Temperature sensing and signal conditioning circuit

For vial temperature: PANW103395-395

For heat sink temperature: NTCALUG02A103F161

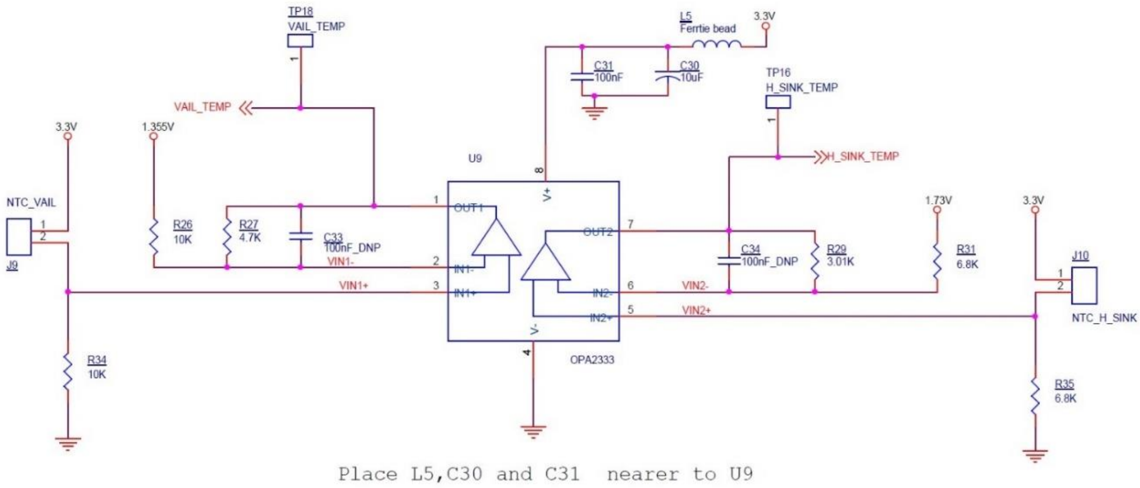


Figure 21: Schematic of NTC thermistor interfacing

1. Vial temperature sensing

Our design goals are

Range of temperature to be measured: -10^0C to 60^0C.

Output Voltage swing: 0.05V TO 3.25V.(microcontroller is working on 3.3V, hence the ADC values can be range from 0V to 3.3V, a margin of 0.05 V is for accuracy reasons.)

Selected OPAMP for amplifying the temperature signal is OPA333 from Texas Instruments, which is a general purpose, low cost OPAMP which meets our requirements. It has two gates, so one can be used for vial temperature and another one is for heat sink temperature. Decoupling capacitors are connected to the VCC pin of OPA333, its values are recommended in datasheet.

Both the output of the gates is connected to two ADC pins of the microcontroller.

For simplicity of explanation, taking R34 as R1, R26 as R2 and R27 as R3 from the schematic in figure 21.

1. Calculation of R1

From the datasheet of selected NTC Thermistor,

R_{NTC}@25^0 C is 10K.

R_{NTC} @-10^{0}C =55.33 K ohm. = R_{NTC_MAX}

R_{NTC} @60^{0}C = 2.488 K ohm. = R_{NTC_MIN}

The gain of the amplifier is given by,

$V_{OUT\ C}$ =V_{DD}* $(\frac{R1}{R1+RNTC})*(\frac{R3+R2}{R2})$ -$V_{REF}\frac{R3}{R2}$

R1=$\surd(RNTC@-10C*RNTC@60C)$

R1=$\sqrt{55.3K*2.488K}$

=11.7K ohm.

Selecting std 10k ohm.

2. Calculate the input voltage range

V_{IN_MIN}=V_{DD}*$\frac{R1}{R1+RNTC\_MAX}$ =3.3*$\frac{10K}{55.33K+10K}$ = 0.505V

V_{IN_MAX}=V_{DD}*$\frac{R1}{R1+RNTC\_MIN}$ =3.3*$\frac{10K}{2.488K+10K}$ = 2.642V

3. Calculate the gain required to produce the maximum output swing

G_{IDEAL} =$\frac{VOUT\_MAX - VOUT\_MIN}{VINMAX - VIN\ MIN}$

Selected values are:

V_{OUT_MAX} = 3.25V

V_{OUT_MIN} = 00.05V

V_{IN_MAX} = 2.642V

V_{IN_MIN} = 0.505V

When substituting values, G_{IDEAL}=1.5

4. calculating actual gain,

G_{ACTUAL} =(R2+R3)/R2

Taking R2= 10K,

Then G_{IDEAL} = (R2+R3) /R2,

From this,1.5 =(10K+R3)/10K

Rearranging, we get R3 =5 K Ohms,

Taking R3 a 4.7k, then actual gain is

G_{ACTUAL} = (10K+4.7K)/10K = 1.47 V/V.

