How to Design
Temperature sensing with PTC thermistor circuit

General Purpose Amplifiers

www.ti.com/general-amps

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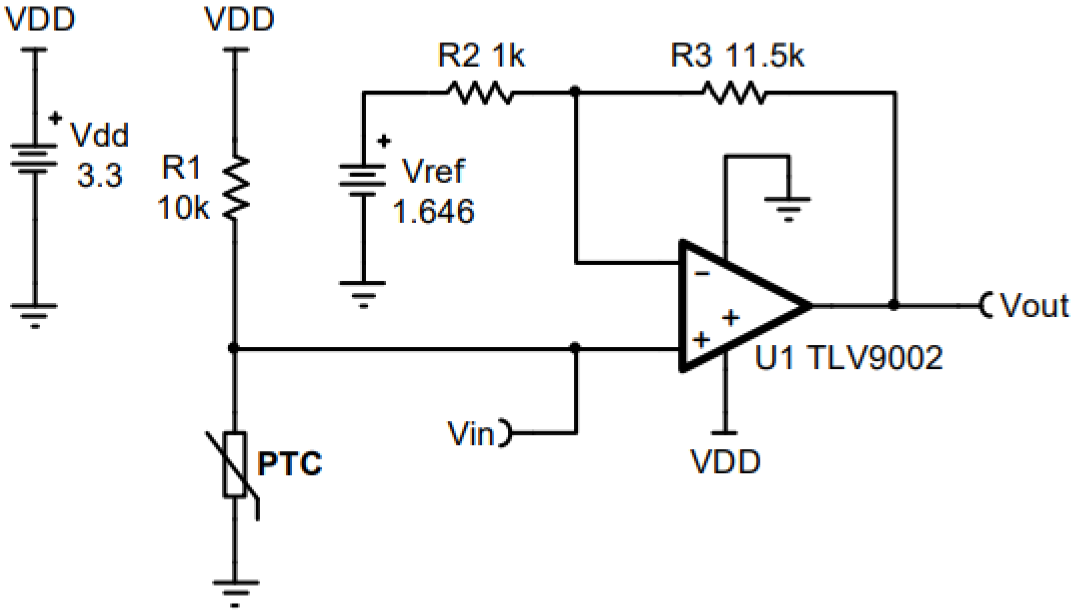
Analog Engineer's

Circuit Cookbook: Op Amps

Texas Instruments

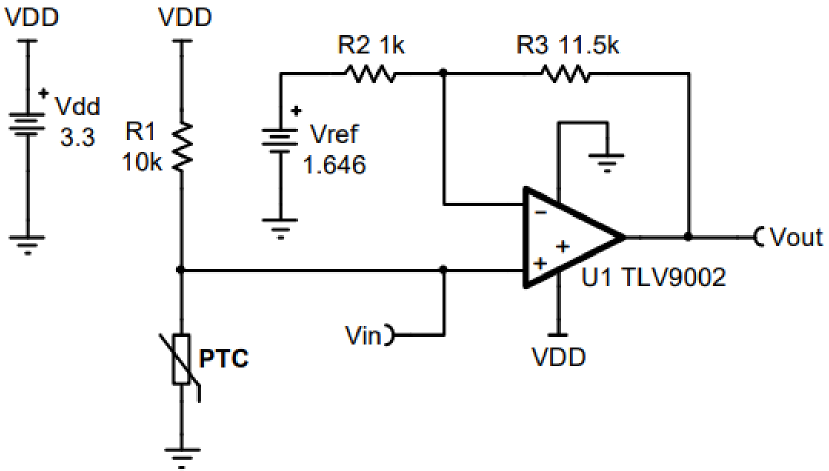
Circuit Description



$$V_O = VDD \times \frac{RPTC}{R1+RPTC} \times \frac{R3+R2}{R2} - \mathrm{Vref} \times \frac{\mathrm{R3}}{\mathrm{R2}}$$

Design Steps

Temperature		Output		Supply		
T_{Min}	T_{max}	V_{outMin}	V_{outMax}	V_{dd}	V_{ee}	V_{ref}
0 °C	50 °C	50mV	3.25V	3.3V	0V	1.646V



