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4-bit Digital Phase Meter

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1 Introduction

The aim of our project is to design a 4-bit Digital Phase Meter. We choose this subject because a phase meter can be useful in a lot of applications: audio, radio...

To design it, we need a strong knowledge about n-mos, p-mos, digital and analog electonics.

To make this project, we have used *Microwind* software.

In this report, we will introduce first the phase meter architecture that we have decided to implement. In a second part, we will explain how we have designed each part of our phase meter in *Microwind*, and all the simulation results associated.

2 Component description

2.1 Concept

Our phase meter receive two analogs signals in imput, and has a 4-bit output sending the value of the phase (16 intervals between 0° and 180°, wich means a precision of 11.25°). After a measure was taken, there is a reboot button to take another one.

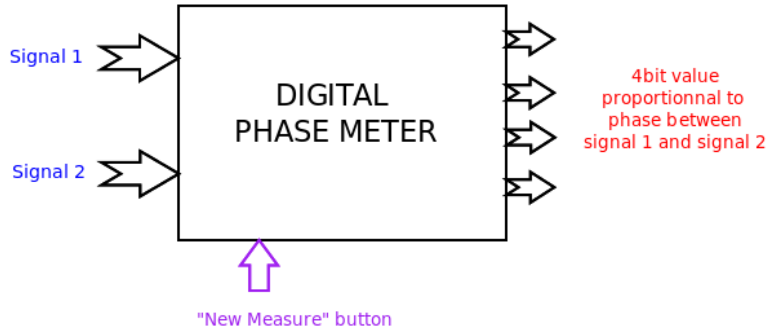

Figure 1: General schematic of 4-bit phase meter

We have made this choice of 4-bit to have clear schematics, but all the concepts introduced in this report stay valid for a n-bit phase meter.

2.2 Electronic circuit

The phase meter can be divided in two independant functions :

- An analog phase meter.
- An Analog-to-Digital Converter.

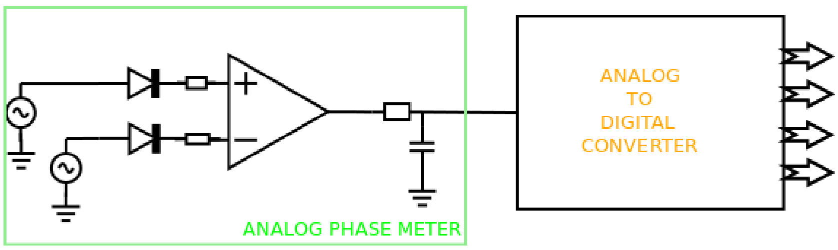

Figure 2: Detailed schematic of 4-bit phase meter

3 Analog to Digital Converter

We choose to design an iterative ADC. This converter is shown on the *figure 3* below.

