Institut National des Sciences Appliquées de Toulouse

Physics and Modeling of Semiconductor Devices

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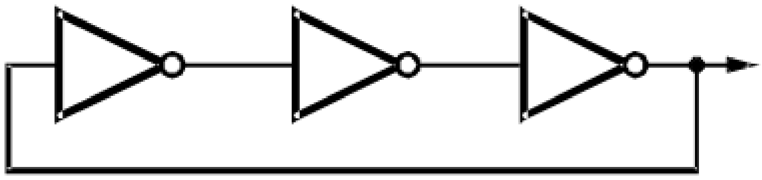
Introduction

With this we intend to study the Voltage-Controlled Oscillator (VCO), an oscillator that varies its frequency based on the input DC voltage applied (Vcontrol). With this circuit we hope to create a modulator in comparing two outputs of two different VCOs, the first one drived by the signal to be modulated and the second one by a constant tension (creating a clock).

The design of the circuit will be done with the software Microwind, creating the layers for fabrication in silicium wafers.

Voltage-Controlled Oscillator

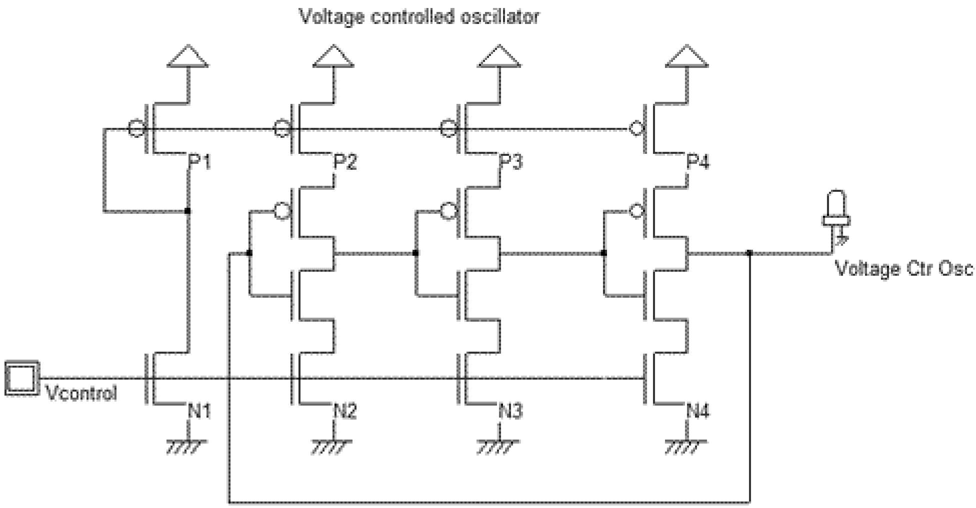
There are some different known architetures for a VCO, the one used here is the Delay-Based Ring VCO, where delay cells are connected in a loop, making a Ring Oscillator (shown below).



Simple 3-inverter Ring Oscillator

This circuit is based in the delay of the inverter gate switch. The output of each inverter changes in a finit amount of time after the input has changed, then the loop of an odd number of inverter gates creates an oscillation.
To reduce the frequency of oscillation, is necessary to add more inverter gates to the loop, increasing the total propagation delay.

