



Analog Temperature Sensor – LM335A

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

Rev 1.1
28/04/20

Description

The LM335A 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 LM335A has a typical accuracy of 0.5°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
- 0.5% 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

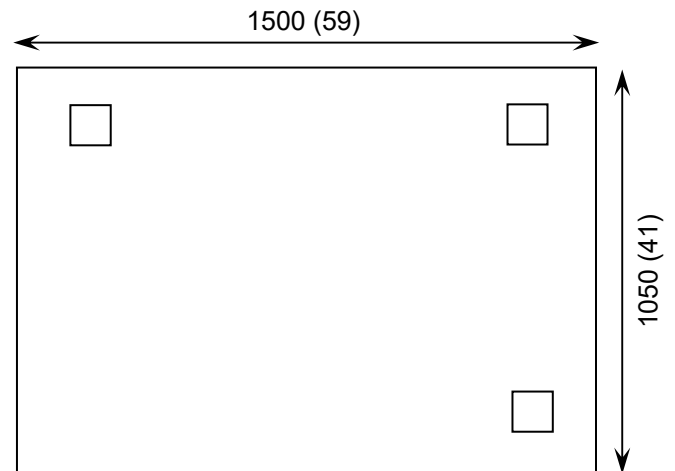
The following part suffixes apply:

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

For High Reliability versions of this product please see

[LM135](#) and [LM135A](#)

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	

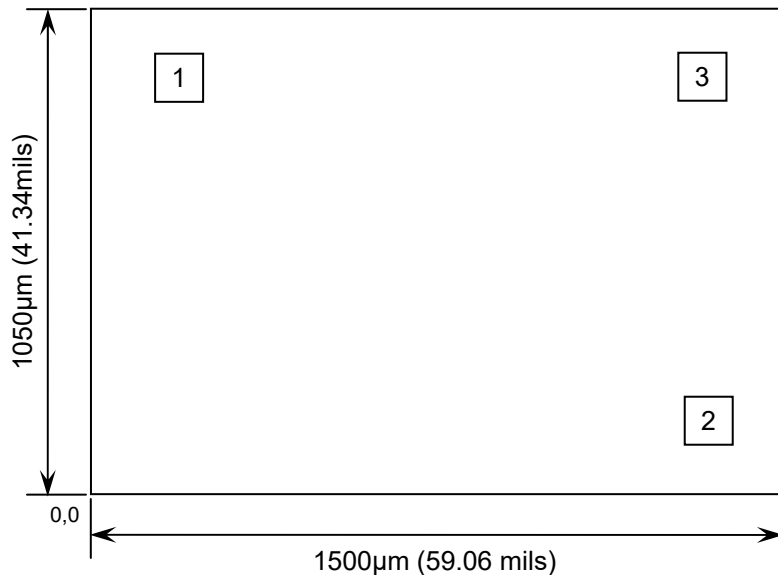




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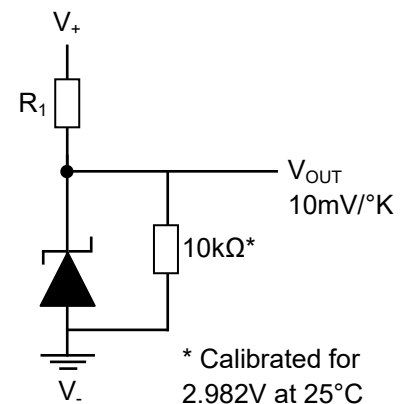
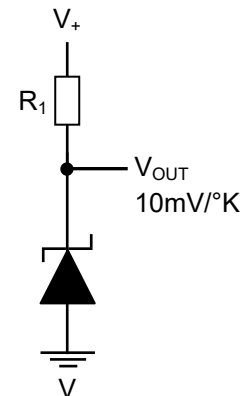
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Pad Layout and Functions



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 LM335A 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:

$$V_{OUT_T} + V_{OUT_{T_0}} \times \frac{T}{T_0}$$

Where:

- T is the unknown temperature
- T₀ is the reference temperature (in °K).

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

Application Note:

Self-heating can decrease accuracy; LM335A 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.





