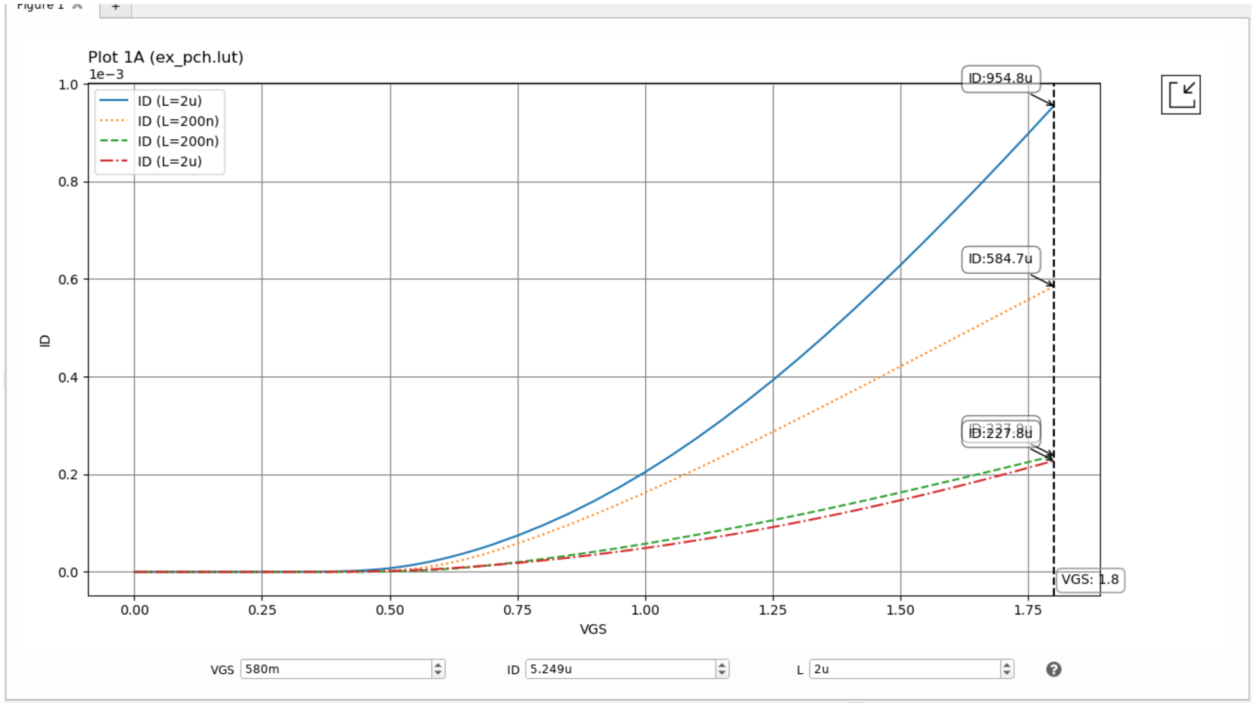
Lab 01 part 2

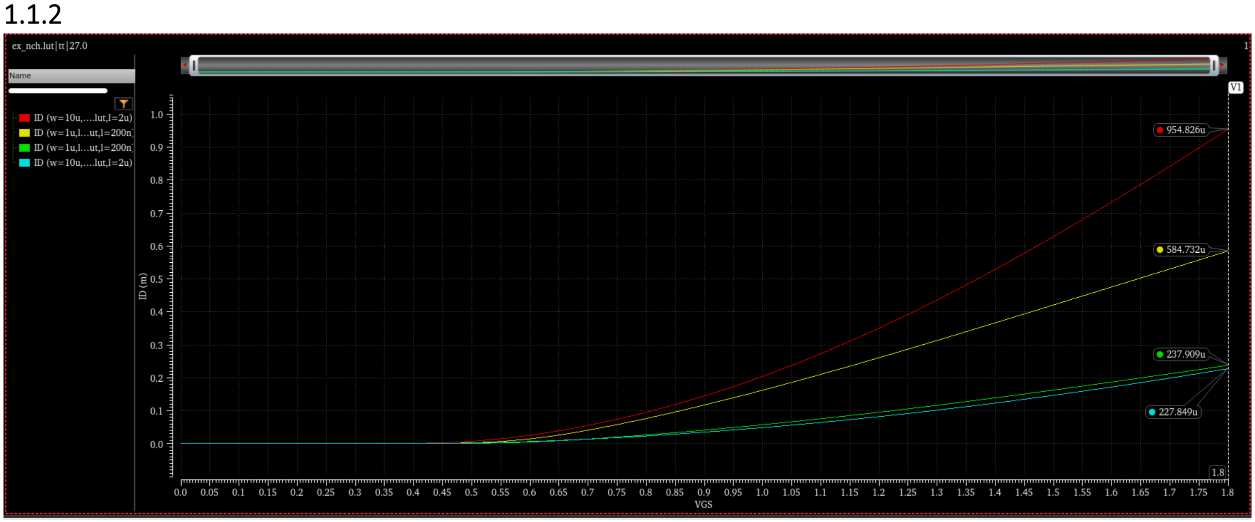
1 ID vs VGS

1.1 Plot $ID - VGS$ characteristics for NMOS and PMOS devices.

1.1.1



1.1.2



1.2 COMMENT ON THE DIFFERENCES BETWEEN SHORT CHANNEL AND LONG CHANNEL RESULTS.

1.2.1 Which one has higher current? Why?

Long channel has higher current, because of mobility degradation effect (increase of vertical electric field) & velocity saturation effect (increase of lateral electric field) when decreasing the channel length the electric field becomes very large to become critical electric field, so the velocity also saturate with specific Vds_{sat} even before the Pinch off saturation (Vov) , so it affects the small channel current to become lower as it saturates quicker .