PTC Voltage Divider, Vin

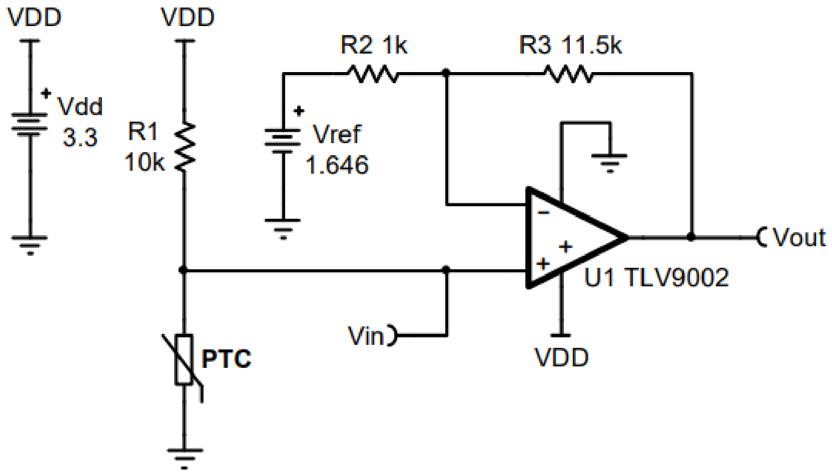
Inverting gain times Vref

$$V_O = VDD \times \frac{RPTC}{R1+RPTC} \times \frac{R3+R2}{R2} + \mathrm{Vref} \times \left(-\frac{\mathrm{R3}}{\mathrm{R2}}\right)$$

Non-inverting amplifier gain

Design Steps

Temperature		Output		Supply		
T_{Min}	T_{max}	V_{outMin}	V_{outMax}	V_{dd}	V_{ee}	V_{ref}
0 °C	50 °C	50mV	3.25V	3.3V	0V	1.646V



$$RPTC\_\max = RPTC@50°C = 11.611\ k\Omega$$

$$RPTC\_\min = RPTC@0°C = 8.525\ k\Omega$$

$$R1 = \sqrt{RPTC@50° + RPTC@0°C}$$

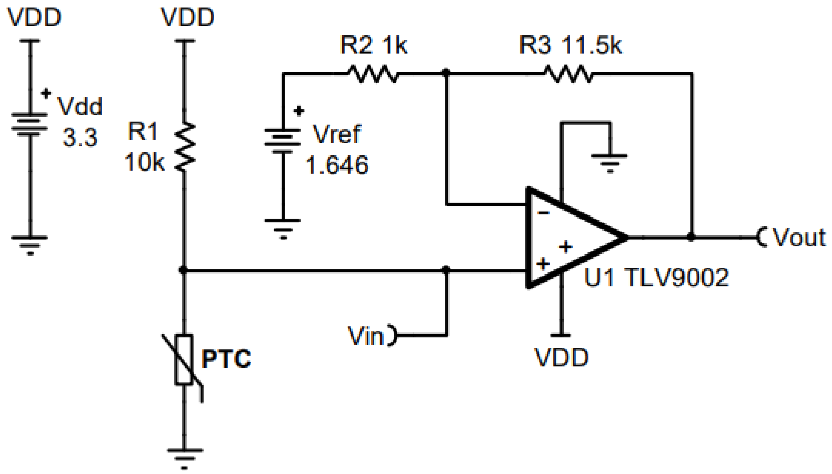
$$R1 = \sqrt{11.611\ k\Omega + 8.525\ k\Omega} = 9.95\ k\Omega$$

$$VinMax = Vdd \times \frac{RPTC\_max}{RPTC\_max + R1} = 1.773\ V$$

$$VinMin = Vdd \times \frac{RPTC\_min}{RNTC\_min + R1} = 1.519\ V$$

Design Steps

Temperature		Output		Supply		
T_{Min}	T_{max}	V_{outMin}	V_{outMax}	V_{dd}	V_{ee}	V_{ref}
0 °C	50 °C	50mV	3.25V	3.3V	0V	1.646V



