Analog IC Design

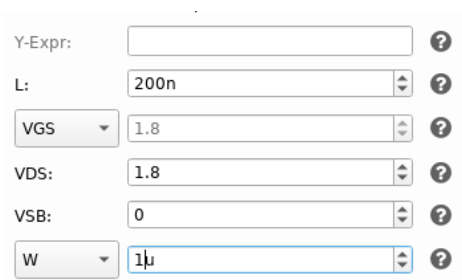
Lab 1 Part2: MOSFET Characteristics

Note: Comments are written only in part (A) to avoid redundancy.

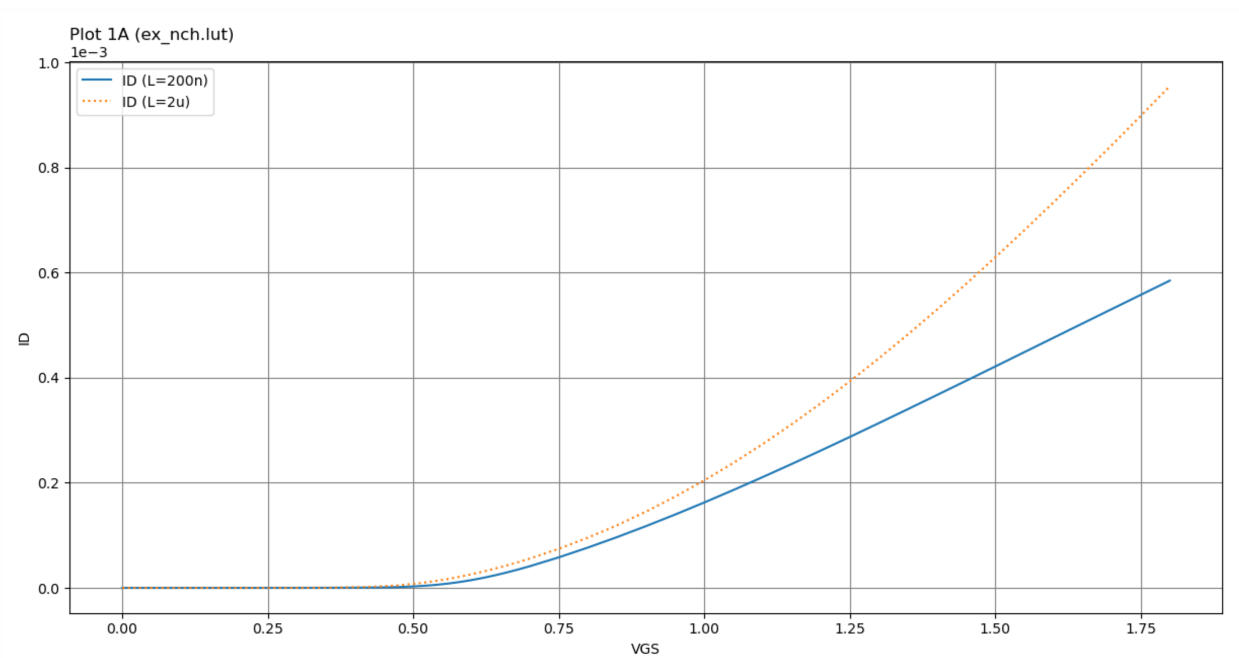
A) Using ADT

ID vs VGS