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Absolute Maximum Ratings¹

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 Parameters² ($T_A = 25^\circ\text{C}$ unless otherwise specified)

PARAMETER	SYMBOL	CONDITIONS	LIMITS			UNITS
			MIN	TYP	MAX	
Output Voltage	V_{OUT}	$T_J = 25^\circ\text{C}, I_R = 1\text{mA}$	2.95	2.98	3.01	V
Un-calibrated Temperature Error	ΔT_1	$T_A = 25^\circ\text{C}, I_R = 1\text{mA}$	-	1	3	°C
	ΔT_2	$-40^\circ\text{C} \leq T_A \leq +100^\circ\text{C}, I_R = 1\text{mA}$	-	2	5	°C
25°C Calibrated Temperature Error	ΔT_3	$-40^\circ\text{C} \leq T_A \leq +100^\circ\text{C}, I_R = 1\text{mA}$	-	0.5	1	°C
Non-linearity	ΔT_4	$-40^\circ\text{C} \leq T_A \leq +100^\circ\text{C}, I_R = 1\text{mA}$	-	0.3	1.5	°C

Electrical Parameters² ($T_A = 25^\circ\text{C}$ unless otherwise specified)

PARAMETER	SYMBOL	CONDITIONS	LIMITS			UNITS
			MIN	TYP	MAX	
Output voltage change with current	ΔV_{OUT}	$450\mu\text{A} \leq I_R \leq 5\text{mA}$, Constant temperature	-	3	14	mV
Dynamic impedance	ΔR_1	$T_J = 25^\circ\text{C}, I_R = 1\text{mA}$	-	0.6	-	Ω
Temperature coefficient of output voltage	TC	$T_J = 25^\circ\text{C}, I_R = 1\text{mA}$	-	+10	-	mV/°C
Time constant	τ_T	Still air	-	80	-	s
		Air 0.5m/s	-	10	-	
		Stirred oil	-	1	-	
Time stability	T_{STAB}	$T_J = 125^\circ\text{C}$	-	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 ($T_J = 25^\circ\text{C}$ unless otherwise specified)

