NOVA SCHOOL OF
SCIENCE & TECHNOLOGY

MEEC/MIEEC

Electronics for Micro-Systems

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

Authors:

Martim Duarte Agostinho (70392) md.agostinho@campus.fct.unl.pt
Francisco Simões Coelho Sá da Costa (70386) fsc.costa@campus.fct.unl.pt
Sofia Margarida Mafra Dias Inácio (58079) sm.inacio@campus.fct.unl.pt

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Contents

1 Introduction 3

2 Temperature Sensors 4
2.1 NTC - Negative Temperature Coefficient 4
2.2 LM35 - Precision Centigrade Temperature Sensor 4
2.3 DS18B20 - Digital Thermometer 4

3 System Design 4
3.1 Analog FrontEnd (AFE) NTC 4
3.2 LM35 7
3.3 DS18B20 ??(Este tem Dimensionamento?) 8
3.4 Relé de saída 8

4 Simulations 8

5 Implementation and Experimental Tests 8

6 Results Analysis 8

7 Conclusion 8

List of Figures

1 Temperature sensing system with 3 three types of sensors. 3
2 NTC voltage divider. 5
3 Output Voltage vs Temperature 6
4 NTC's AFE topology 6
5 LM35 Differential Amplifier. 7
6 AFE for the LM35 sensor. 8

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

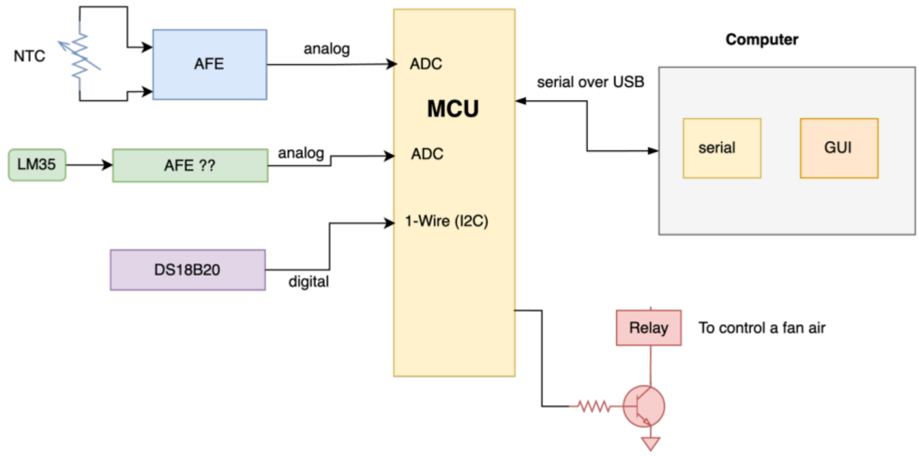


Figure 1: Temperature sensing system with 3 three types of sensors.

2 Temperature Sensors

2.1 NTC - Negative Temperature Coefficient

2.2 LM35 - Precision Centigrade Temperature Sensor

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 $T \in [10°; 40°]$. 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.

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

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.

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

Para poder dimensionar o AFE do NTC primeiro é necessario definir o intrevalo de temperaturas em que o circuito irá operar. Foi então decidido que seria adequado um temperatura $T \in [10°; 40°]$. E pelo datasheet do NTC foi obtido o intrevalo 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.

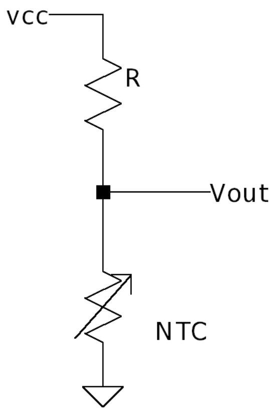


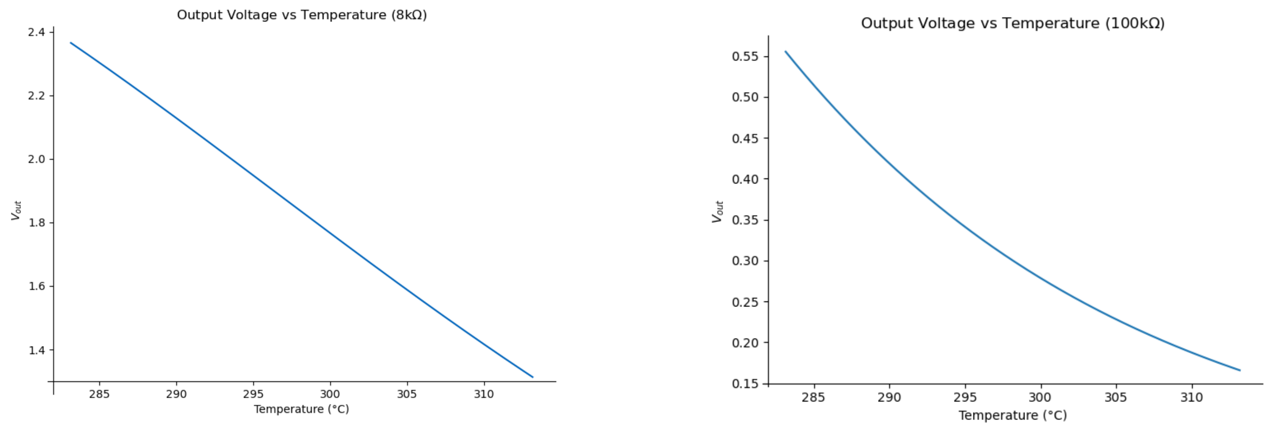
Figure 2: NTC voltage divider.

