HW1

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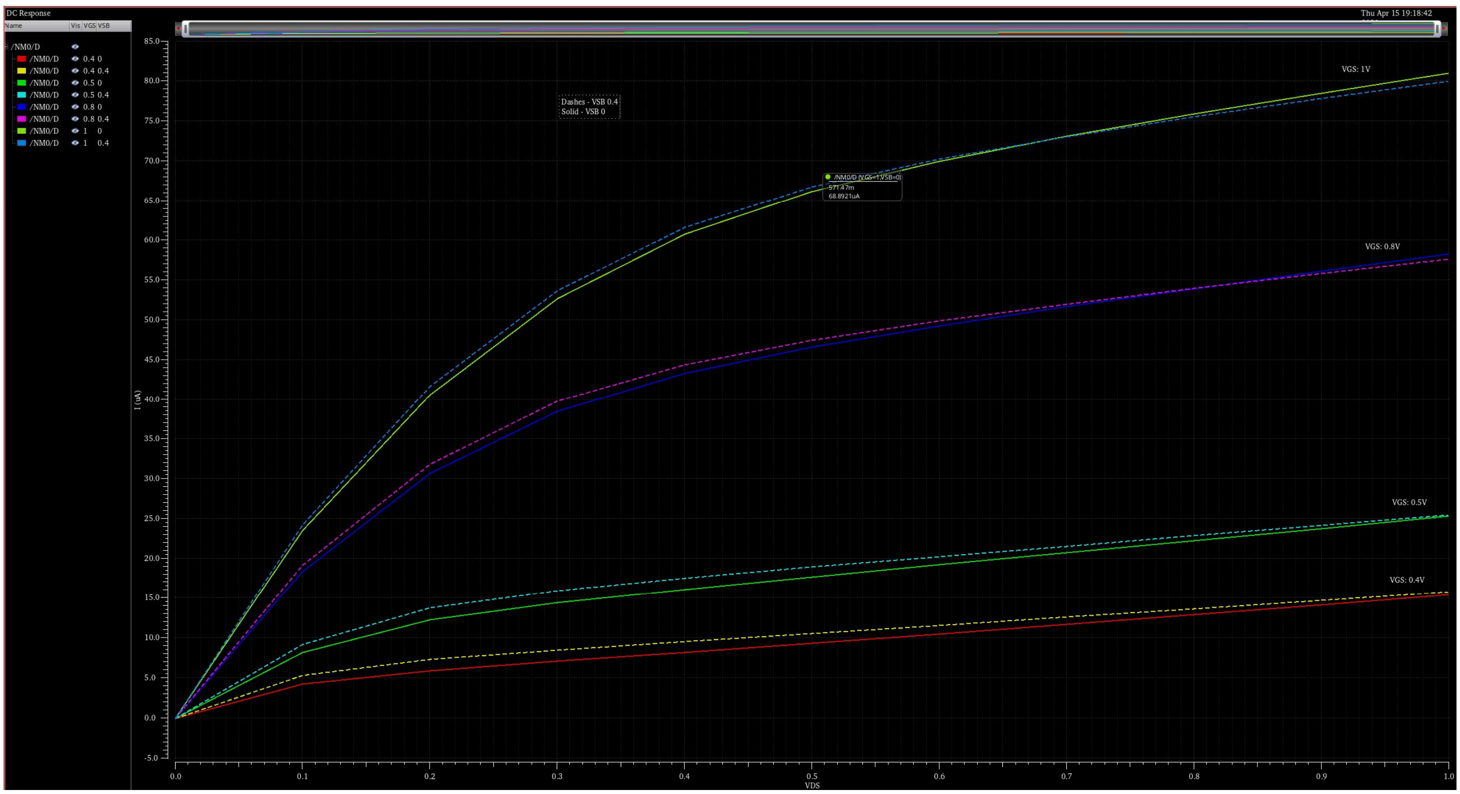
NAME: Chris Baker
UID: 105180929

1A: Using Spectre, generate the family of I-V curves (help: online Tutorial 1.2 on wiki has detailed instructions on how to do this) for an NMOS transistor with the following parameters: W/L = 120nm/100nm Sweep VDS from 0V to 1V in 100mV increments VGS = 0.4V, 0.5V, 0.8V, 1.0V VSB = 0V, 0.4V

In case it is hard to see, I labeled each line with the appropriate VGS value on the right from the top being 1.0 V to the bottom being the 0.4 V. The dashed lines and solid lines distinguish between the VDS values of 0 and 0.4 V .



