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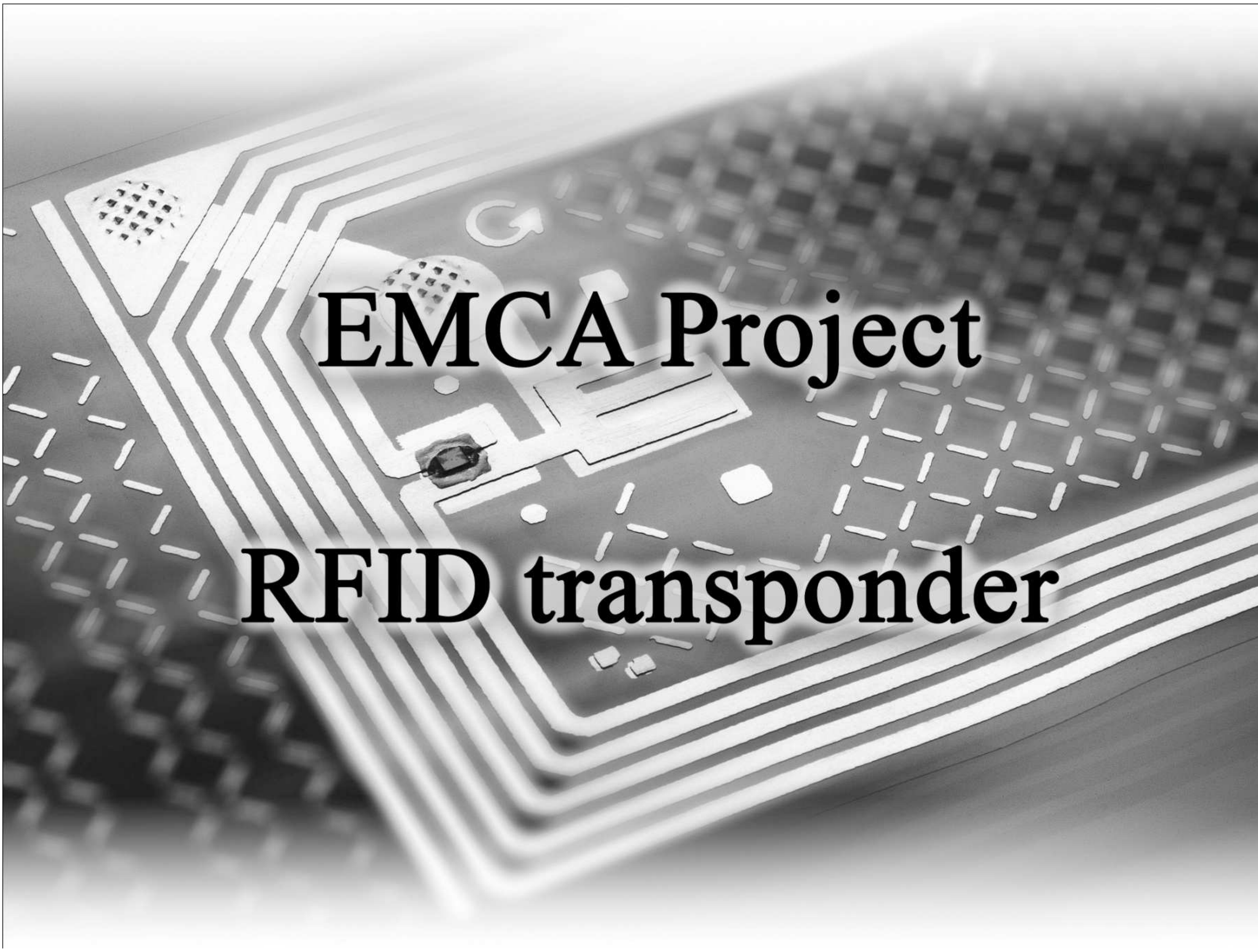

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Sommaire

Introducing RFID tags

Radio frequency identification (RFID) is a technology commonly used nowadays to track objects and identify people using radio waves. Some RFID tags can be read from several meters away and beyond the line of sight of the reader. For example, the INSA student card is using an RFID tag which enables paying for lunch and photocopies.

Most RFID tags contain at least two parts. One is an antenna for receiving and transmitting the signal. The second one is an integrated circuit for storing and processing information, modulating and demodulating a radio-frequency (RF) signal, and other specialized functions.

There are generally three types of RFID tags : active RFID tags, which contain a battery and can transmit signals autonomously, passive RFID tags, which have no battery and require an external source to provoke signal transmission, and battery assisted passive (BAP) which require an external source to wake up but have significant higher forward link capability providing great read range.

Here is the global scheme of a passive RFID tag:

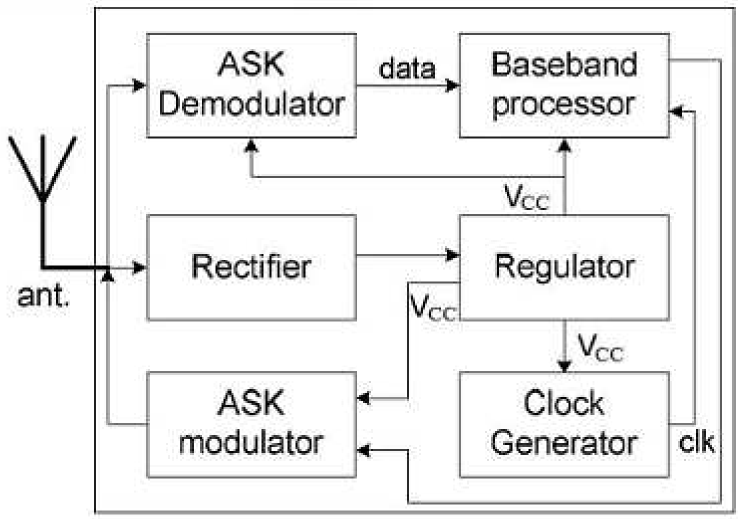


Fig. 1: Passive UHF RFID tag diagram.

We aimed to design the whole RFID tag but due to its complexity we had to revise our plan and limit ourselves to part of it. Due to the difficulty to design diodes using Microwind environment we couldn't realize the Rectifier. Therefore we chose to design the regulator and the clock generator. One of the reasons is that both are very useful for other applications.

1. The Voltage Regulator

The rectifier converts AC voltage from antenna to DC voltage. We need then to regulate this voltage to obtain a stable Vcc output to supply power to the different circuits in the tag. This voltage regulator would give a stable Vcc in output which stays always the same when the rectifier output voltage changes. This circuit is built to cover the variations of the rectifier within a given range.