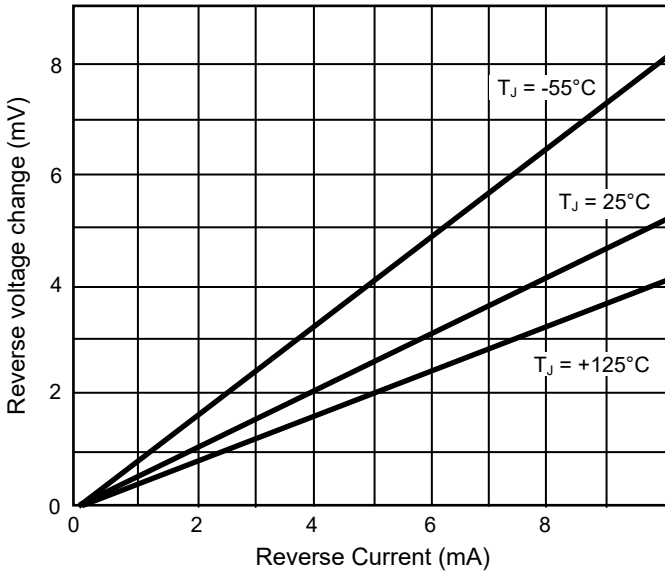


FIGURE 1. Reverse Voltage Change

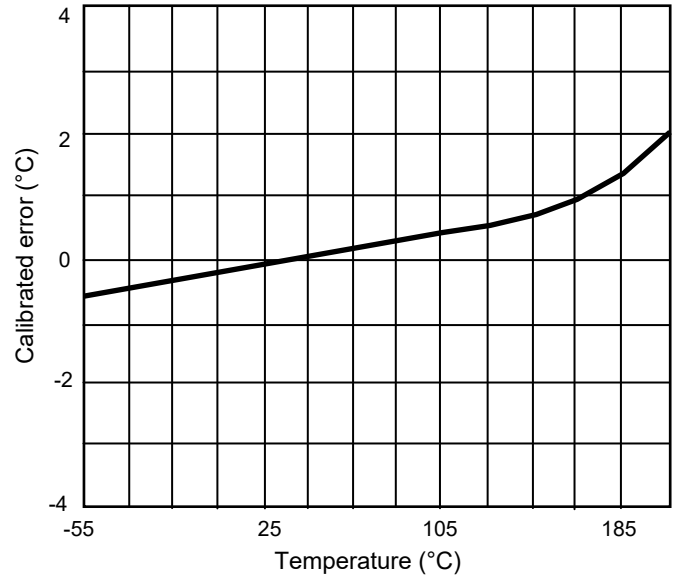


FIGURE 2. Calibrated error

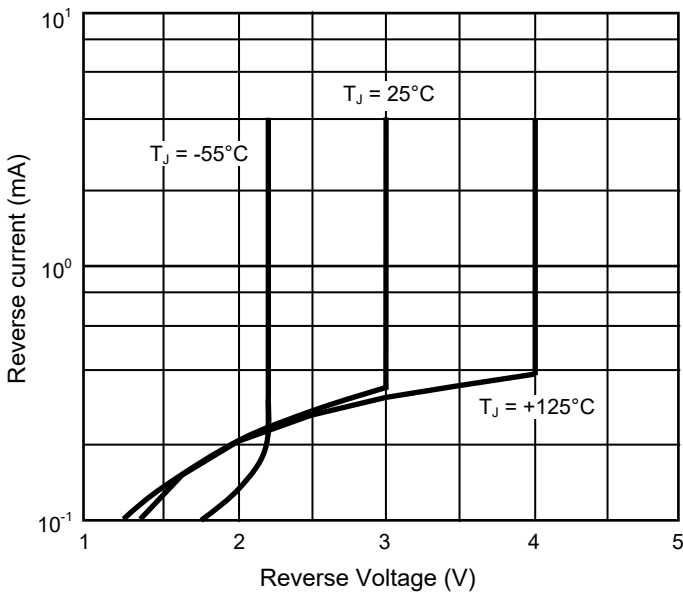


FIGURE 3. Reverse characteristics

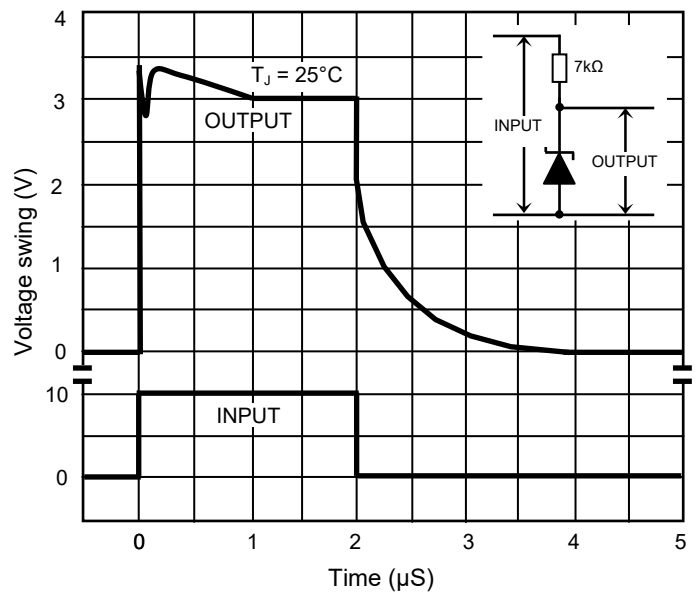


FIGURE 4. Response time





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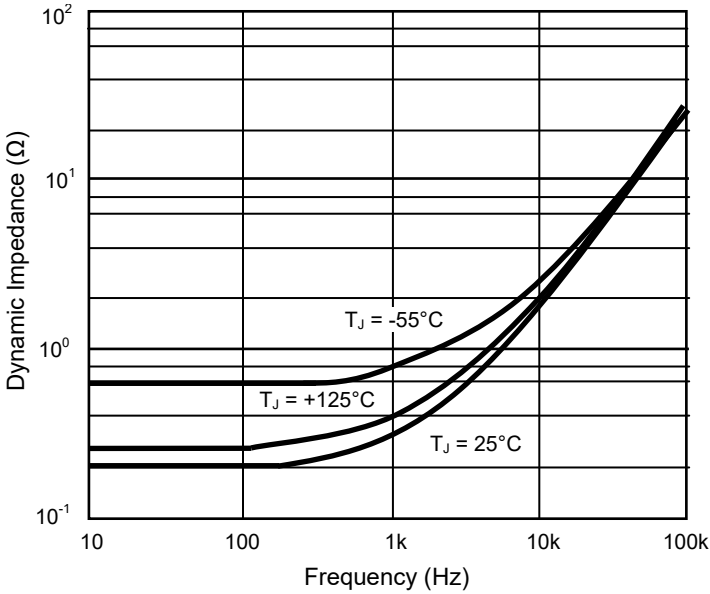