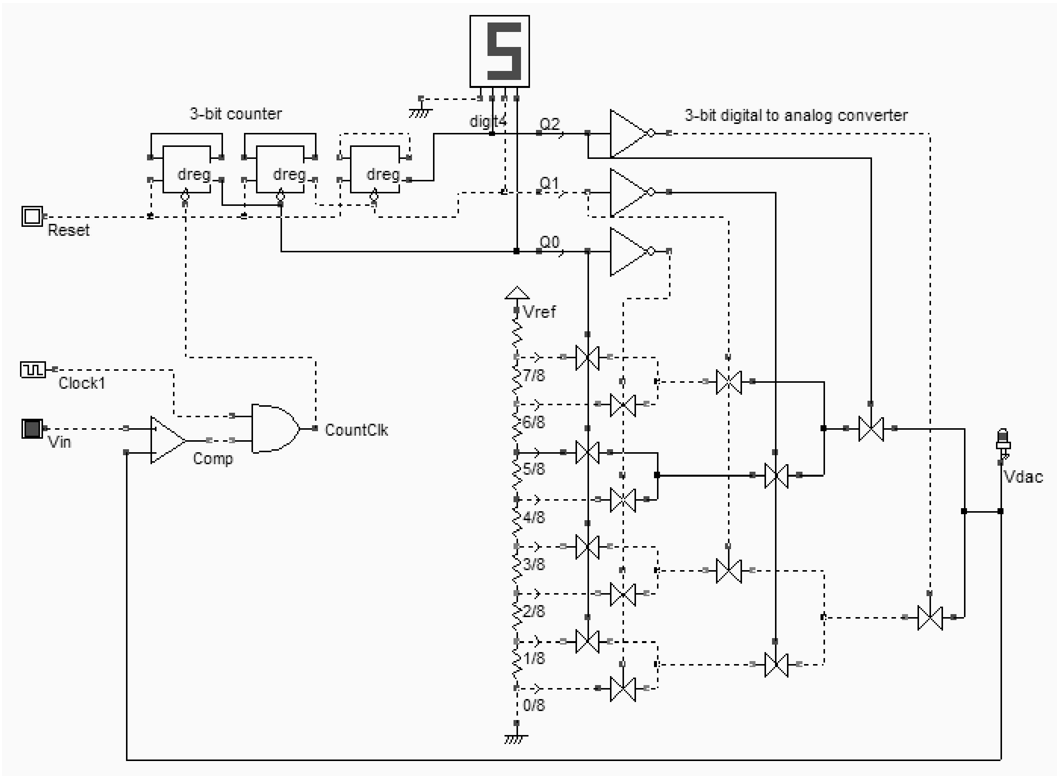

Figure 3: Detailed schematic of a 3-bit iterative ADC (E.Sicard ©)

To design it, we need to design first:

- A 4-bit Digital to Analog Converter.
- A 4-bit asynchronous counter.
- A Comparator (differential pair and amplifier).

We will first see how we design each part of our ADC, and we will analyse our simulation results.

3.1 Design of the asycnhronous counter

An asynchronous counter can be seen as a follow of D-registers. The first thing to do so is to design the D-reg :

The D-register : The D-register is an association of n-mos and p-mos transistors, and inverters *(figure 4)*.

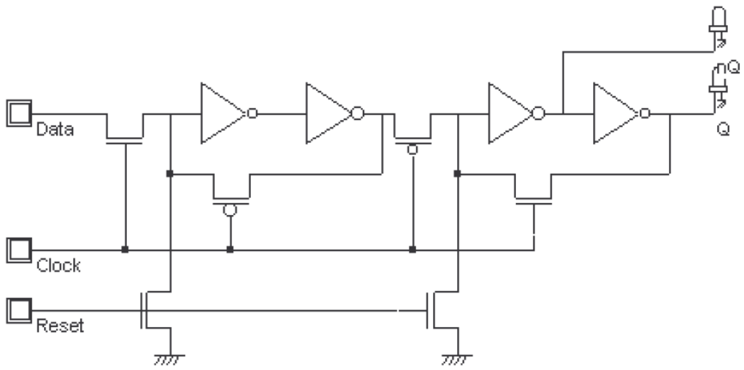

Figure 4: Electonic schematic of a D-register (E.Sicard ©)

We have tried to optimized the space used in our layer.*(figure 5)*

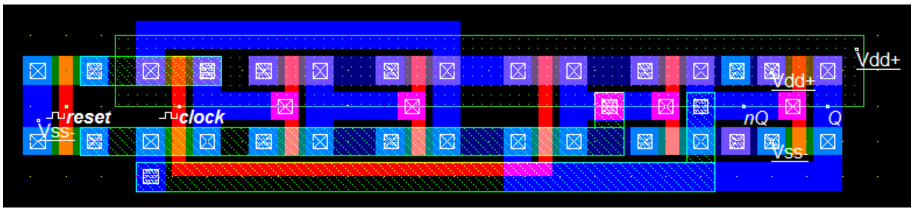

Figure 5: D-register design

The counter itself : To obtain a 4-bit asynchronous counter, we just have to link properly 4 D-registers like on the figure up : `nQ` outputs are connected to `Data` inputs and each D-register `Q` output is used as a clock for the next D-register. All the`reset` inputs are connected together to make a start button. *(figure 6 p. 7)*

