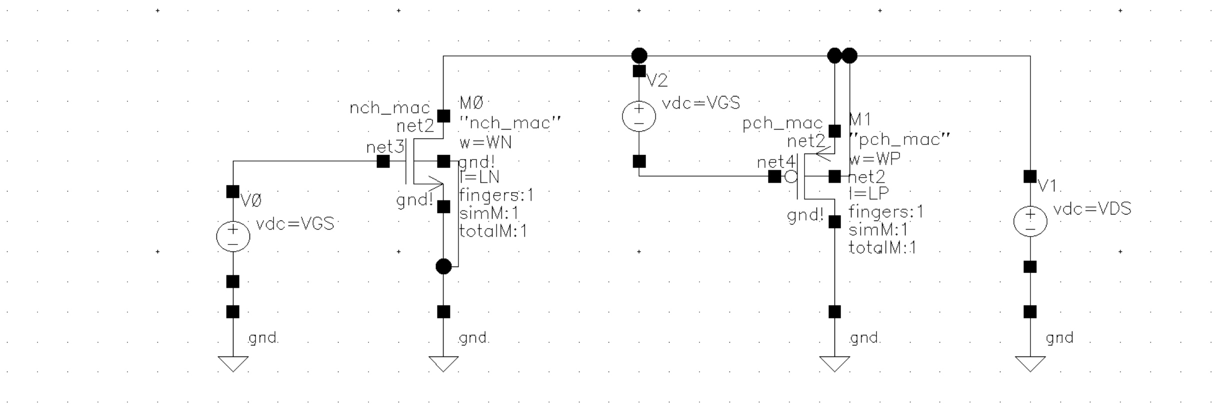
LAB 01 MOSFET Characteristics

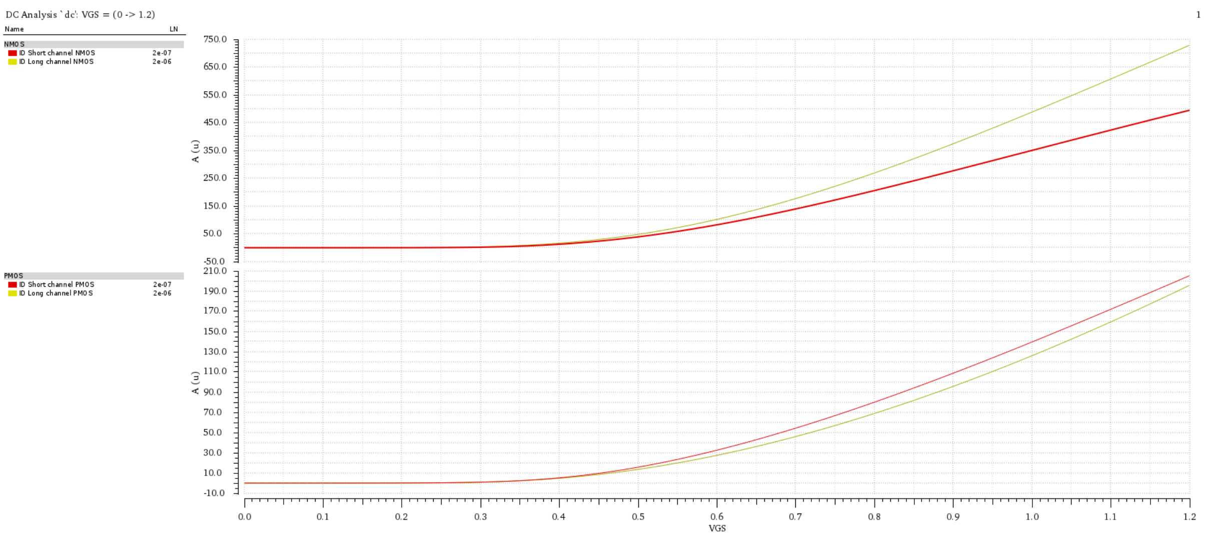
Create a testbench to characterize NMOS and PMOS devices as shown in the figure below.



