Analog IC Design – Xschem/Ngspice and ADT

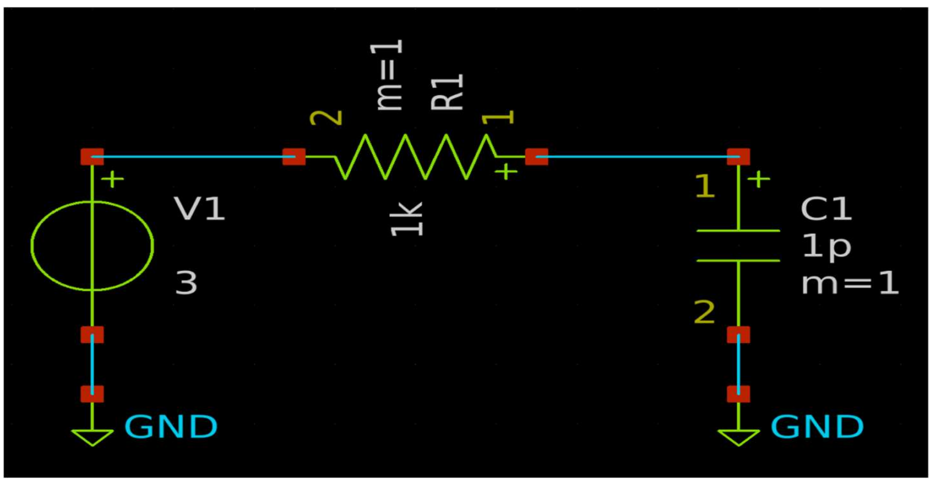
Lab 01

LPF Simulation and MOSFET Characteristics

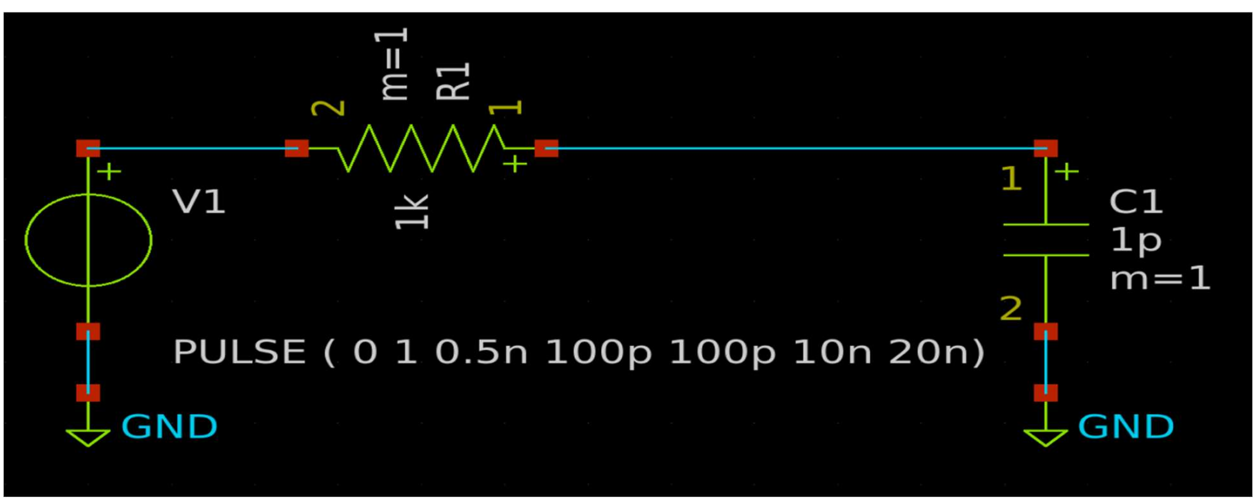
PART 1: Low Pass Filter Simulation (LPF)

1. Transient Analysis

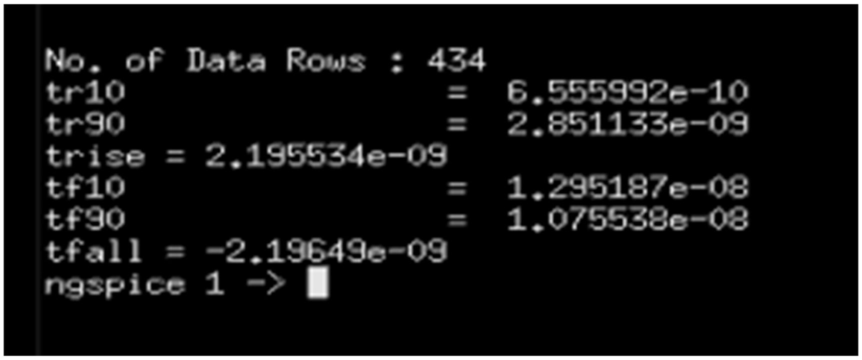
1) Design a first order low pass filter that has $R = 1k\Omega$ and 1ns time constant.