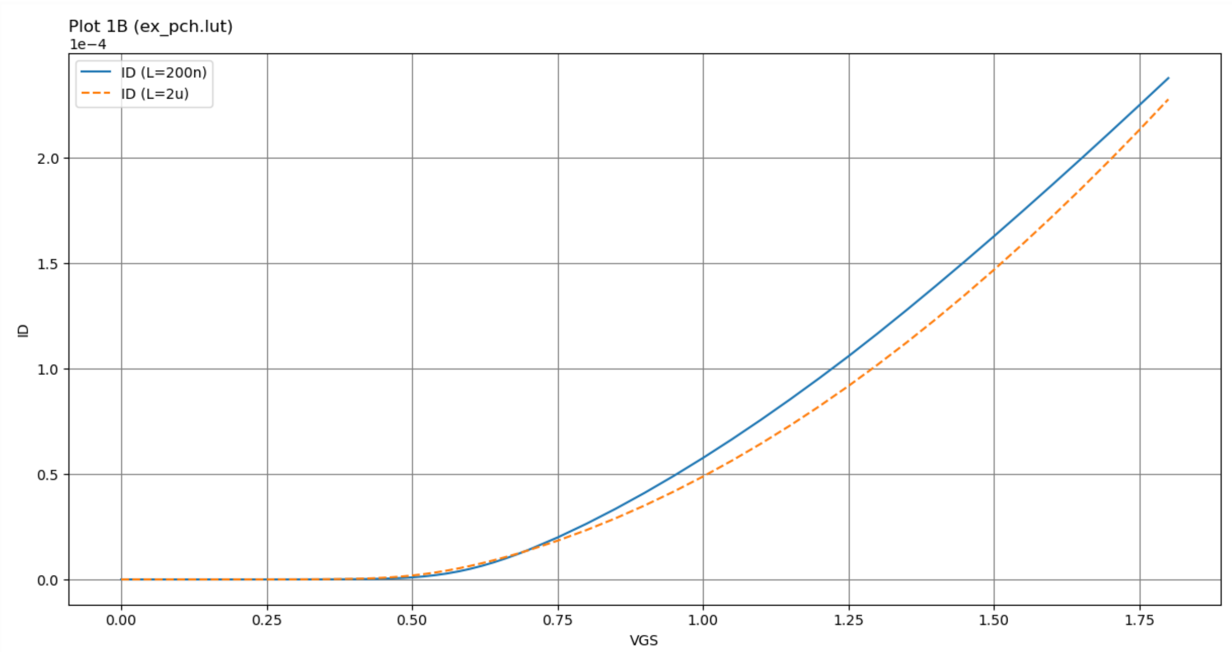
Desired Sizes



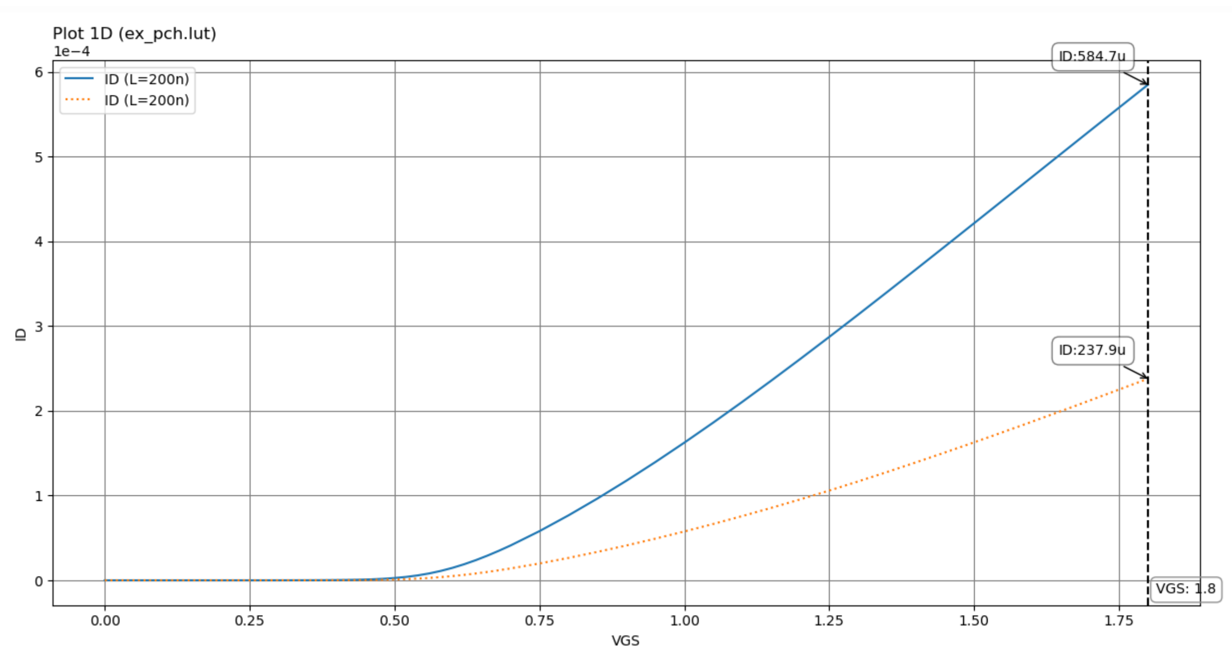
NMOS (Short Channel vs Long Channel)



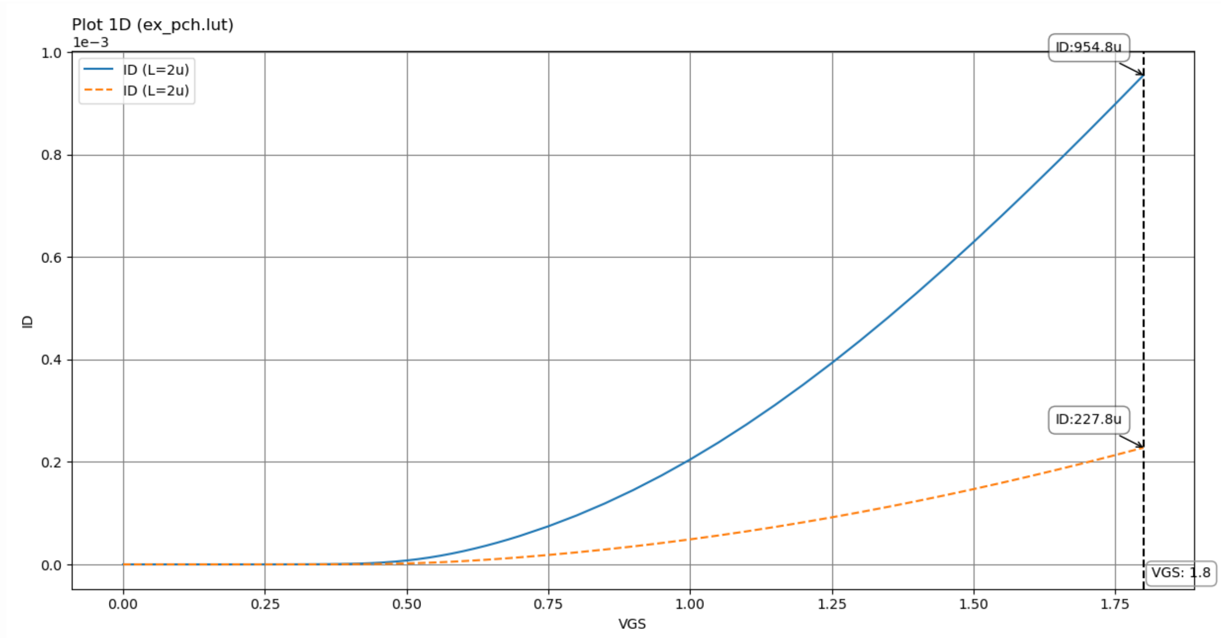
PMOS (Short Channel vs Long Channel)



