Analog IC Design – Cadence Tools

LPF Simulation and MOSFET Characteristics

Lab 01

PART 1: Low Pass Filter Simulation (LPF)

1. Transient Analysis

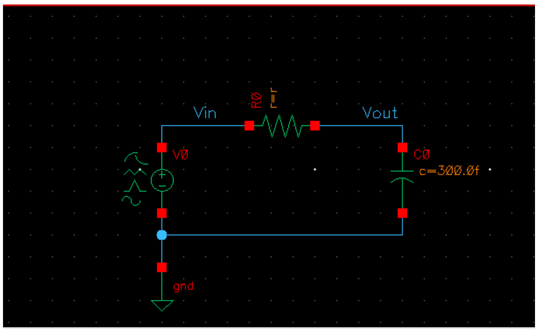

Figure 1:schematic

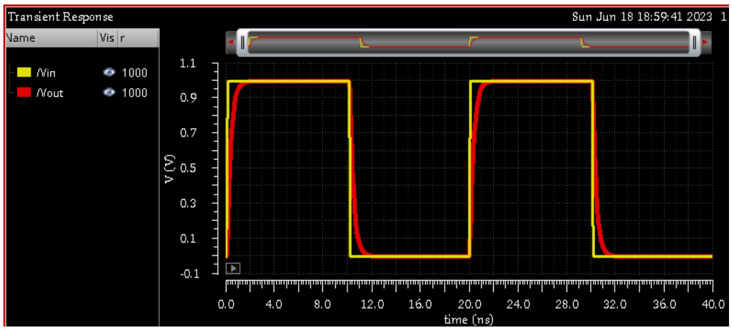

Figure 2:Transient Analysis

When the pulse starts to rise, the capacitor starts to charge according to the exponential equation,and at steady state the capacitor becomes open circuit, and in the falling the capacitor starts to decharge according to the exponential equation ,and so on.

The Rise and Fall Time (10% to 90%)

	Simulation Results	Analytical Results
Rise	661.8 p	659.167 p
Fall	661.8 p	659.167 p

Parametric Sweep for R = 1: 1: 5kΩ

	R=1K	R=2K	R=3K	R=4K	R=5K
Rise	661.8 p	1.319 n	1.977 n	2.641 n	3.283 n
fall	661.8 p	1.319 n	1.977 n	2.641 n	3.283 n

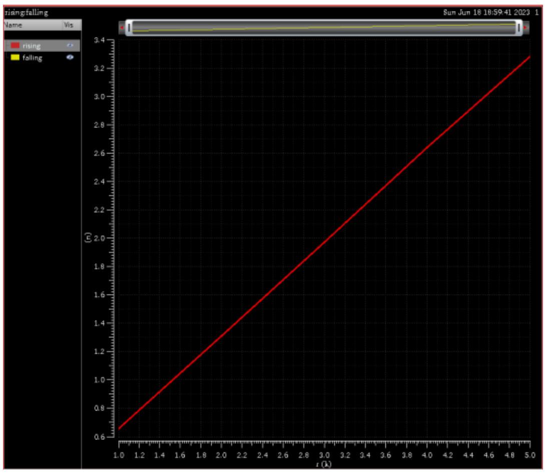

Figure 4:(Rising and Falling Time) VS (R)

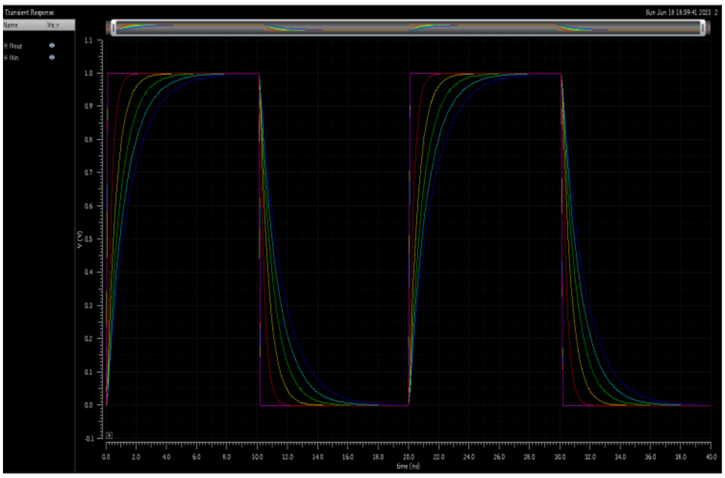

Figure 3:Transient Analysis for Parametric Sweep

Comments and Equations

- $C = \frac{\tau}{R} = 0.3\ p$
- $t_f = -\tau * ln\frac{V_c}{V_S}$
- $T_f = t_{f10\%} - t_{f90\%} = \tau * (\ln(0.9) - \ln(0.1)) = 659.167\ p$
- $t_r = -\tau * \ln\left(1 - \frac{V_c}{V_S}\right)$
- $T_r = t_{r90\%} - t_{r10\%} = \tau * (\ln(1-0.1) - \ln(1-0.9)) = 659.167\ p$