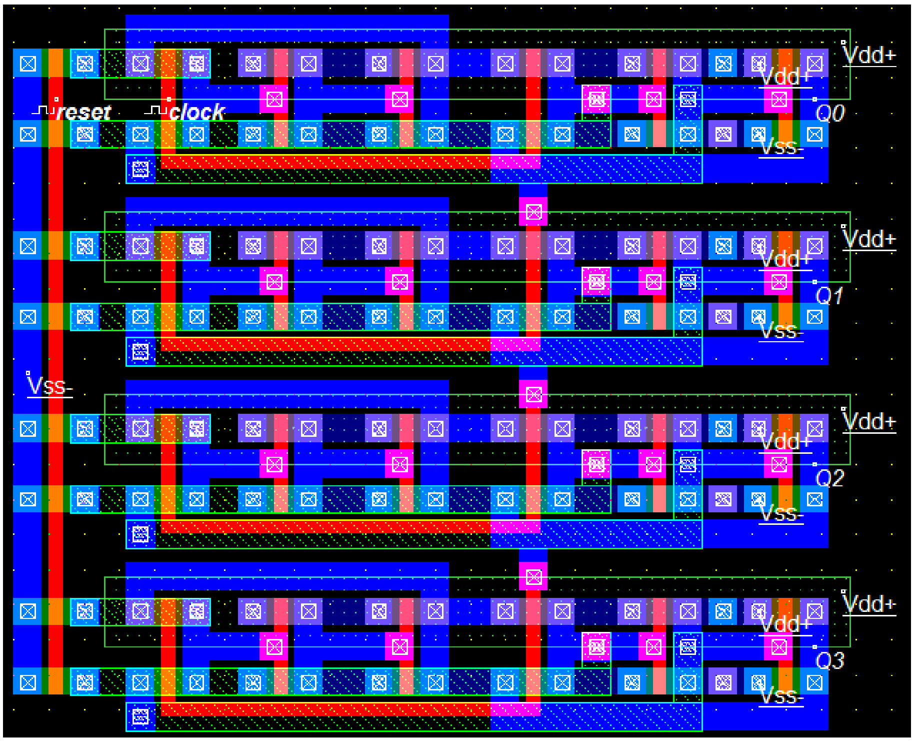

Figure 6: 4-bit asynchronous counter design

3.2 Design of the comparator

The comparator is used to compare the current DAC output value to the real input analog value. It is composed of a differential pair and two logical inverters (used to set the output in high or low saturation) *(figure 7)*

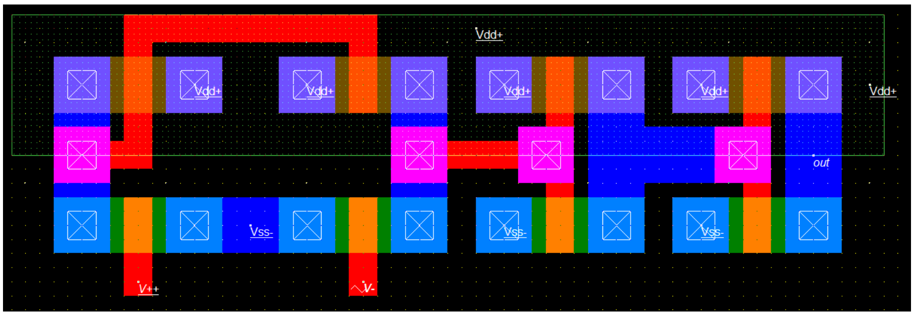

Figure 7: Comparator design design

3.3 Design of the DAC

Our Digital-to-Analog Converter is an association of a resistors'bridge, transmission gates, and logical inverters *(figure 3 p. 5)*.

The *figure 8* below is the 2-bit version of our DAC, to have a better readability.