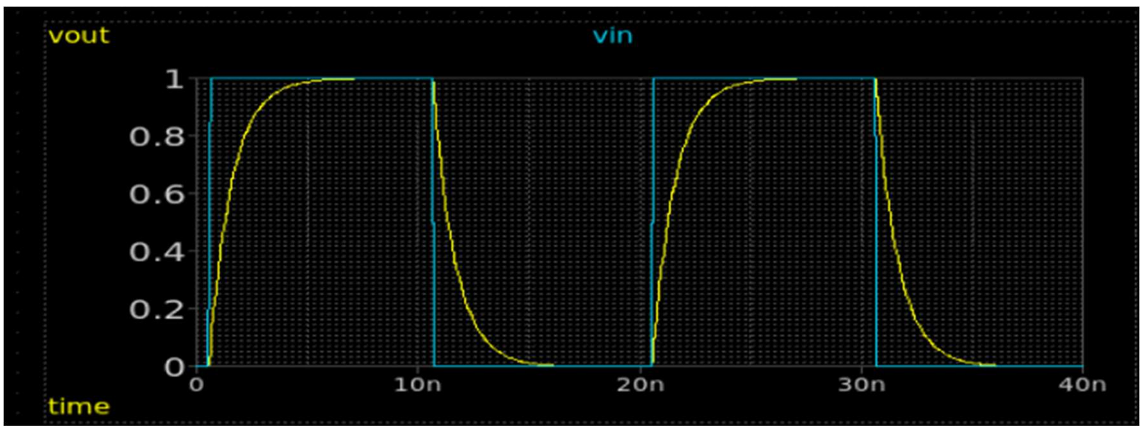
2) Apply a square wave input with $T_{high} = Pulse\ Width = 10ns$, $T_{clk} = Period = 20ns$, and $T_{rise} = T_{fall} = 100ps$.

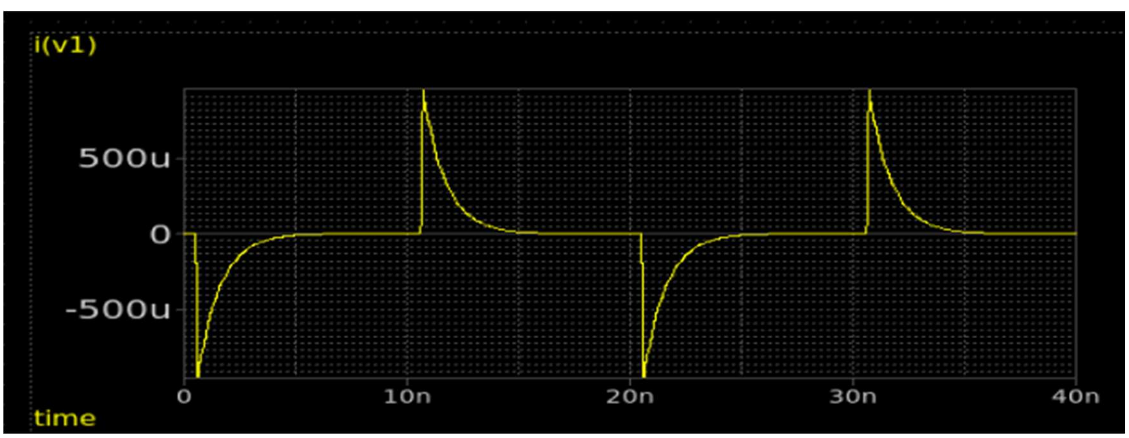


3) Run Simulations



```
No. of Data Rows : 434
tr10                    =  6.555992e-10
tr90                    =  2.851133e-09
trise = 2.195534e-09
tf10                    =  1.295187e-08
tf90                    =  1.075538e-08
tfall = -2.19649e-09
ngspice 1 ->
```