The time of rise and fall must be the same according to the exponential equation for every two values that follow the relationship (t1=1-t2), So they are same for borders 10% and 90%.

And for Parametric Sweep when we increase the value of R then time constant (τ) will increase then the rising and the falling time will increase by the same factor according to the previous equations.

2. AC Analysis

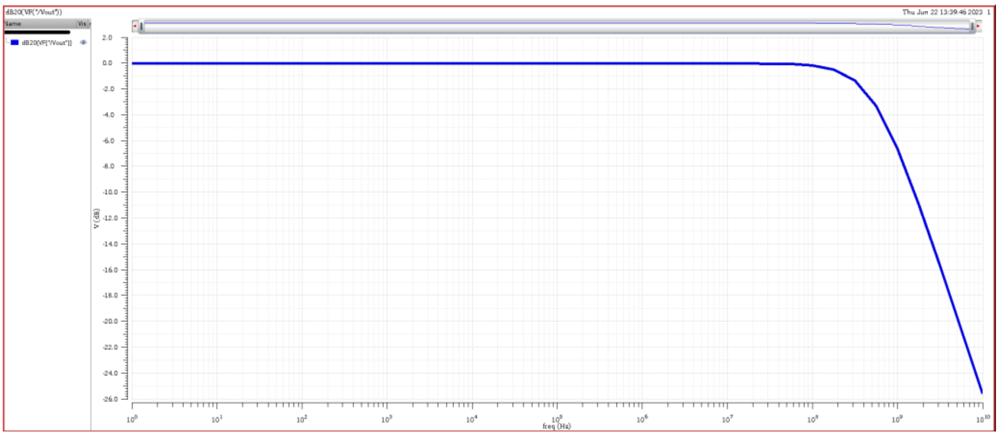

Figure 5:Bode Plot Magnitude

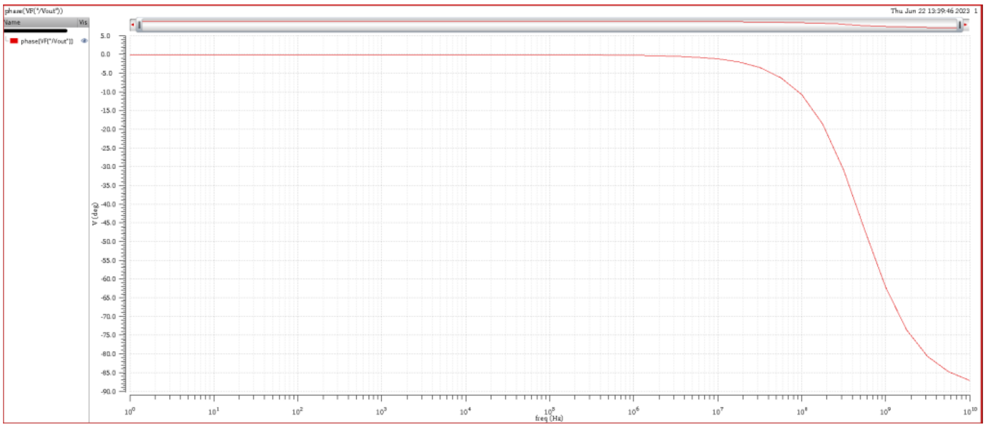

Figure 6 Bode Plot Phase

2)**Bandwidth** = 531.4 M

3)