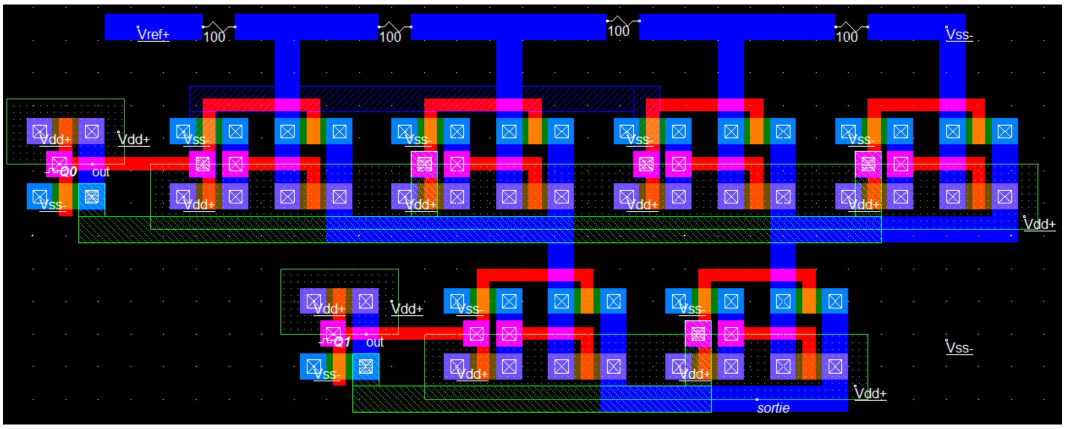

Figure 8: 2-bit Digital-to-Analog Converter design

3.4 Final link and simulation

Now we link all those parts to have our final ADC *(figure 9)*.

