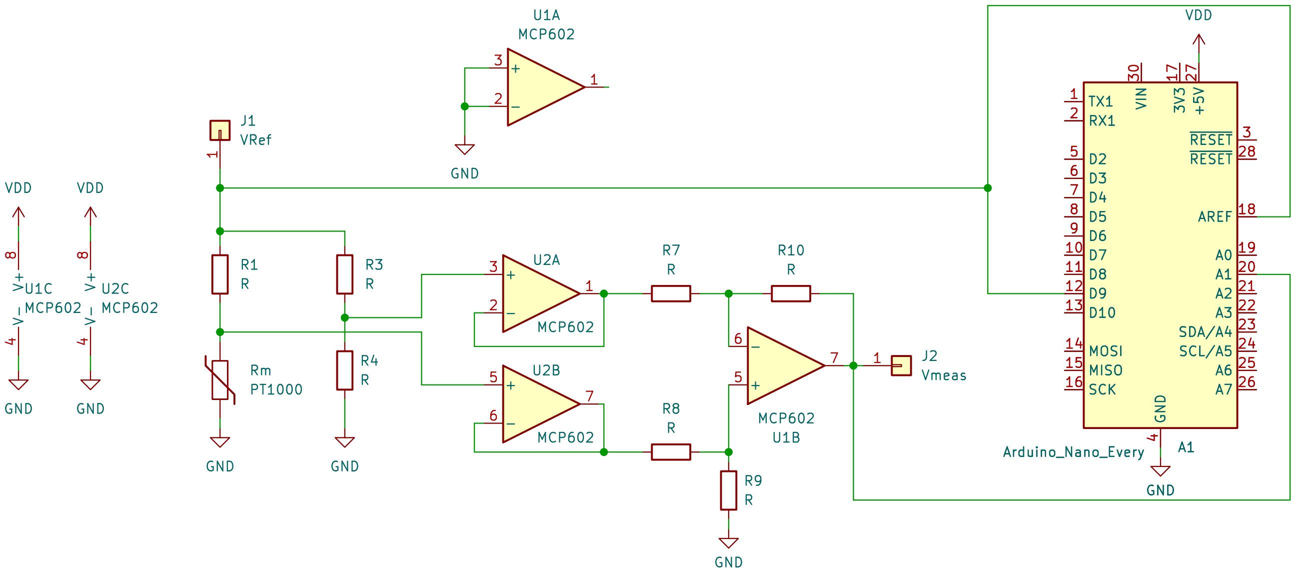
Thermometer with PT1000

Circuit



Dimensioning

Temperature measuring range should be from $-20\,°\mathrm{C}$ to $60\,°\mathrm{C}$. The resistance of the PT1000 is therefore in range $R_{\mathrm{min}} = 921.6\,\Omega$ to $R_{\mathrm{max}} = 1232.4\,\Omega$.

The bridge circuit R_1, R_{m}, R_3, R_4 should deliver approximately $0\,\mathrm{V}$ at minimum temperature. Thus R_4 should be R_{min}. So R_4 is choosen $10\,\mathrm{k}\Omega \parallel 1\,\mathrm{k}\Omega = 0.909\,\mathrm{k}\Omega$, $R_1 = R_3 = 1\,\mathrm{k}\Omega$.

For the temperature measuring range and a reference voltage of $\approx 4.7\,\mathrm{V}$ the bridge output voltage is

$$V_{\mathrm{a}} = V_{\mathrm{ref}} \left(\frac{R_{\mathrm{m}}}{R_1 + R_{\mathrm{m}}} - \frac{R_4}{R_3 + R_4} \right) = 0.016\,\mathrm{V} \ldots 0.356\,\mathrm{V}$$

The bridge output voltage is buffered by $U_{2\mathrm{A}}$ and $U_{2\mathrm{B}}$ and fed to a subtractor $U_{1\mathrm{B}}$ with a gain

$$v = \frac{R_{10}}{R_7} = \frac{R_9}{R_8} = 13$$

So $V_{\mathrm{meas}} = v * V_{\mathrm{a}}$ is in range $0.208\,\mathrm{V} \ldots 4.635\,\mathrm{V}$.

V_{meas} is measured by an 10 bit ADC with the reference voltage V_{ref}.

Relationship of temperature and ADC value

In the temperature measuring range the value of PT1000 resistor could be approximated [1] by

$$R_\mathrm{m} = R_0(1 + AT + BT^2)$$

with $R_0 = 1000\,\Omega$, $A = 3.9083 \cdot 10^{-3}\,\frac{1}{^\circ\mathrm{C}}$ and $B = -5.7750 \cdot 10^{-7}\,\frac{1}{^\circ\mathrm{C}^2}$ within the accuracy of the ADC.

Vice versa the temperature could be calculated with

$$T_{1,2} = -\frac{A}{2B}\sqrt{\left(\frac{A}{2B}\right)^2 - \frac{1}{B}\left(1 - \frac{R_\mathrm{m}}{R_0}\right)}$$

The value of PT1000 resistor is calculated

$$V_\mathrm{a} = \frac{V_\mathrm{meas}}{v} + V_\mathrm{ref}\frac{R_4}{R_3 + R_4}$$

$$R_\mathrm{m} = R_1\frac{V_\mathrm{a}}{V_\mathrm{ref} - V_\mathrm{a}}$$

The V_meas could be determined from ADC value D by

$$V_\mathrm{meas} = \frac{DV_\mathrm{ref}}{2^{10}}$$

Simplification

$$\begin{aligned}
V_\mathrm{meas} &= D\frac{V_\mathrm{ref}}{1024} && (1)\\
V_\mathrm{a} &= \frac{V_\mathrm{meas}}{v} + kV_\mathrm{ref} \qquad \text{with} \qquad k = \frac{R_4}{R_3 + R_4} && (2)\\
&= D\frac{V_\mathrm{ref}}{1024v} + kV_\mathrm{ref} && (3)\\
R_\mathrm{m} &= R_1\frac{V_\mathrm{a}}{V_\mathrm{ref} - V_\mathrm{a}} && (4)\\
&= R_1\frac{D\frac{V_\mathrm{ref}}{1024v} + kV_\mathrm{ref}}{V_\mathrm{ref} - \left(D\frac{V_\mathrm{ref}}{1024v} + kV_\mathrm{ref}\right)} = R_1\frac{\frac{D}{1024v} + k}{1 - \left(\frac{D}{1024v} + k\right)} && (5)\\
&= R_1\frac{D + 1024vk}{1024v\,(1 - k) - D} && (6)
\end{aligned}$$

Note, the value of R_m does not depend on V_ref!

Measuring

The measurement of the temperature is done as follows

- drive the output D9, which actually supplies V_{ref}, to high
- wait 10 ms
- measure voltage
- drive the output to low
- wait 2 s to let the PT1000 cool down

References

[1] Application Note, A Basic Guide to RTD Measurements. https://www.ti.com/lit/an/sbaa275a/sbaa275a.pdf. Retrieved 2024-01-07