FIGURE 5. Dynamic Impedance

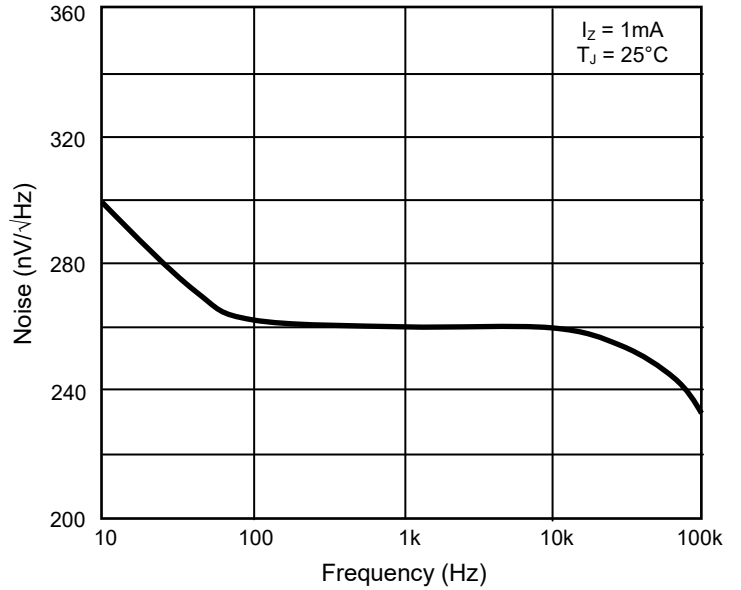


FIGURE 6. Noise voltage

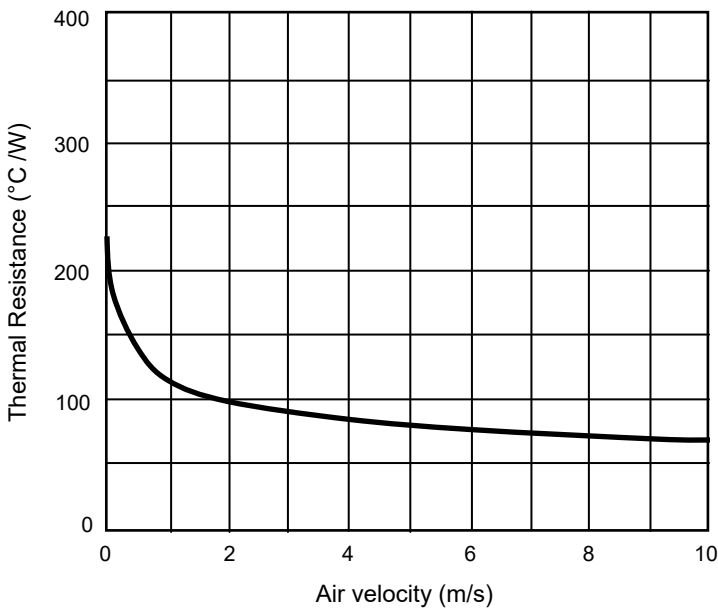


FIGURE 8. Thermal resistance, junction-to-air

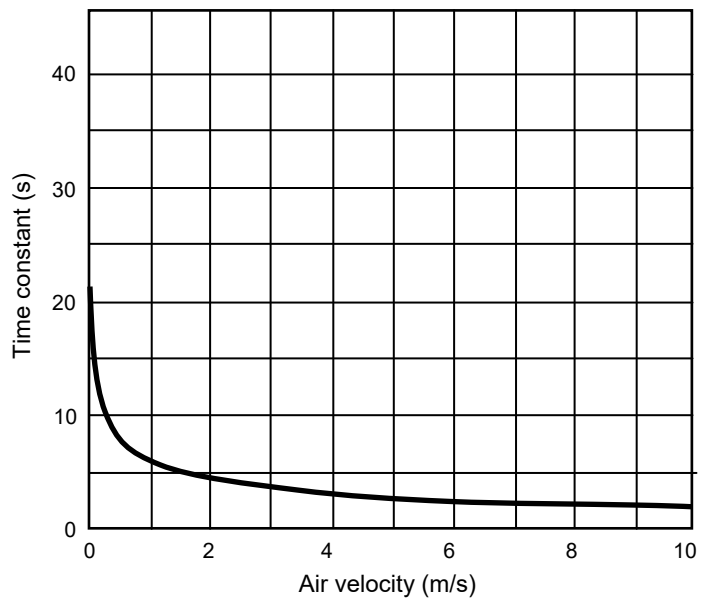


FIGURE 9. Thermal time constant





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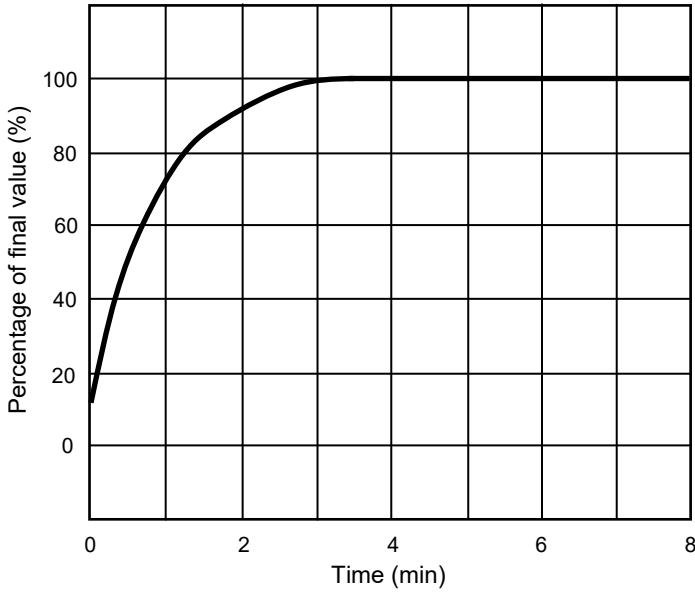