To do so we will use the following scheme:

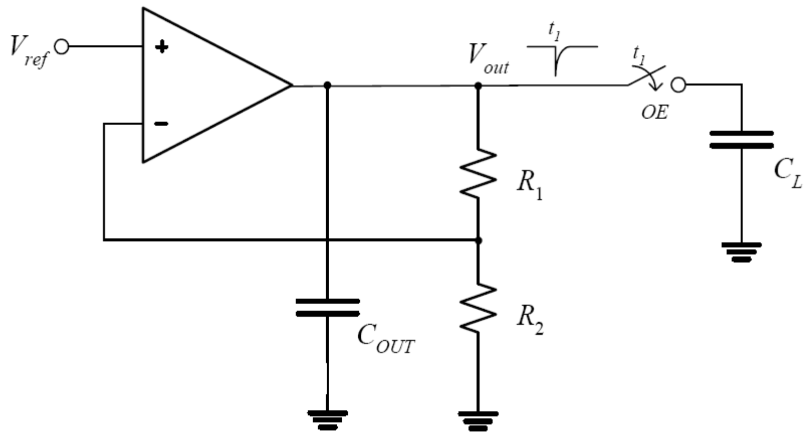


Fig. 2: Typical voltage regulator scheme.

- **Scheme explanation :**

The main element of this design is the Operational Amplifier. Vref - an on-chip voltage reference created usually thanks to a band-gap based circuit - is applied to V+ and compared to a given percentage of Vout which depends of the values of R1 and R2.

Basic calculations give:

$$V_{out} = V_{ref} * (1 + \frac{R1}{R2})$$

Therefore if Vout > Vref then Vout decreases and if Vout < Vref, Vout increases.

On the end even if the Operational Amplifier voltage supply (equivalent to the rectifier output) varies slightly, the voltage regulator output will stay the same. Of course Vout must remain lower than Vdd.

Vout is wanted to be 0.9V (usual Vcc for RFID tags) so we choose R1/R2=0.28 which is correspond to R1=4.5KΩ and R2=15.75KΩ.

- **Design and simulation using Pspice and Microwind:**

Simulation on Pspice shows that our design is working well:

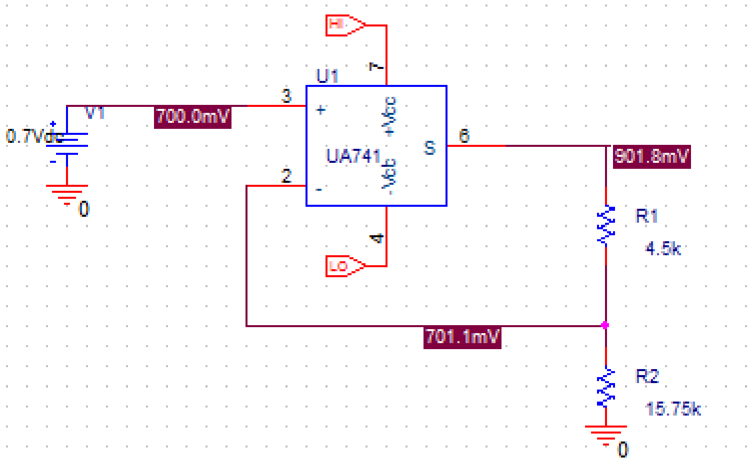


Fig. 3: Voltage regulator scheme using Pspice.

Now we need to design the Operational Amplifier using MOS transistors. A very simple design is a differential amplifier with an Nmos output stage. To obtain a high gain, an active load will be used instead of a resistor. The resulting scheme is the following:

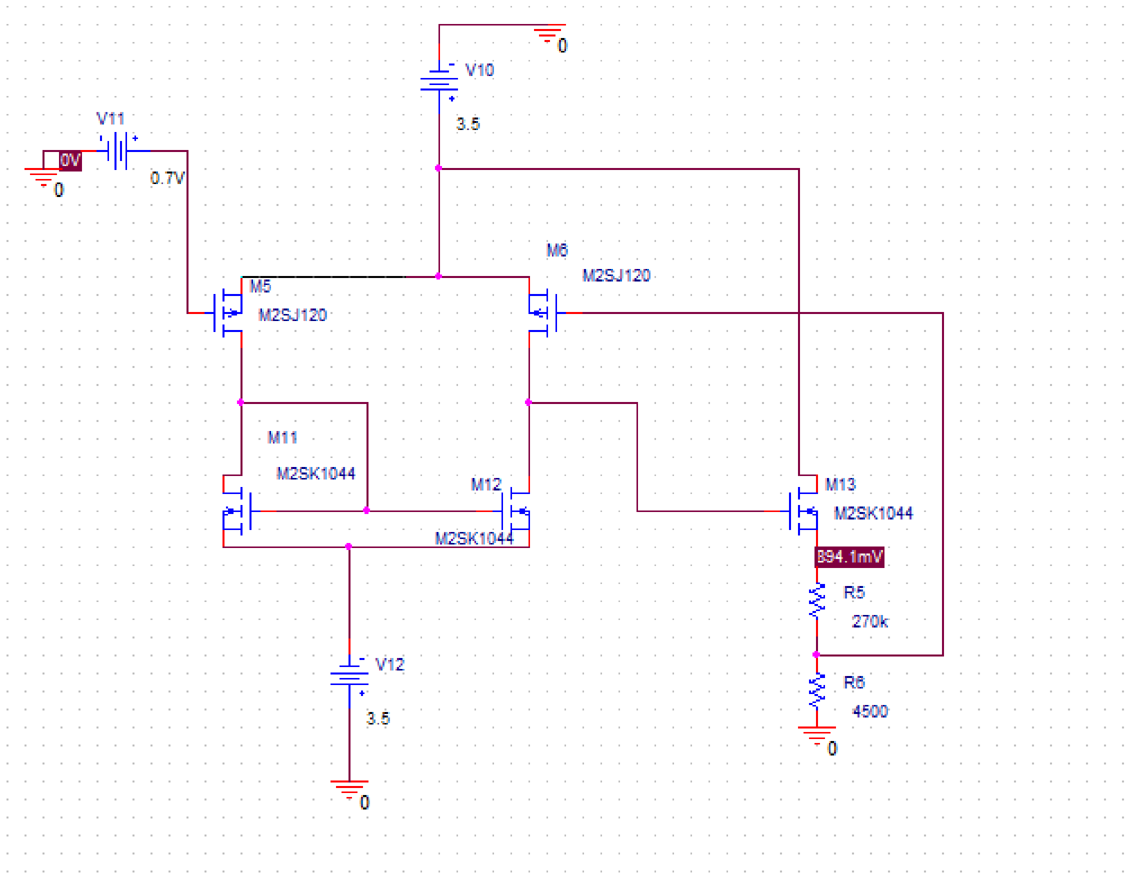


Fig. 4: Voltage regulator scheme using NMOS transistors using Pspice.