1 | ID Vs VGS

1 | Plot ID Vs VGS for short and long channel device

Short Channel: W = 1um and L = 200nm	Long Channel: W = 10um and L = 2um



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

- Which one has higher current? Why?

\- NMOS long channel device has higher current as it less suffering from short channel effects (e.g., velocity saturation)

\- PMOS device is less suffering from short channel effects so almost both long channel and short channel have same current although short channel has higher current

- Is the relation linear or quadratic? Why?

\- Short channel devices relation starts quadratic until Vov > VDSsat then linear as they suffer from velocity saturation

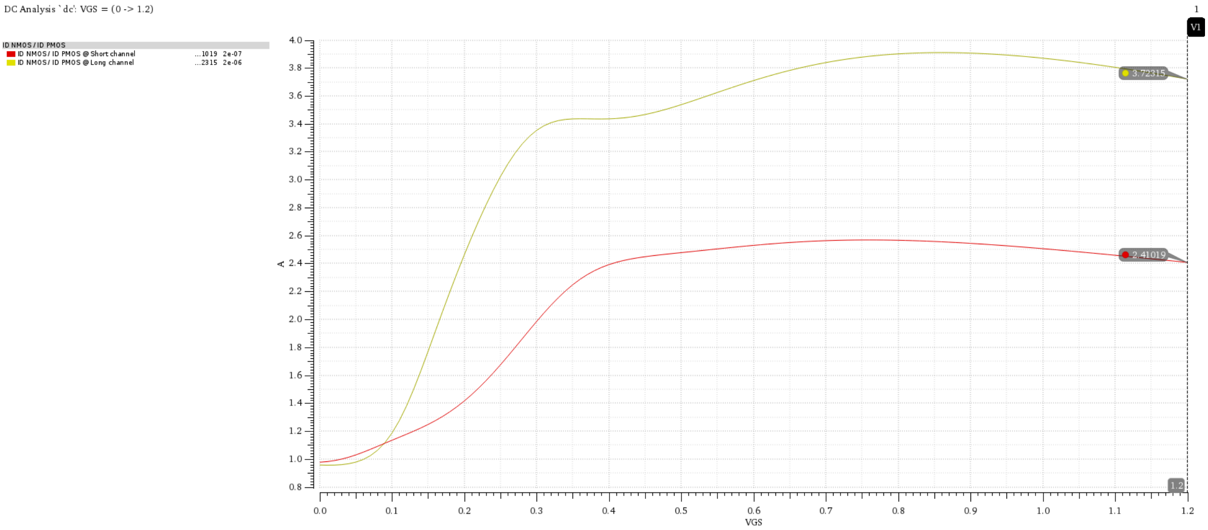
\- Long channel devices have quadratic relation as they less suffering form velocity saturation

3 | Comment on the differences between NMOS and PMOS.

- Which one has higher current? Why?

\- NMOS devices have higher mobility than PMOS devices so, they have higher current

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



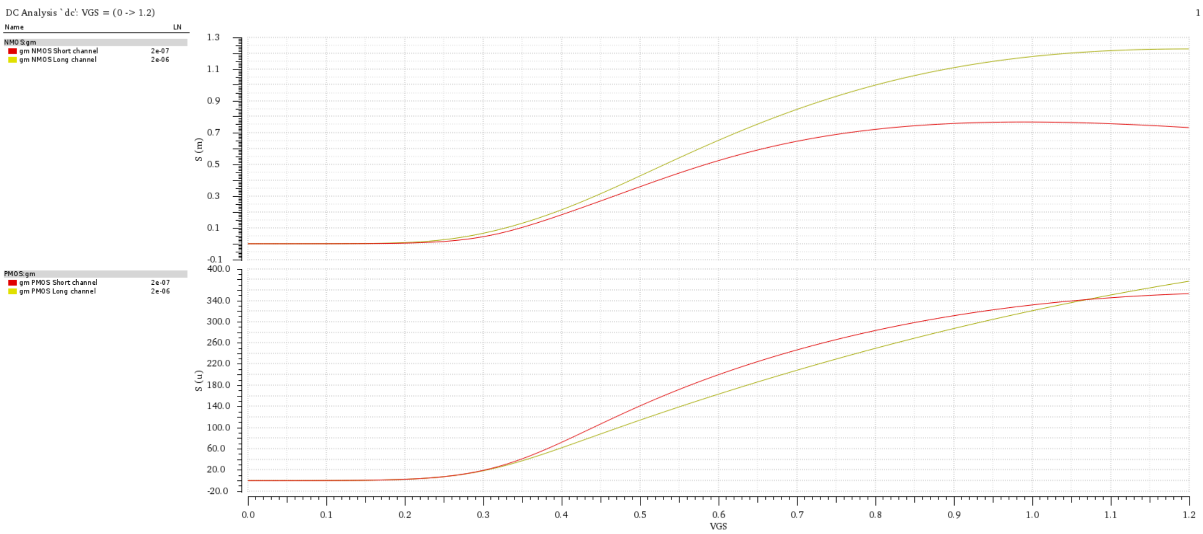
- Which one is more affected by short channel effects?