$$Gain\_ideal = \frac{VoutMax - VoutMin}{VinMax - VinMin} = 12.598V/V$$

$$Gain = \frac{R2 + R3}{R2}$$

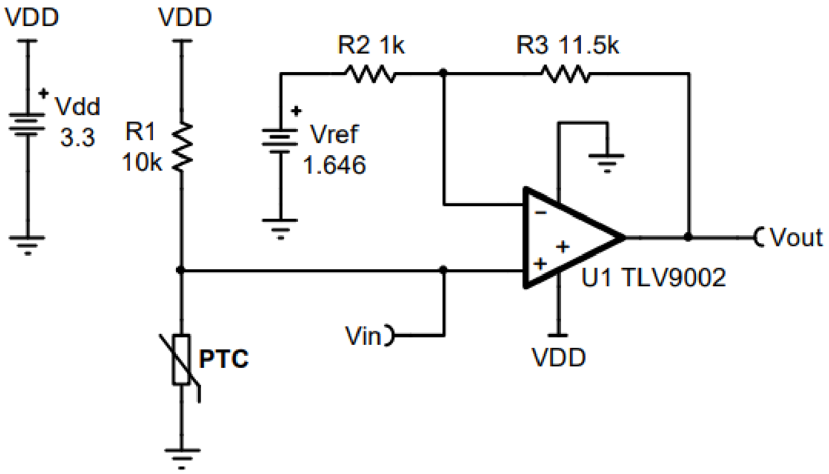
$$R2 = 1\ k\Omega$$

$$R3 = R2 \times (Gain\_ideal - 1) = 11.598\ k\Omega$$

$$Gain\_actual = \frac{R2 + R3}{R2} = 12.5\ V/V$$

Design Steps

Temperature		Output		Supply		
T_{Min}	T_{max}	V_{outMin}	V_{outMax}	V_{dd}	V_{ee}	V_{ref}
0 °C	50 °C	50mV	3.25V	3.3V	0V	1.646V



$$Vo\_swing = (VinMax - VinMin) \times Gain\_actual$$

$$Vo\_swing = (1.773\,V - 1.519\,V) \times 12.5\frac{V}{V} = 3.175V$$

$$VoMax = Vmid - supply + \frac{Vo\_swing}{2}$$

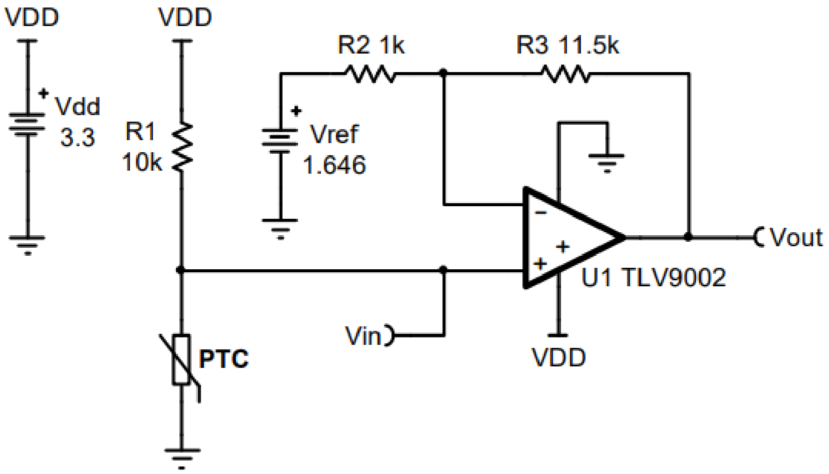
$$VoMax = 1.65\,V + \frac{3.175V}{2} = 3.238V$$