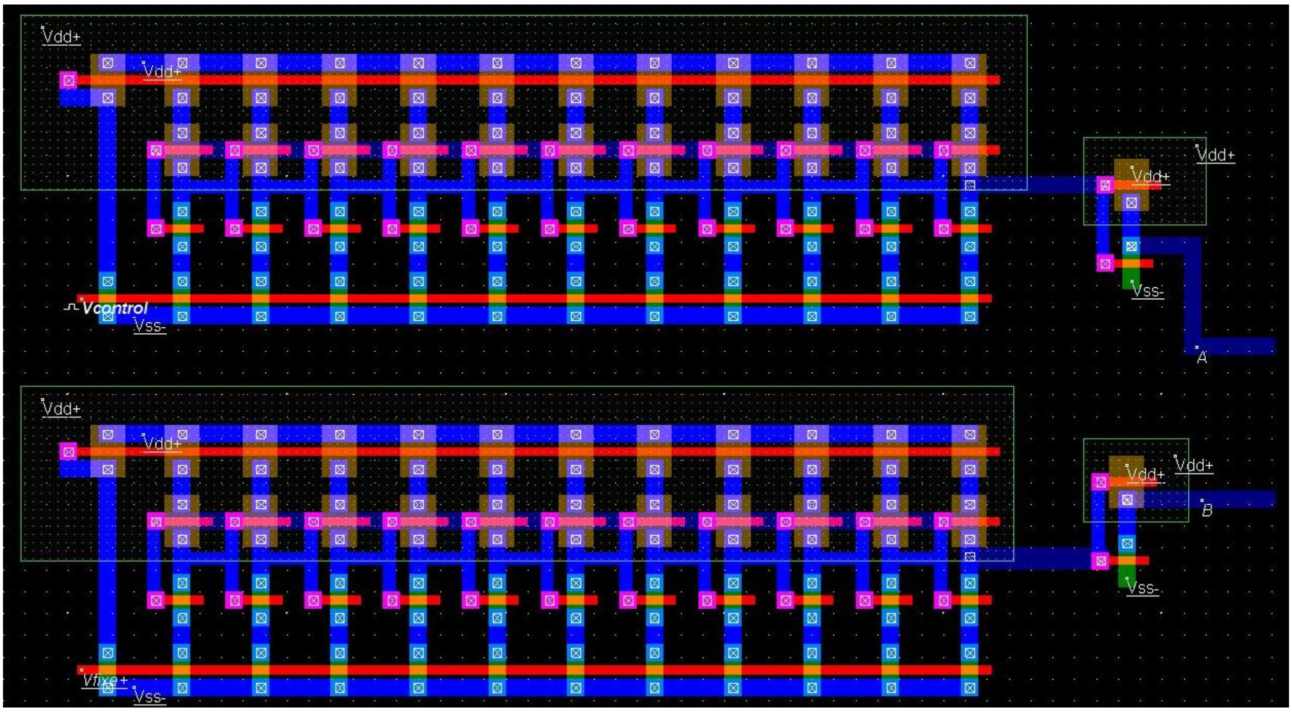
The VCO based on this architeture uses the alimentation of the inverter gates to change the delay time, changing the global oscillation frequency. The basic schema is shown below.