FIGURE 10. Thermal response in still air

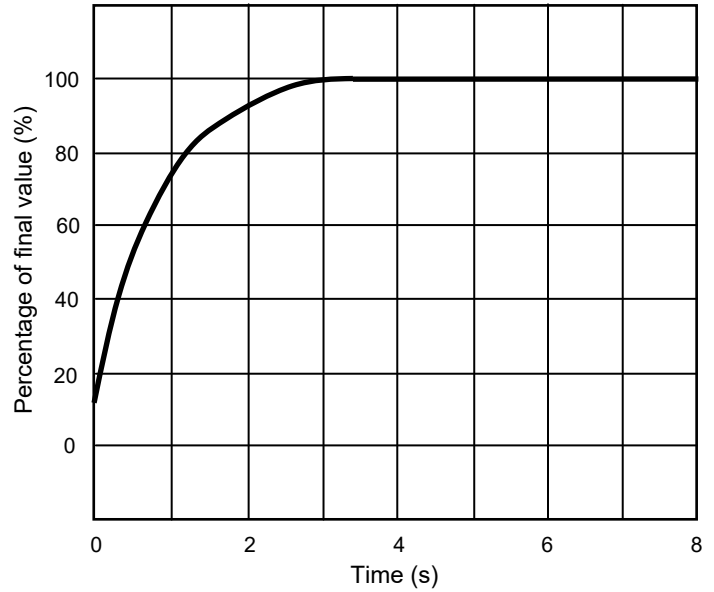


FIGURE 11. Thermal response in stirred-oil bath

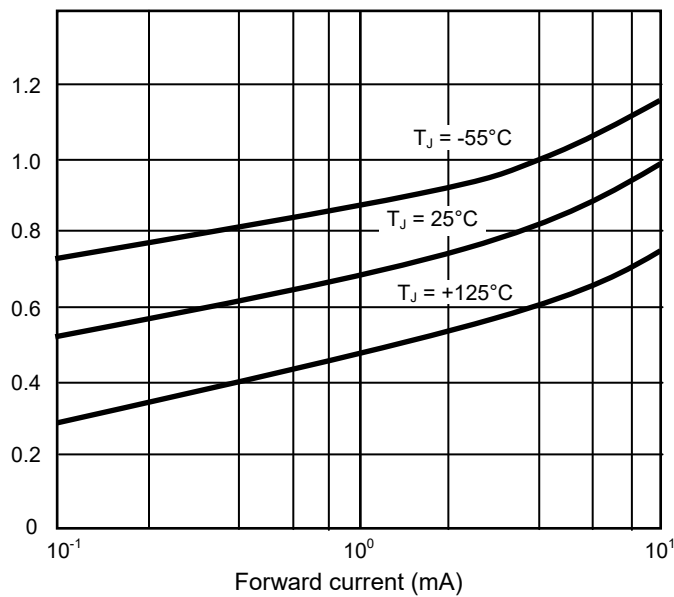


FIGURE 12. Forward characteristics





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Typical Applications

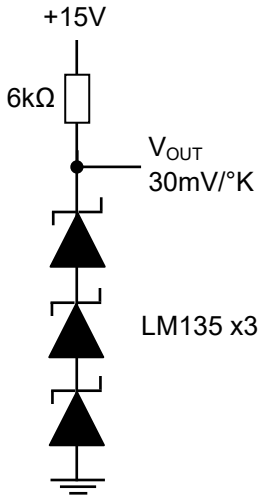


FIGURE 13.

Average Temperature Sensing

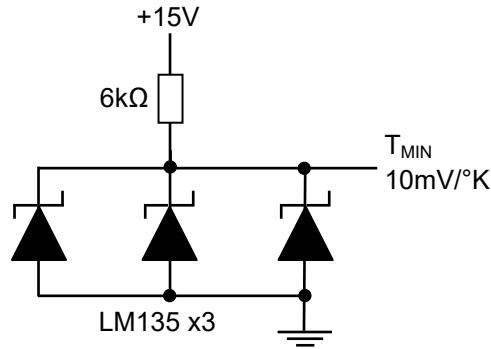


FIGURE 14.

