

MEEC/MIEEC

ELECTRONICS FOR MICRO-SYSTEMS

Lab#1 P1 A Temperature Meter System with 3 Sensors, Relay and GUI

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1 Introduction

explain the requirements and the main objectives of the project Se calhar dizer aqui quais sao as metricas por onde podemos avaliar a nossa solucao Linearidade de output para conseguir aproveitar melhor a resolucao do adc Consumo erro

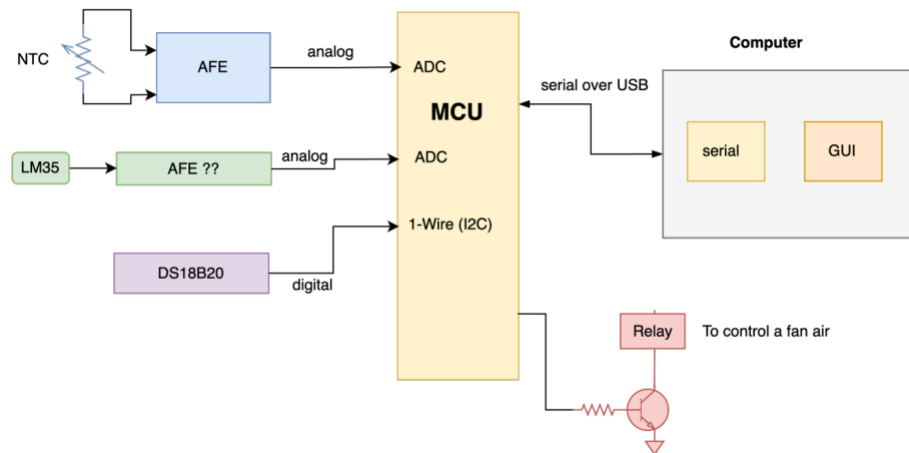


Figure 1: Temperature sensing system with 3 three types of sensors.

2 Temperature Sensors

2.1 NTC - Negative Temperature Coefficient

2.2 LM35 - Precision Centigrade Temperature Sensor

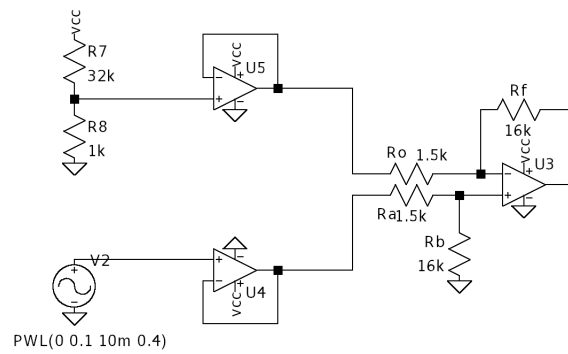


Figure 2: AFE for the LM35 sensor.

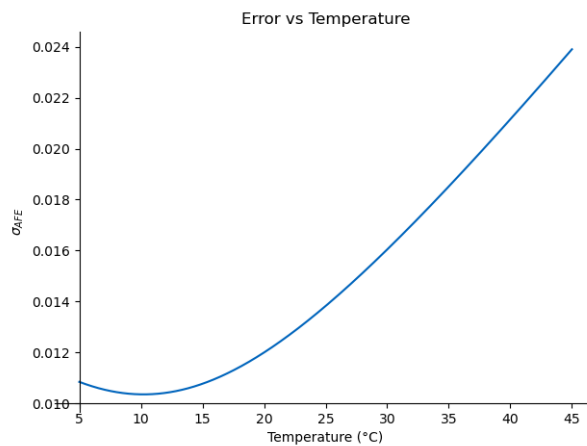


Figure 3: AFE error curve.