NMOS vs PMOS (Short Channel)



NMOS vs PMOS (Long Channel)



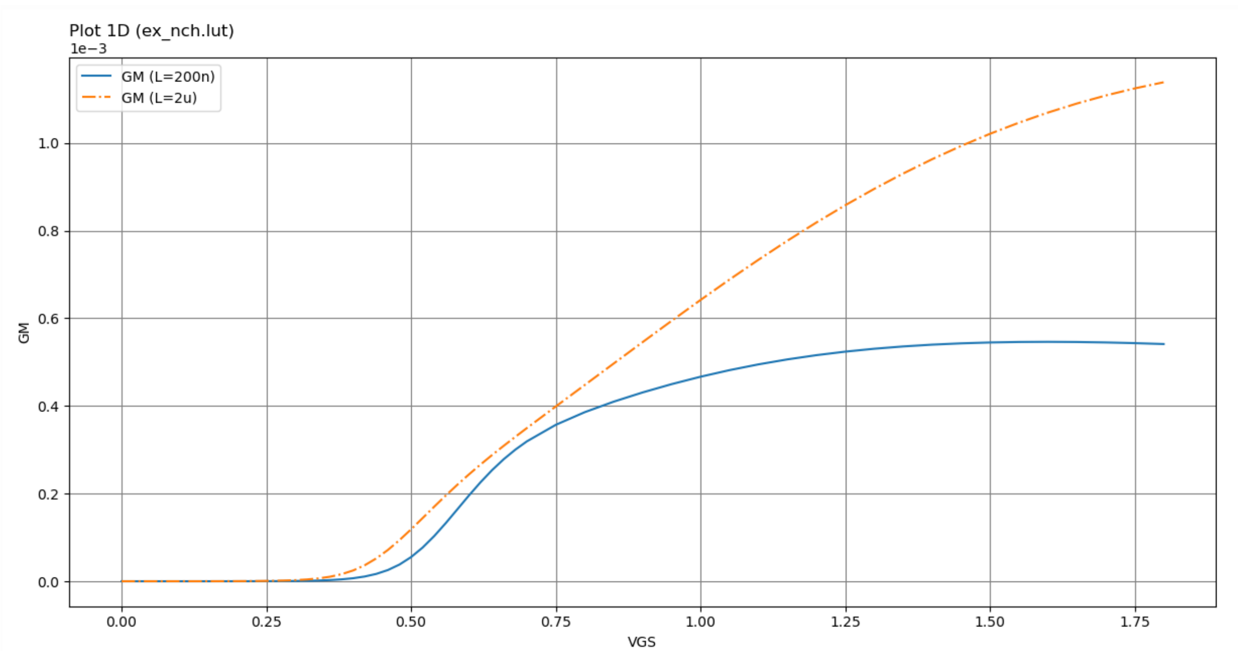
Comments on Short Channel vs Long Channel

- The short channel MOSFET has a lower current than long channel MOSFET due to velocity saturation. In short channel, velocity saturation occurs before pinch-off when $VDS_{sat} > V_{ov}$. This means that the carriers reach their maximum velocity in the channel before the channel is fully depleted near the drain.
- The drain current (ID) varies quadratically with VGS in both channels until VGS = Vth + VDS_{sat}. After this point, the drain current (ID) varies **linearly** with VGS in **short** channel (ID = $C_{ox}.W.v_{sat} . (V_{ov} - VDS_{sat}/2) . (1 + \lambda.VDS)$). The drain current (ID) continues to vary **quadratically** with VGS in **long** channel (ID = $(\mu_n C_{ox}/2).(W/L).(V_{ov})^2$).

Comments on NMOS vs PMOS

- NMOS has higher current than PMOS, because electrons have higher mobility than holes in silicon.
- Current ratio (NMOS/PMOS) at VGS = VDD:
    1. **Short Channel:** 584.7/237.6 = **2.46**
    2. **Long Channel:** 954.8/227.8 = **4.19**
- PMOS is less affected by short channel effects, because holes have lower mobility than electrons, which means that the carrier speed is usually smaller than v_{sat}.

gm vs VGS (NMOS)