\- NMOS is more affected by short channel effects

2 | gm Vs VGS

1 | Plot gm Vs VGS for short and long channel device

Short Channel: W = 1um and L = 200nm	Long Channel: W = 10um and L = 2um



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

- Does gm increase linearly? Why?

- No, as $g_m = \frac{\partial I_D}{\partial V_{GS}}$ and ID relation change with VGS as follow:

@ VGS<VTH : ID = 0 → gm = 0

@ VGS>VTH and Vov<VDSsat : $I_D = \frac{uC_{ox}}{2} \times \frac{W}{L} (V_{GS} - V_{TH})^2 \rightarrow g_m = \frac{uC_{ox}}{2} \times \frac{W}{L} (V_{GS} - V_{TH}) \rightarrow$ Linear

@ VGS>VTH and Vov>VDSsat : $I_D = C_{ox} W \times v_{sat} \left(V_{GS} - V_{TH} - \frac{V_{DSsat}}{2}\right) \rightarrow g_m = C_{ox} W \times v_{sat} \rightarrow$ saturate

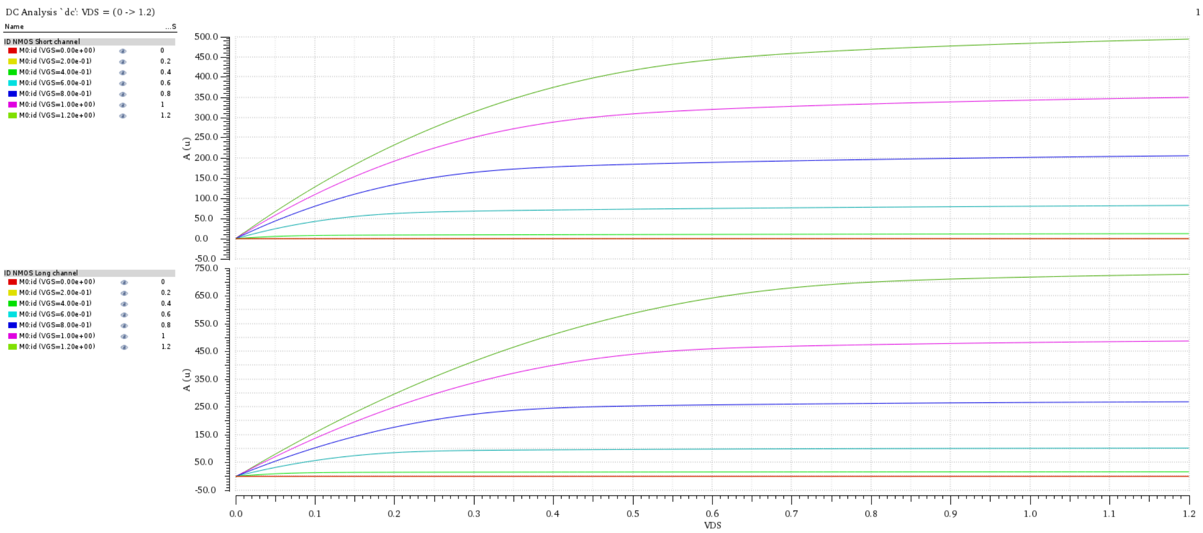
- Does gm saturate? Why?