2.3 DS18B20 - Digital Thermometer

3 System Design

3.1 Analog FrontEnd (AFE) NTC

A parte onde definimos o intervalo de temperatura nao devia estar aqui pq é para todos os circuitos

In order to design the *NTF AFE* first it's necessary to define the temperature interval in which this circuit will work, thus it was define as $T \in [10^{\circ}; 40^{\circ}]$. Through the *NTC*'s datasheet the interval of its resistance values is $R_{NTC} \in [5,282k ; 19,98k]$

For an accurate reading of the temperature it was used the *Steinhart-Hart equation*.

$$\frac{1}{T} = A + B \cdot \ln(R_{NTC}) + C \cdot [\ln(R_{NTC})]^3 \quad (1)$$

In order to find the parameters A , B and C , its necessary to use 3 points from the datasheet. The points chosen were the two extremes and the middles point.

$$\begin{cases} R(283, 15) = 1,998 \cdot 10^4 \Omega \\ R(298, 15) = 10^4 \Omega \\ R(313, 15) = 0,5282 \cdot 10^4 \Omega \end{cases} \Leftrightarrow \begin{cases} A = 1,2 \cdot 10^{-3} \\ B = 2,1 \cdot 10^{-4} \\ C = 1,3 \cdot 10^{-7} \end{cases} \quad (2)$$

Para poder dimensionar o AFE do NTC primeiro é necessario definir o intervalo de temperaturas em que o circuito irá operar. Foi então decidido que seria adequado um temperatura $T \in [10^\circ; 40^\circ]$. E pelo datasheet do NTC foi obtido o intervalo da sua resistencia $R_{NTC} \in [5,282k ; 19,98k]$

Para usar equacao Steinhart-Hart $\frac{1}{T} = A + B \cdot \ln(R) + C \cdot [\ln(R)]^3$, precisamos de usar 3 pontos para encontrar as constantes A , B e C . $R(T) = R_{NTC}$ onde T é a temperatura em kelvin e R_{NTC} é o valor da resistencia do thermistor NTC

The simplest way to convert the resistance to voltage, is to use a voltage divider circuit.

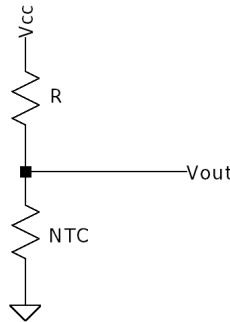


Figure 4: NTC voltage divider.

This approach has a few problems:

- The output resistance is really high $R \parallel NTC$,
- The output voltage is highly non linear, which is a problem because this way some ADC resolution is lost.

The first problem is solved through a buffer at the entrance of the AFE, and the second is somewhat mitigated by using a resistor value around $8k\Omega$. To achieve this value it was used the beta model for the NTC and through a python script, the resistor value was iterated until an almost linear output was achieved.

