VLSI FINAL PROJECT Ring oscillator

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In this project our main goal is to achieve ring oscillator with frequency of 400Mhz,

To do that we will have to use an odd number of inverters to create oscillation. (reference)

$$f_{osc} = \frac{1}{n \cdot (t_{PHL} + t_{PLH})}$$

Ref (Baker Cmos the book page 339)

Also $t_{PHL} + t_{PLH} = 0.7 \cdot (R_n + R_p) \cdot C_{tot}$

$$in\ our\ case: 400Mhz = \frac{1}{n(t_{phl} + t_{plh})} \to n(t_{phl} + t_{plh}) = \frac{1}{400Mhz} = 2.5 \cdot 10^{-9}[sec]$$

$$\to if\ n = 5 \to t_{phl} + t_{plh} = 5 \cdot 10^{-10}[sec]$$

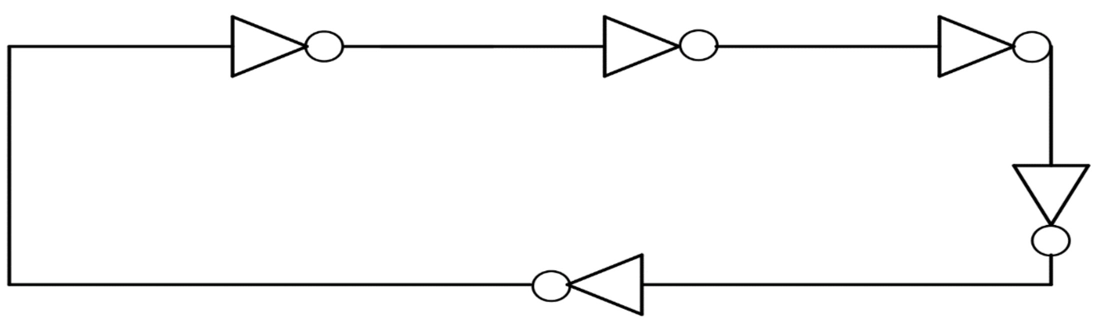


Figure 1.1

Again, in our scenario each inverter will "see" the capacitance of 4 inverters as its load.

$$C_{tot} = \overbrace{C_{oxp} + C_{oxn}}^{C_{out}} + \overbrace{\frac{3}{2} \cdot (C_{oxp} + C_{oxn})}^{C_{in}} = \frac{5}{2} \cdot (C_{oxp} + C_{oxn}) \qquad (11.12)$$

Using this formula, we can achieve the total capacitance of the circuit.

Also, using the following formula $R_n = \frac{VDD}{\frac{KP_n}{2}\frac{W}{L} \cdot (VDD - V_{THN})^2} = R_n' \cdot \frac{L}{W}$ we can get the resistance of the MOSFET device while its in saturation.

Putting these formulas in our excel, tweaking our W and L parameters to get the result we are looking for, 400Mhz oscillation.

We get that for 18nm technology, our Pmos width should be ~3.13μm and the Nmos width should be 1μm for these widths we get oscillation of ~400Mhz

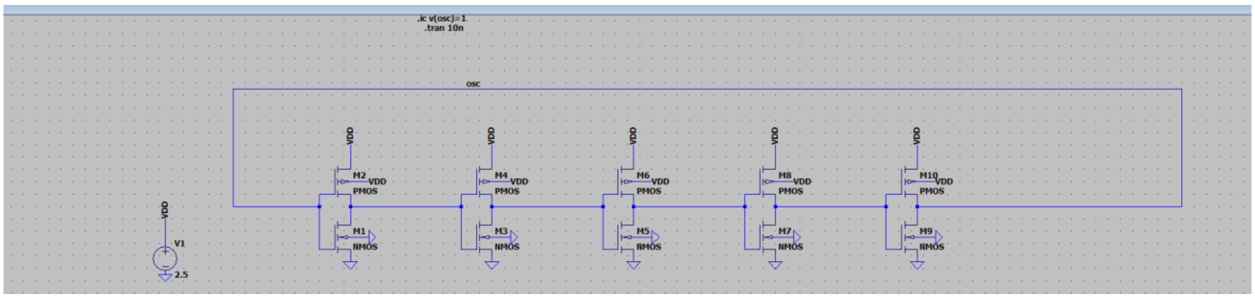
$$freq. = \frac{1}{0.7N\left(R_{on_n} + R_{on_p}\right)C_{tot}}$$

