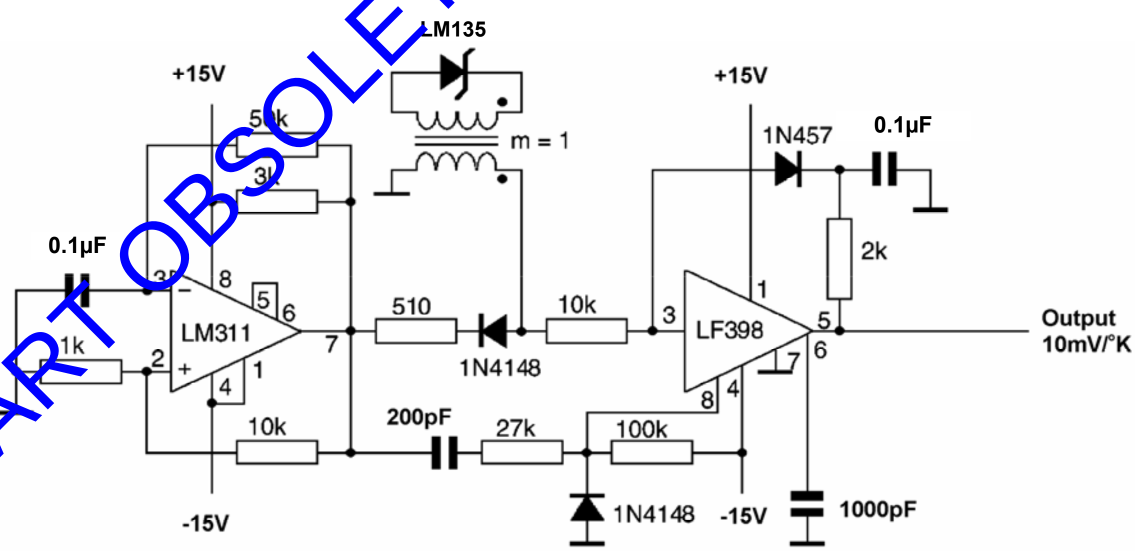

FIGURE 16.

Isolated Temperature Sensor

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Typical Applications continued

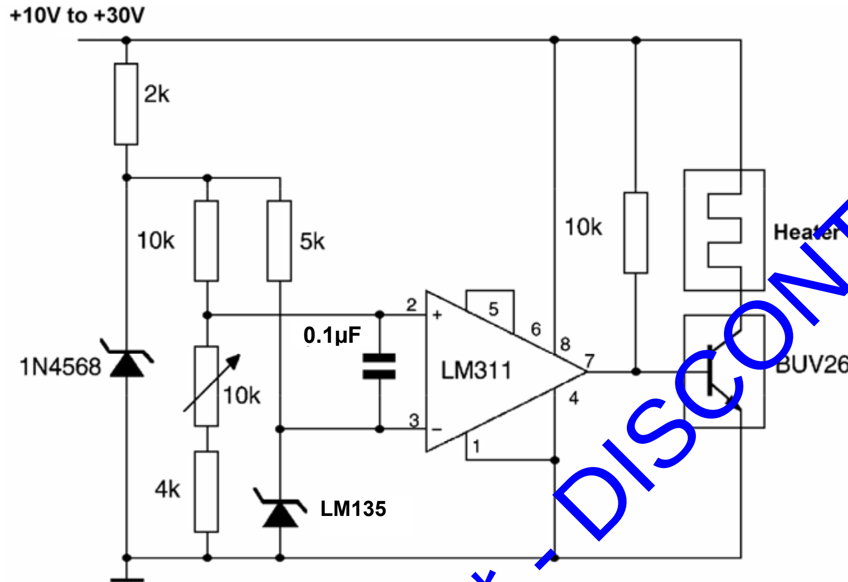


FIGURE 16.

Temperature Controller

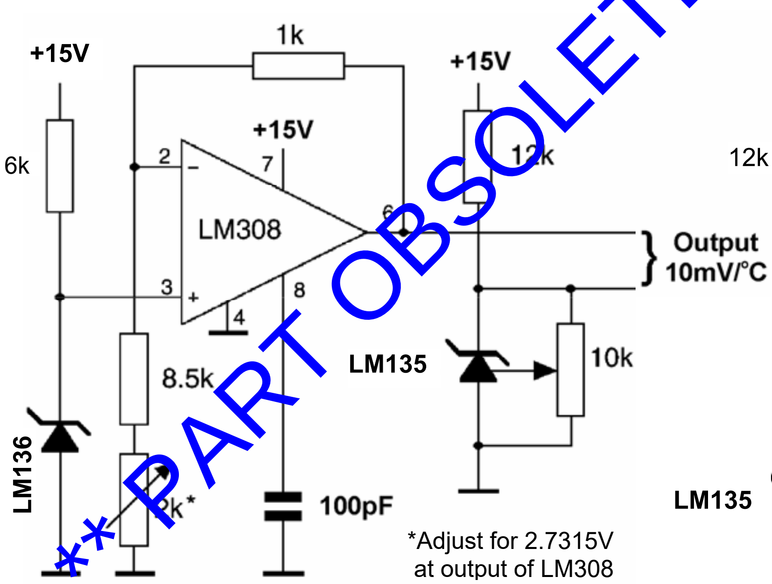


FIGURE 17.