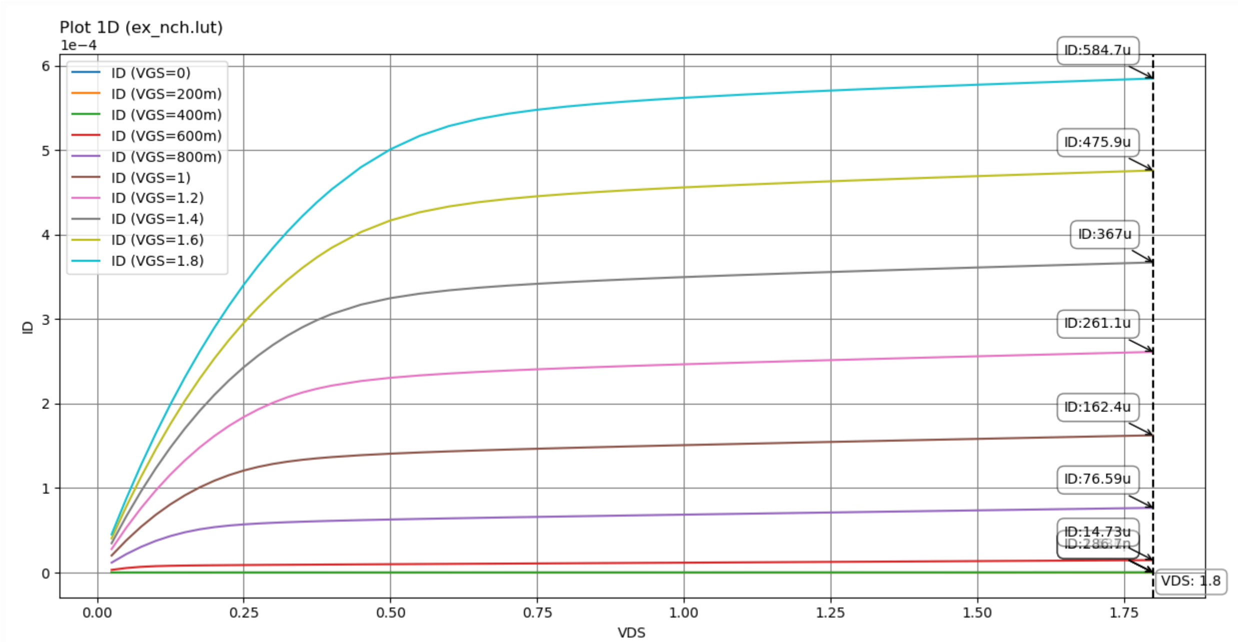


Comments

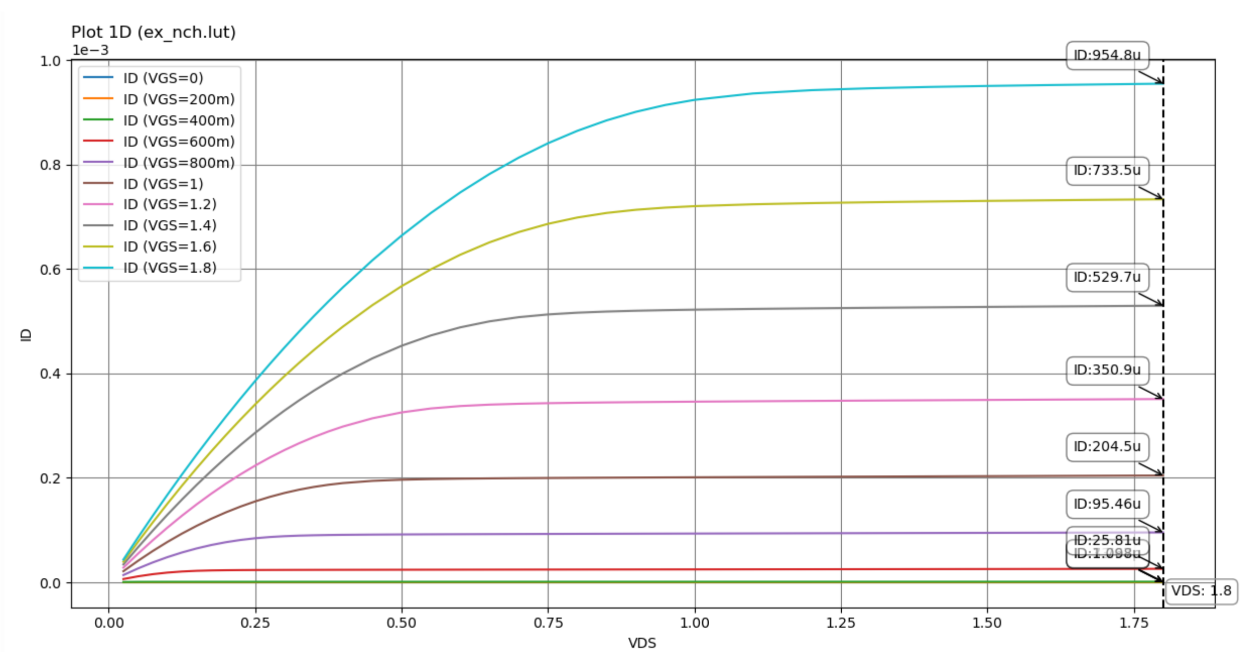
- gm = $\frac{\partial ID}{\partial VGS}$
- In long channel, the graph is linear as it is the derivative of a quadratic function.
- In short channel, the graph saturates as it is the derivative of a linear function.
- Due to mobility degradation, gm might decrease if VGS is further increased than 1.8 (VDD).

ID vs VDS (NMOS)