Again, Pspice confirms that the design is supposed to be working. Therefore we implemented it on Microwind.

Now, it's possible to simulate the voltage regulator using Microwind:

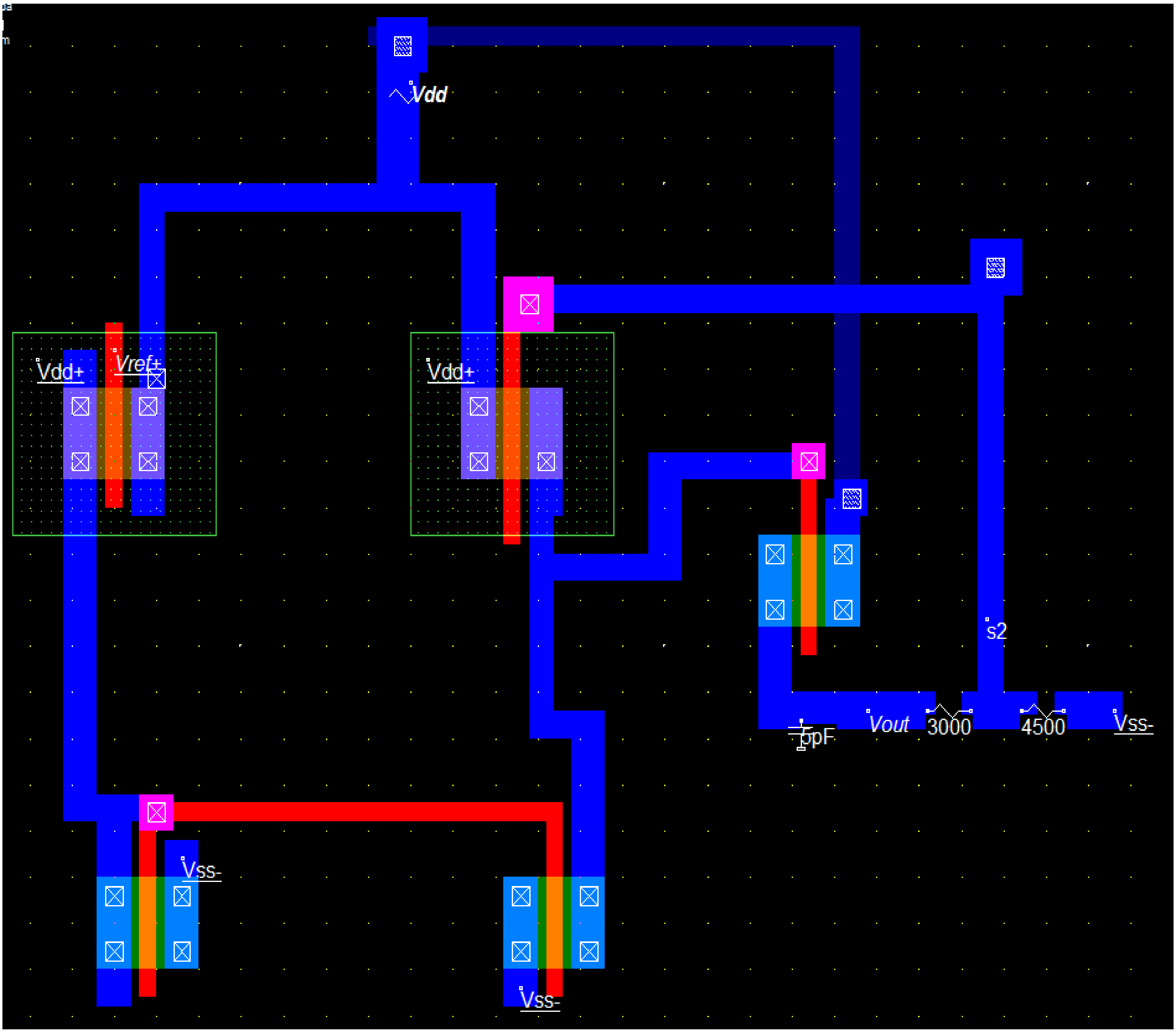


Fig. 5: Simple Voltage Regulator design using Microwind.

We didn't manage to get this design to work using a 12um technology. Indeed, the maximum Vdd voltage in that case is 1.2V and it was not enough to achieve a 0.9V output. Therefore we used a 35um technology and a 3.5V Vdd supply. It was then possible to obtain the correct output.

Next we tested the behavior of our design when perturbations of Vdd (the output of the rectifier) occurred. As we said, the rectifier converts AC voltage from the antenna to DC voltage. Therefore its output level only depends on the input power, that is to say the distance between the tag and the reader. Thus the DC voltage given by the rectifier is not likely to vary very quickly. On the end we decided to use a frequency of 500 KHz and a variation of 0.2V (3.3 to 3.5V) to test the design. In fact the 500 KHz frequency is probably too important but it's not possible to view simulation results using a lower one. Anyway, if the circuit is quick enough to work properly at 500 KHz, it will be able to handle a lower frequency.

Here is the simulation result using these parameters:

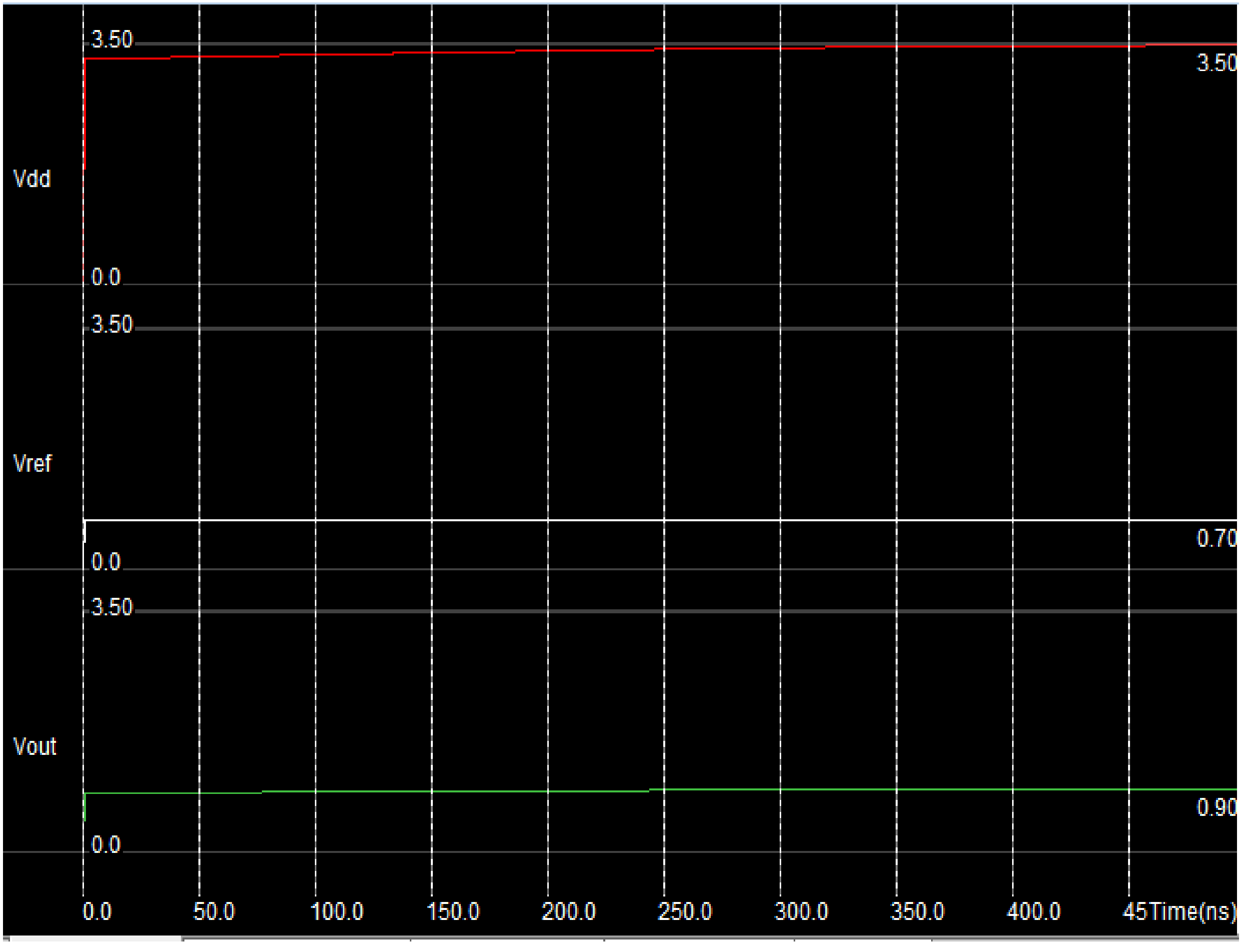


Fig. 6: Simulation on the voltage regulator using Microwind.

We can see that Vout varies very slightly which means that the regulation is working well. Nevertheless after a few others tests, it appeared that Vout was not that stable. For example if Vdd is set to 3.3V then Vout equals to 0.84V. Moreover, the resistors values are not those we calculated before.

➔ The design is then not equivalent to a real Operational Amplifier.

Next the fact that a 3.5V supply voltage is required is a very bad point seeing that it means the RFID tag must be very close to the card reader.

The following document shows the output voltage which can be achieved depending on the input power.

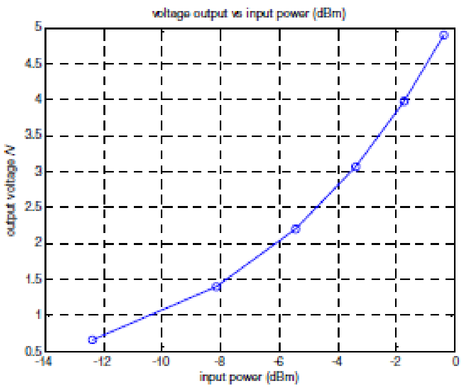


Fig. 7: Output voltage vs. Input power.

In our case a minimum of -3dBm would be required.

On the end we were not very satisfied with our design so we decided to improve it. The issue is that we simplified the design of a “real” Operational Amplifier. We will now try with a whole one instead. The next part of the document shows the design and the simulation of a such scheme.

- **Simulation with a “real” Operational Amplifier:**

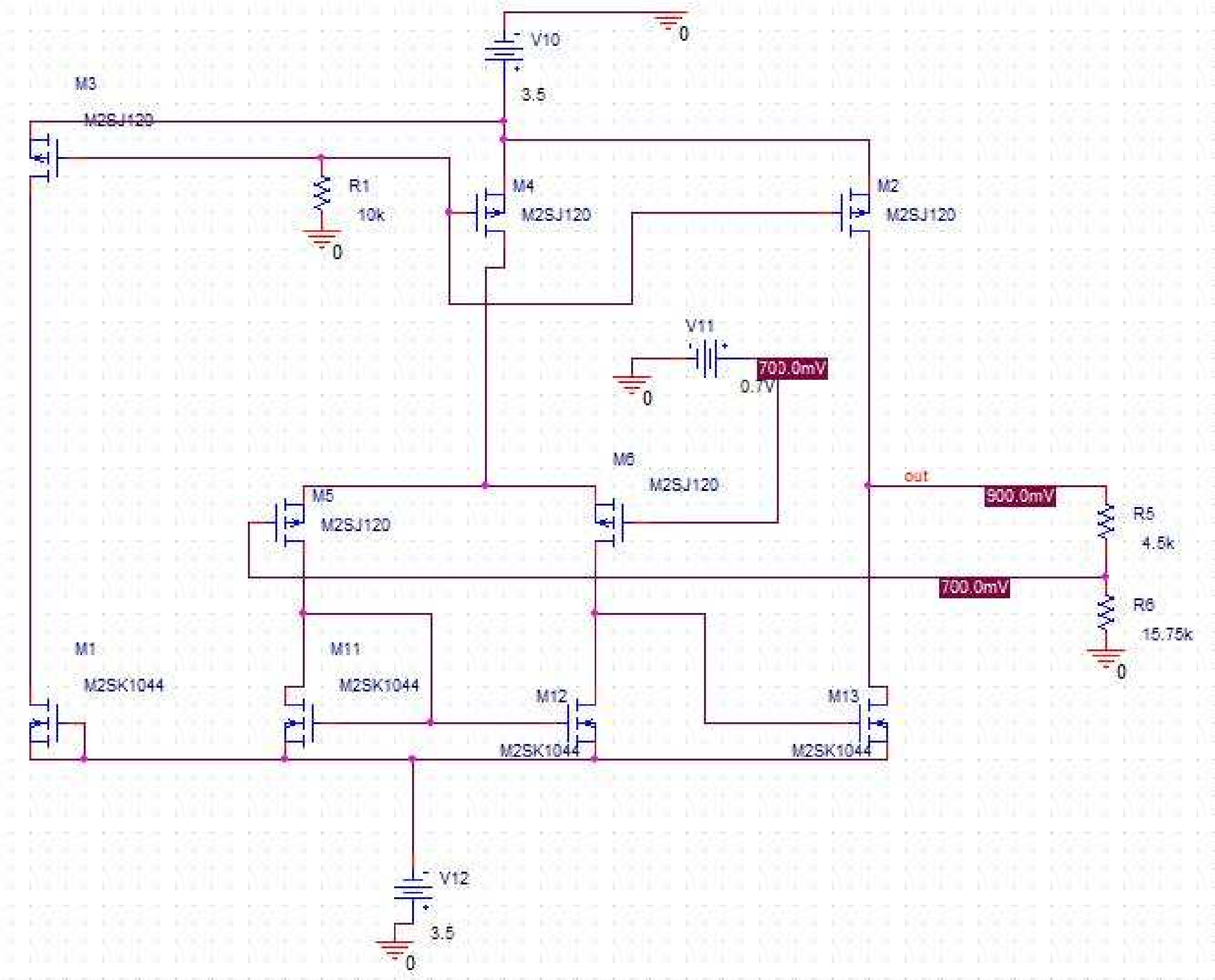


Fig. 8: Voltage regulator scheme using NMOS transistors using Pspice.