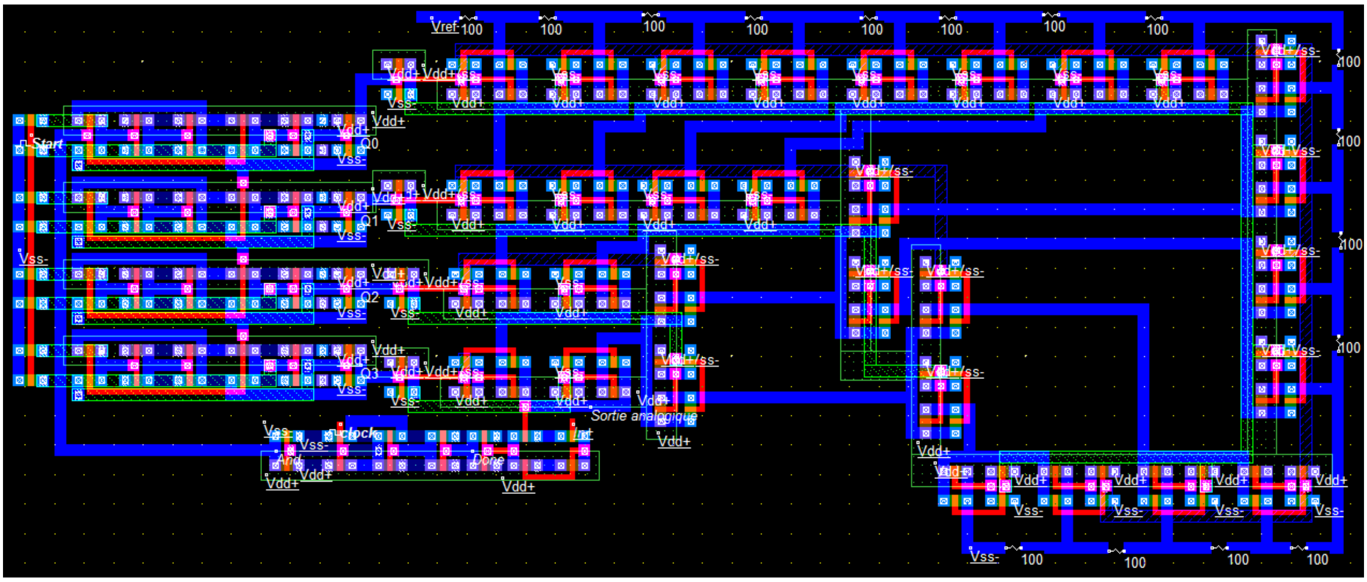

Figure 9: 4-bit Analog-to-Digital Converter design

Let us analyse the simulation results *(figure 10)*

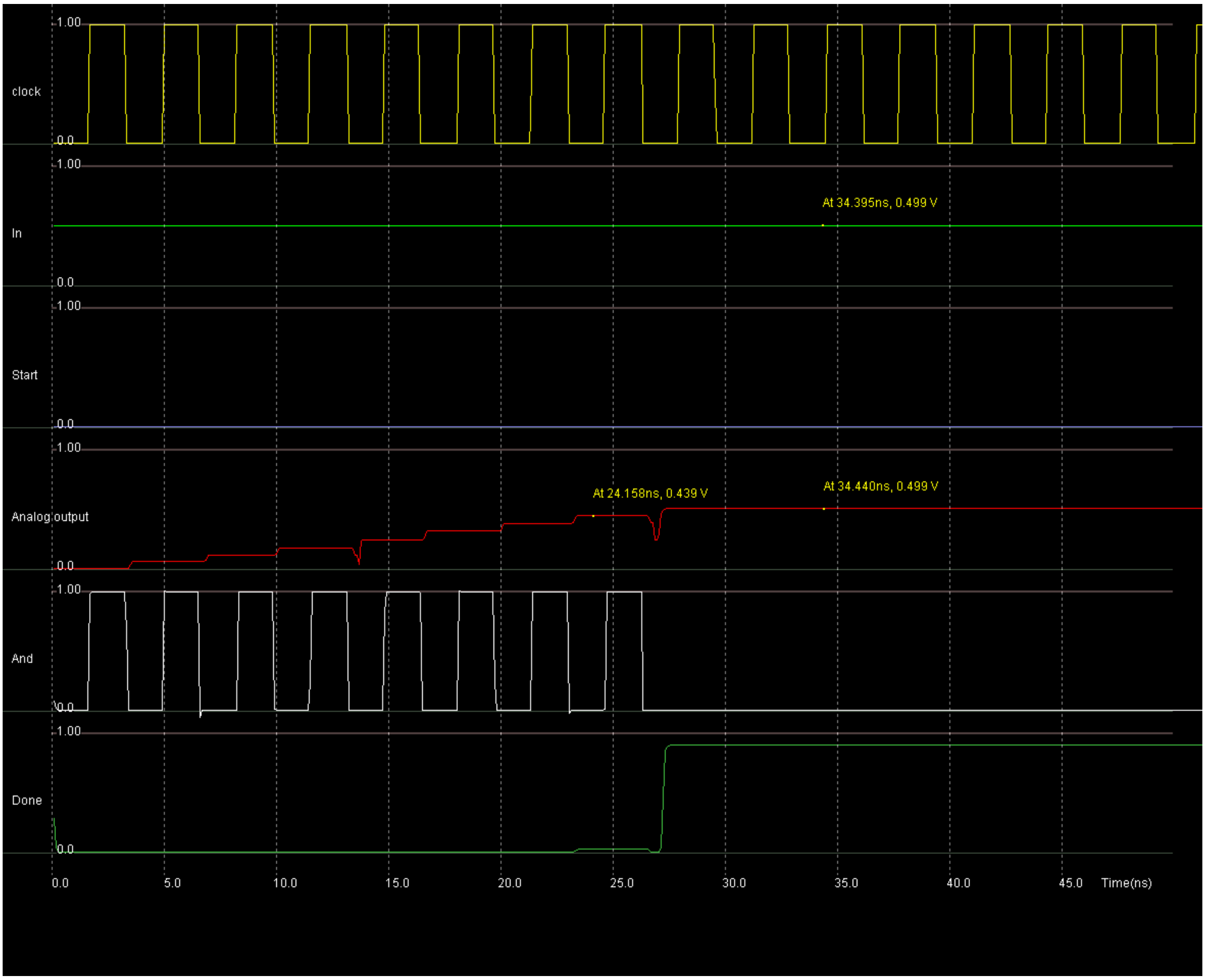

Figure 10: Functional simulation of the ADC

The analog output of the DAC follow perfectly the imput after $34ns$. It means that the ADC works correctly and we have the good values in the digital outputs `Q0` to `Q3`.