parametric sweep

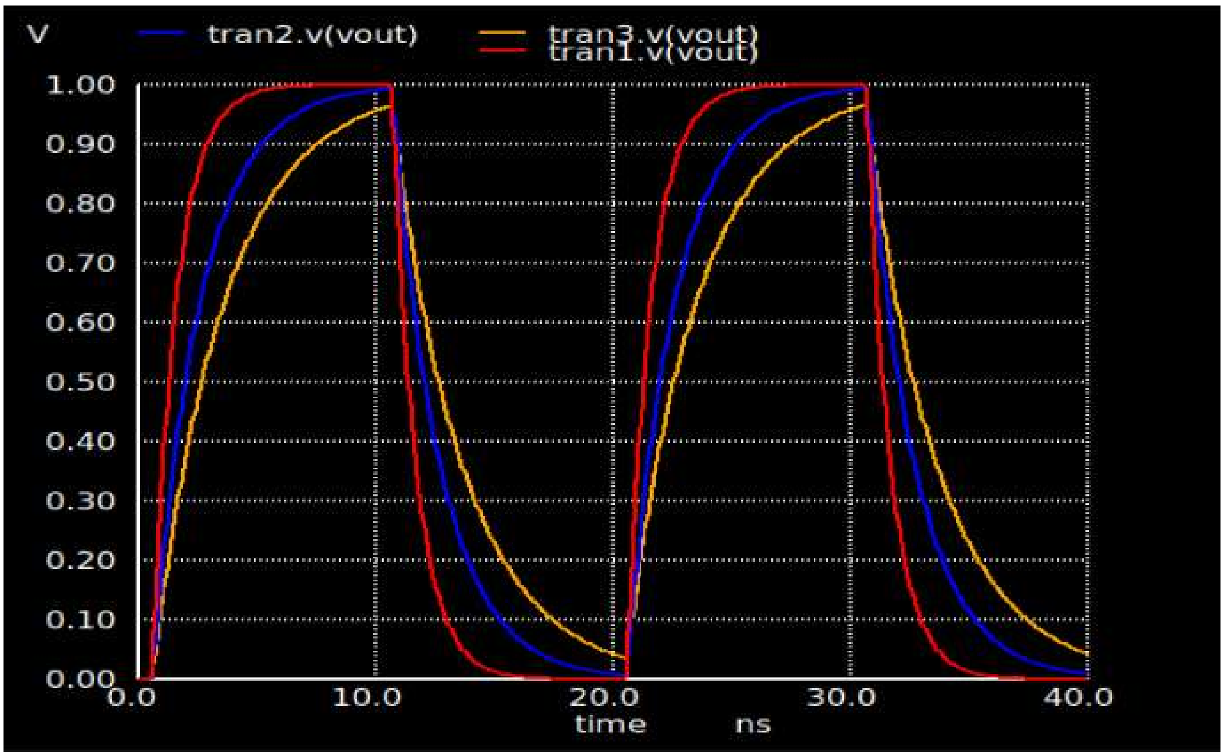
```
Initial Transient Solution
--------------------------

Node                                   Voltage
----                                   -------
vout                                         0
vin                                          0
v1#branch                                    0


No. of Data Rows : 434
tr10                =  6.555992e-10
tr90                =  2.851133e-09
trise = 2.195534e-09
Reset re-loads circuit ** sch_path: /home/tare/lap_00/lap_01/lap_1_m1.sch

Circuit: ** sch_path: /home/tare/lap_00/lap_01/lap_1_m1.sch

binary raw file "RC_CKT.raw"
Doing analysis at TEMP = 27.000000 and TNOM = 27.000000
```

```
Initial Transient Solution
--------------------------

Node                                   Voltage
----                                   -------
vout                                         0
vin                                          0
v1#branch                                    0


No. of Data Rows : 434
tr10                =  7.605891e-10
tr90                =  5.154053e-09
trise = 4.393464e-09
Reset re-loads circuit ** sch_path: /home/tare/lap_00/lap_01/lap_1_m1.sch

Circuit: ** sch_path: /home/tare/lap_00/lap_01/lap_1_m1.sch

binary raw file "RC_CKT.raw"
Doing analysis at TEMP = 27.000000 and TNOM = 27.000000
```

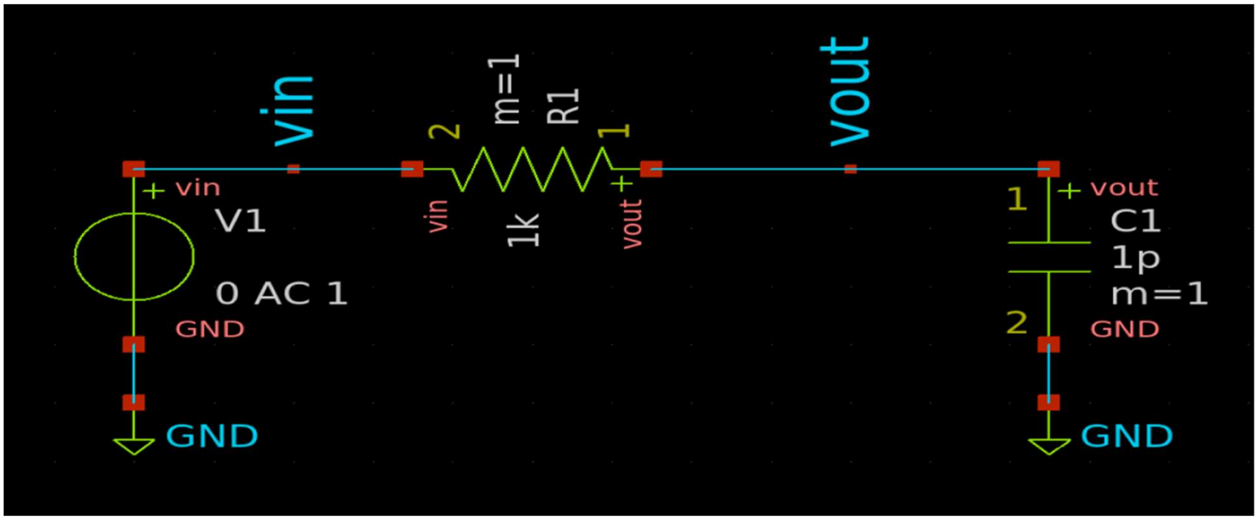
```
Initial Transient Solution
--------------------------

Node                                   Voltage
----                                   -------
vout                                         0
vin                                          0
v1#branch                                    0


No. of Data Rows : 433
tr10                =  8.658120e-10
tr90                =  7.456885e-09
trise = 6.591073e-09
Reset re-loads circuit ** sch_path: /home/tare/lap_00/lap_01/lap_1_m1.sch

Circuit: ** sch_path: /home/tare/lap_00/lap_01/lap_1_m1.sch

binary raw file "RC_CKT.raw"
Doing analysis at TEMP = 27.000000 and TNOM = 27.000000
```

```
Initial Transient Solution
--------------------------

Node                                   Voltage
----                                   -------
vout                                         0
vin                                          0
v1#branch                                    0


No. of Data Rows : 433
tr10                =  9.712214e-10
tr90                =  9.759747e-09
trise = 8.788526e-09
Reset re-loads circuit ** sch_path: /home/tare/lap_00/lap_01/lap_1_m1.sch

Circuit: ** sch_path: /home/tare/lap_00/lap_01/lap_1_m1.sch

binary raw file "RC_CKT.raw"
Doing analysis at TEMP = 27.000000 and TNOM = 27.000000
```