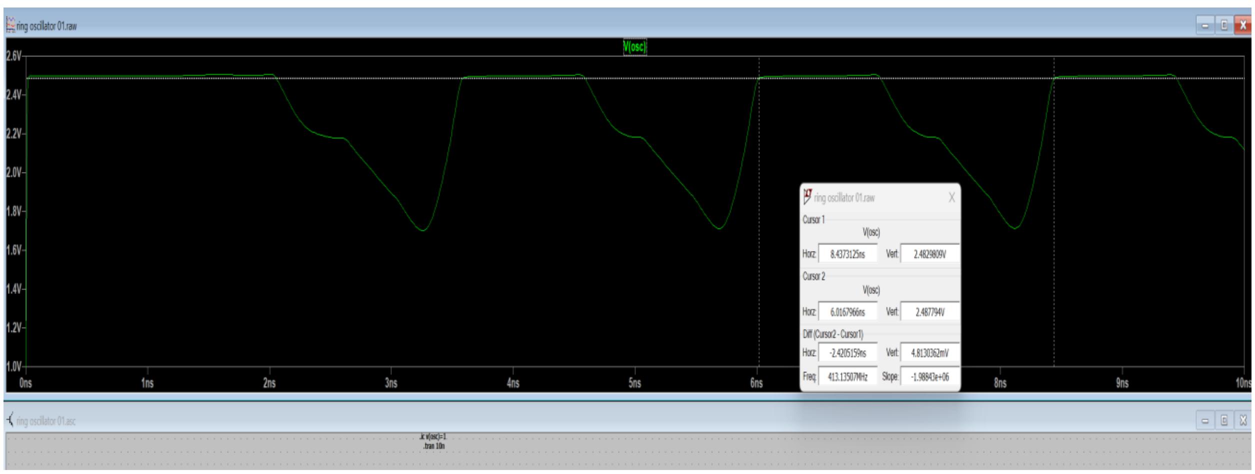
Excel:

W_P [cm]	W_N [cm]	L [cm]	epsilon_0	epsilon	tox [cm]	Vg [v]	Vs [v]	Vdd [v]	vth_p [v]	Vth_n [v]	u0_N [cm^2/V*sec]	u0_P [cm^2/V*sec]	cox' = epsilon*epsilon0[f/cm^2]
2.80E-04	1.00E-04	2.50E-05	8.85E-14	3.9	5.60E-11	1	0	2.5	0.49	0.37	283	100	6.16E-03

Kp_n= u0_N*cox [f/v*sec]	Kp_P=u0_P*cox [f/v*sec]	c_total [f]	Ron_P=2*VDD/(Kp_p*W_P/L)*(VDD-VT_P)^2 [ohm]	Ron_N=2*VDD/(Kp*W_N/L)*(VDD-VT_N)^2[ohm]	F = 1/0.7*n*(Ron_N+Ron_p)C_total [hz]	n
1.74E+00	6.16E-01	1.16E-10	2.93E+00	3.25E+00	4.00E+08	5

LTspice:

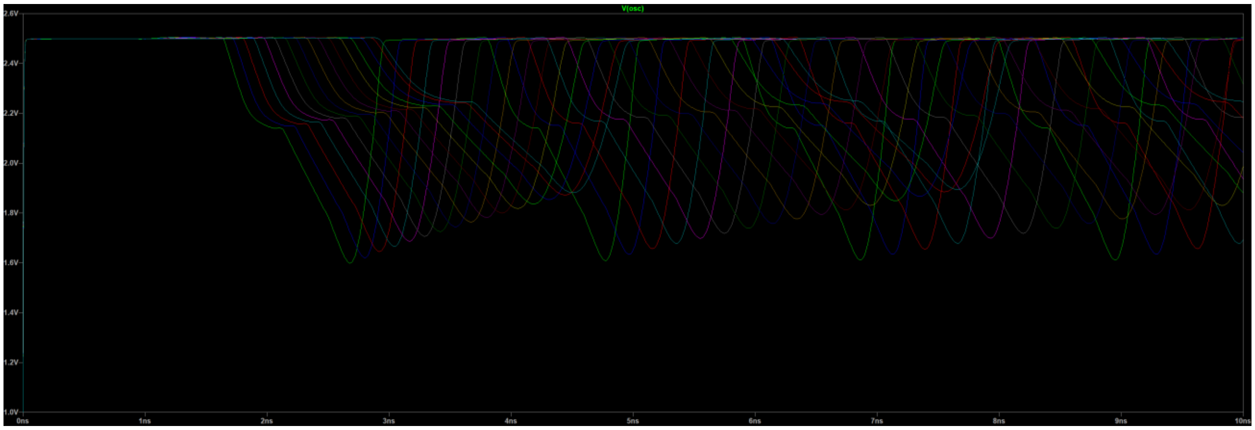


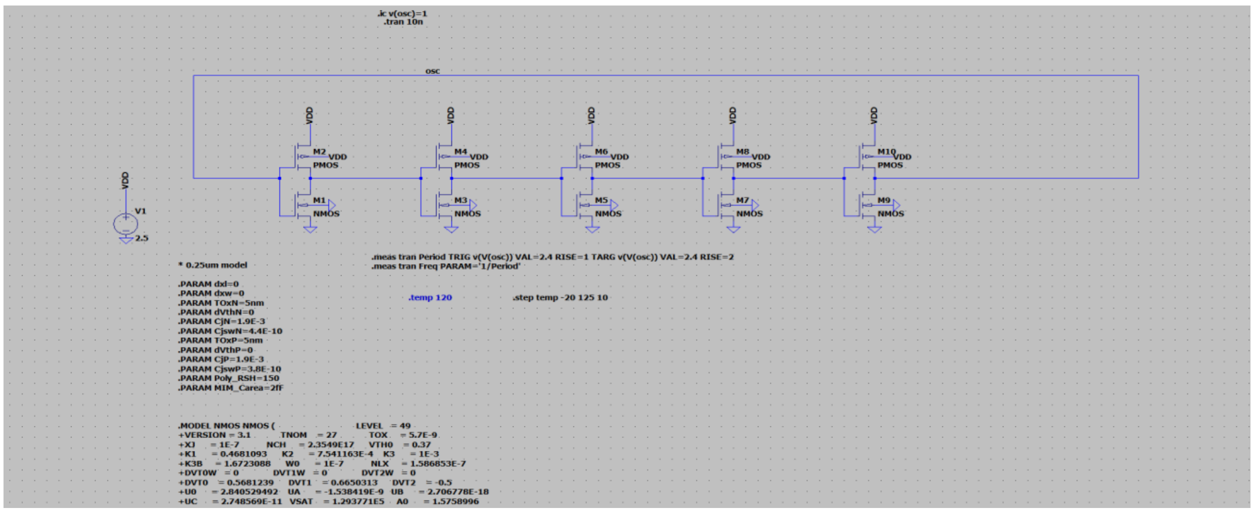


In the simulation the frequency is 413Mhz very close to our estimated value.

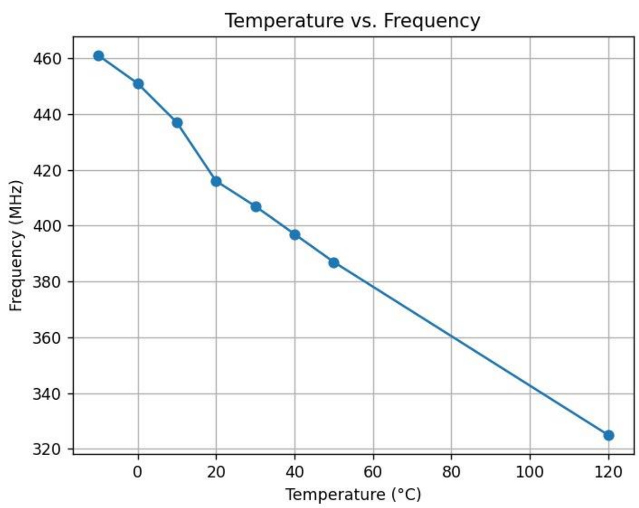
The error is given by $ERROR(\%) = \frac{|ACUTAL\ VALUE - EXPECTED\ VALUE|}{ACTUAL\ VALUE} \cdot 100\% = \frac{413 \cdot 10^6 - 400 \cdot 10^6}{413 \cdot 10^6} \cdot 100\% = 3.14\%$