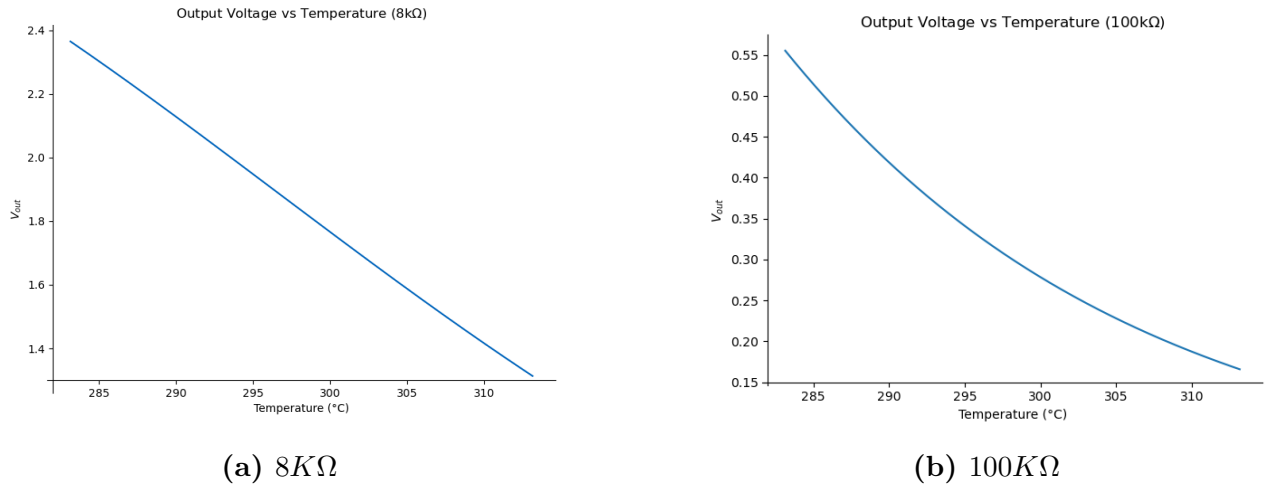


Figure 5: Output Voltage vs Temperature

With $R = 8k$ the output signal is $V_{out} \in [1.31V; 2.36V]$. But the *ADC* as resolution of 12 bits and a voltage range of $3.3V$, meaning that to have the best resolution possible the signal needs an offset and a gain of 2.87 and -1.75 respectively. It's important to note that a $0.1V$ margin was added to V_{out} in order to ensure that the *AFE* works properly in the specified range. This gain and offset was achieved through the following topology.

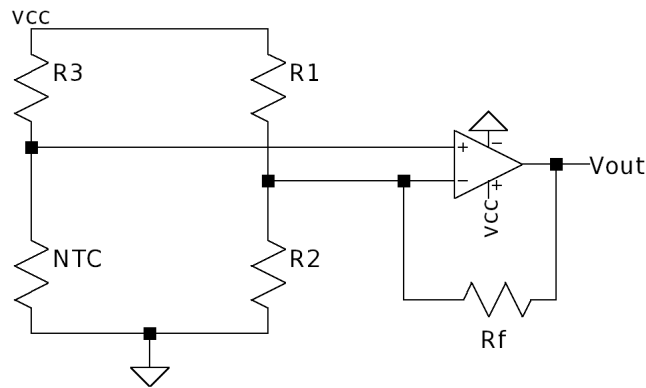


Figure 6: NTC's AFE topology

Nao esquecer de fazer referencia ao codigo funcao AfeNtc()

As already specified the R_3 value is $8K \Omega$ and for the purpose circuit dimensioning the circuit the positive node of the opamp will be treated as a variable V_p .

Using python the circuit function $V_{out}(V_p)$:

$$V_{out} = V_p \left[1 + R_f \cdot \left(\frac{1}{R_1} + \frac{1}{R_2} \right) \right] - V_{cc} \cdot \frac{R_f}{R_1} \quad (3)$$

Now it's clear to see what part of the equation is responsible for the circuit gain and offset.

$$\begin{cases} V_{offset} = -V_{cc} \cdot \frac{R_f}{R_1} \\ G = \left[1 + R_f \cdot \left(\frac{1}{R_1} + \frac{1}{R_2} \right) \right] \end{cases} \quad (4)$$

Setting $R_f = 10K$ the values that satisfy the equation system are $R_1 = 9348\Omega$ and $R_2 = 11760\Omega$. In the simulation this values are a bit too close to the limits so in order to have better margins and to use the available resistors the final values are $R_1 = 8.2K\Omega$ and $R_2 = 12K\Omega$.

3.2 LM35

This integrated-circuit temperature sensor, generates an output voltage linearly proportional to the Centigrade temperature

$$V_{out} = 10^{-2} \cdot T$$

Thus in the specified conditions $V_{out} \in [0.1; 0.4]$, as done in the last section we will be using a differential amplifier to fit this interval in the *ADC*'s range.

3.3 DS18B20 ??(Este tem Dimensionamento?)

3.4 Relé de saída

4 Simulations

5 Implementation and Experimental Tests

6 Results Analysis

7 Conclusion