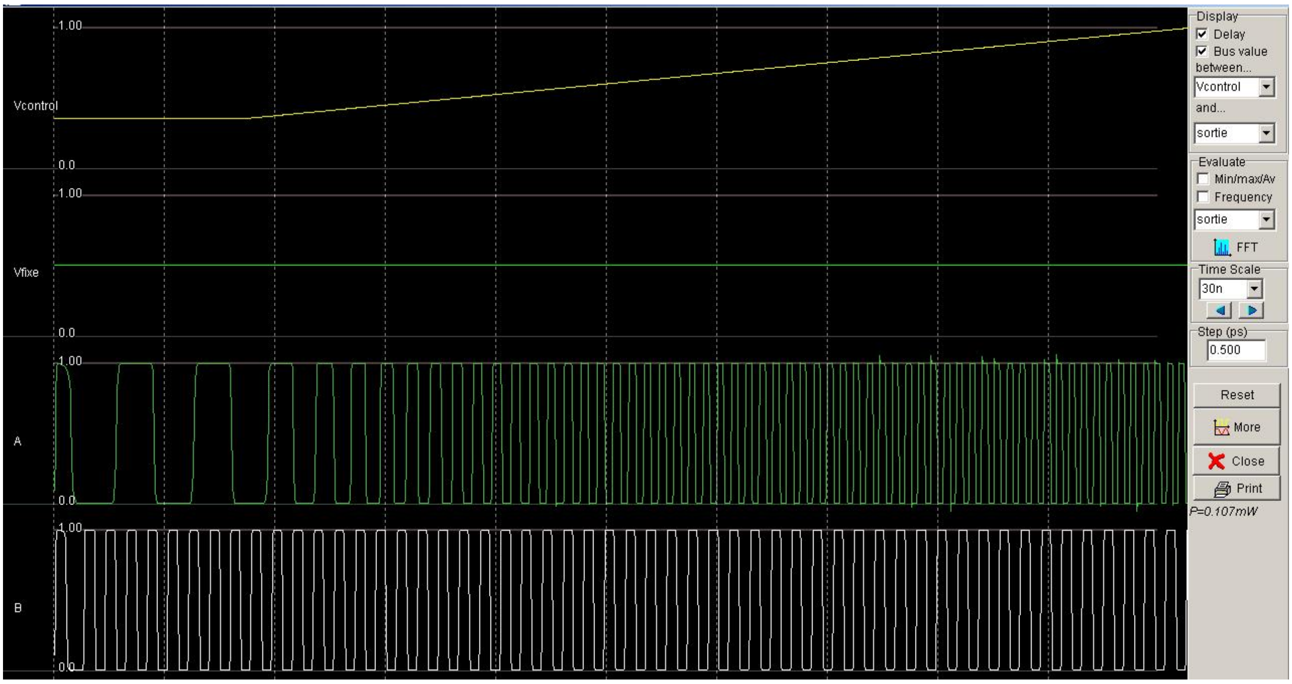
Schema of a VCO

The first attempt of design was the schma show above, but the low number of inverter gates (3) was not enough to create a good oscillation on the output. Then a higher number of inverters were added, creating the configuration shown below, with eleven inverter gates.

Another inverter was added in the output in order to create a more quadratic wave, removing the rounded corners created by the charging capacitances of the mos gates.



Two VCO's were added in order to create two different waves for comparition in the output. The first one was controlled with a variable tension Vcontrol and the second one with a DC tension Vfixe. With this setup, the simulation has given the following results.



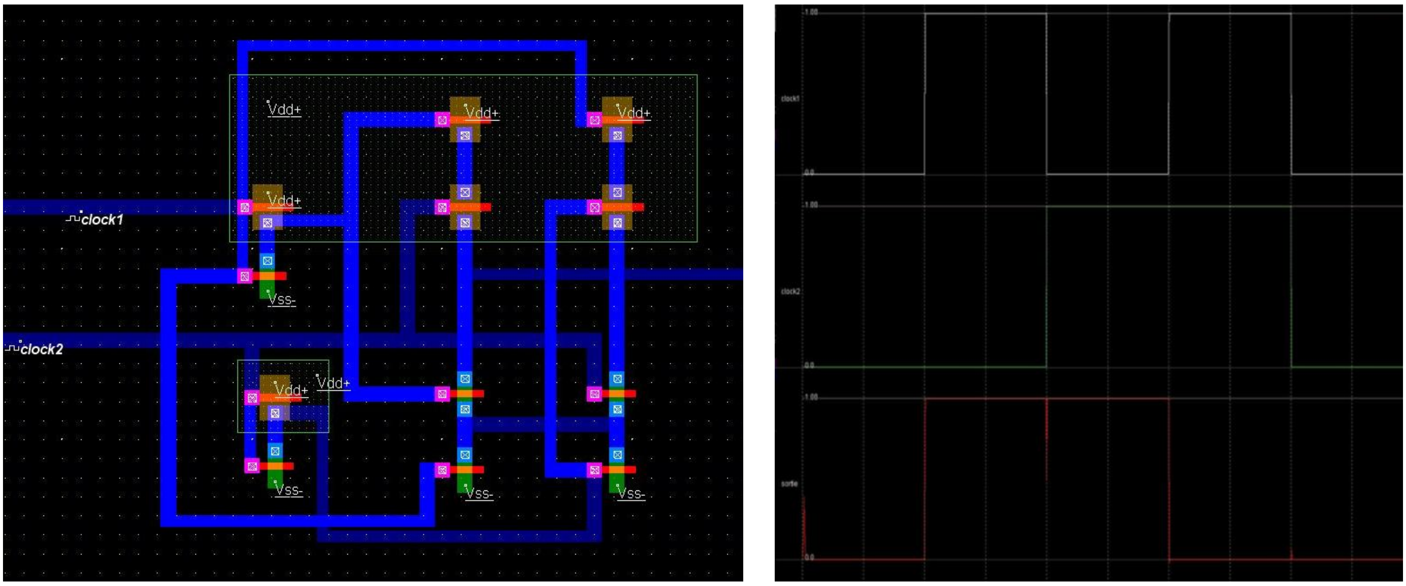
As expected the output of the first VCO rises its frequency as Vcontrol rises, and on the second VCO the frequency stays the same, creating a clock pulse.

One of the most common applications of this VCO circuit is for clock generation in phase lock loop circuits, used for signal synchronization.