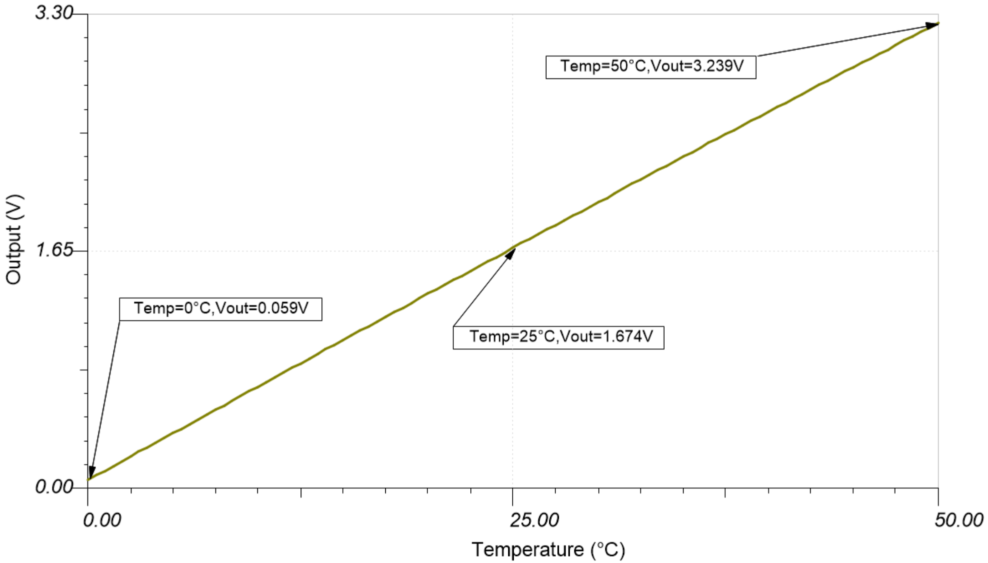
$$VoMax = VinMax \times Gain\_actual - \mathrm{Vref} \times \frac{\mathrm{R3}}{\mathrm{R2}}$$

$$Vref = \frac{1.773\,V \times 12.5\frac{V}{V} - 3.238\,V}{\frac{11.5\,k\Omega}{1\,k\Omega}} = 1.646V$$

DC Results

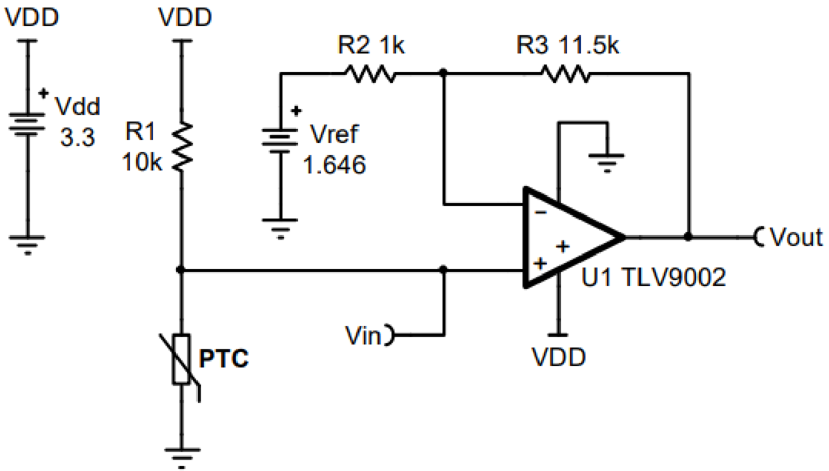
Temperature		Output		Supply		
T_{Min}	T_{max}	V_{outMin}	V_{outMax}	V_{dd}	V_{ee}	V_{ref}
0 °C	50 °C	50mV	3.25V	3.3V	0V	1.646V