Minimum Temperature Sensing

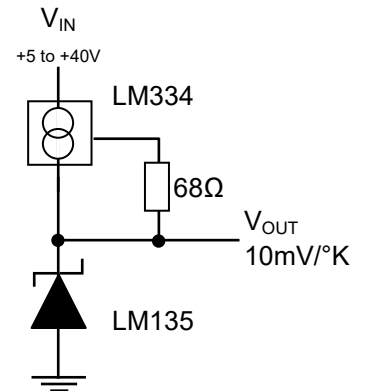


FIGURE 15.

Wide operating supply

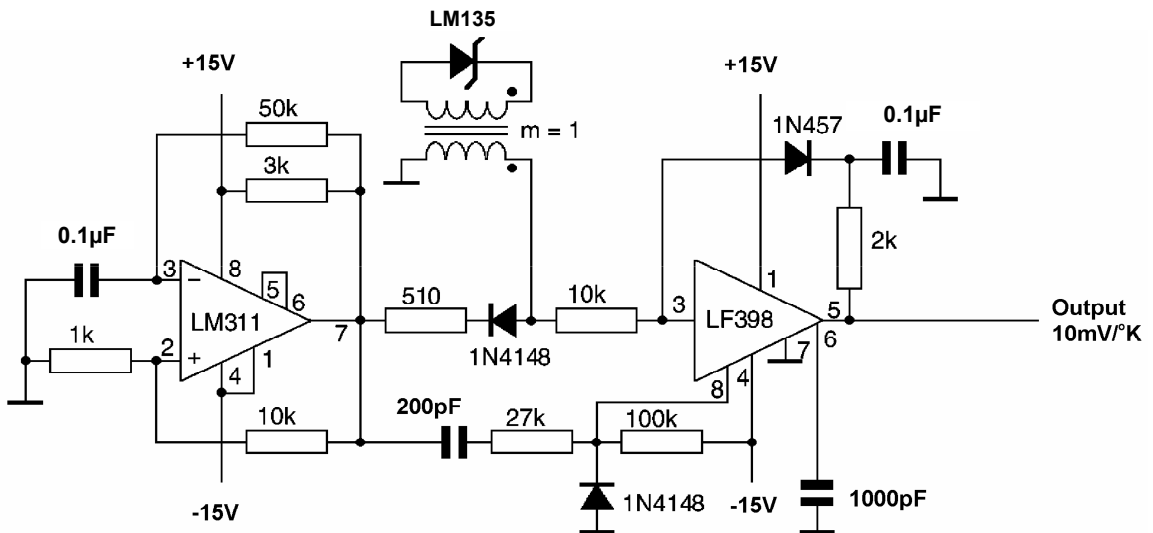


FIGURE 16.

Isolated Temperature Sensor





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Typical Applications continued

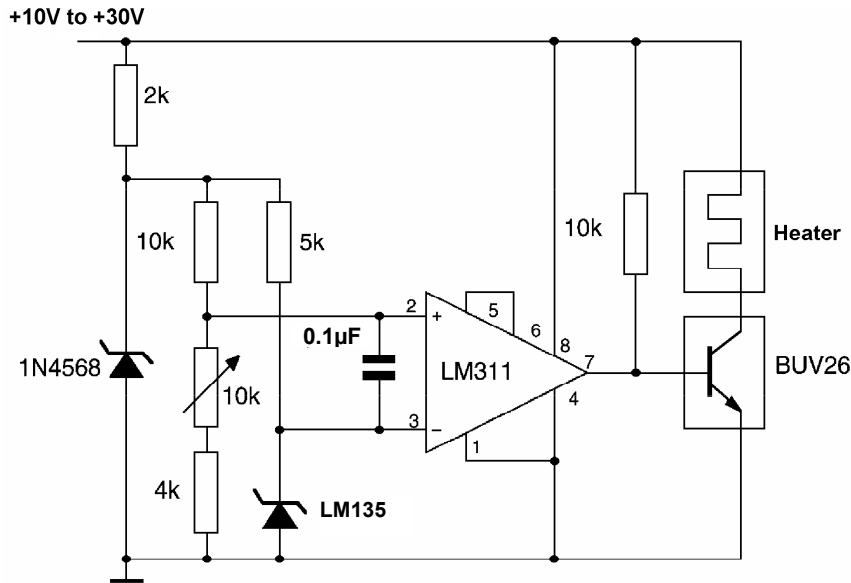


FIGURE 16.