Comparison

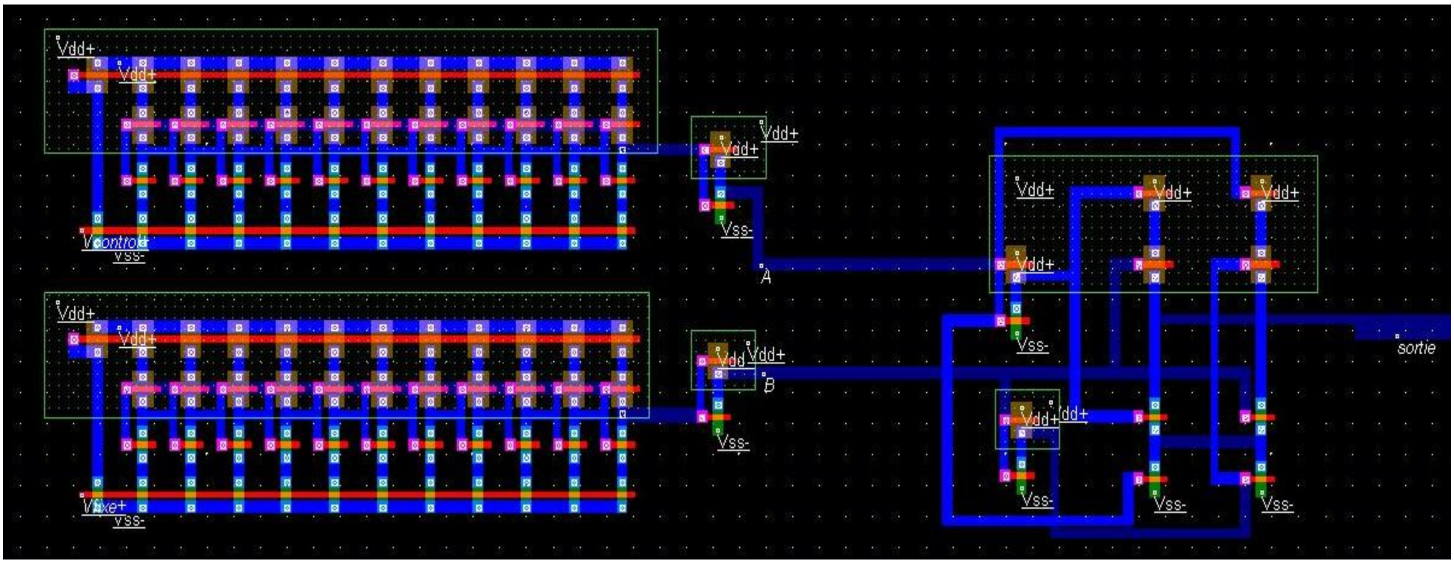
Now that we can have two sources of frequencies, we want to compare them with one of the different gates: AND, OR and XOR.
The problem with the AND and the OR is the inequality between the high and low states, whereas the XOR offers us a perfect balanced signal, which allows us to obtain the most accurate signal with an optimal range of values, in this application field.

That is why we decided to study two different XOR architectures, and we chose the one with the least noise. With this XOR on the left, we obtain the following test results on the right.