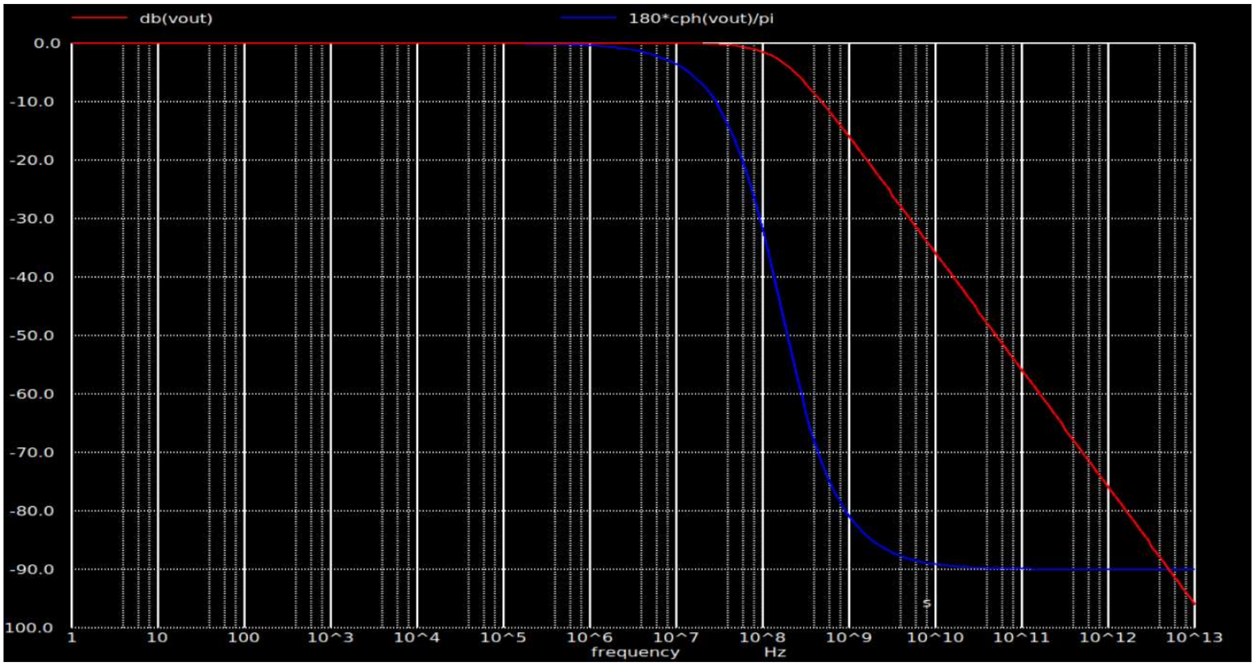
```
Initial Transient Solution
--------------------------

Node                                    Voltage
----                                    -------
vout                                          0
vin                                           0
v1#branch                                     0

No. of Data Rows : 432
tr10                 =  1.076581e-09

Error: measure  tr90  when(WHEN) : out of interval
 meas tran tr90 when vout=0.9 rise=1 failed!

Warning from checkvalid: vector tr90 is not available or has zero length.
Error: RHS "tr90-tr10" invalid
Warning from checkvalid: vector trise is not available or has zero length.
Reset re-loads circuit ** sch_path: /home/tare/lap_00/lap_01/lap_1_m1.sch
```