We can notice that the scheme is basically the same. A differential pair with an active load is used and followed with an Nmos output stage. More transistors have been added to give a better gain and a better input and output load. Simulating on Pspice gives very good results.

Design using Microwind:

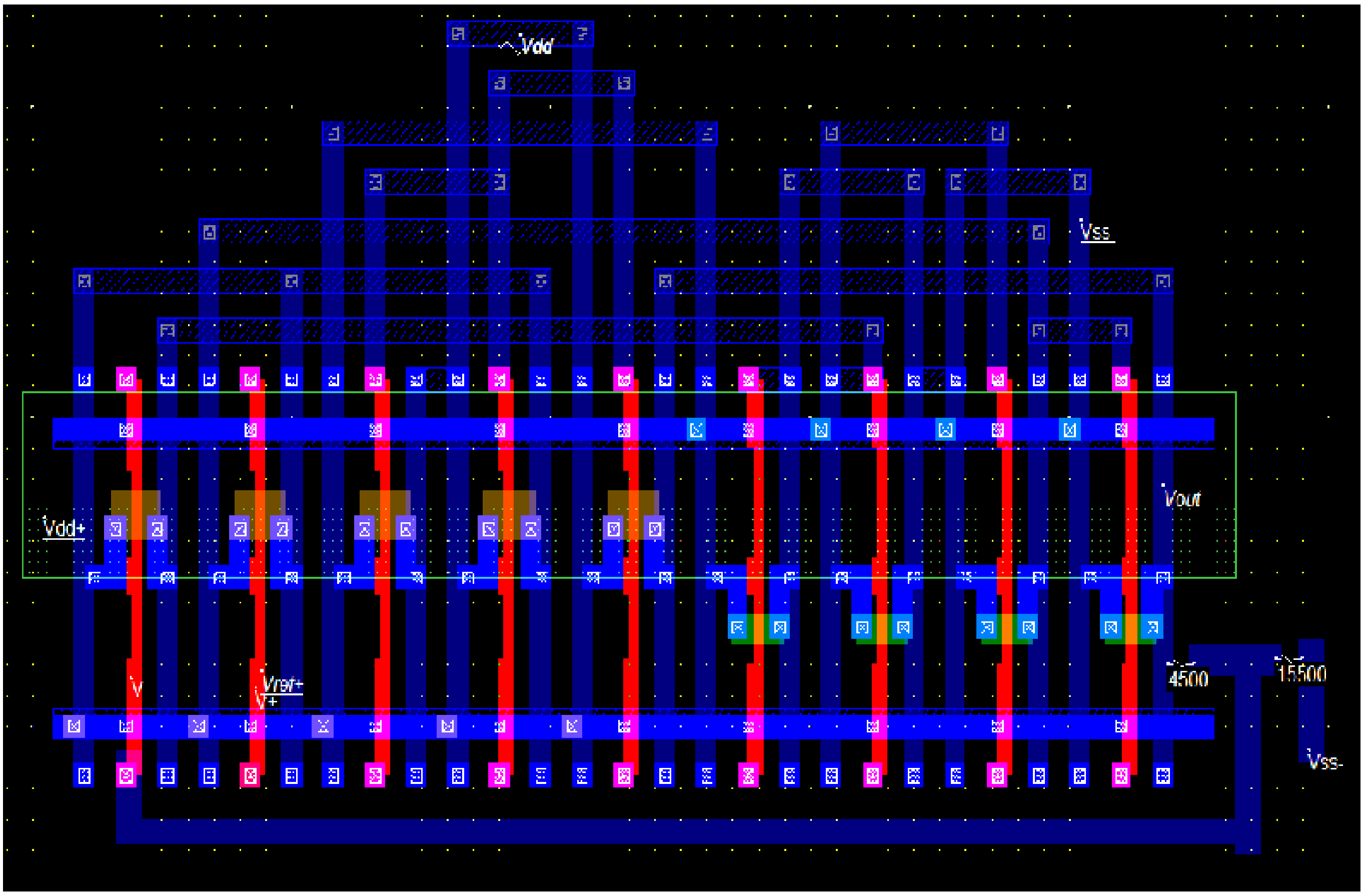


Fig. 9: Design of the voltage regulator using Microwind.

In that case, the 12um technology and its 1.2V maximum supply voltage was enough to obtain a correct output. Simulation using the same parameters as before showed a very stable output with an excellent response time. We noticed nevertheless that if the input frequency was higher than 10 MHz, then Vout was oscillating but it's very unlikely to happen in case of RFID tags.

More tests showed that if Vdd is higher than 1V then the Vout value was always 0.9V which means that it only requires a minimum input power of -10.5dBm.

Therefore our voltage regulator is working very well, as shown in figure 10.