1.2.2 Is the relation linear or quadratic? Why?

In long channel it is quadratic (square law is applicable), but in short channel it is more like a linear after the effect happens with $\boldsymbol{V}ds_{sat}$ (VGS= VDSsat+Vth) because of velocity saturation effect, as VDS is saturated so the relation between ID and Vov (VGS-VTH) becomes linear.

1.3 COMMENT ON THE DIFFERENCES BETWEEN NMOS AND PMOS :

1.3.1 Which one has higher current? Why?

NMOS has higher current because electrons has higher mobility than holes.

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

From calculator :

	NMOS	PMOS	RATIO
SHORT CHANNEL	584.7 u	237.9 u	2.45
LONG CHANNEL	954.8 u	227.8 u	4.19

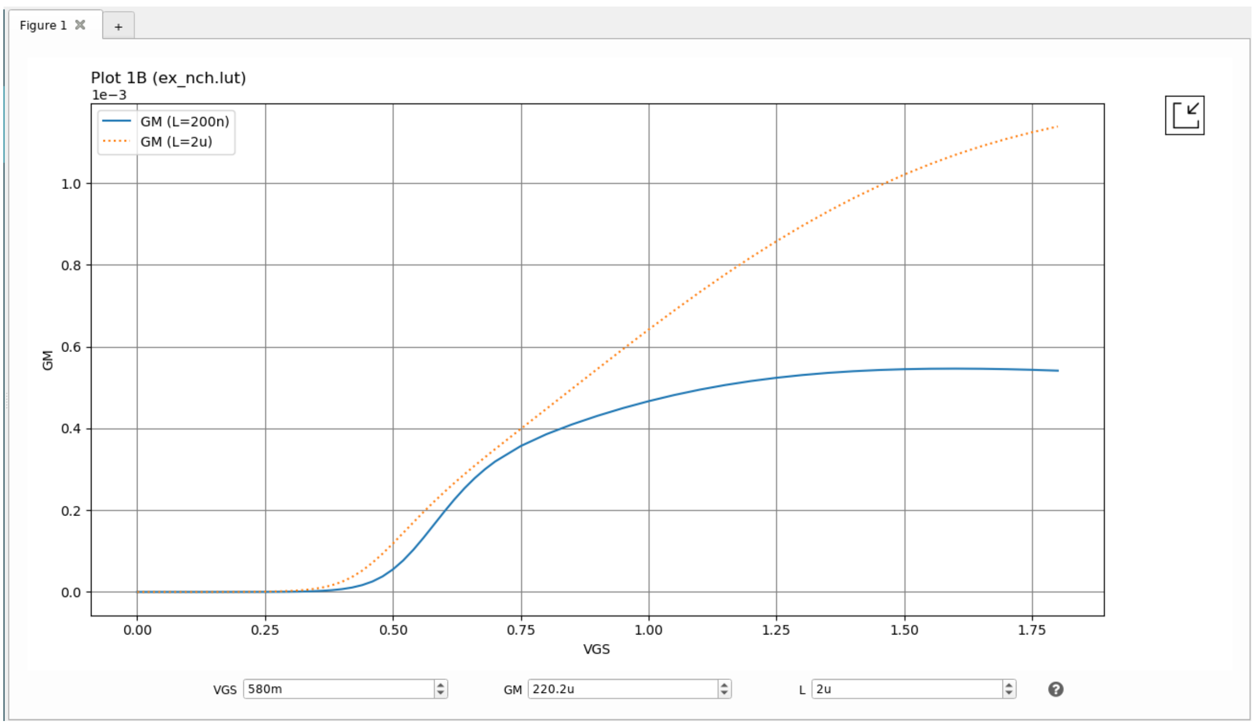
1.3.3 Which one is more affected by short channel effects?