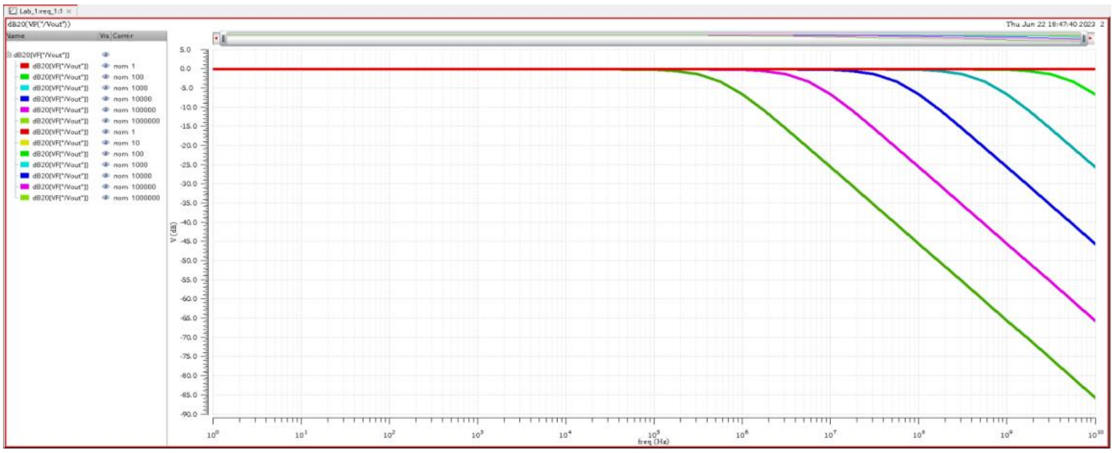

Figure 7 Bode Plot Magnitude Parametric Sweep

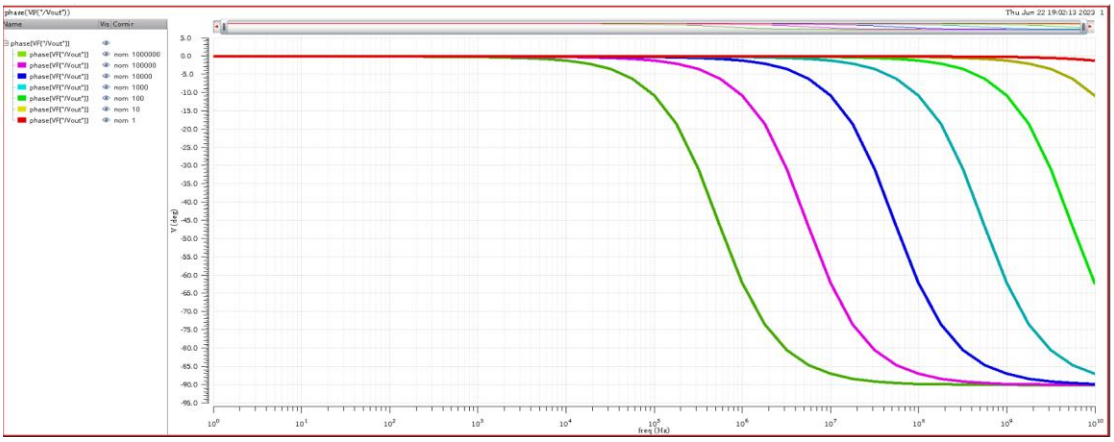

Figure 8 Bode Plot Phase Parametric Sweep

R	Simulation Results	Analytical Results
1k	531.4 M	530.516 M
10k	53.14 M	53.0516 M
100k	5.314 M	5.30516 M
1000k	531.4 k	531.4 k

1. **Comments and Equations**

$$V_o = \frac{1}{1 + R * SC} * V_s$$

$$V\ in(20dB) = 20 \log{(V)}$$

$$Phase = -\tan(\omega RC)$$

$$BW = \frac{1}{2 * \pi * R * C}$$

- This filter is a lowpass filter of degree 1, so for the Magnitude curve when the frequency reaches the Bandwidth frequency the slope of the curve starts to decrease by 20 dB/Dec.

- the Slope phase Curve when the frequency reaches the Bandwidth frequency the slope value will decrease by 90 degrees (on 1 Dec) and then settles on this value.
- The Bandwidth is inversely proportional to the value of R, then when R increases BW decrease by the same factor.