Temperature Controller

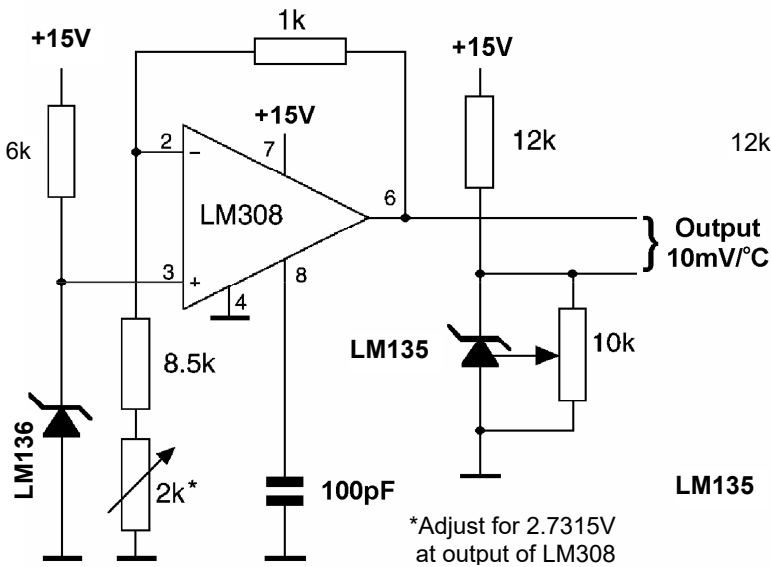


FIGURE 17.

Centigrade Thermometer

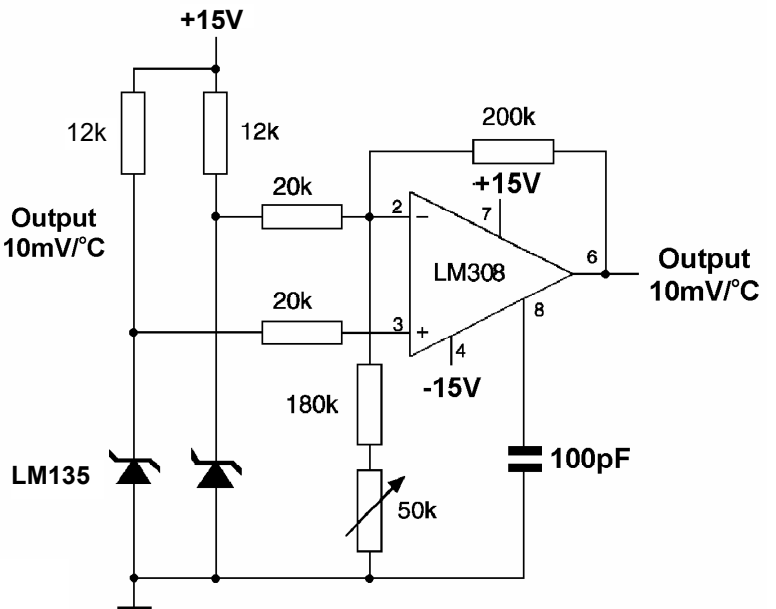


FIGURE 18.

