Homework 1

Deliver to Homework Dropbox in PHL 2nd floor, February 9, 2018 no later than 6:00pm

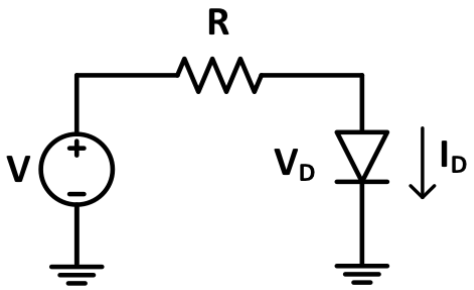
Name: _____ NetID: _____

Important: You may collaborate with other students on this homework assignment, but each student must turn in their own assignment and in their own writing. In addition, you must specify the names of all your collaborators and all the resources used to solve the homework assignment. Failing to specify your collaborator(s) or resources will result in a 20% penalty. Late homework will receive a 20% penalty for every day late (including submissions made after 6:00pm); homework more than 3 days late will not be accepted.

Get bonus points! Follow these instructions to receive **5 bonus points**: Put your name and NetID on the first page. All your answers must be within the blank spaces of this homework. You have to print the homework two-sided and staple it prior to submission in the top-left corner. In the exceptional case you have source code, Cadence schematics, or plots you want to include in your submission, you are allowed to add *one* printed page per plot *after* the associated question; do not forget to clearly label each additional sheet. ***Clearly mark all your final answers.***

Question	**Maximum Points**	**Points**
1	15	
2	20	
3	30	
4	35	
Follow the rules	+5 bonus	
Total	**100 (+5 bonus)**	

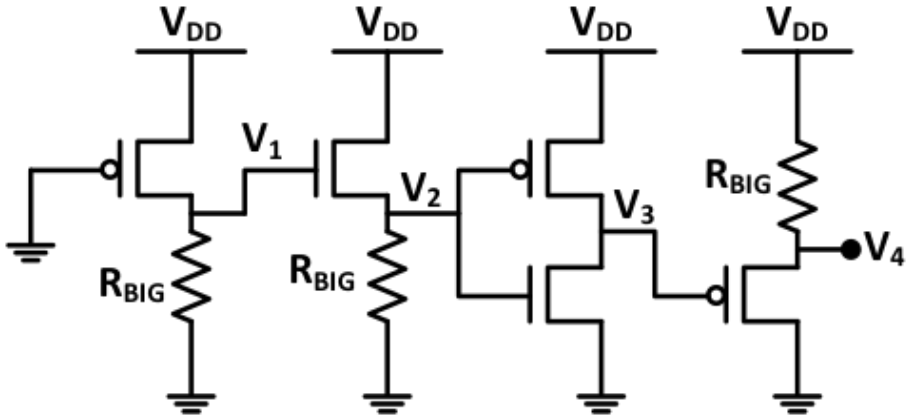
Problem 1 (15pts): "Fun" with a Diode



1. Find the supply voltage V that needs to be provided so that the voltage across the diode, V_D, is equal to 1.6 V. Use $R = 3\text{k}\Omega$ and $n = 1.8$, $I_s = 10^{-18}\text{A}$, and $\phi_T = 26\text{mV}$. Use the ideal Shockley diode equation from the lecture notes.

2. Assume $R = 500\Omega$ and $V = 9$V, and the diode parameters above. Compute V_D. Compute this voltage graphically and/or numerically but without the use of scientific software.

Problem 2 (20pts): Transistor Chain

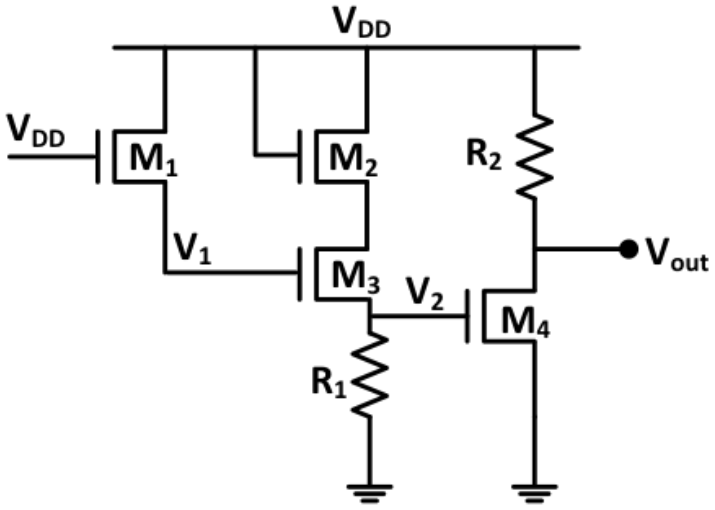


1. Find all voltages V_1 to V_4 in the following circuit using the switch models introduced in class. Assume $R_{\text{ON}} < R_{\text{BIG}} < R_{\text{OFF}}$ and $V_{DD} > 2|V_{\text{Tp}}|$ and $V_{\text{Tn}} < |V_{\text{Tp}}|$.