Short Channel



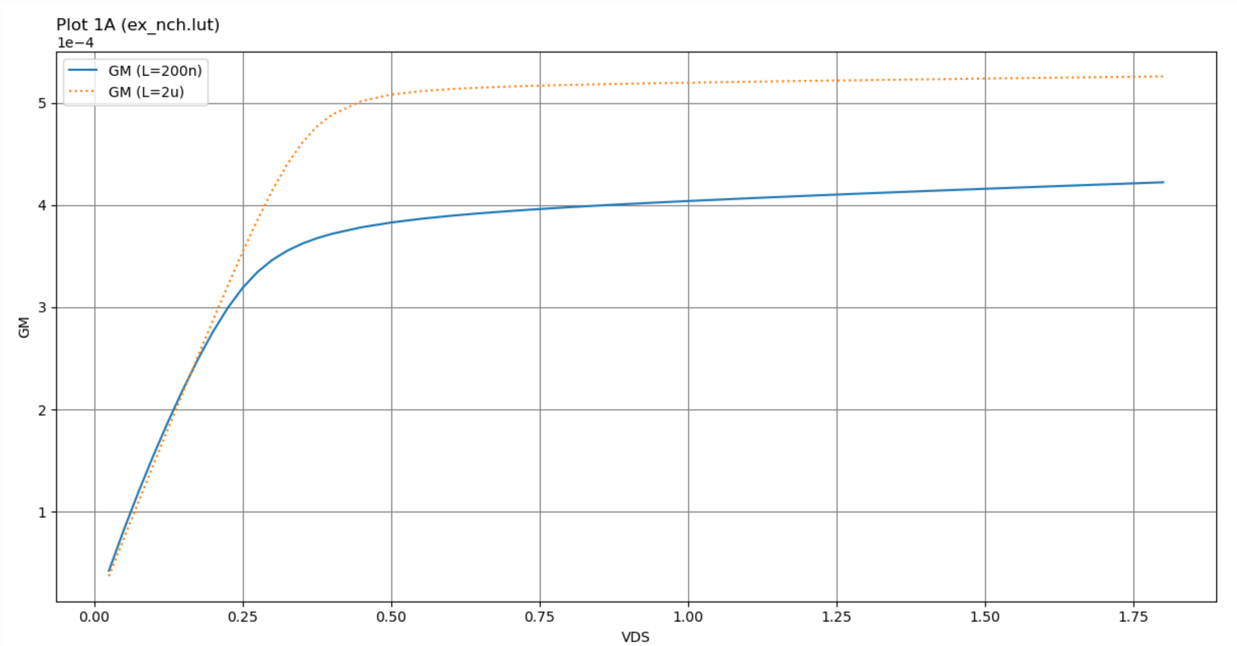
Long Channel

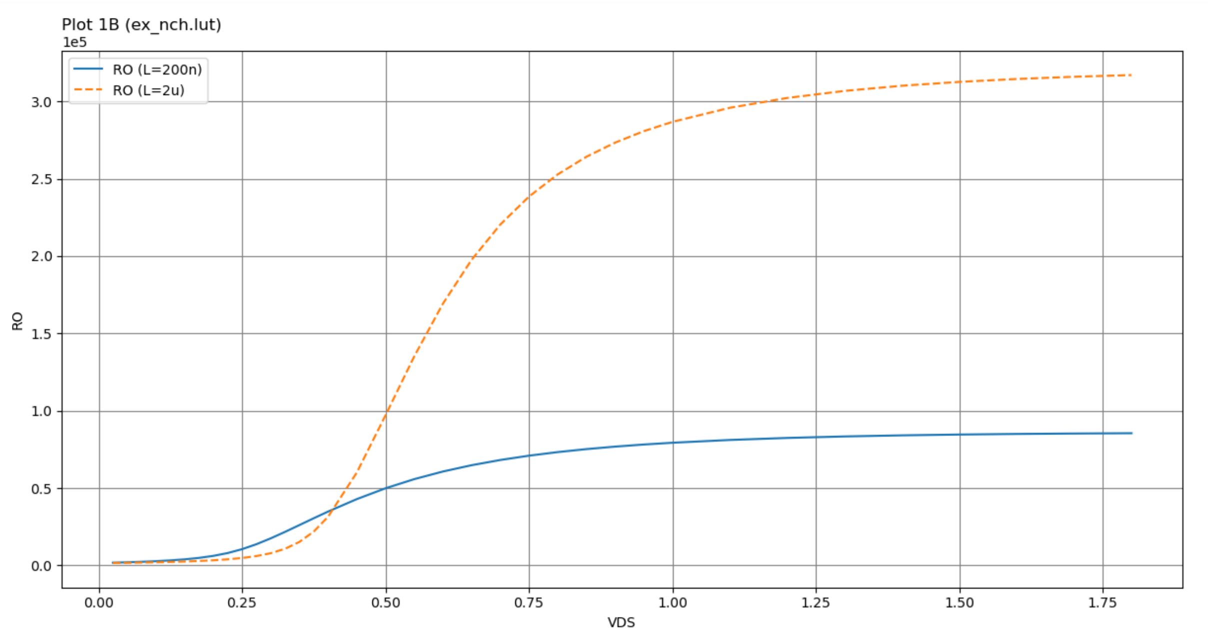


Comments

- Long channel has a higher current than short channel, as short channel is incredibly affected by velocity saturation as well as mobility degradation.
- Slope of short channel in saturation region is higher than long channel due to channel length modulation as well as drain-induced barrier lowering.

gm and ro in Triode and Saturation (NMOS)





gm Comments

- In triode region (first part of curve where VDS < VGS - vth), the transconductance is given by the derivative of drain current with respect to VGS [gm = $(\mu_n)(C_{ox})(W/L)(VDS - VDS^2/2)$]. In this region, VDS has a small value so ($VDS^2/2$) term can be neglected making a **linear** relation between gm and VDS in this region.
- gm saturates in saturation region, where VDS > VGS – vth. The transconductance is given by this equation [gm = $(\mu_n)(C_{ox})(W/L)(V_{ov})$]. Therefore, gm is independent on VDS in this region.
- In analog amplifier applications, we want to operate in saturation region. In saturation region, we can obtain high values of gm and ro. Therefore, we can get a large gain from the circuit (intrinsic gain = gmro).