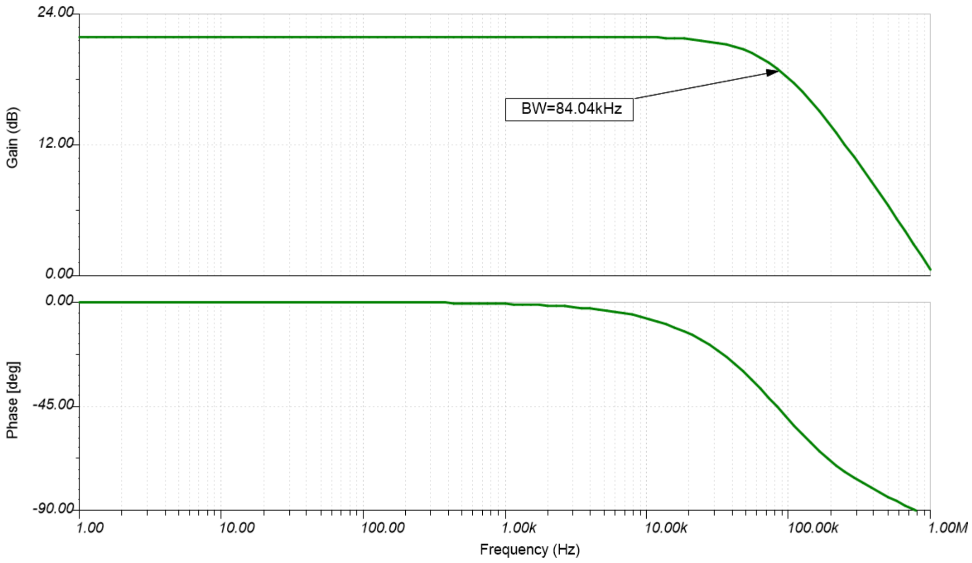




AC Results

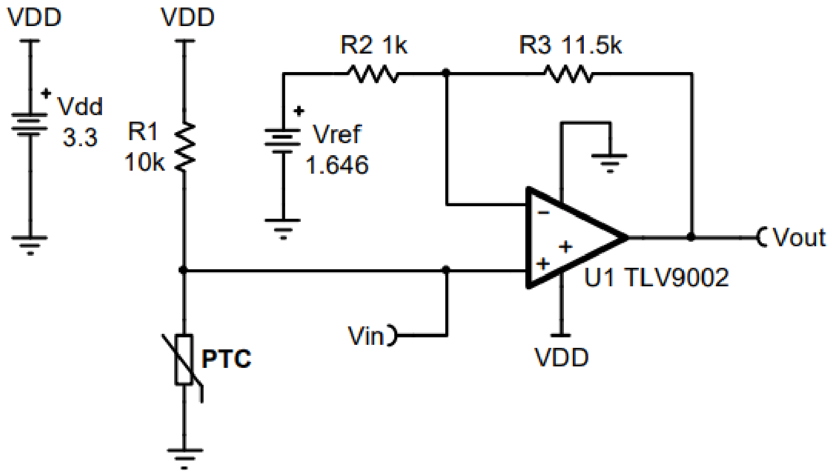
Temperature		Output		Supply		
T_{Min}	T_{max}	V_{outMin}	V_{outMax}	V_{dd}	V_{ee}	V_{ref}
0 °C	50 °C	50mV	3.25V	3.3V	0V	1.646V





Design Notes

Temperature		Output		Supply		
T_{Min}	T_{max}	V_{outMin}	V_{outMax}	V_{dd}	V_{ee}	V_{ref}
0 °C	50 °C	50mV	3.25V	3.3V	0V	1.646V



Design Notes:

1. For temperature sensing using a PTC thermistor, the resistor, R1, is chosen based on the temperature range and the PTC's value.

2. Operate within the linear output voltage swing (See A_{OL} specification) to minimize non-linearity errors.

3. The reference voltage, Vref, can be created using a DAC or voltage divider. If a voltage divider is used the equivalent resistance of the voltage divider will influence the gain of the circuit.

Design Resources

EE Cookbook: Op Amp
www.ti.com/circuitcookbooks
Step-by-step circuit design of common op amp building block circuits.

TI Designs
www.TI.com/tidesigns
Ready-to-use reference designs with
theory, calculations, simulations
schematics, PCB files, bench test results

Analog Engineer's Pocket Reference
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Evaluation module providing engineers with SC70, SOT23, SOIC packaging and 12 popular amplifier configurations

The Signal
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A compendium of blog posts on op amp design topics including
offset voltage, input bias current, stability, noise and more

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