NMOS is more affected because it has higher mobility than PMOS so it reaches velocity saturation faster, $\epsilon = \frac{vsat}{\mu} = \frac{Vsat}{L}$, $Vsat = \frac{L*vsat}{\mu}$.

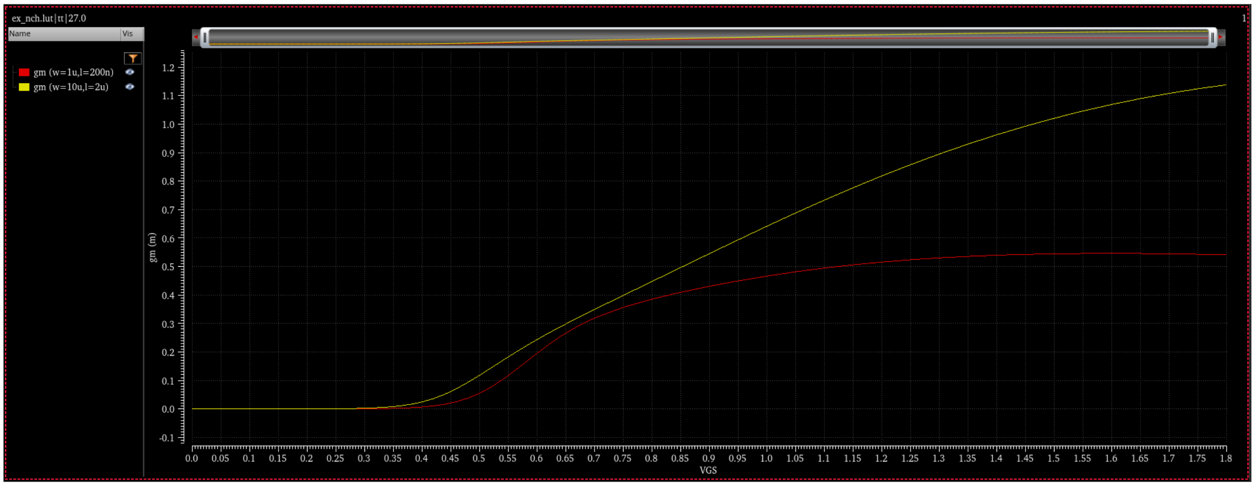
2 gm VS VGS

2.1 PLOT gm VS VGS FOR NMOS DEVICE.

2.1.1



2.1.2



2.2 COMMENT ON THE DIFFERENCES BETWEEN SHORT CHANNEL AND LONG CHANNEL RESULTS.

2.2.1 Does gm increase linearly? Why?

not ideally linear, but It kind of increasing linearly because the characteristic of Id vs vgs is quadratic and gm is the slope of it .

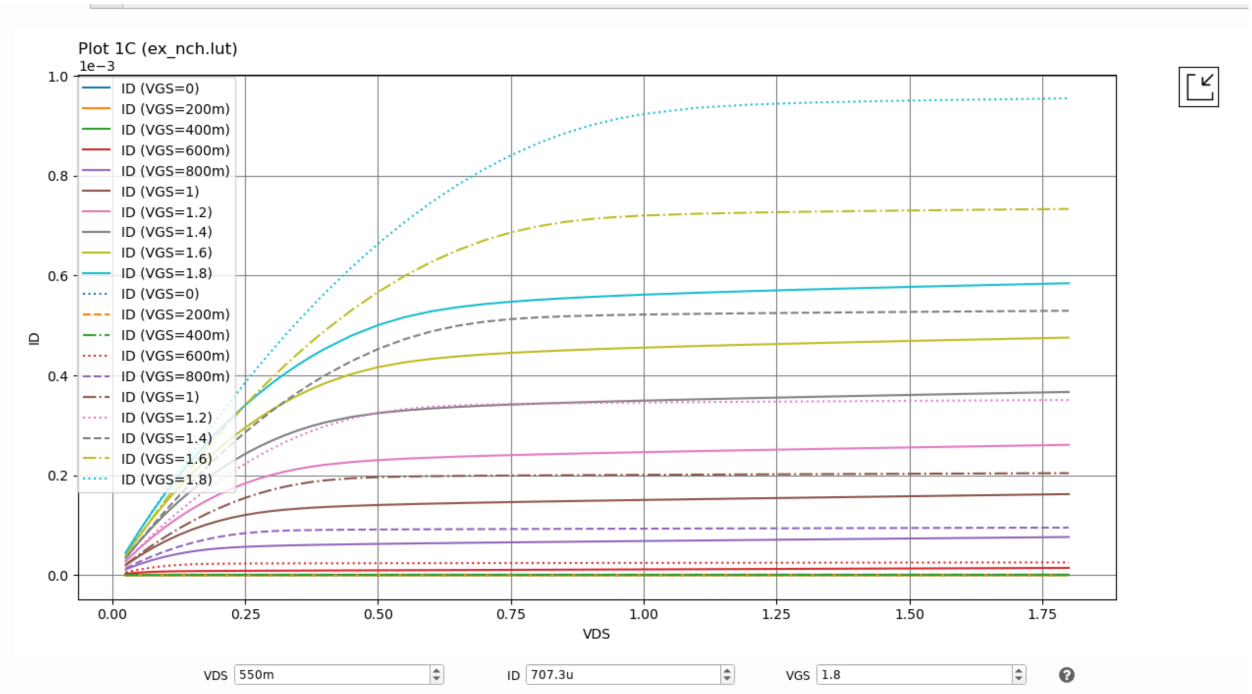
2.2.2 Does gm saturate? Why?