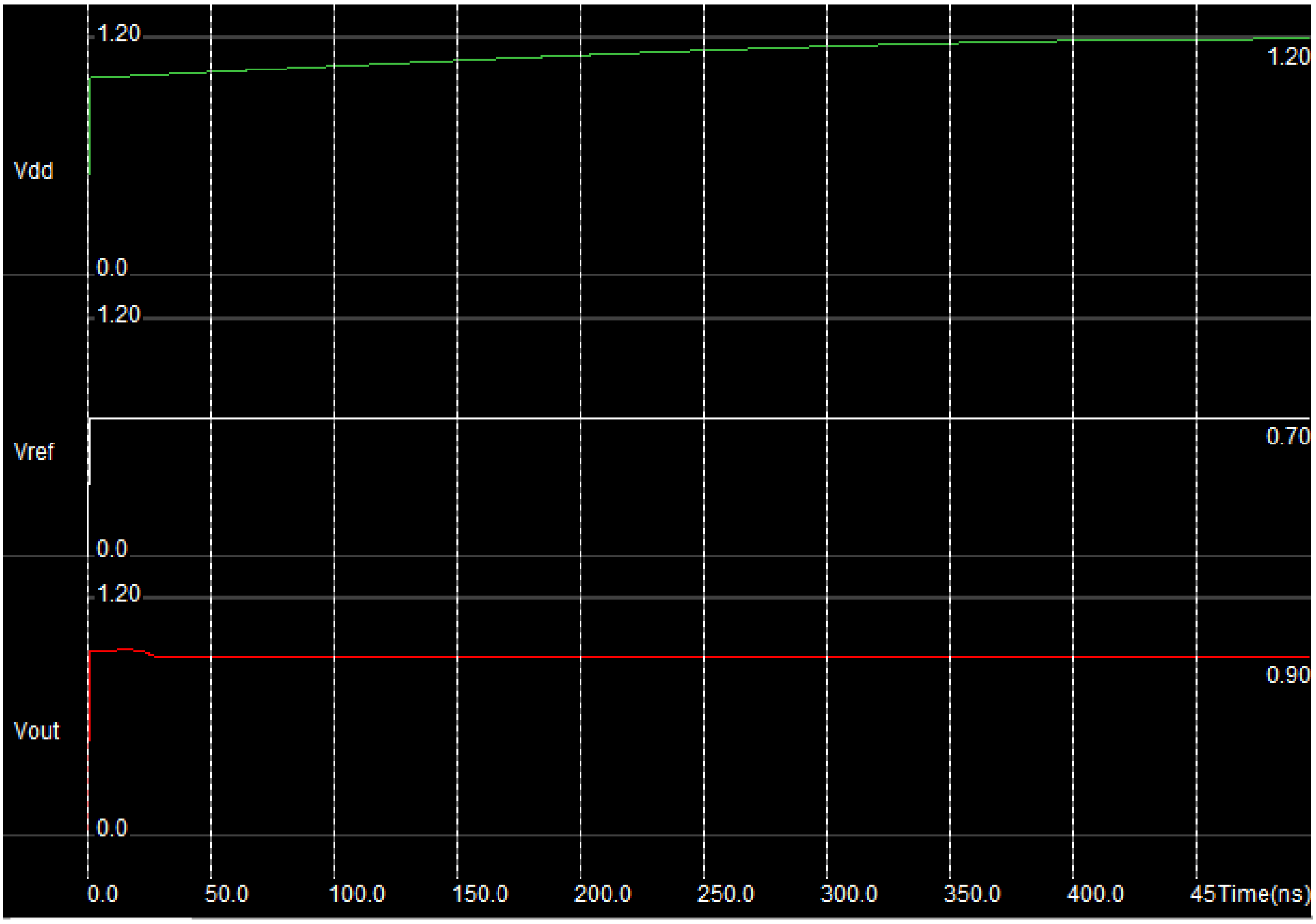


Fig. 10: Simulation using Microwind.

The minimum supply voltage which gives a correct Vout value is 1V. If the Vdd value is lower than 1V (the tag is too far from the reader) then the RFID tag can't work or at least should not be working. That is to say that the base-band processor must not be sending data anymore.

- **Power-on-Reset circuit:**

A Power-on-Reset circuit can be used for that purpose. It detects when the tag is close enough (power on) or too far from the reader (power off) according to the Vdd voltage and sends the corresponding message to the processor. This guarantees the good behavior of the tag.

Here is the scheme of a Power-on-Reset circuit:

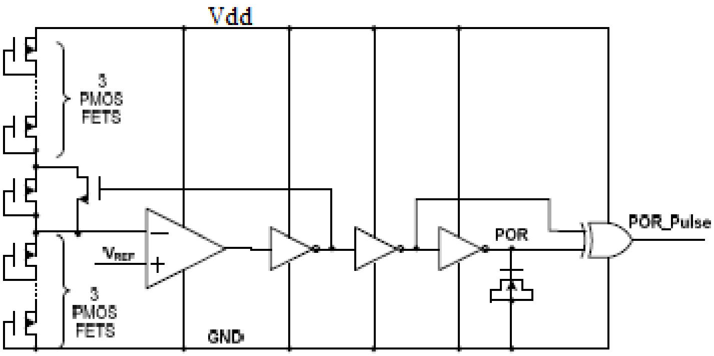
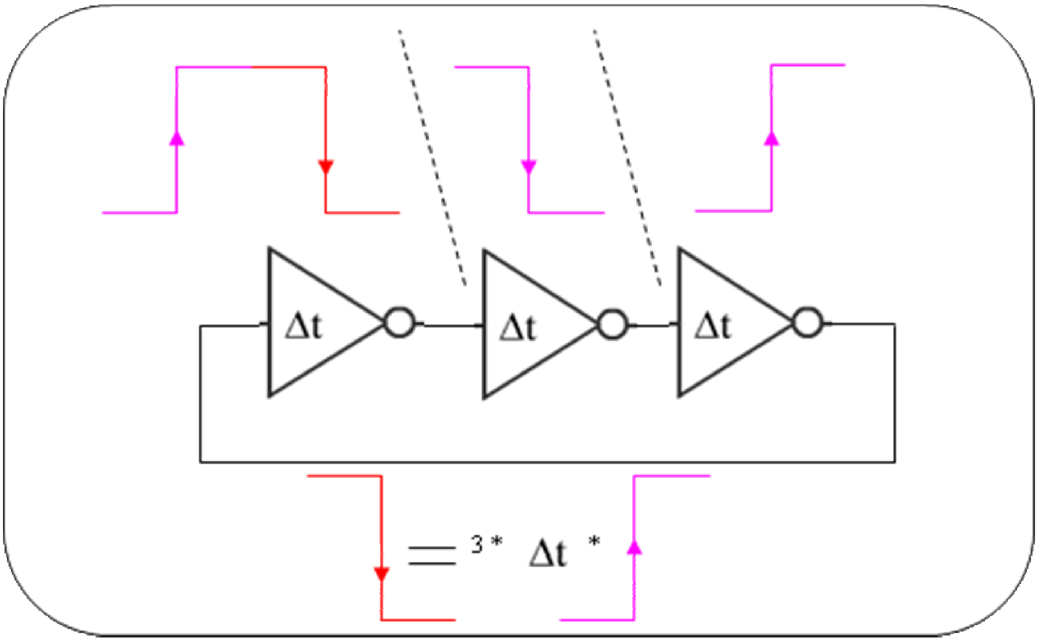


Fig. 11: Power-on-Reset circuit scheme.

2. The clock generator

The clock generator or voltage controlled oscillator (VCO) is an oscillator designed to be controlled in oscillation frequency by a voltage input. The frequency of oscillation is varied by the applied DC voltage of the regulator.