5. Output voltage swing according to actual gain,

V_{OUT_SWING} = ($V_{IN\_MA`X}$ -V_{IN_MIN}) * $G_{ACTUAL.}$

= (2.6425 -0.5051) *1.47

=3.141 V

6. calculate the maximum output voltage when the output voltage is symmetrical about the mid supply.

V_{OUT_MAX} = V_{MID_SUPPLY} + (V_{OUTPUT_SWING}/2)

= (3.3-0)/2 + 3.1419/2

= 3.221 V.

7. Calculate the reference voltage

V_{OUT_MAX}= (V_{IN_MAX} * G_{ACTUAL}) – (R3/R2) * V_{REF}

3.221 V = (2.6425 * 1.47) -(4.7K/10K) * $V_{REF,}$

Rearranging for $V_{REF,}$ and calculating V_{REF} =1.3353V.

Then selected values are,

R1 = 10K

R2 = 10K

R3 = 4.7k,

Using resistors with lesser tolerance value for accuracy.

Generation of voltage reference

For generating reference voltage, we need a voltage reference IC which have reference voltage value lesser than our requirement. For this we have selected LMV431 from Texas Instruments. This IC have a minimum reference value of 1.24 V, which is less than 1.3553V. for acting as a shunt voltage reference we need other extra three resistors.

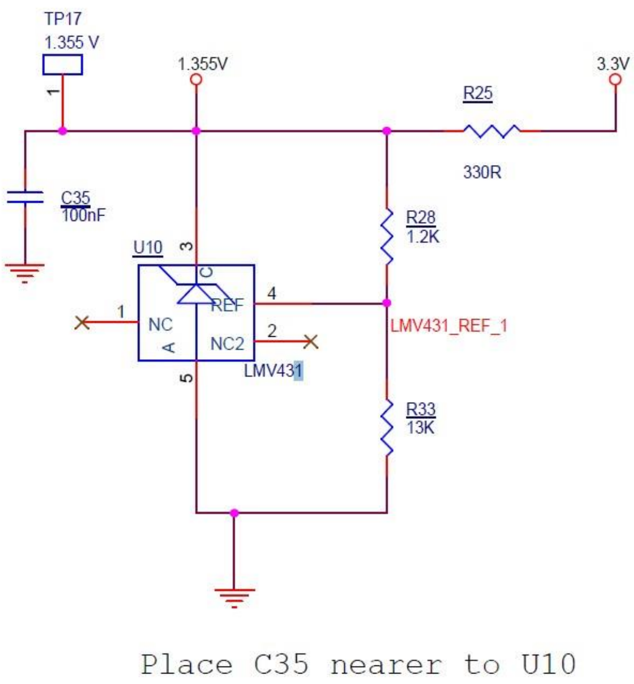


Figure 22: Voltage reference circuit for 1.3553V.

For simplicity of explanation, taking R28 as R1, R33 as R2, and R25 as R3 from the schematic in figure 22.

V_{OUT}LMV431 is given by,

$$V_{OUT} = (1+R1/R2)\ V_{REF}$$

V_{REF} of selected LMV431 is 1.24V.

Required output voltage is 1.3553 V,

And taking R1 as 1.2K. then,

1.3553 = (1+1.2k/R2) *1.24

Then R2 = $\frac{R1}{(\frac{VOUT}{VREF}-1)}$

From this, R2=12.9105K, Taking 13K std.

Then the actual output voltage is 1.24(1+(1.2K/13K)) = 1.3544 V.

An input resistor of 330 ohm(R3) is also connected for limiting the current.

Simulation Results

We have simulated the amplifier in TINA. The input signal to the OPAMP is provided as a voltage source, I.e., the voltage drops across the NTC thermistor at maximum resistance and minimum resistance (our range of interest). the simulated circuit is given below.