4 Analog phase meter

The analog phase meter presented in *figure 11* is an association of:

- Two rectifiers.
- A comparator.
- A first-order low-pass filter.

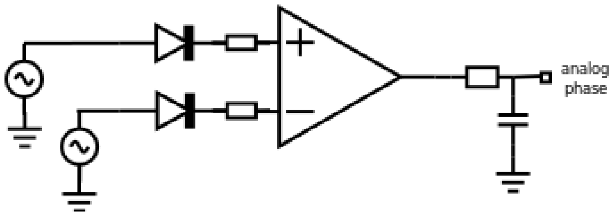

Figure 11: Analog phase meter schematic

4.1 Design of the rectifier

Microwind only allows us to create diodes linked to the ground. Then, we create a device using a comparator and a transmission gate to take the positive part of each input channel. *(figure 12)*.

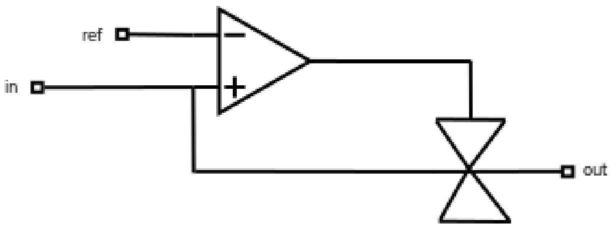

Figure 12: Rectifier schematic

We compare the signal to the chosen level (here $\frac{1}{2}Vdd+$). The transmission gate is driven by the comparator output. If the signal is lower than the reference the gate is locked, else it is passing.

We obtained a variable level diode.

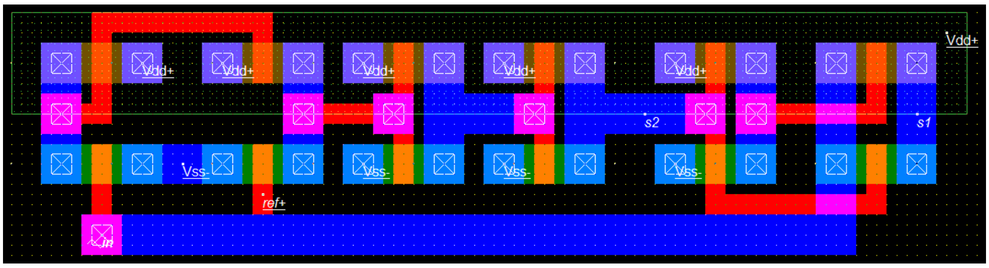

Figure 13: Rectifier design

4.2 Design of the comparator

The comparator has the same design than the one used previously for the ADC design *(figure 7 p. 7)*.

Here, the two rectified signals are compared in the aim to create a PWM signal which the ratio is proportional to the phase between the two signals.

4.3 The low-pass filter

The PWM is filtered to obtain a DC voltage proportional to the PWM ratio. A simple first order RC filter is enough here *(figure 11 p. 10)*

4.4 Analog phase meter simulation

Analog phase meter simulation results are directly presented on next section with the main simulation.

5 Digital phase meter

The digital phase meter is the association of analog phase meter and ADC *(figure 2 p. 4)*.

5.1 Final design

The final design of our digital phase meter is given here *(figure 14)*.