- **The principle of the VCO :**

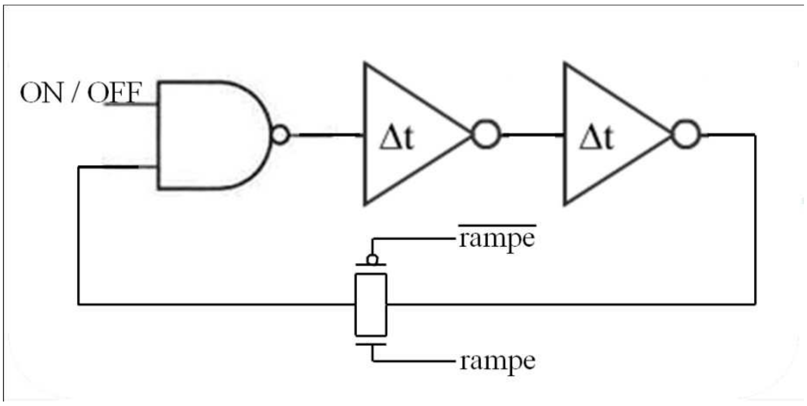


We use inverters logic gates to toggle the signal and as a gate as a delay, we can make a constant output frequency. So the output frequency is then a function of the delay in each of logic gates.
Of course we must use an odd number of gates to make an oscillation.

This scheme is the base of the generator and it works for a RFID tags because the required frequency is constant. However if the application is a linear command; we need a variable frequency controlled by a voltage input.

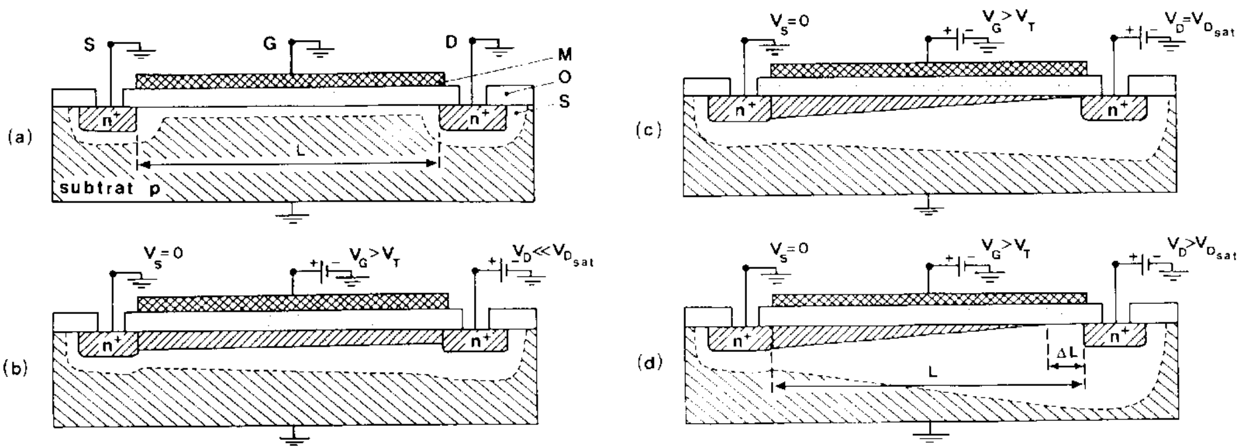
- **Control of frequency in VCOs**

To control the frequency, we will modify the scheme:



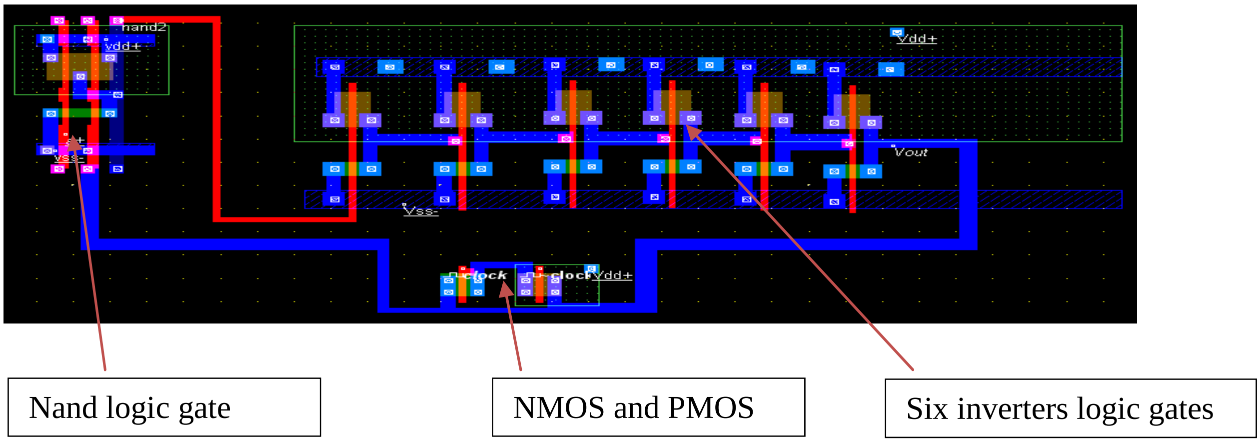
We find again our logic gates which make a delay in the signal. An inverter was replaced by a NAND to activate or not the oscillator. And the particularity is the ramp.

This is a PMOS and a NMOS in parallel to make an interrupter. To the gate, we connect the signal of frequency to be controlled. So when the signal is low level, the interrupter is off and in output we have a low level. When the signal is high level, the interrupter toggle on and we can control its period. To the drain of transistors, we connect the stable Vdd output of the voltage regulator. So more the voltage is large and more the channel of transistors will be large. Then the signal goes faster and then we will be able to control the period.