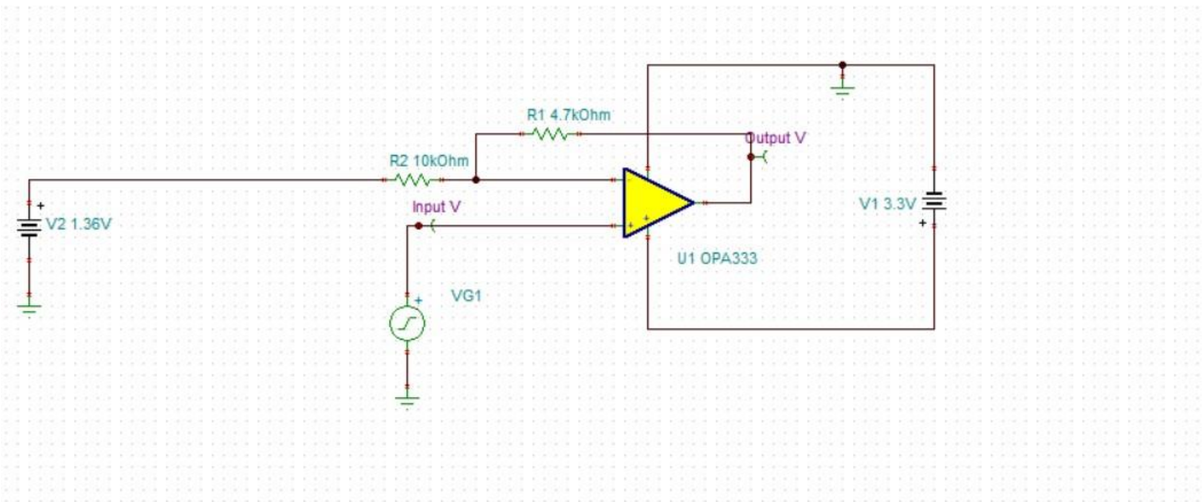


Figure23: Vial temperature sensor signal conditioning circuit done in TINA.

The simulation is done with a DC voltage sweep from 0.505 V to 2.6425 V is provided at the non-inverting input of the OPAMP. Our aim is to convert this range of values to 0 to3.3V scale. The simulated DC transfer characteristics of this circuit is given below.

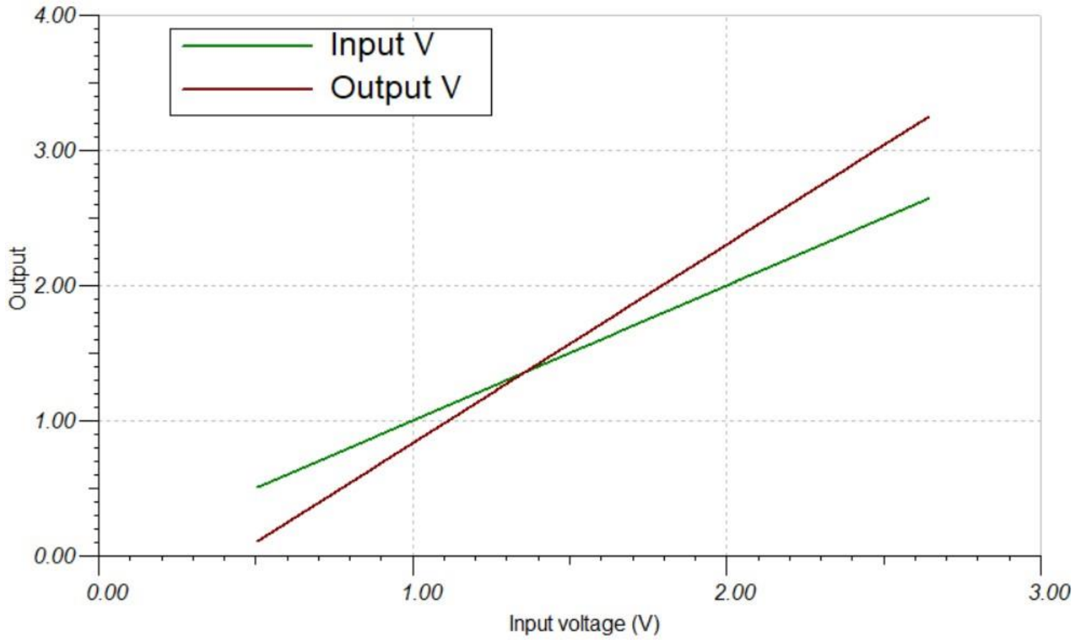


Figure24: DC transfer characteristic result of the Vial temperature sensing circuit.

2. Heat sink temperature sensing

For simplicity of explanation, taking R35 as R1, R31 as R2 and R29 as R3 from the schematic in figure21.

The range of interest of temperature: the heat sink is used to cool the hot side of the Peltier element; hence its temperature does not go too below the ambient temperature .so our range of interest is 0^0C to 80^0C.we are planning to paste the NTC at the side of the heat sink using proper epoxy.

1. Calculation of R1

From the datasheet of selected NTC Thermistor,

R_{NTC}@25^0 C is 10K.