It saturates in short channel because the (id vs Vgs) becomes liner because of velocity saturation, mobility degradation and gm is the slope of this linear characteristic (gm is constant) but it doesn't saturate in large channel model.

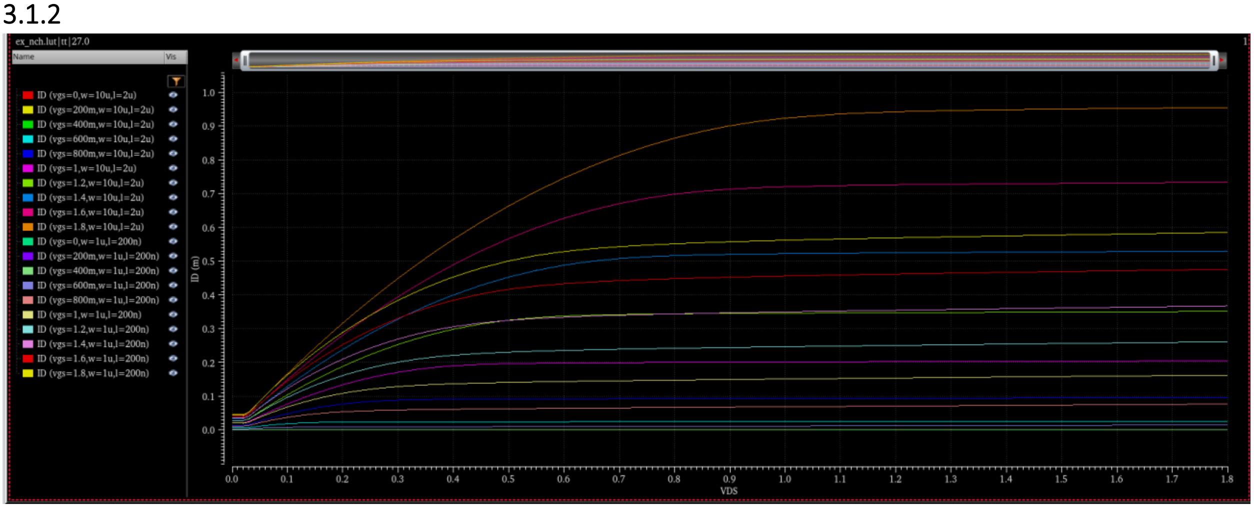
3 ID vs VDS

3.1 Plot $ID - VDS$ characteristics for NMOS device

3.1.1



3.1.2



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

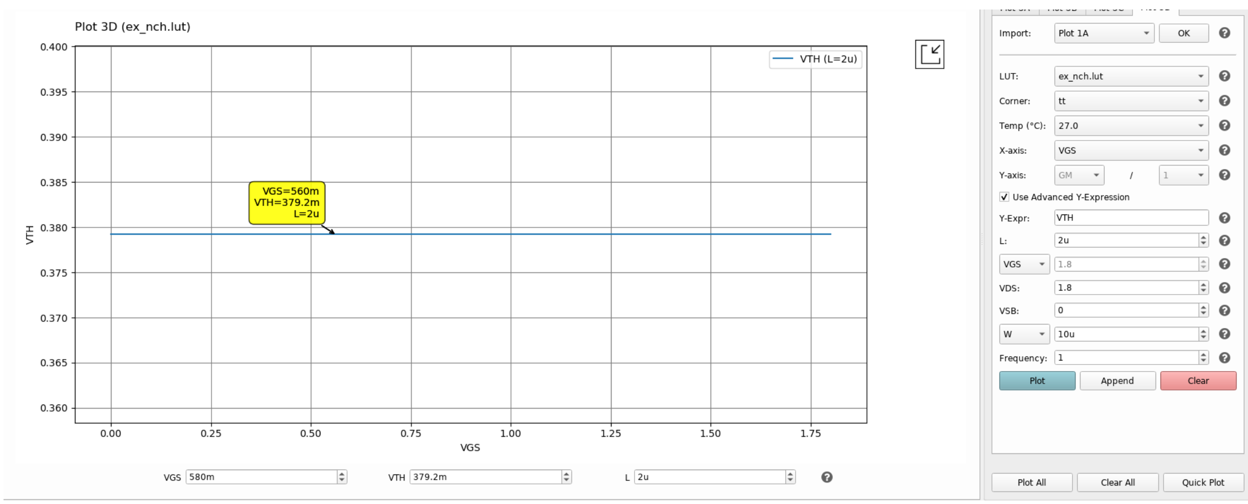
3.2.1 Which one has higher current? Why?

Long channel has higher current, because of velocity saturation(increase lateral electric field) and mobility degradation (increase