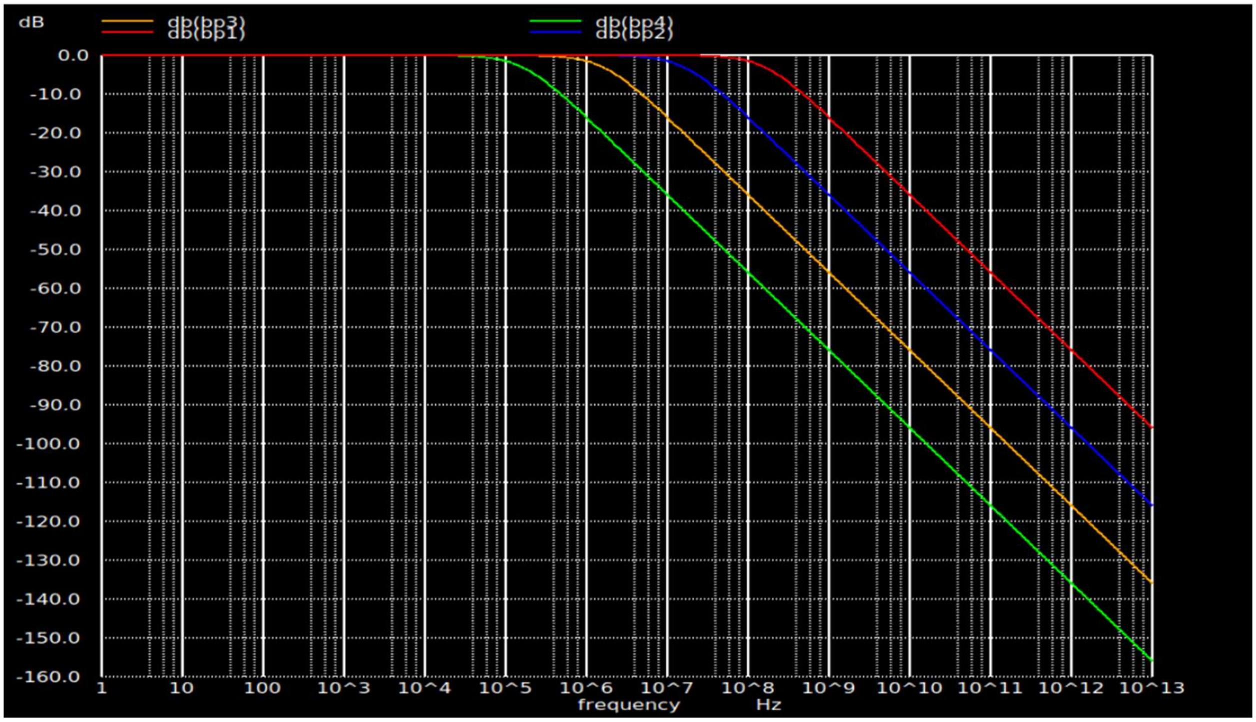
2. AC Analysis



Use “plot db(vout) 180*cph(vout)/pi” in the command to report the bodeplot.