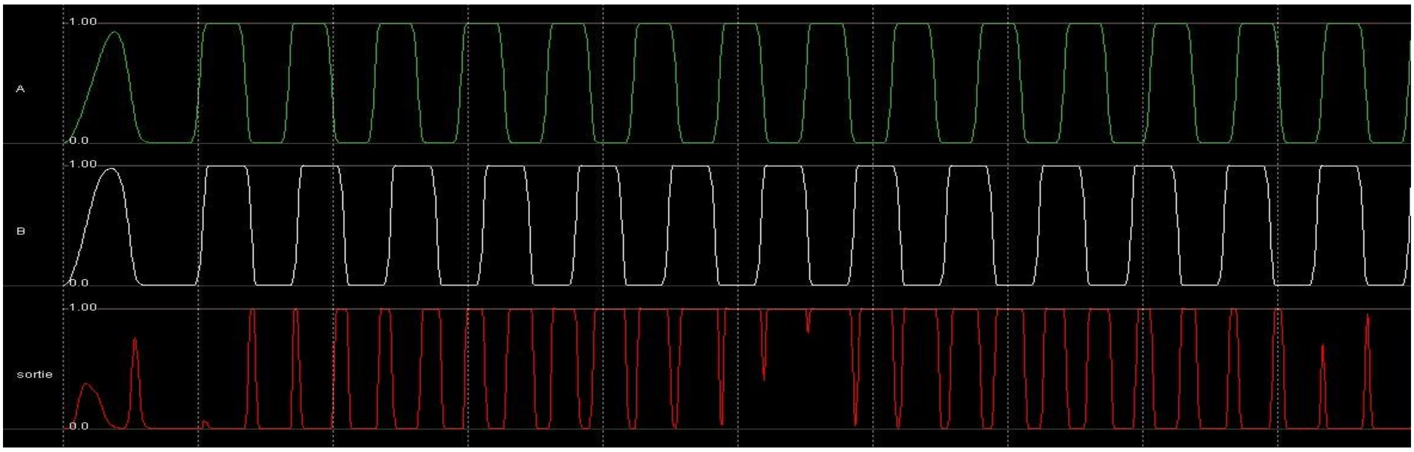


XOR with its test

Now, we can place the two VCOs in the XOR inputs.

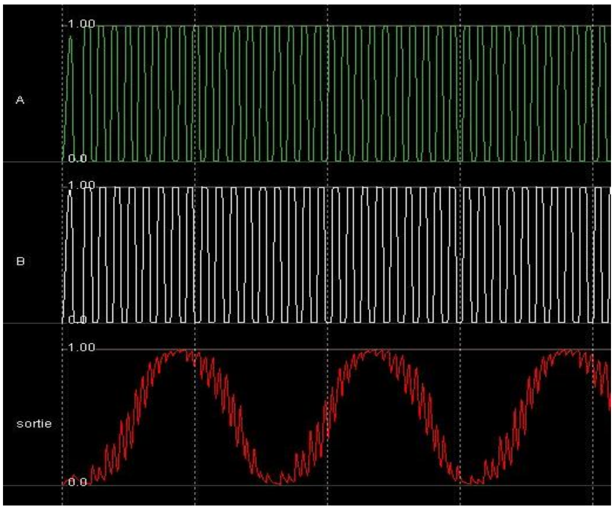


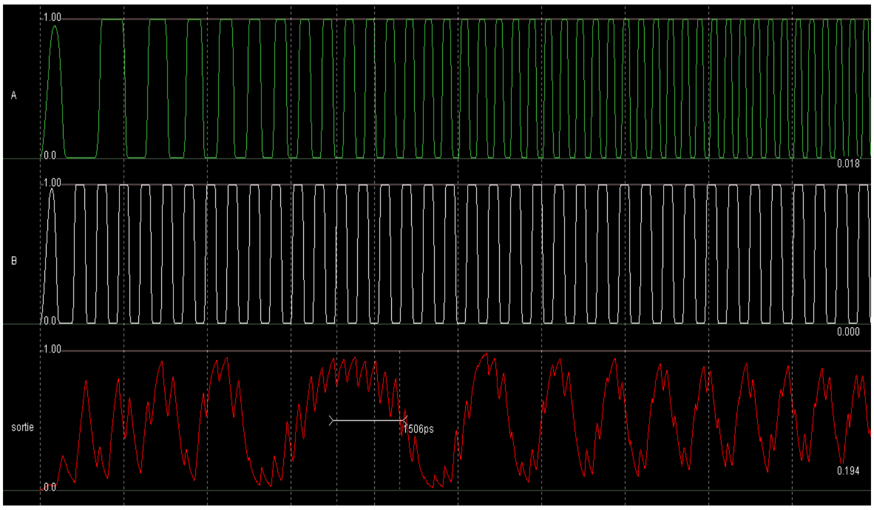
The following picture shows us the final output, with different constant inputs.



We can see a variation of a duty cycle, which increases then decreases. This structure of the signal is repeated, so we can hope that with a capacitor, there will be a periodic signal in output.

That is what we prove now: on the left is the result with two different constant input frequencies, and on the right is the result with a constant frequency and the other one increasing.





Due to the choice of the capacitor, we did not obtain a perfect signal, but we can confirm its periodic aspect. Furthermore, its frequency goes up when the two in input move away. It is also important to notice that the final output frequency is equal to the difference between the two from the VCOs.

Possible application

As an application we can mention the radio FM. If we use only one VCO to have a reference frequency, and if the other entry of the XOR directly catches a frequency modulated signal, we can obtain in output, with good parameters, a demodulated one. That is finally a frequency demodulator.

References

[1] https://intranet.insa-toulouse.fr/view/431/content/rfc_oscillators.html
[2] Advanced CMOS Cell Design, by Sonia Delmas Bendhia and Etienne Sicard
[3] Basics of CMOS Cell Design, by Sonia Delmas Bendhia and Etienne Sicard