- **3.Pole Zero Analysis**

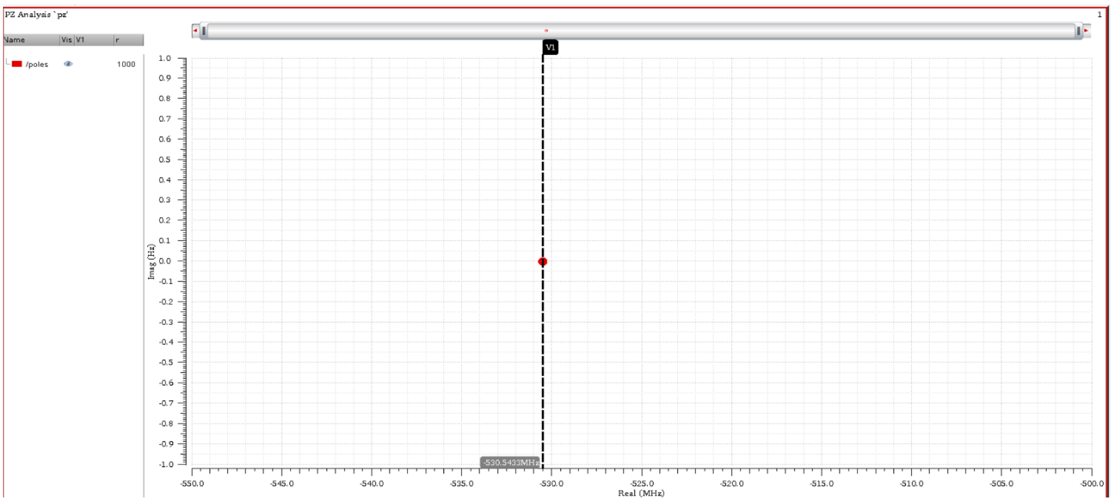

Figure 9 Pole

$$H = \frac{1}{1 + R * SC}$$

- There is one pole at -530.516 M with phase 0; its value is equal to the Bandwidth.

Part 2: MOSFET Characteristics

1. ID vs VGS

- **Short channel device: W = 6μm and L = 200nm**

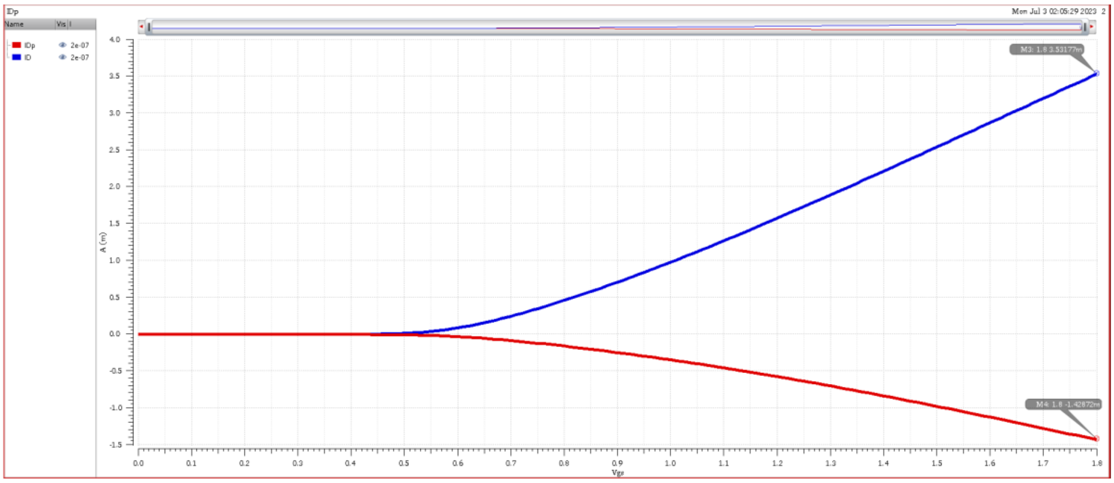

Figure 10 Short channel devices (M0 , M1)