vertical electric field which leads to decrease mobility) affect small channel current to become less & also ID increases with VGS in short and long channel, so Long channel with highest VGS has the highest current.

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

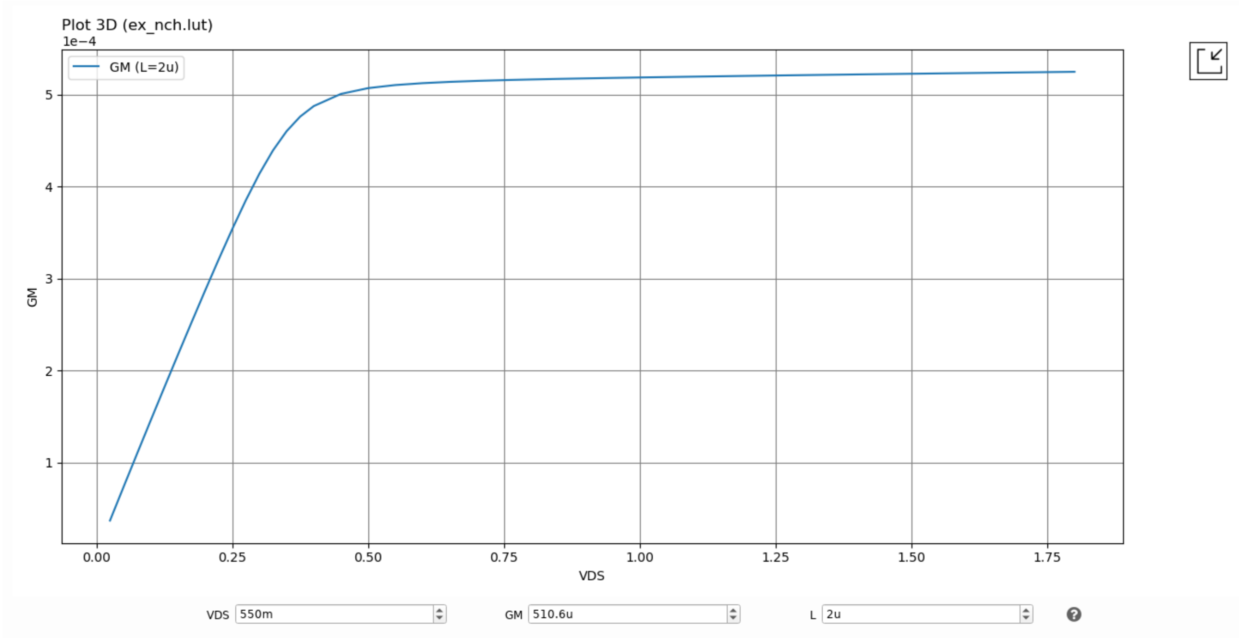
small channel current has higher slope because of DIBL & channel length modulation effect as it has higher **λ** because when L is small the pinch off point shift effect when increasing Vds more than Vov is higher than long channel case as Leff clearly becomes less in short channel case, so it has smaller r0 .