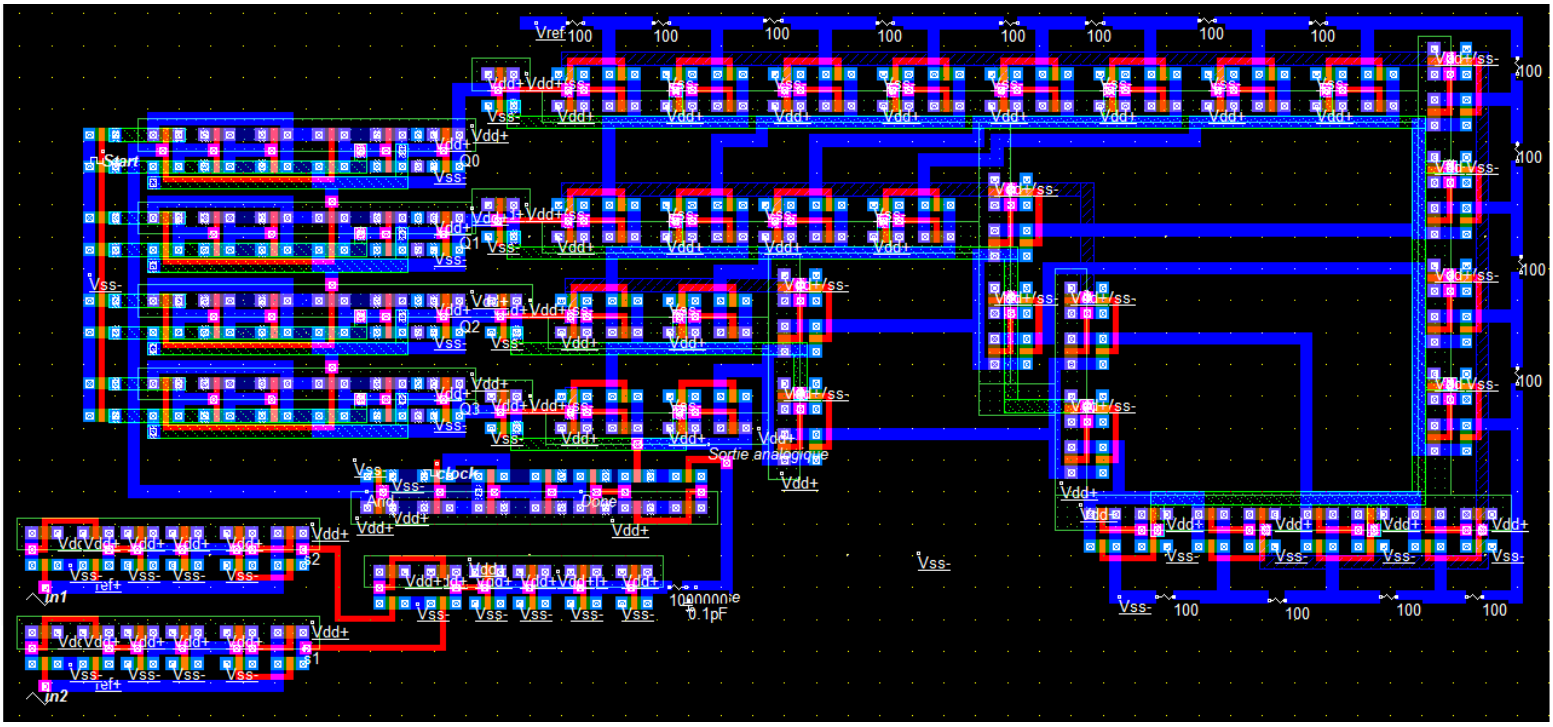

Figure 14: 4-bit digital phase meter design

The space used on our layer is really optimized: the differents parts of our phase meter are smartly placed, and connected with as small as possible metal connections.

5.2 Simulation results

Figure 15 is useful to check the two components:

- As much as the phase is increasing beetween the two input signals, the analog phase meter output is increasing too : this analog phase meter works fine.
- The digital 4-bit output is increasing too at the same time : ADC works fine too.