R_{NTC} @0^0C =32.65 K ohm. = R_{NTC_MAX}

R_{NTC} @80^0C =1.258 K ohm. = R_{NTC_MIN}

The gain of the amplifier is given by,

$V_{OUT\ C}$ =V_{DD}* $(\frac{R1}{R1+RNTC})$*$(\frac{R3+R2}{R2})$ -$V_{REF}\frac{R3}{R2}$

R1=$\sqrt{}(RNTC@0C * RNTC@80C)$

R1=$\sqrt{32.65K * 1.258K}$

=6.408K ohm.

Selecting std 6.80K ohm.

2.Calculate the input voltage range

V_{IN_MIN}=V_{DD}*$\frac{R1}{R1+RNTC\_MAX}$ =3.3*$\frac{6.8K}{32.65K+6.8K}$ = 0.5688V

V_{IN_MAX}=V_{DD}*$\frac{R1}{R1+RNTC\_MIN}$ =3.3*$\frac{6.8K}{1.258K+6.8K}$ = 2.7848V

3.Calculate the gain required to produce the maximum output swing

G_{IDEAL} =$\frac{VOUT\_MAX - VOUT\_MIN}{VINMAX - VIN\ MIN}$

Selected values are:

V_{OUT_MAX} = 3.25V

V_{OUT_MIN} = 0.05V

V_{IN_MAX} = 2.7848V

V_{IN_MIN} = 0.5688V

When substituting values, G_{IDEAL}=1.444

4. calculating actual gain,

G_{ACTUAL}=(R2+R3)/R2

Taking R2= 6.8K,

Then G_{IDEAL} = (R2+R3) /R2,

From this,1.444 =(10K+R3)/10K

Rearranging, we get R3 =3.0192K Ohms,

Taking R3 as3.01k, then actual gain is

G_{ACTUAL} = (6.8K+3.01K)/6.8K = 1.442 V/V.

5.Output voltage swing according to actual gain,

$V_{OUT\_SWING} = (V_{IN\_MAX} - V_{IN\_MIN}) * G_{ACTUAL}$

= (2.7848 -0.5688) *1.442

=3.195 V

6.calculate the maximum output voltage when the output voltage is symmetrical about the mid supply.

$V_{OUT\_MAX} = V_{MID\_SUPPLY} + (V_{OUTPUT\_SWING}/2)$

= (3.3-0)/2 + 3.195/2

= 3.2475V.

7.Calculate the reference voltage

$V_{OUT\_MAX} = (V_{IN\_MAX} * G_{ACTUAL}) – (R3/R2) * V_{REF}$

3.2475V = (2.7848*1.442) -(3.01K/6.8K) *$V_{REF,}$

Rearranging for $V_{REF,}$ and calculating V_{REF} =1.7377V.

Then selected values are,

R1 = 6.8K

R2 = 6.8K

R3 =3.01K,

Using resistors with lesser tolerance value for accuracy.

Generation of voltage reference

For simplicity of explanation, taking R30 as R1, R24as R2, and R32 as R3 from the schematic in figure 25.

V_{OUT} of LMV431 is given by,

V_{OUT} = (1+R1/R2) V_{REF}

V_{REF} of selected LMV431 is 1.24V.

Required output voltage is 1.7377 V,

And taking R2 as 6.8K. then,

1.7377 = (1+6.8k/R2) *1.24

From this, R2=2.7288K, Taking 2.7K std.

Then the actual output voltage is 1.24(1+(2.7K/6.8K)) = 1.732 V.

An input resistor of 330 (R3) ohm is also connected for limiting the current.