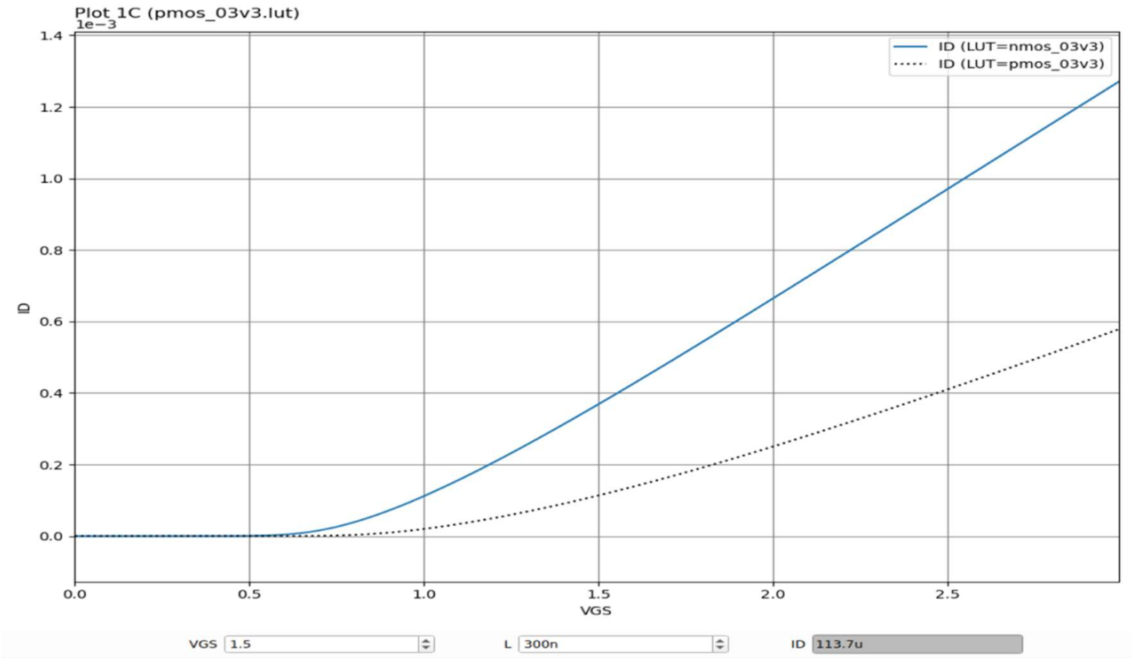
parametric sweep



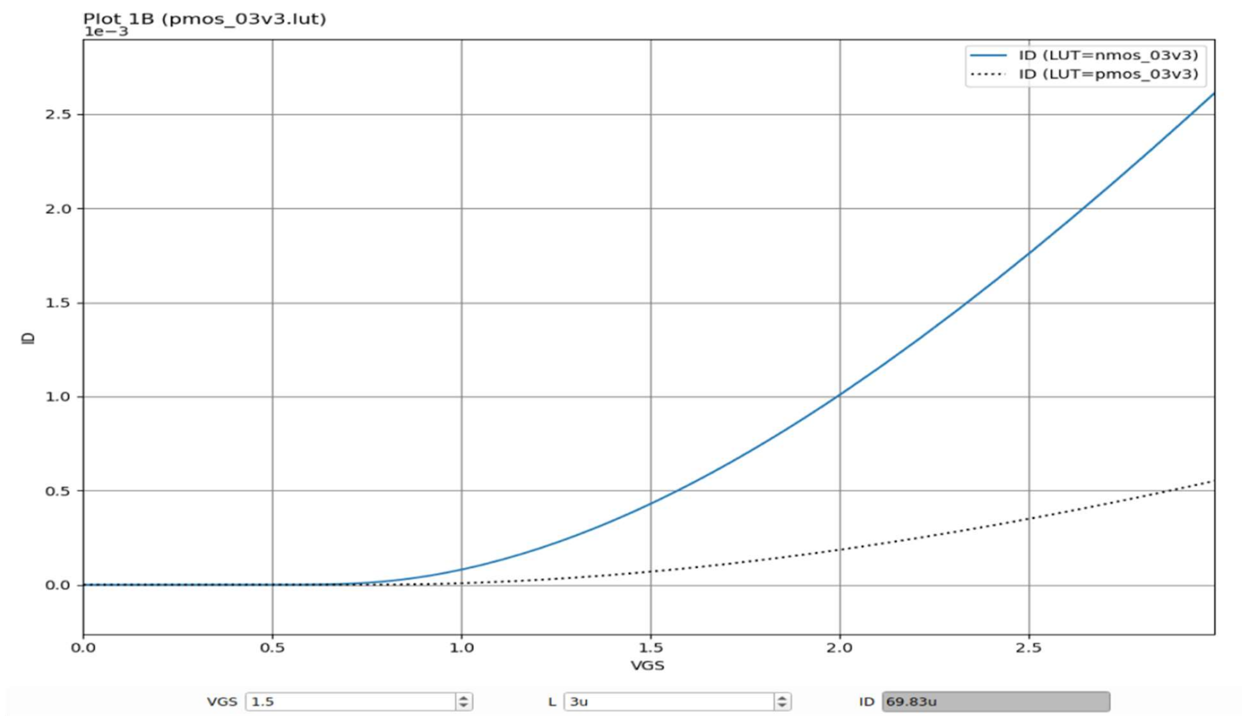
Part 2: MOSFET Characteristics

1. ID vs VGS

- Short channel



• Long channel



Comment on the differences between short channel and long channel results.

• <u>Which one has higher current? Why?</u>

For NMOS, a high-channel device provides a better display compared to a low-channel device. The reason for this is that the device suffers from a lack of weight due to its effect on speed saturation,

which leads to a smaller output than usual, because it does not saturate before it reaches the starting point.
In case of PMOS devices, the current in the short-channel device is higher than the current in the longchannel device. This is due to the effect of voltage-induced barrier lowering (DIBL).

• Is the relation linear or quadratic? Why?

For short-channel devices, the relationship is linear, because the amplification factor (gm) reaches a saturated value and does not increase with increasing Vgs.
As for long-channel devices, the relationship is quadratic, as the amplification factor (g_m) increases with increasing Vgs.

Comment on the differences between NMOS and PMOS.

• Which one has higher current? Why?

NMOS device has the highest comparison with PMOS device. The reason for this is that the alternating current in an NMOS device consists of electrons, while the alternating current in a PMOS device consists of radio. Therefore, the electrons move faster than the radio.

• What is the ratio between NMOS and PMOS currents at VGS = VDD?

