E 140/240A Prof. Pister
Spring 2018

Lab #4

Due by online submission on **March 15**

For each problem you will be exploring the models of four different devices: short channel and long channel, NMOS and PMOS. Both short and long channel devices will have W/L=10. For short channel use W/L= 450n/45n and for long channel use W/L=10u/1u. In general you will have four answers to each question, e.g. "PMOS short channels look quadratic over the range ..., NMOS long channels look quadratic over the range...," etc. You may find it easiest to plot each device on a different plot.

1. With |Vds|=0.6V, use Cadence to simulate I_d vs V_{gs} for V_{gs} from 0 to V_{DD}=1.2V.

a. Plot all of the currents. Do the short channel devices look like our velocity saturation model? Do the long channel devices look quadratic? Over what range of Vgs for each?

b. Over the range where the device looks velocity saturated (if any), estimate $C_{ox}V_{scl}$ and V_t,

c. Plot sqrt(Id). What is the range of Vgs for which the curves look linear? For that range, estimate $\mu_n C_{ox}$ and V_t .

d. Compare your estimates of Vt for each device from parts b and c.

e. Plot log10(I_d). What is the range over which each curve looks straight? Estimate n and I_S/W for each subthreshold model in those regions.

f. Plot g_m for all devices vs. V_{gs}. Which device, at what bias point, gives the best g_m?

g. Plot g_m/I_d for all devices vs. Vgs. How does this compare to theory for sub-threshold, quadratic, and saturation models? Where are the transitions?

h. Which device, at what bias point, gives the best g_m per microamp? This is one of the most important metrics of performance.

2. For the same devices as above, simulate I_{ds} vs V_{ds} from 0 to V_{DD}=1.2V with V_{GS}=0.6V.
   a. Plot I_{ds} and r_o on the same plot.
   b. Is there a clear transition to saturation for each device? Does it happen where you expect, relative to Vt values calculated above?
   c. Try to pick the best value for λ that you can, and sketch by hand what you expect . Is $r_o=(1+\lambda V_{ds})/(\lambda I_d)$ a good model for output resistance for any/some/all of these devices?
   d. Which device, at what bias point, gives the highest intrinsic gain?

3. Repeat problem 2 with V_{GS}=0.3V.
4. Estimate Cgs for each device. Estimate the unity gain frequency for each device in a common source amplifier with an ideal current source load when driving a copy of itself.