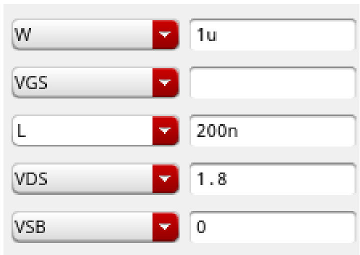
ro Comments

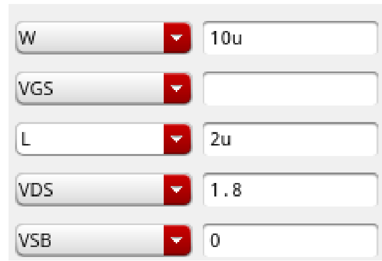
- ro does **not** saturate just after the transistor enters saturation. This is due to dependence of Early voltage on VDS; VA increases with VDS and ro = VA/IDS.
- ro **increases** if the transistor is biased more into saturation. In the beginning of saturation region, the curve has a big slope (small ro), while in deep saturation the slope is small (big ro) as slope = 1/ro.
- We should **not** operate at the edge of saturation. Despite having the maximum gm at edge of saturation, ro is small as well as signal swing is limited.
- In analog amplifier applications, we want to operate in saturation region. In saturation region, we can obtain high values of gm and ro. Therefore, we can get a large gain from the circuit (intrinsic gain = gmro).