Differential Temperature Sensor

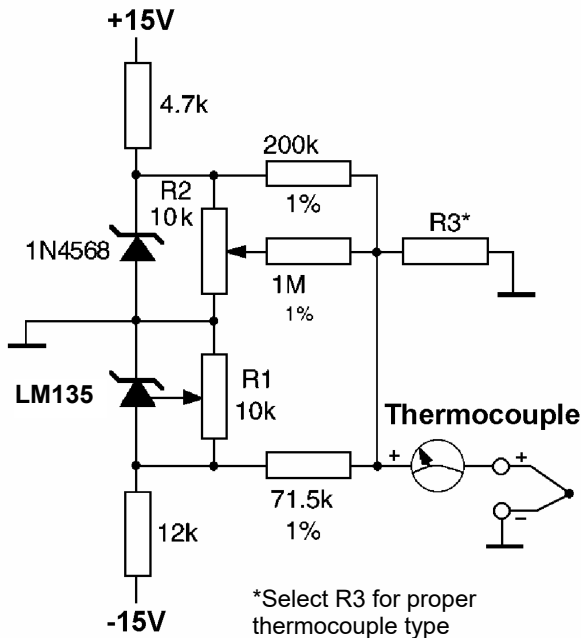




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Thermocouple compensation



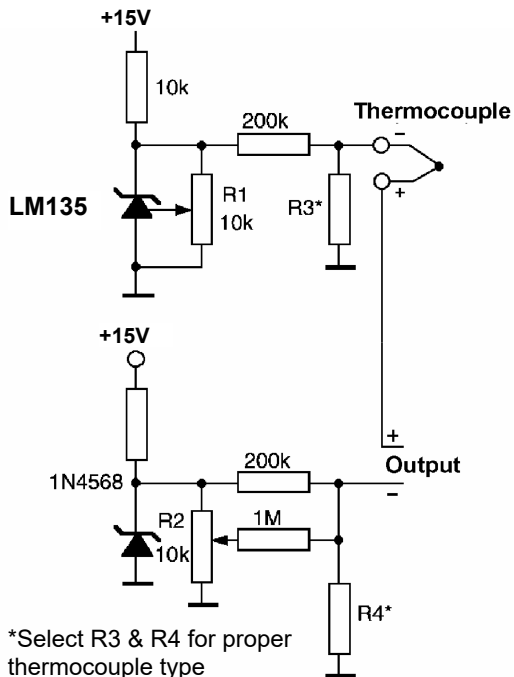
Thermocouple	R3	SEEBECK Coefficient
J	377Ω	52.3μV/°C
T	308Ω	42.8μV/°C
K	293Ω	40.8μV/°C
S	45.8Ω	6.4μV/°C

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

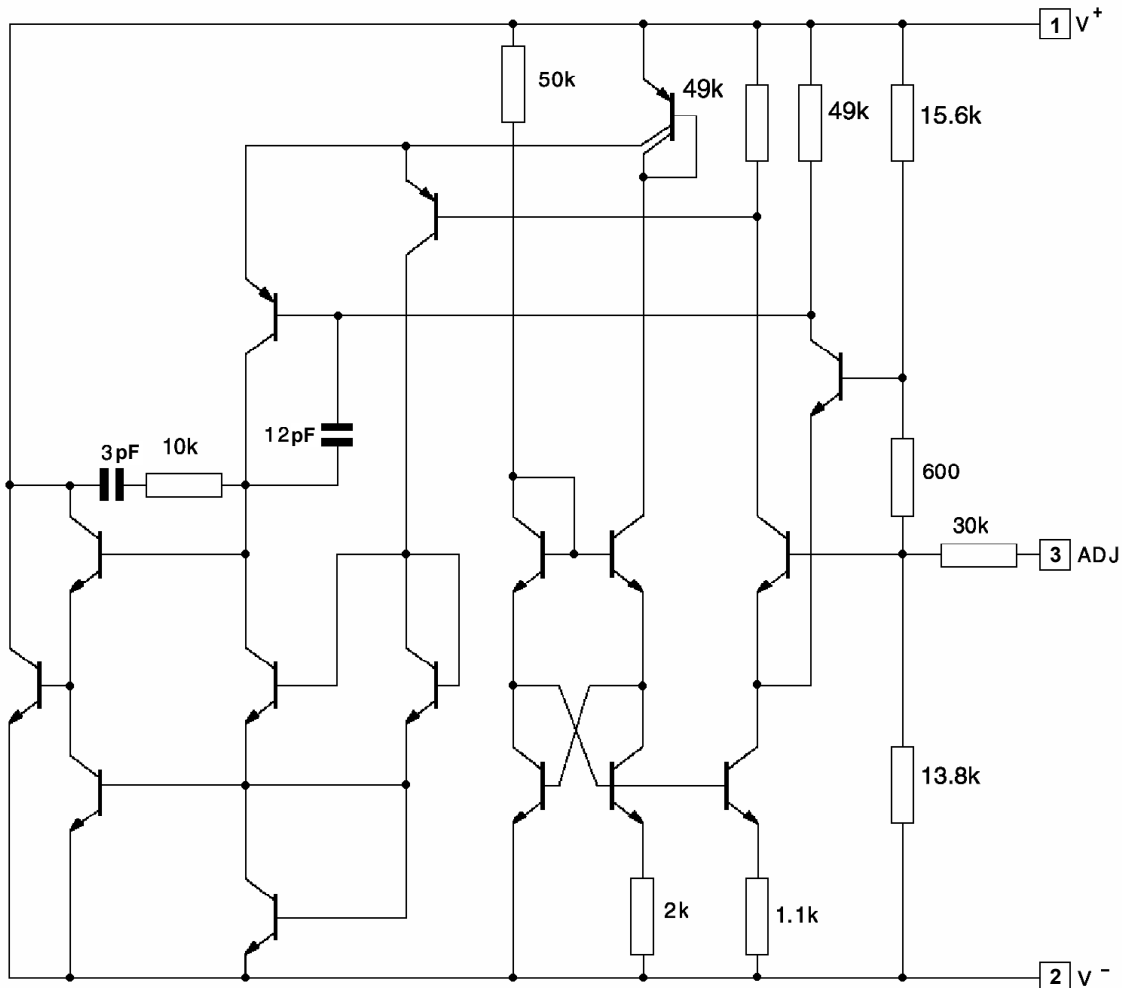




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Circuit schematic



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