Centigrade Thermometer

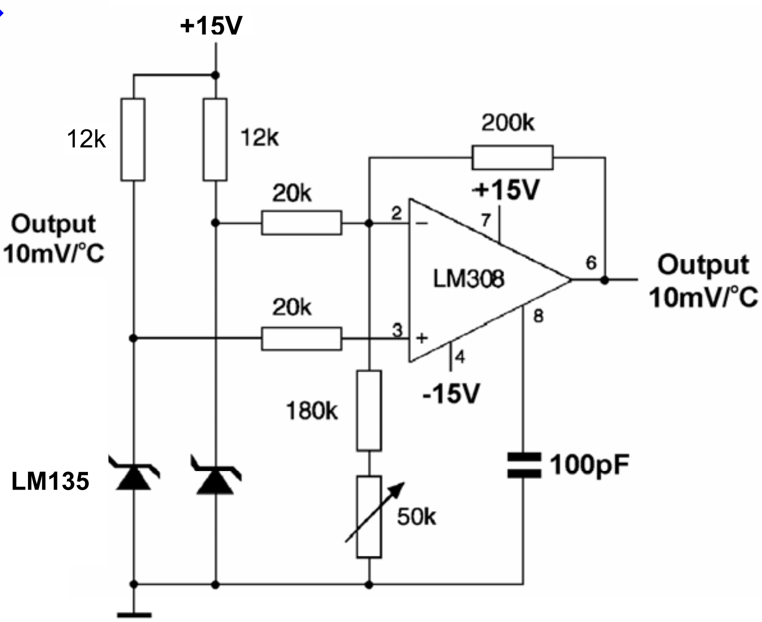
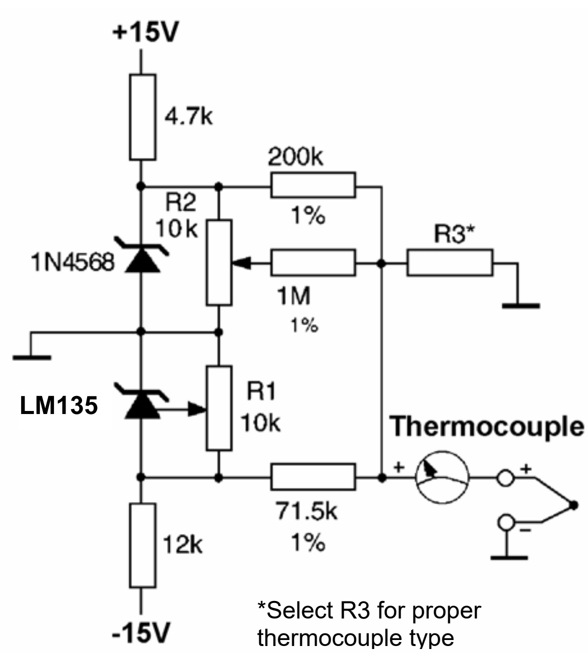


FIGURE 18.

Differential Temperature Sensor

Thermocouple compensation



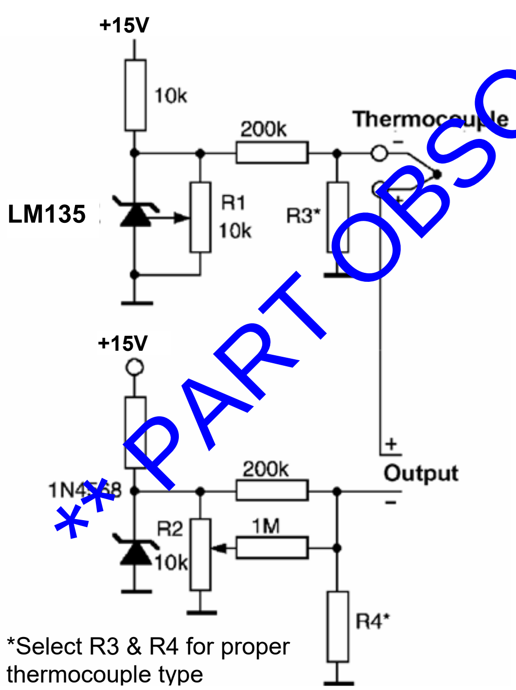
Thermocouple	R3	SEEBECK Coefficient
J	377Ω	52.3µV/°C
T	308Ω	42.8µV/°C
K	293Ω	40.8µV/°C
S	45.8Ω	6.4µV/°C

Adjustments:

1. Short 1N4568.
2. Adjust R1 for SEEBECK coefficient times ambient temperature in degrees Kelvin across R3.
3. Short LM135 and adjust R2 for voltage across R3 corresponding to thermocouple type as below:

J	14.32mV	K	11.17mV
T	11.9mV	S	1.768mV

FIGURE 19. Thermocouple cold junction compensation (compensation for grounded thermocouple)



Thermocouple	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 the thermocouple as below:

J	14.32mV	K	11.17mV
T	11.9mV	S	1.768mV

FIGURE 20. Single power supply cold junction compensation

Circuit schematic