4 [Optional] gm and ro in Triode and Saturation

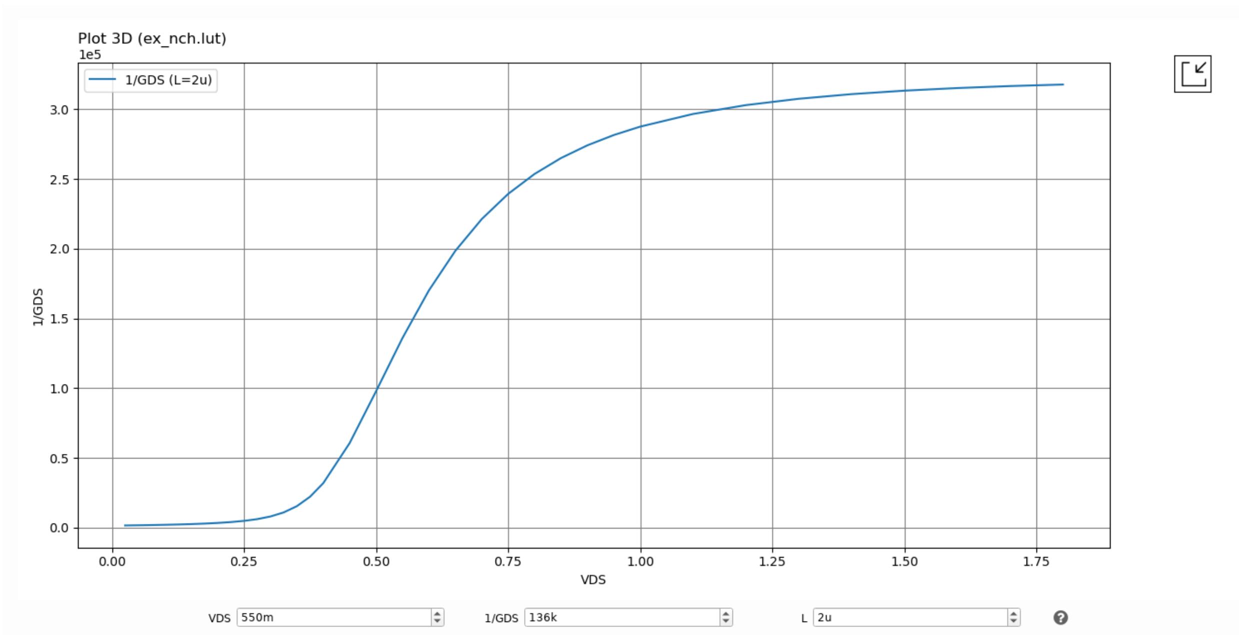


we can estimate Vth = 0.379 , so VGS = 0.5+0.379 = 0.879 V

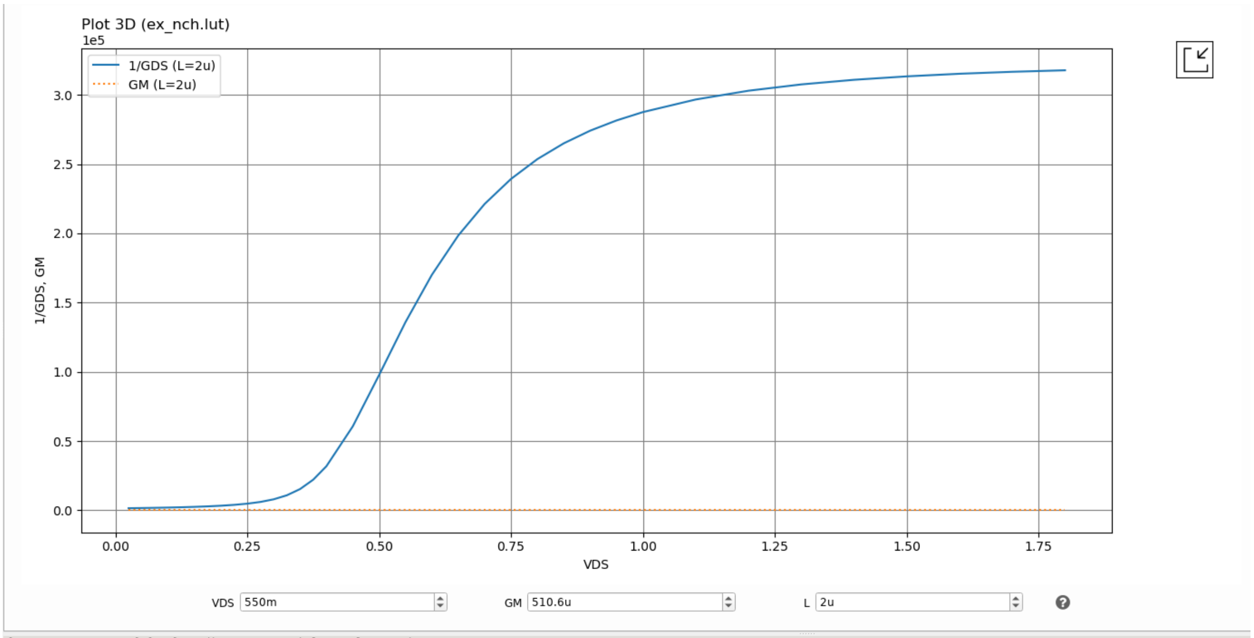
4.1.1



Plot 3D (ex_nch.lut)
1e−4
GM (L=2u)
GM
VDS
VDS 550m
GM 510.6u
L 2u