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.



(a) $8K\Omega$ **(b)** $100K\Omega$

Figure 3: 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.

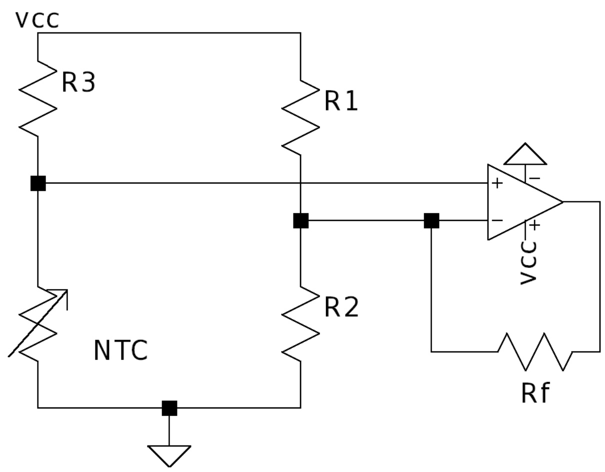


Figure 4: NTC's AFE topology

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 $V_{out}(V_p)$:

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

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

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

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.

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

Hence, in the specified conditions $V_{out} \in [0.1; 0.4]$. To increase resolution as done in NTC's AFE subsection, it's needed to add gain and an offset. For this purpose a differential amplifier can be used.

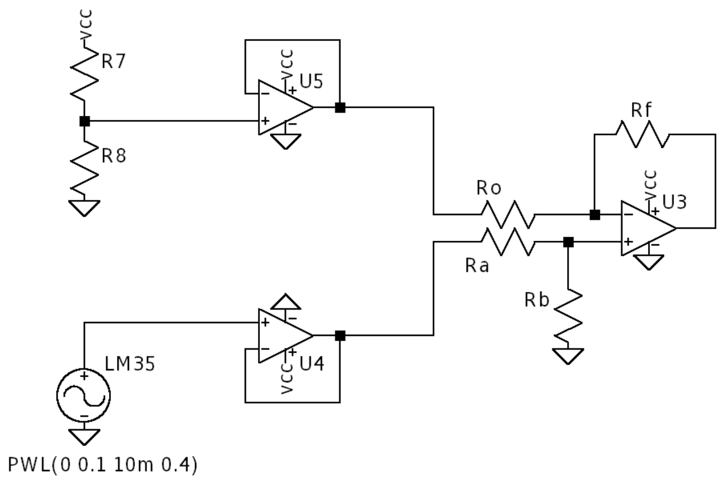


Figure 5: LM35 Differential Amplifier.

Although this circuit achieves the expected output, the amount of components, increases noise and power consumption, thus the used topology was a non-inverting amplifier.

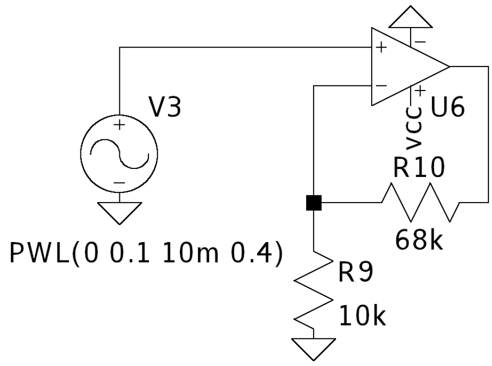


Figure 6: AFE for the LM35 sensor.

This way the input impedance is high, only one OpAmp and two resistors are used. But this comes with the cost of lost resolution. With a gain of 8 $V_{out} \in [0.8V, 3.2V]$ $0.8V$ of range in the ADC are lost.

3.3 DS18B20 ??(Este tem Dimensionamento?)

3.4 Relé de saída

4 Simulations

5 Implementation and Experimental Tests

6 Results Analysis

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