- **Long channel device: W = 60μm and L = 2μm.**

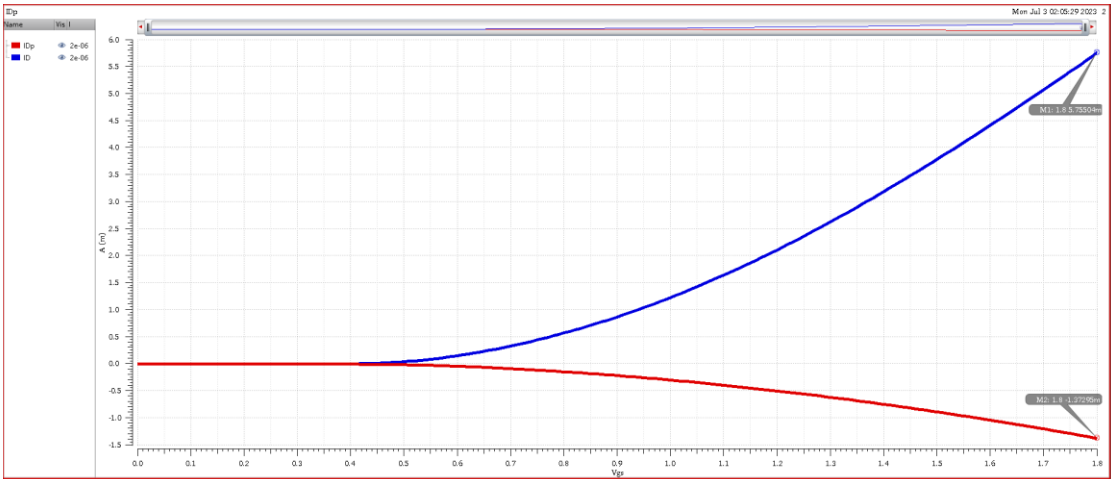

Figure 11 Long channel devices (M0 , M1)

the differences between short-channel and long-channel results.

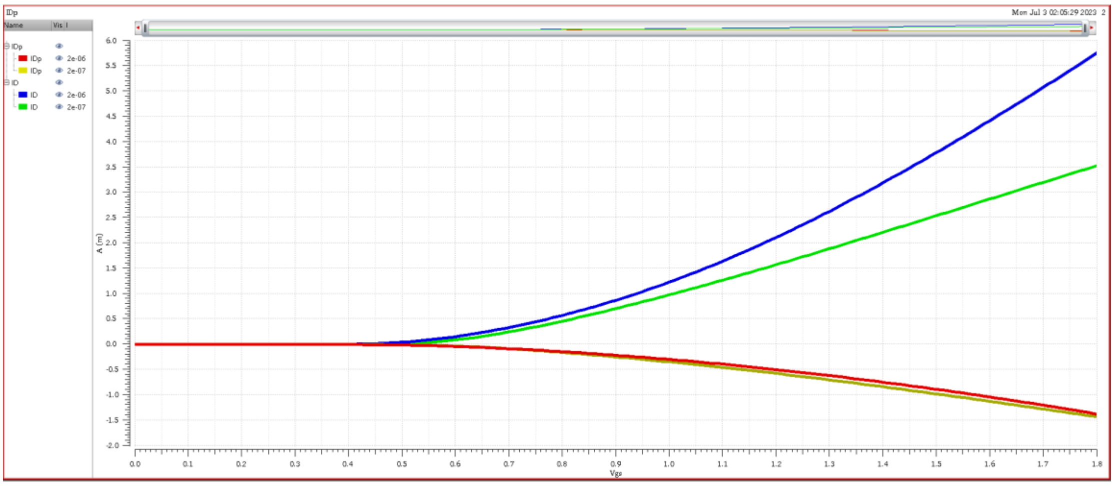

Figure 12 Short channel & Long channel

Comment

The ID value is negative because of the direction of the current, but we will use the magnitude of it.

Short Channel vs Long Channel

The long channel device has a higher current than the short channel, this is different from what we deduce from the square law that the two currents are equal if the value of the VGS is equal and the characteristics are constant. This means that the square law is not reliable in this case because of the effect of the channel length modulation, which comes from the change of the electric field, which is related to the length when the voltage is constant.

The relation for the Short Channel device is more linear than the Long Channel, because of the Velocity-Saturation, as the electrical field along the channel reaches a critical value the velocity of carriers tends to saturate and the mobility degrades, which make the curve more linear.

But the long channel device hasn't Velocity-Saturation so that it is follow the square low and the curve more quadratic not linear.

The differences between NMOS and PMOS.

NMOS has a higher current than PMOS, Because NMOS uses electrons while PMOS devices use holes, and the mobility of electrons is more than that of holes, This means that electrons can move more easily and quickly through the channel, resulting in higher current flow in NMOS devices.

The ratio between NMOS and PMOS currents at VGS = VDD is

For Short channel = $\frac{I_{Dn}}{I_{Dp}} = \frac{3.36622}{1.27867} = \frac{\mu_n}{\mu_p} = 2.471982$

For Long channel = $\frac{I_{Dn}}{I_{Dp}} = \frac{5.75504}{1.37295} = \frac{\mu_n}{\mu_p} = 4.191733$

NMOS is more affected by short-channel effects, as it changes by larger factor than PMOS.