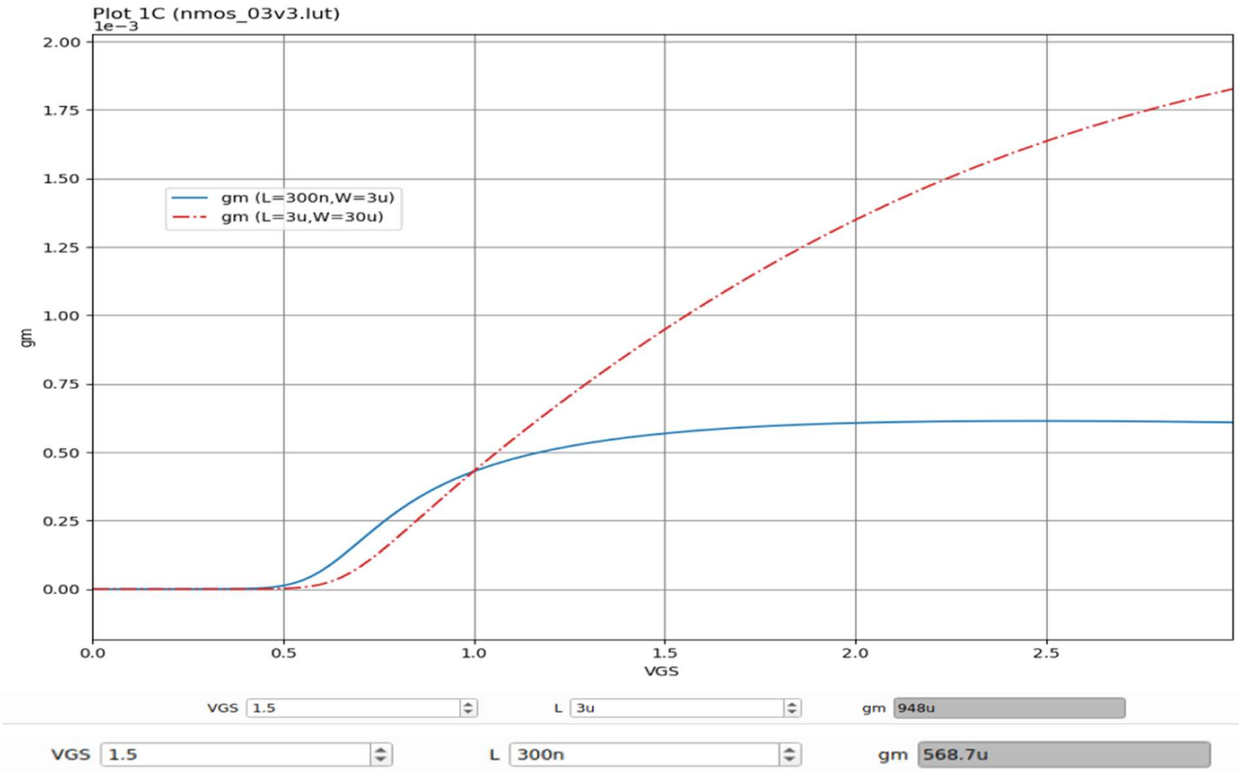
The ratio of the currents between the NMOS and PMOS devices at
VGS = VDD un/up
. This is because both devices have the same bias and size and differ only in the movement of the carriers.
For long channel ratio = 6.235.
For short channel ratio = 3.2524.

• Which one is more affected by short channel effects?

The NMOS device is more affected by short channel effects. This can be clearly seen from the graph of id vs vgs.

2. g_m vs VGS

1) Plot g_m vs V_{GS} for NMOS



2) Comment on the differences between short channel and long channel results.

• Does increase linearly? Why?

In case of a long channel device, increases.
gm is approximately linear because the device reaches the interruption saturation point before it reaches the speed saturation point and thus a relationship is formed.
ID-VGS quadratic, resulting in a linear relationship between
gm-VGS but in case of short channel device, g does not increase linearly.

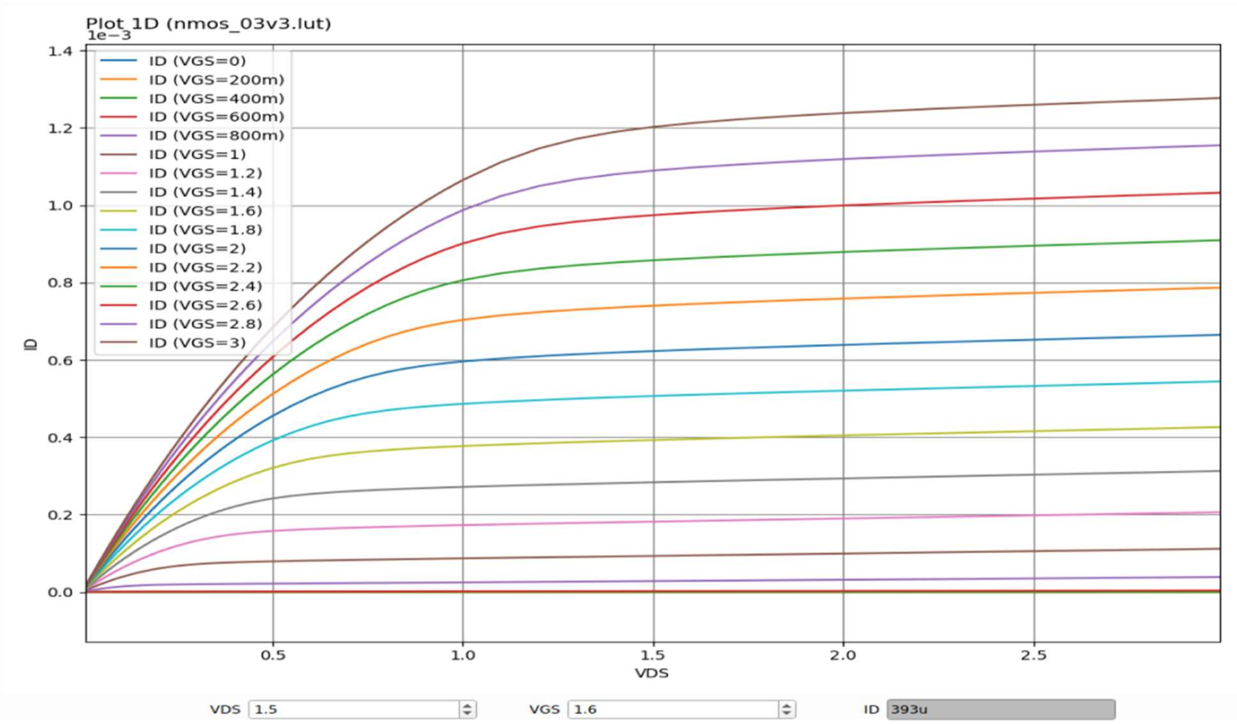
• Does saturate? Why?