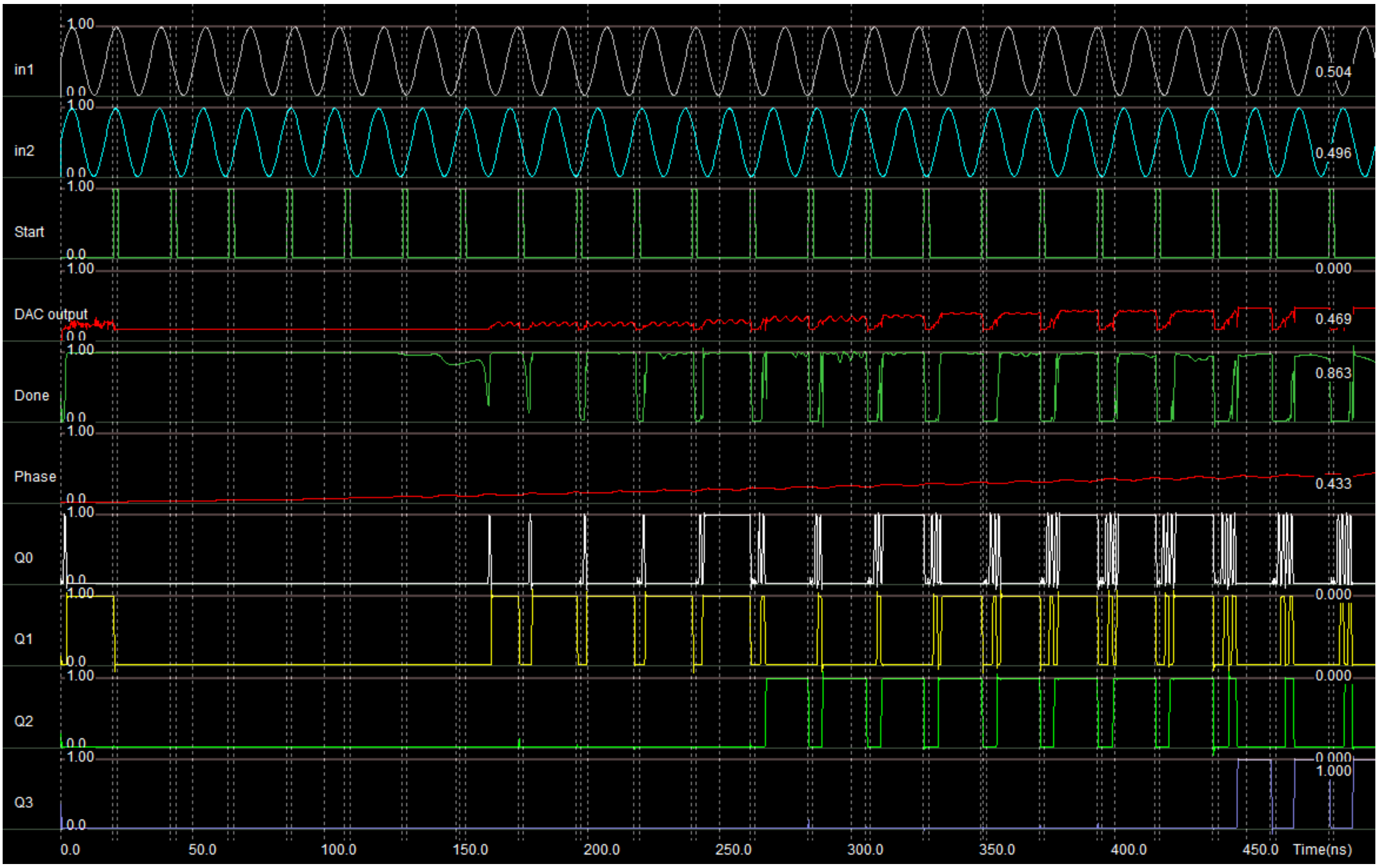

Figure 15: Final digital phase meter simulation results

At the beginning of the simulation, the analog phase seems too low, it is normal because the capacitor is not yet charged. After the value stay beetween 0.2 and 0.7.

We have so changed resistors'bridge reference tensions to use the full-scale of our ADC.

6 Conclusion

Our phase meter works correctly and was operational: our project was a success! It was very instructive: we have acquired a basic knowledge in micro-electronics design wich can always be useful.

But we have met some difficulties due to the fact that *Microwind* is really efficient with digital signals, but not as much with analog signals.

We are sorry too to not have respected all the conception rules (space beetween metals...) because we have noticed this mistake too late to fix it.