How the frequency depends on the temperature



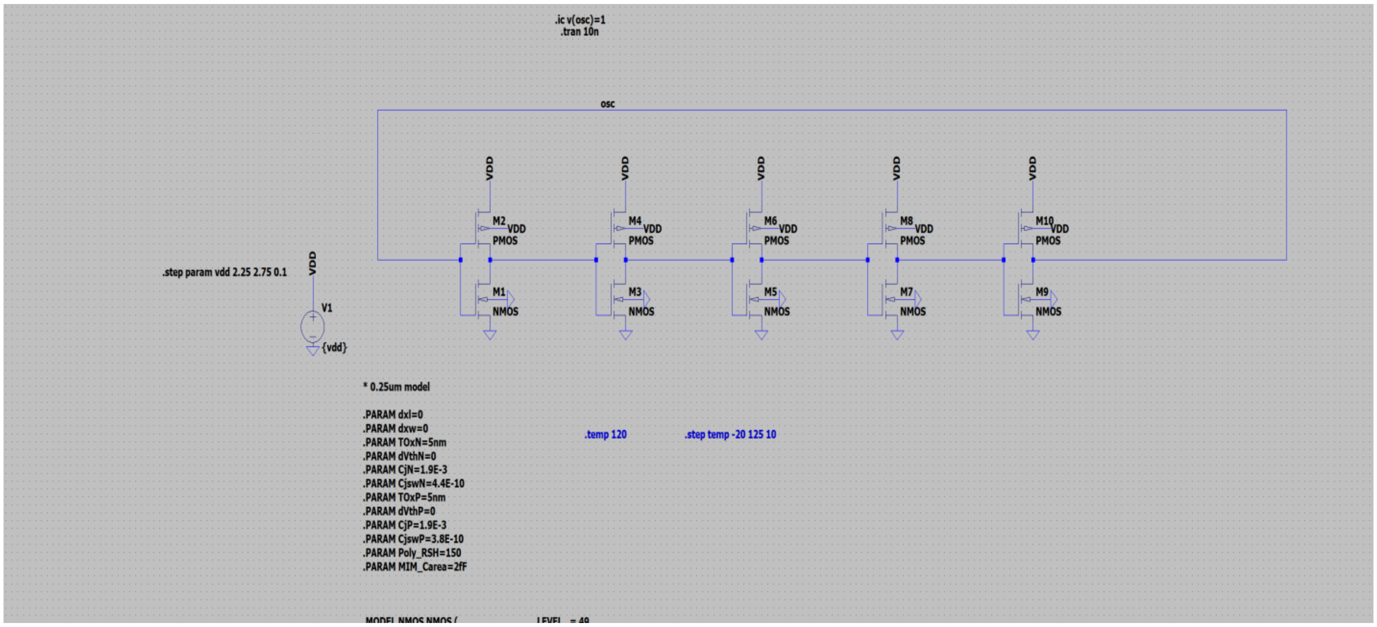


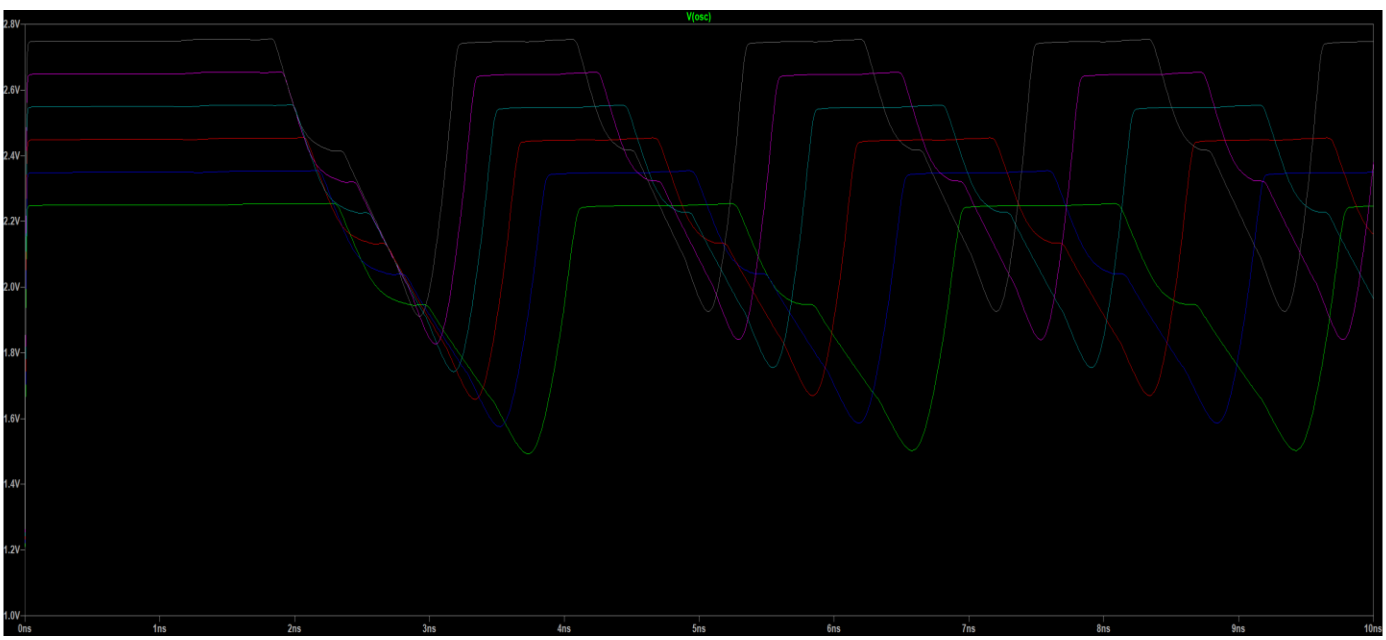
in this graph we can see that an increase in the temperature will result in decreasing frequency and vice versa.