2. gm vs VGS

- **Short channel device: W = 6μm and L = 200nm**

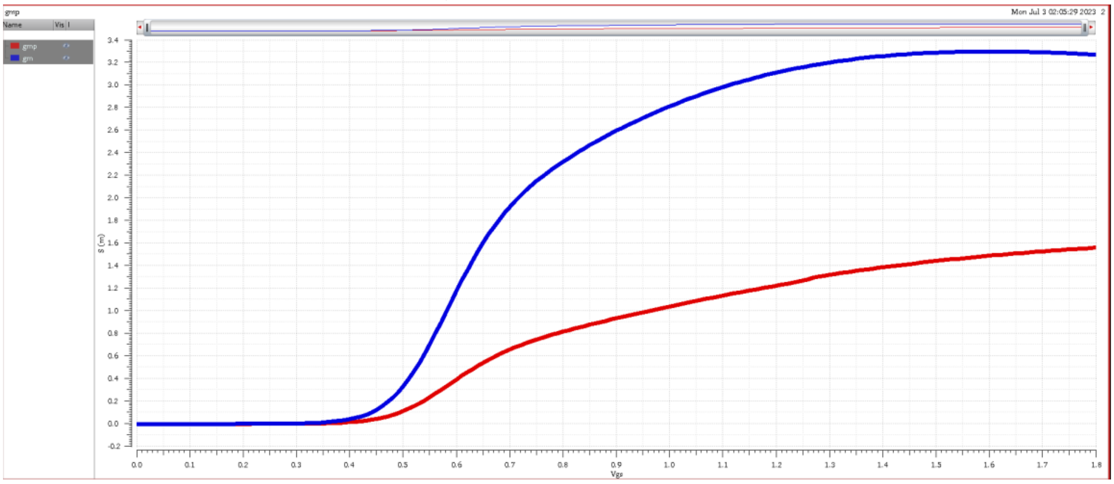

Figure 13 Short channel devices (M0 , M1)

• **Long channel device: W = 60µm and L = 2µm.**

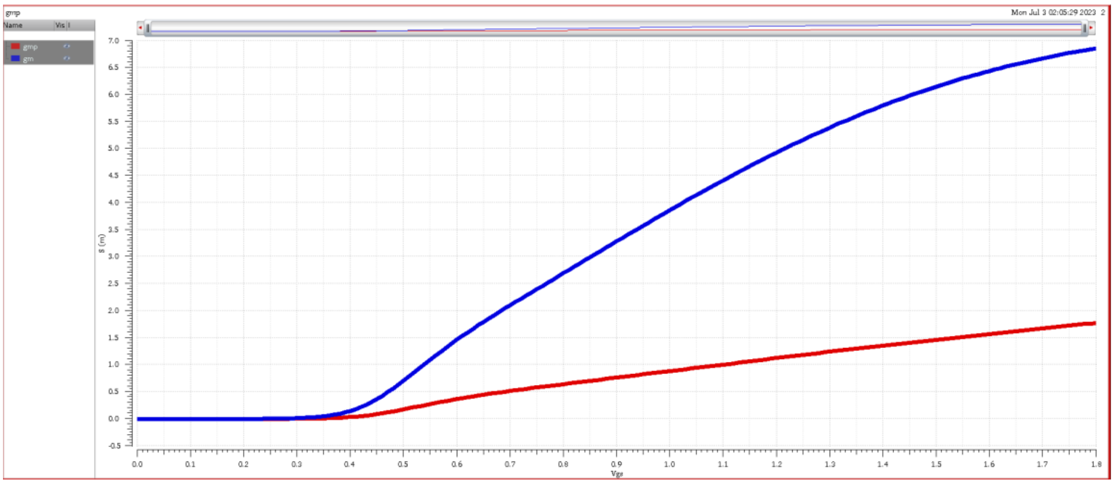

Figure 14 Long channel devices (M0 , M1)

the differences between short-channel and long-channel results:

gm saturates in Short channel & Long channel, as gm = $\frac{\partial I_D}{\partial V_{GS}}$ and the result of this relation is different due to the channel length effect.