B) Using ADTSA

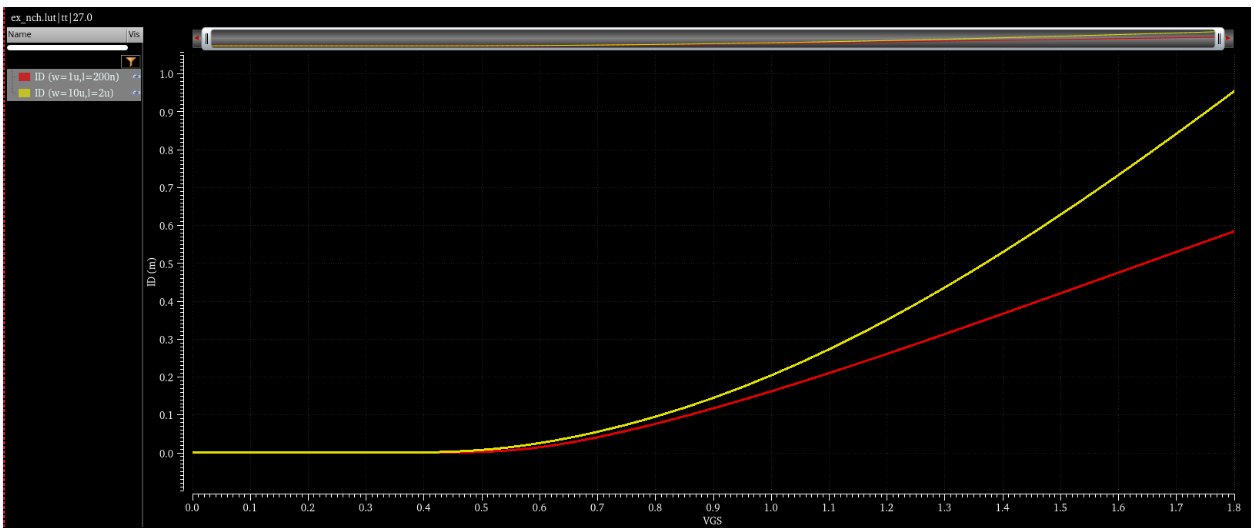
ID vs VGS

Desired Sizing

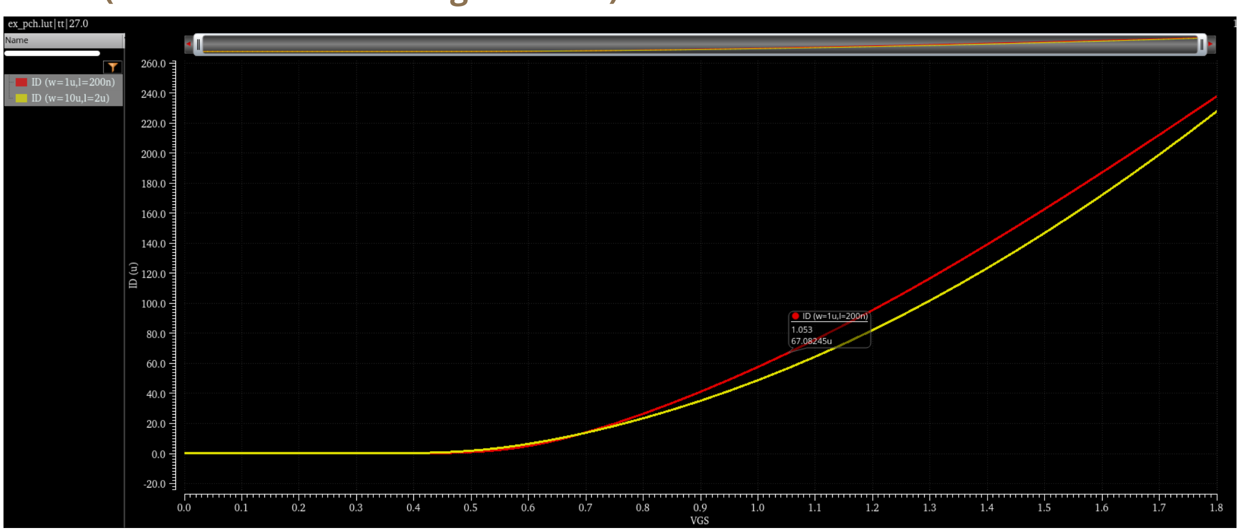




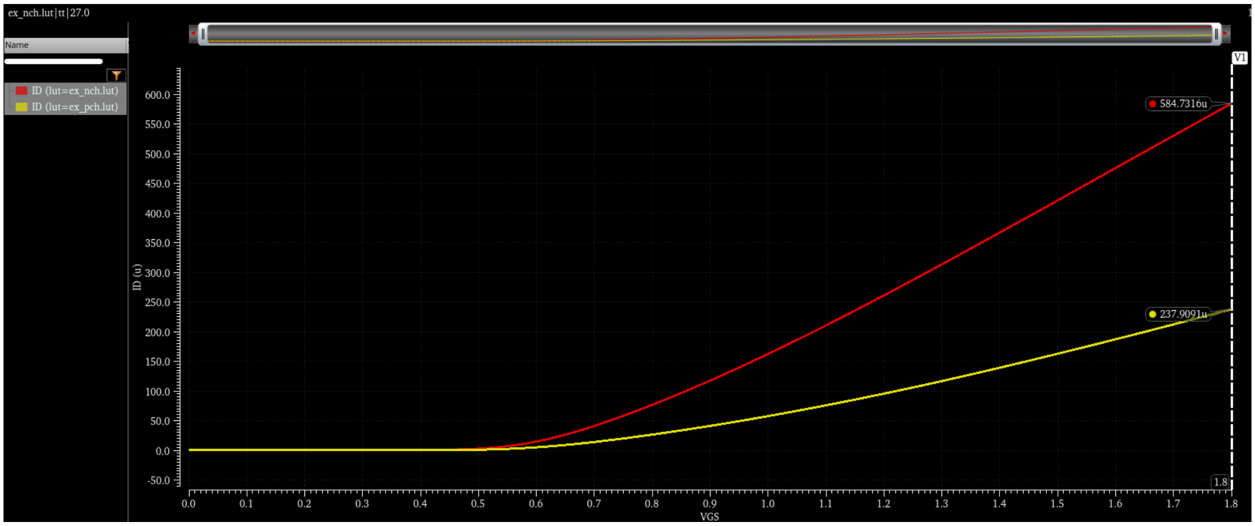
NMOS (Short Channel vs Long Channel)



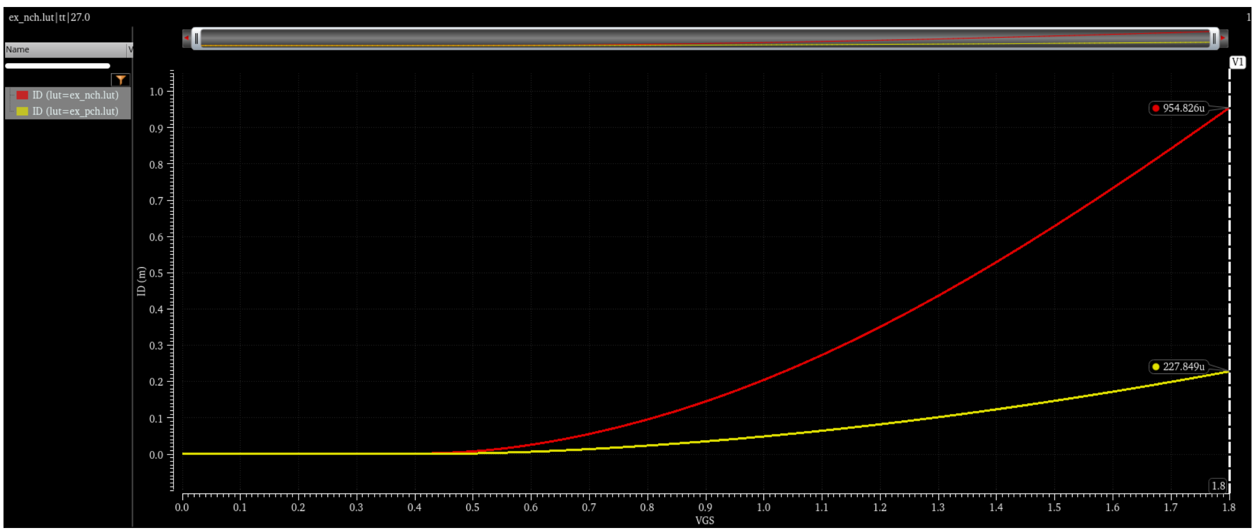
PMOS (Short Channel vs Long Channel)



NMOS vs PMOS (Short Channel)



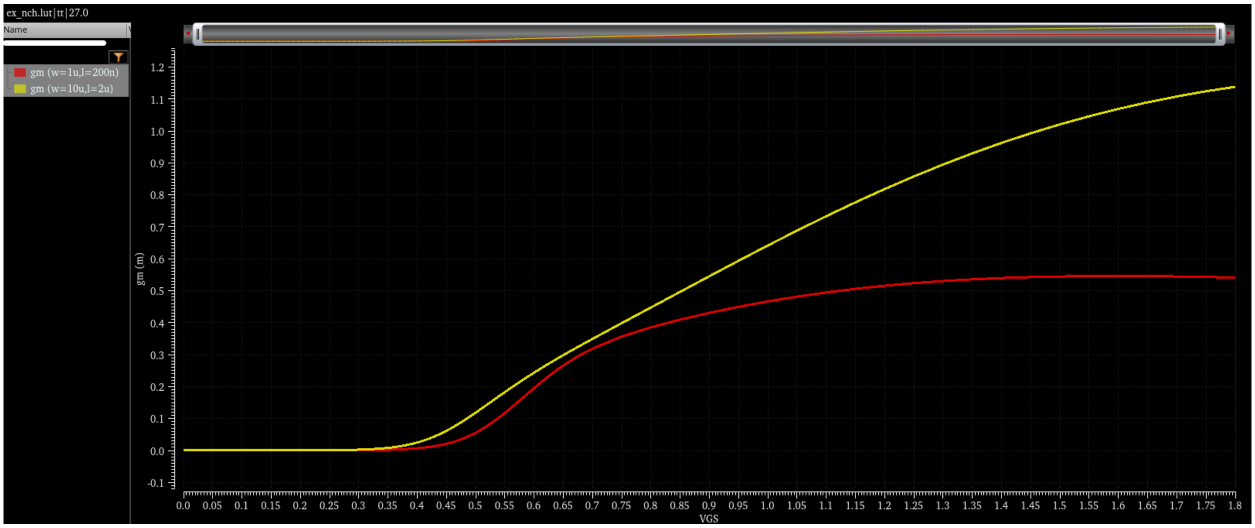
NMOS vs PMOS (Long Channel)