2. Replace all NMOS with PMOS and vice versa. Find all voltages V_1 to V_4.

Problem 3 (30pts): Read the Hint

Determine the voltages V_1, V_2, and V_{out}. Ignore the body effect and channel-length modulation. Note that transistor M_2 is diode connected and M_3 is biased at the onset of saturation (meaning M_3 operates at the boundary of saturation and the linear regime). Size of M_3 is unknown and the rest of transistors are sized by W/L provided below. *Hint: assume the switch model for* M_1.



$V_{DD} = 1\text{V}$	$\mu_n C_{\text{ox}} = 50\mu\text{A/V}^2$	$R_1 = 30\text{k}\Omega$
$V_T = 0.25\text{V}$	$W/L = 4\text{m}/0.5\text{m}$	$R_2 = 250\text{k}\Omega$
$\lambda, \gamma = 0$		

Problem 4 (35pts): DIBL a Little in Cadence

Make the schematic in Cadence with the minimum dimensions ($W = 120$nm, $L = 100$nm). Turn in three plots total, one plot for each part, i.e., overlay parametric sweeps onto one plot. *Hint: Before solving this problem, finish Part 1 of Lab 1.*

To save the threshold voltage for DC sweeps, create a file using `gedit` called "saveop.scs". Add the line "save NM0:all" and this will save all the DC operating point information. In your ADE go to Setup→Model Libraries and add saveop.scs.

Id results can be plotted directly. For threshold voltage results, go to Tools→Results Browser, find the "dc" folder and select NM0/Vth.

1. Plot Id vs. VDS

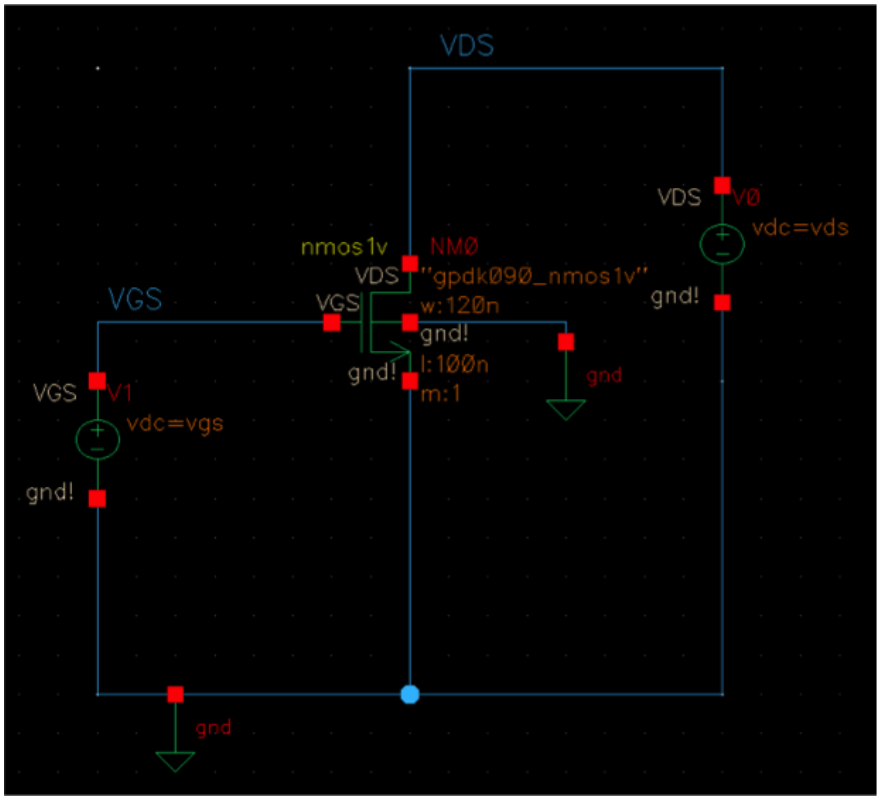
   Use DC analysis (dc analysis→Design Variable) to set up a sweep of VDS from 0V to 1.2V and plot Id (Outputs→Save All, select device currents). When setting up the Id plot, make sure to select the transistor as an output variable so that Id actually plots. Use a parametric sweep (Tools→Parametric Analysis) with 4 steps for VGS (0V, 0.4V, 0.8V, 1.2V). Press the run button on the parametric sweep screen.

2. Plot VT vs. L

   Sweep length from 100n to 5μ (dc analysis→Component Parameter) and plot threshold voltage. Use a parametric sweep with 4 VDS voltages (0V, 0.4V, 0.8V, 1.2V).

3. Plot VT vs. VDS

   Sweep VDS from 0V to 1.2V and plot threshold voltage. Use a parametric sweep with 4 steps for VGS (0V, 0.4V, 0.8V, 1.2V).


VDS
VDS
V0
vdc=vds
nmos1v
NM0
VDS
"gpdk090_nmos1v"
VGS
VGS
w:120n
gnd!
gnd!
l:100n
gnd
VGS
V1
m:1
vdc=vgs
gnd!
gnd