In the long channel device gm increases linearly because of the square low, and it's following the equation:

$$g_m = \frac{\partial I_D}{\partial V_{GS}} = K_n * (V_{GS} - V_{TH})$$

But for the long channel device it is not linear because the Velocity-Saturation which have an average due to phonon scattering which mean that its derivative isn't a linear relation.

3.ID vs VDS

• **Short channel device: W = 6µm and L = 200nm**

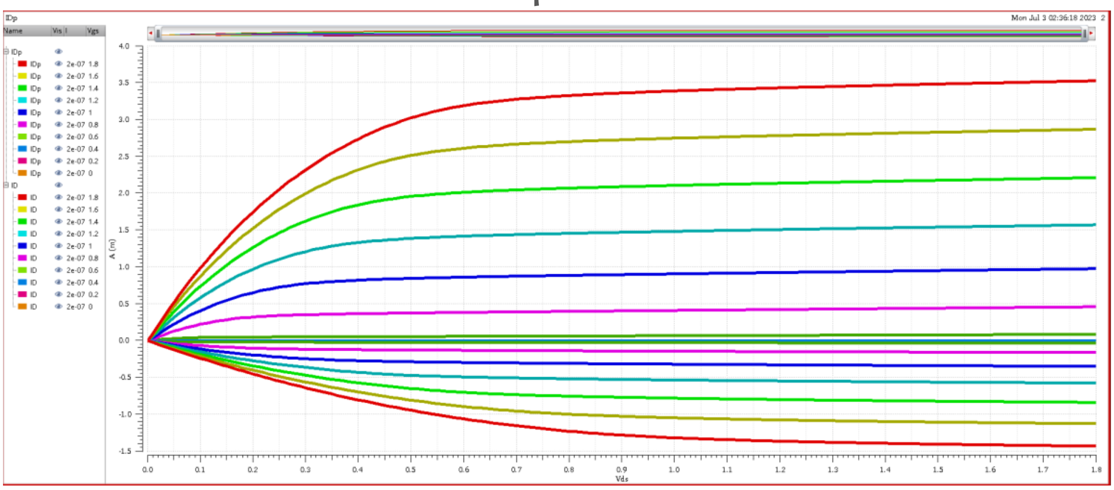

Figure 15 Short channel devices (M0 , M1)

• **Long channel device: W = 60µm and L = 2µm.**

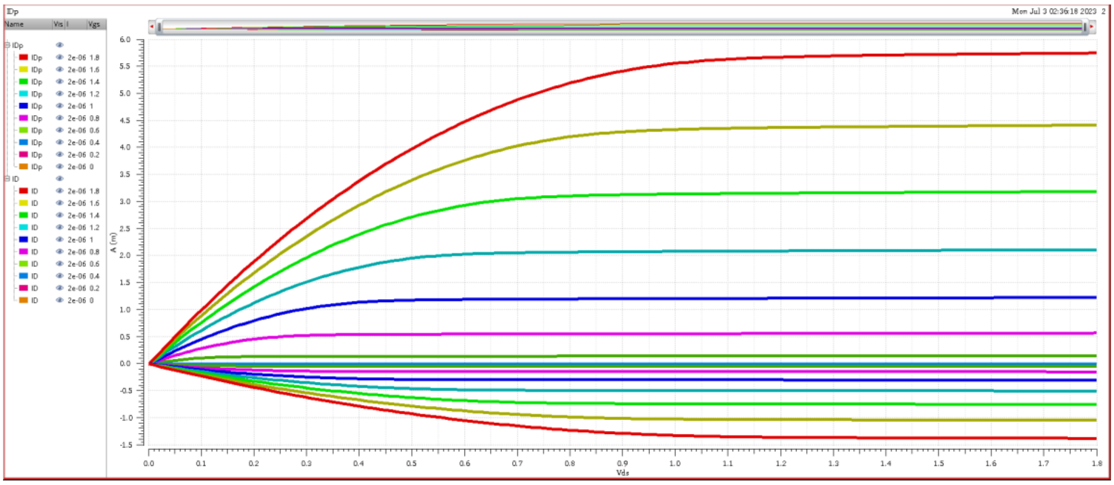

Figure 16 Long channel devices (M0 , M1)

The differences between short channel and long channel results.

Long channel has higher current, because the effect of the Velocity-Saturation in the short channel device which come because the phonon scattering.

Short channel has higher slope in the saturation region, because the channel length modulation effect as a resistance and the length of the channel is inverse proportional with the value of the resistance, and Short channel has higher resistance so it has higher slope in the saturation region.