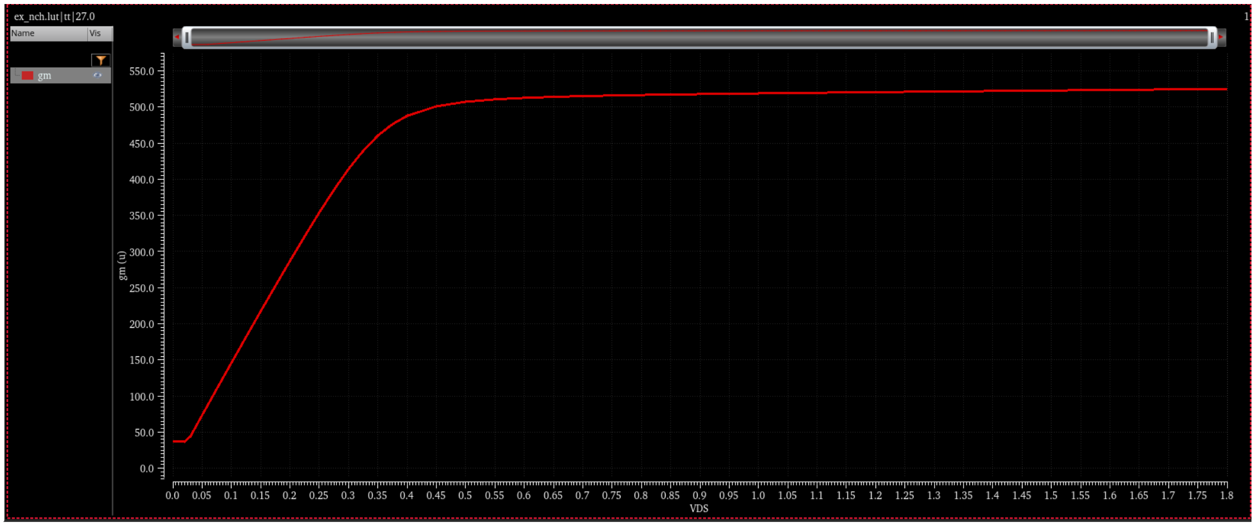


Plot 3D (ex_nch.lut)
1e5
1/GDS (L=2u)
1/GDS
VDS
VDS 550m
1/GDS 136k
L 2u



Plot 3D (ex_nch.lut)
1e5
1/GDS (L=2u)
GM (L=2u)
1/GDS, GM
0.0
0.5
1.0
1.5
2.0
2.5
3.0
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
VDS
VDS 550m
GM 510.6u
L 2u