In the case of a short channel device, it is saturated gm at a certain value because the device reaches the speed saturation point before it reaches the interruption saturation point, thus a linear ID-VGS relationship is formed, and gm is saturated. But in the case of long channel device, the gm does not saturate, but increases linearly

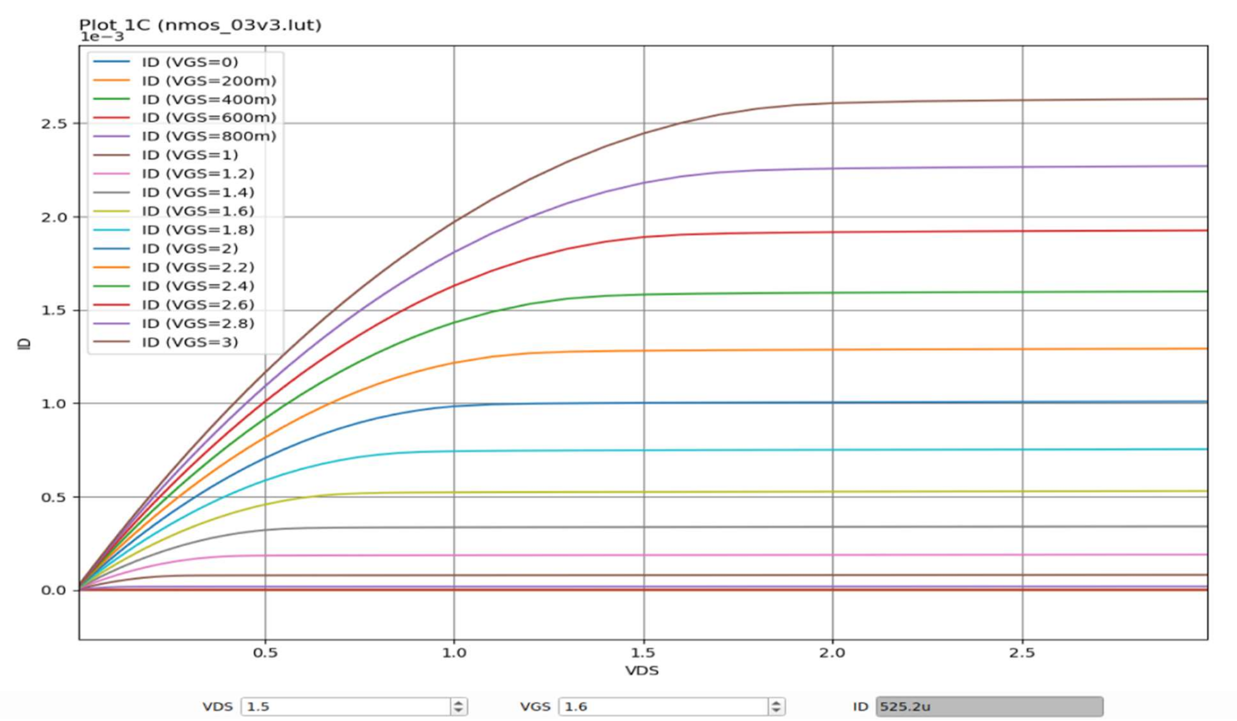
3. ID vs VDS

1) Plot I_D - V_{DS} characteristics for NMOS

Short channel



Long channel



2) Comment on the differences between short channel and long channel results.

• Which one has higher current? Why?

Long channel devices produce higher currents compared to short channel devices due to short channel effects, particularly velocity saturation.

• Which one has higher slope in the saturation region? Why?

Short Channel devices have higher slope in saturation region as the slope of ID ,VDS is 1/ro and ro Proportionate with L , so short channel devices have lower ro which results in bigger slope