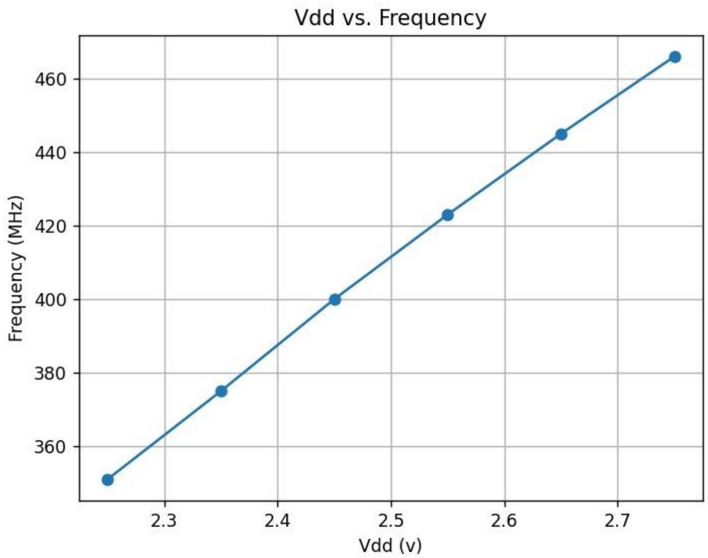
Temp [C°]	Freq[Mhz]
-10	461
0	451
10	437
20	416
30	407
40	397
50	385
120	325

the effect of $\pm 10\%$ VDD on freq.





in this graph we can see that increase in the vdd voltage will result in increased frequency and decrease in vdd voltage will result in decreased frequency.



Vdd[v]	Freq.[Mhz]
2.25	351
2.35	375
2.45	400
2.55	423
2.65	445
2.75	466

Conclusions:

- In this project we've learned how to create a ring oscillator using Pmos and Nmos transistors, we saw that excel could use as a rough estimation but a good one.
- We also learned that in order to create a ring oscillator we need to use an odd number of inverters.
- We had to pay attention to units, our excel was in cm while the LTspice using meters.
- We saw the effect of the ambient temperature on the frequency which is very important in real life and should be taken into consideration.
- We also saw how a little deviation in Vdd could result in a huge difference in the frequency.
- We saw that for range of $\pm 10\%$ Vdd the increase in frequency was almost linear.
- We saw that for the range of the temperature -10C – 50C the decrease in frequency was piecewise linear.
- We also learned that the frequency depends on the number of inverters, $freq. = \frac{1}{0.7N\left(R_{on_n}+R_{on_p}\right)C_{tot}}$ while N is the number of inverters.
- We also learned that the frequency is dependent on the t_pd which depends on the size of the transistors.
- We saw that the frequency could be given as $f = \frac{1}{total_{pd}}$ and the total_pd depends on the amount of inverters and the transistors size.
- One last thing that we learned is that we can use this circuit to create a pulse signal but not very accurate one, because this circuit is very sensitive to power supply conditions and process variation.