4.1.2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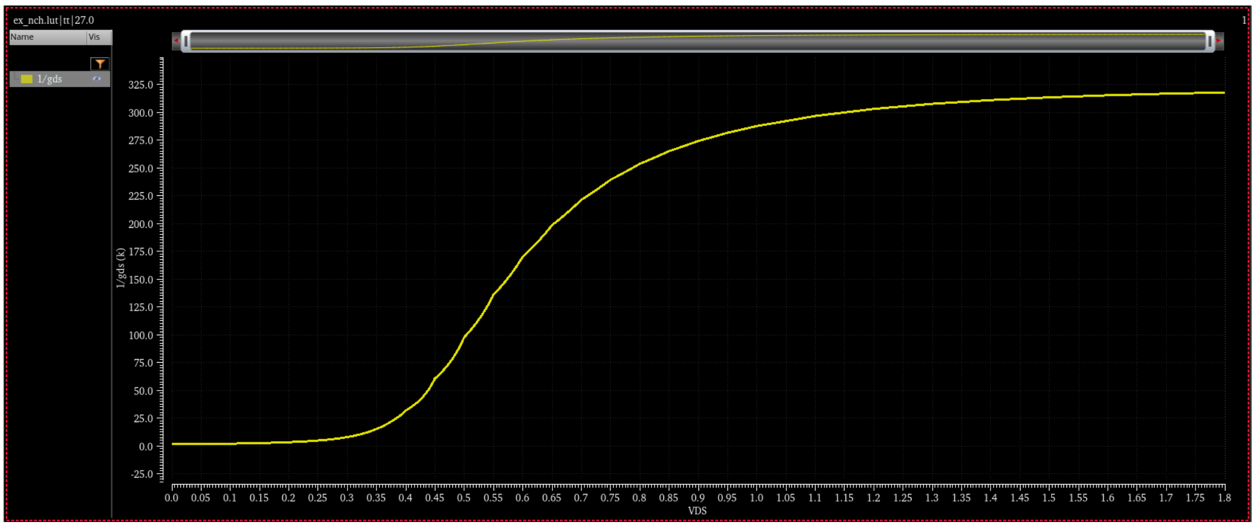
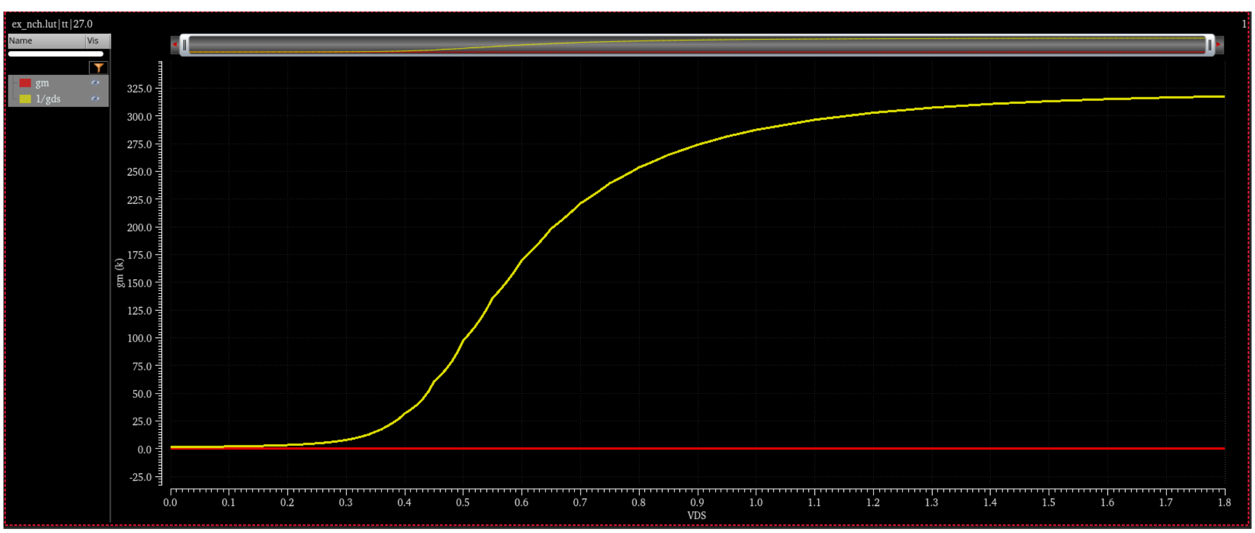
Name
Vis
gm
gm (u)
VDS


ex_nch.lut|tt|27.0
Name
Vis
1/gds
1/gds (k)
VDS


ex_nch.lut|tt|27.0
Name
Vis
gm
1/gds
gm (k)
VDS

4.2 COMMENT ON THE VARIATION OF gm VS VDS.

4.2.1 In the first part of the curve, is the relation linear? Why?

Yes, as we are in triode region [less than VOV (0.5v)], id depends quadratically on VDS, so the derivative gives gm linear dependent on VDS.

4.2.2 Does gm saturate? Why?

Yes, there is kind of saturation, as at higher VDS we are in saturation, so the current become kind of independent on VDS, so gm is not a function of VDS, so it saturates.

4.2.3 Where do you want to operate the transistor for analog amplifier applications? Why?

In saturation, as gm and, as a result also the gain is independent on the change of vds.

4.3 COMMENT ON THE VARIATION OF ro VS VDS.

4.3.1 Does ro saturate just after the transistor enters saturation similar to gm? Why?

NO, as we increases VDS we increases VA which lead to higher r0 ,but the rate of effective length pinching decreases as we increase VDS, because most of VDS drop on the high resistive region, it’s like we weaken the CLM effect as the change in effective L is small, so the change in current, which would give high and saturated r0 independent of changing VDS at higher values of VDS.

4.3.2 Does ro increase if the transistor is biased more into saturation?

YES, as when we go deeper to saturation we increase VDS, so VA increases so r0 also increases and reach more to the ideal case (r0=∞) to get more gain.

4.3.3 Should we operate the transistor at the edge of saturation?

NO, because with small VDS, VA is small, and also there is high slope between I and VDS characteristics, so r0 is small and we always looking for high r0 so we should go deeper into saturation.

4.3.4 Where do you want to operate the transistor for analog amplifier applications? Why?

In saturation, as there is higher r0 as long as we go deeper into saturation.