Comments on NMOS vs PMOS

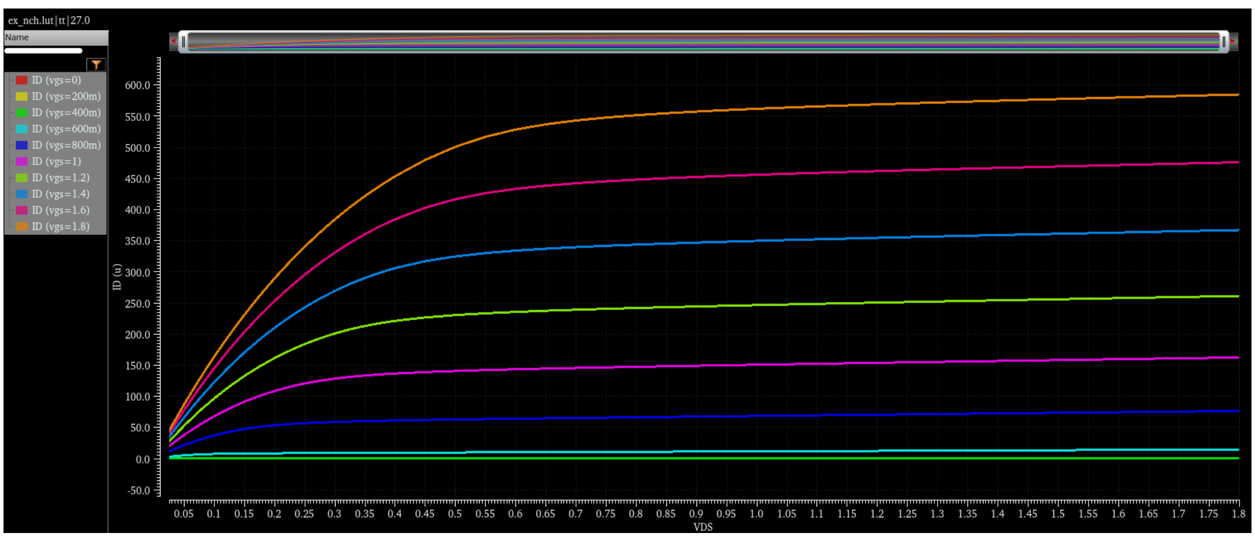
- Current ratio (NMOS/PMOS) at VGS = VDD:
  1. **Short Channel:** 584.731/237.909 = **2.46**
  2. **Long Channel:** 954.826/227.849 = **4.19**

gm vs VGS (NMOS)

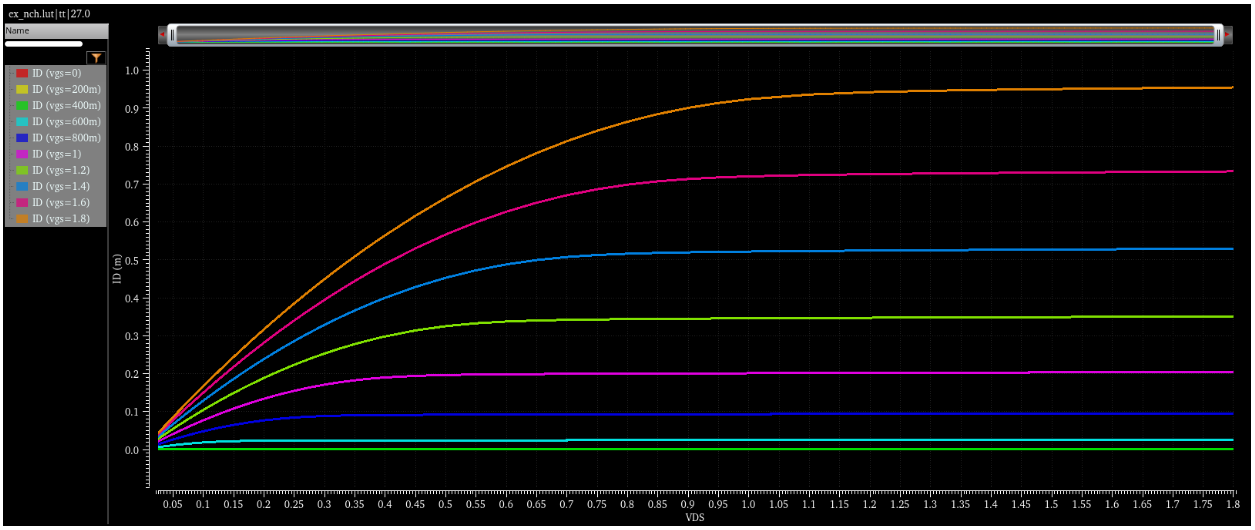


ID vs VDS (NMOS)

Short Channel



Long Channel



gm and ro in Triode and Saturation (NMOS)