- Yes, as the device enters the velocity saturation where the ID depends linearly on VGS, so the gm saturates as it is the derivative of ID

3 | ID Vs VDS

1 | Plot ID vs VDS characteristics for NMOS device for short and long channel

Short Channel: W = 1um and L = 200nm	Long Channel: W = 10um and L = 2um



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

- Which one has higher current? Why?

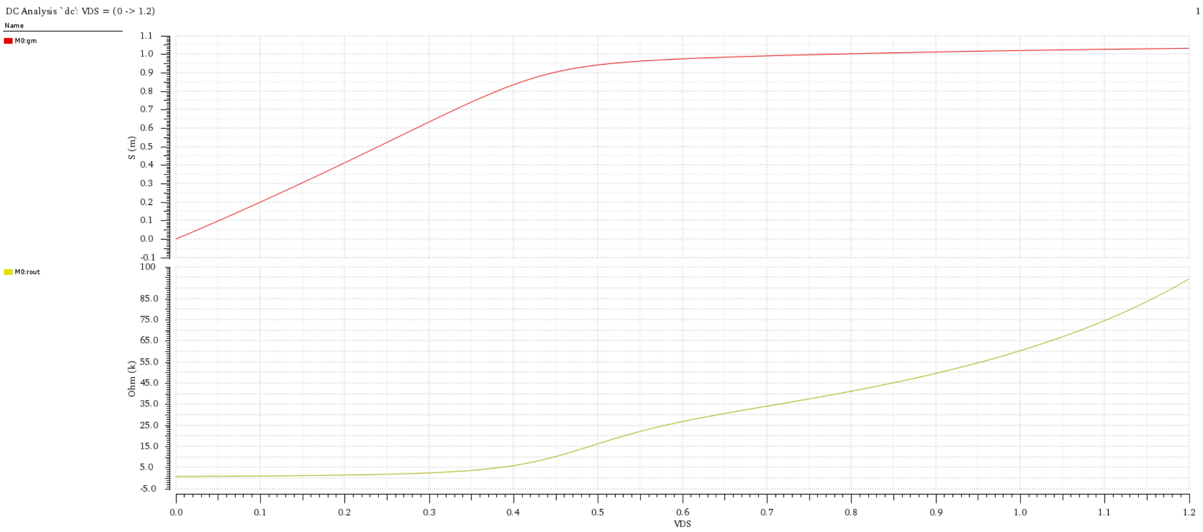
- Long channel device as it less suffering from short channel effects (e.g., velocity saturation)

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

- Short channel device has higher slope in the saturation region as it suffer from short channel effects (e.g., channel length modulation), the slope is 1/ro so, lower L, lower ro, higher slope.

4 | [Optional] gm and ro in Triode and Saturation

1 | Plot gm and ro vs VDS for NMOS device. Use W = 10um and L = 2um, VDS = 0 : 10m : VDD, and VGS = VTH+0.5



2 | Comment on the variation of gm vs VDS

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

\- Yes, as the device in the triode region the current is $I_D = \mu C_{ox}\frac{W}{L}\left(V_{DS}V_{ov} - \frac{V_{DS}^2}{2}\right)$ and since gm is the derivative of ID vs VGS, $g_m = \mu C_{ox}\frac{W}{L}V_{DS}$ linearly depends on VDS

- Does gm saturate? Why?

\- Yes, the device enters the saturation regions and lose its dependance on VDS, so the gm ideally saturate with VDS

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

\- We want to operate the transistor a little deeper into saturation region in analog amplifier applications because gm has larger value and has constant value by changing VDS (gm saturates), and large rout

3 | Comment on the variation of ro vs VDS

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

\- No, because when we go into saturation the slope that represents 1/ro is very small so it means that ro is getting large at this point so ro increases as we go deeper into saturation.

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

\- Yes, small ID/VDS slope means higher ro and slope getting smaller as we go into saturation.

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

\- We shouldn't operate the transistor at the edge of saturation because ro have small value.

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

\- We want to operate the transistor a little deeper into saturation region to get ro with a large value so we would have large gain.