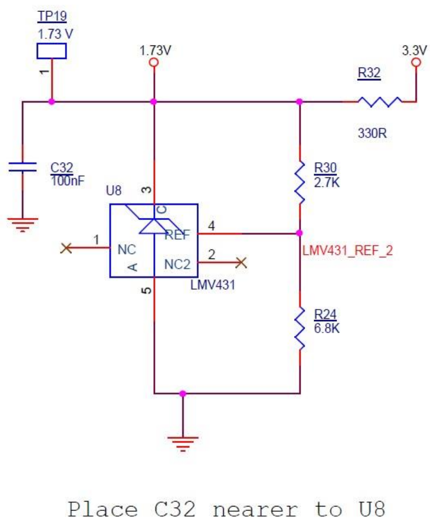
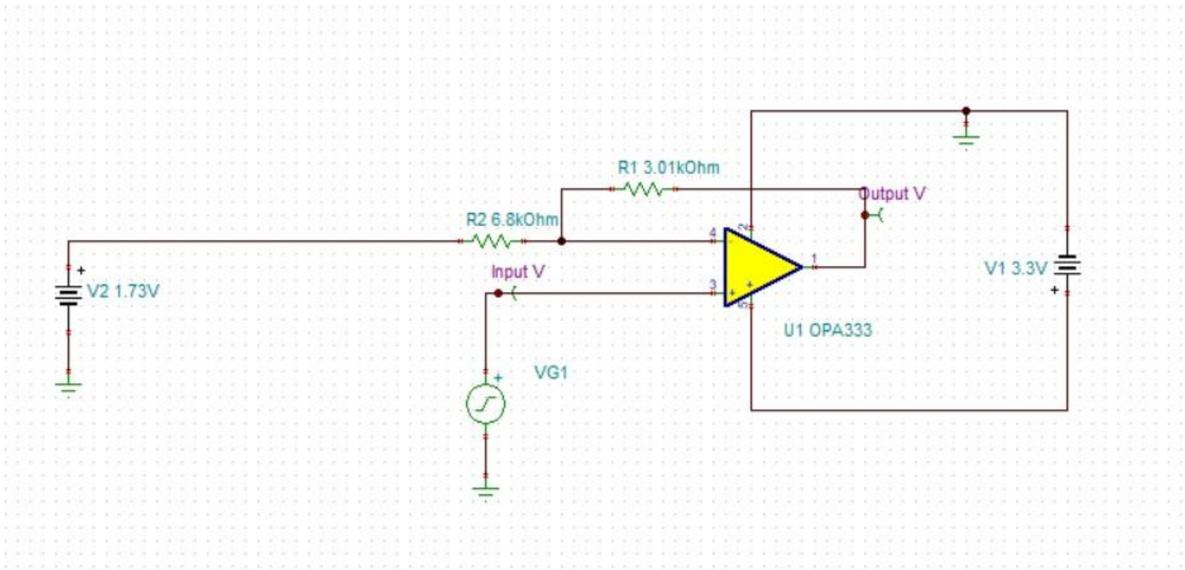


Figure 25: Voltage reference circuit for 1.7377 V

Simulation Results

This circuit was also simulated in TINA. The simulation is done with a DC voltage sweep from 0.5688V to 2.7848 V is provided at the non-inverting input of the OPAMP. Our aim is to convert this range of values to 0 to3.3V scale. The simulated DC transfer characteristics of this circuit is given below.



Figures 26: Heat sink temperature sensor signal conditioning circuit done in TINA.

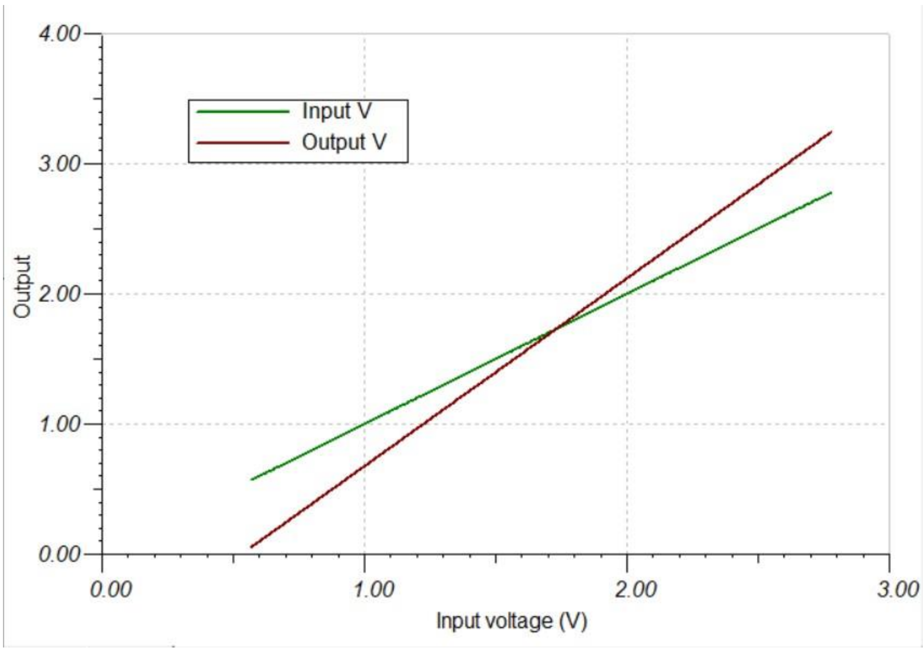


Figure 27: DC transfer characteristic result of the heat sink temperature sensing circuit.