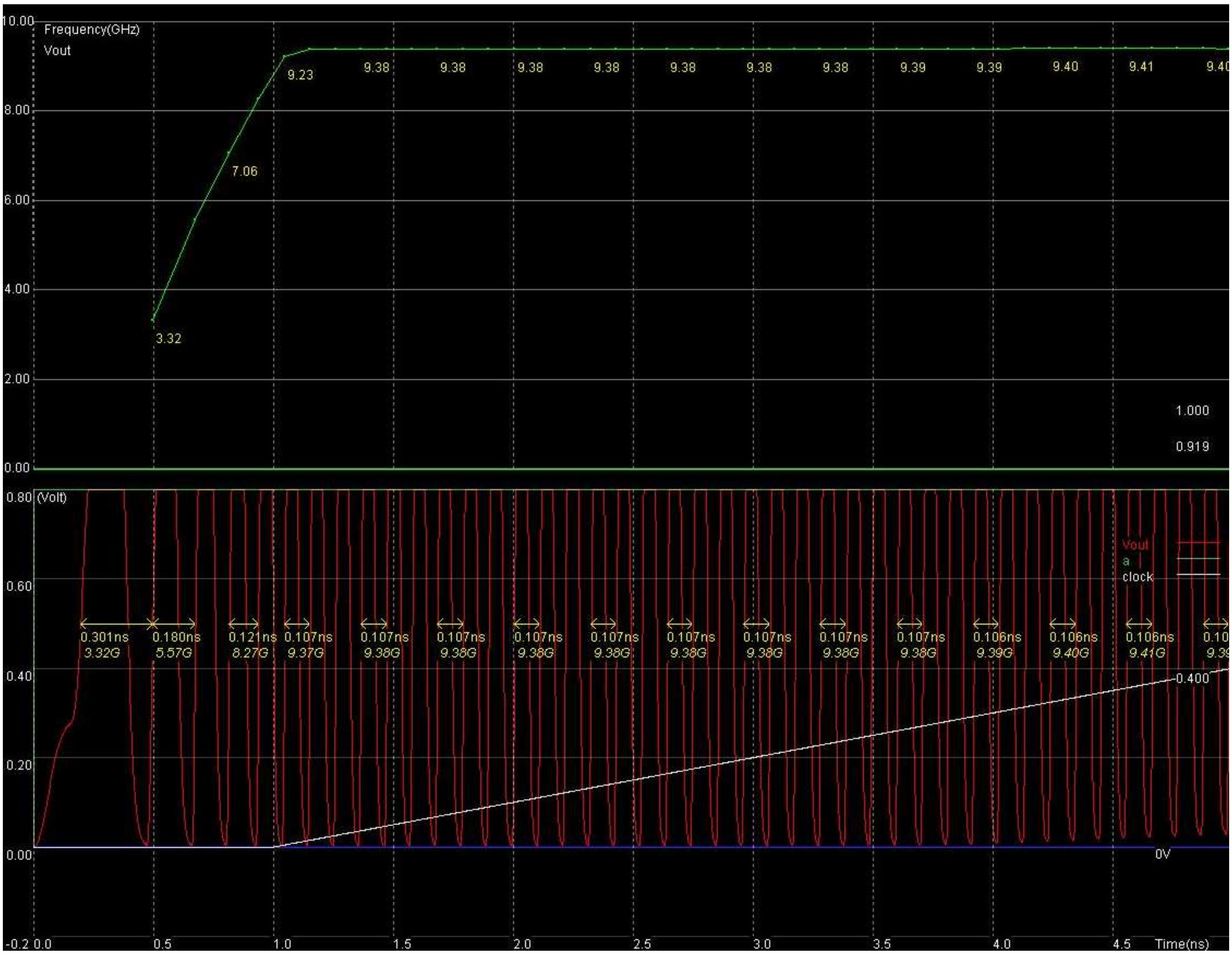


Principle of the creation of the channel of a transistor MOSFET.

- This is the scheme using Microwind :

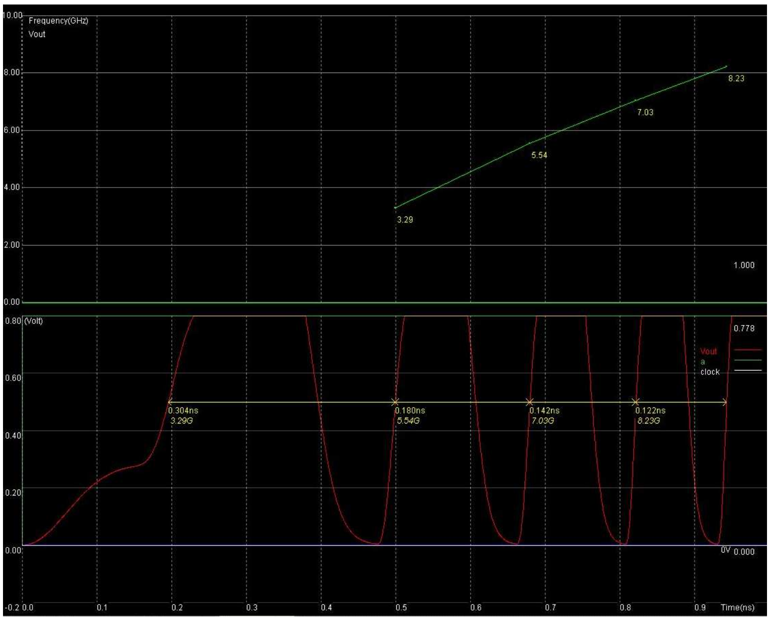


- Then, this is the simulation obtained :



The simulation shows the response in frequency obtained and we can see that the oscillator has a bandwidth included between 3,32GHz and 9,25GHz. It’s linear to 9,25GHz and after the oscillator is saturated, so it’s useless to increase the Vdd voltage of the regulator.

And then it’s a zoom of the same linear response. We can see the increase of the frequency on the signal.



Conclusion

On the end we designed two circuits, a voltage regulator and a voltage controlled oscillator. Both are very useful in common electronic applications and therefore can have very different characteristics from one circuit to another. In our case we were interested in RFID tags so the previous designs are optimized for such a device. The technology used during simulations was 12um.

This project gave us a very valuable insight of electronic design from a physical point of view. Indeed we all knew CMOS transistors as a very nice scheme or component but being able to design ourselves the size of a transistor and to link all of them using different metal layers changed our approach of electronic and revealed to be very helpful to understand modelisations and its limits.

To conclude this project has been very interesting and we were more than satisfied with the results we obtained.

Bibliography

- **Design and challenges of passive UHF RFID tag in 90nm CMOS technology**,

Yang Hong, Chi Fat Chan, Jianping Guo, Yuen Sum Ng, Weiwei Shi, Marco Ho, Lai Kan Leung, Ka Nang Leung, Chiu Sing Choy and Kong Pang Pun from the Department of Electronic Engineering of The Chinese University of Hong Kong.
Downloaded from IEEE Xplore, on December 2009.

- **Design and challenges of passive UHF RFID tag in 130nm CMOS technology**,

Hong, Chi Fat Chan, Jianping Guo, Yuen Sum Ng, Weiwei Shi, Lai Kan Leung, Ka Nang Leung, Chiu Sing Choy and Kong Pang Pun from the Department of Electronic Engineering of The Chinese University of Hong Kong.
Downloaded from IEEE Xplore, on December 2009.

- **Fast-recovery CMOS voltage regulator for large capacitive loads**,

F. Bedeschi, C. Boffino, E. Bonizzoni, O. Khouri, C. Resta and G. Torelli for the International Conference on Signals and Electronic Systems on September 13-15, 2004 in Poznan, POLAND.
Downloaded from IEEE Xplore, on December 2009.