1B

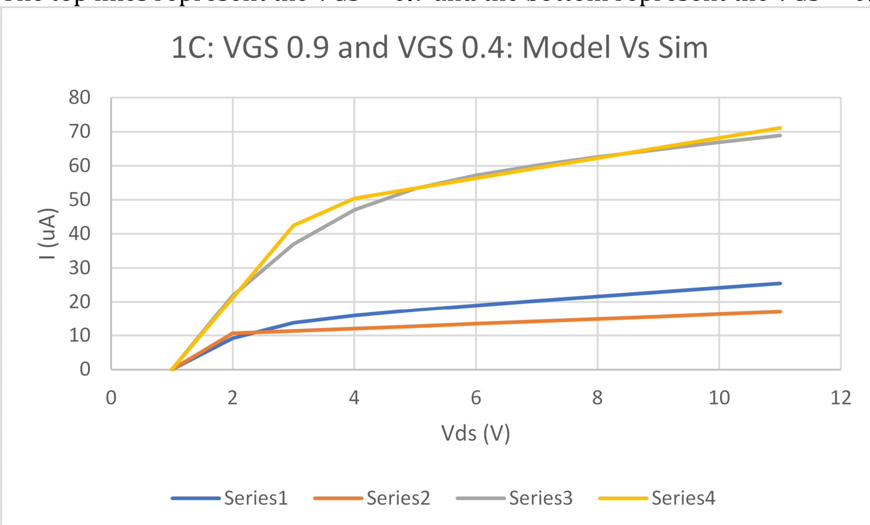
- Find V_{t0}
  - Use different V_{GS} curves with same V_{DS} and current saturation
  - $V_{t0} = \frac{\sqrt{I_B}V_{GSA} - \sqrt{I_A}V_{GSB}}{\sqrt{I_B} - \sqrt{I_A}}$, let $A = \sqrt{I_A}$ and $B = \sqrt{I_B}$
  - Choose 0.6 V_{DS} and 04 and 0.5 V_{GS} , Current were around 19 and 11.1, see graph
  - $V_{t0} = \frac{.4B - .5A}{B - A} = .117\ V$
- Find V_T
  - Similar approach but use Non zero $V_{SB} = 0.4$ here
  - Choose 0.6 V_{DS} and 04 and 0.5 V_{GS} , Current were around 20 and 11.25, see graph
  - $V_T = \frac{.4B - .5A}{B - A} = .089\ V$
- Find γ
  - Use Formula, plug in Vt0 and VT from above. $|2\Phi_f|$ is given as 0.6
  - $\gamma = \frac{V_T - V_{t0}}{\sqrt{|V_{SB}|\ - 2\Phi_f} - \sqrt{-2\Phi_f}} = -.1021$

- *Find λ*
  - *Use 2 points from same V_GS with differ V_DS {.5 and .8} values and formula.*
  - *Using VGS: 0.8 . B = 53.966 , A = 46.6144 .*
  - $\lambda = \frac{I_B - I_A}{V_B I_A - V_A I_B} = \frac{B - A}{.8A - .5B} = \boxed{.713\ V^{-1}}$
- *Find K'*
  - *Use Saturation and formula*
  - $K' = \frac{\frac{L}{W}(2I_D)}{(V_{GS} - V_{t0})^2(1 + \lambda V_{DS})} = \frac{\left(\frac{70}{120}\right)(2 * 20.276)}{(0.5 - .117)^2(1 + .713 * 0.6)} = \boxed{112.944}$

1C

Using the parameters from 1B and running a simulation as well as my own analysis I have the following graph.

The top lines represent the VGS = 0.9 and the bottom represent the VGS = 0.4 V



I notice the fit is probably not as good as it could be, so there is a possibility that there could be better points used in parts of 1B to better estimate parameter values. Further, I notice that the curves have a couple intersection points where they switch past each other. Probably the most important idea is that the current in the model generally has smaller magnitude in VGS saturation when compared with the simulation values.

2

Below is a table of measurements performed on a newly fabricated MOS transistor. We would like to extract information about MOS parameters from these measurements.

Measurement Number	V_{GS}	V_{DS}	V_{SB}	I_D	Operation Region
1	–0.3 V	–0.7 V	0	–12.05 μA	
2	0.3 V	–0.7 V	0	0.0	
3	–0.7 V	–0.7 V	0	–88.98 μA	
4	–0.4 V	–0.6 V	0	–26.42 μA	
5	–0.3 V	–0.6 V	–0.5V	–7.17 μA	
6	–0.7 V	–0.4 V	0	–76.45 μA	
7	–0.7 V	–0.2 V	0	–53.21 μA	

You may assume that $|V_{DSAT}| = 0.4V$ and $2\Phi_F = –0.6V$.

2A

The device is a PMOS because PMOS needs negative voltage between GS to conduct current from DS. Most of the values are negative which matches this intuition and concept.

2B

- Find V_{t0}
  - Use different V_{GS} curves with same V_{DS} and current saturation

$_{GSA}$ $_{GSB}$
$_{t0}$

- $V_{t0} = \frac{\sqrt{I_B}V_{GSA} - \sqrt{I_A}V_{GSB}}{\sqrt{I_B} - \sqrt{I_A}}$, $let\ A = \sqrt{I_A}\ and\ B = \sqrt{I_B}$
- Points 1 and 4: 26.42 and 12.05 uA |currents|
- $V_{t0} = \frac{-0.3B - -0.4A}{B - A} = -0.92\ V$

- *Find* V_T
  - Similar approach but use Non zero $V_{SB} = -0.5$ here
  - Use points 4 and 5: |currents| of 7.17 and 26.42
  - $V_T = \frac{-0.4B - -0.3A}{B - A} = -0.191\ V$
- *Find* γ
  - *Use Formula, plug in Vt0 and VT from above.* $|2\Phi_f|$ *is given as 0.6*
  - $\gamma = \frac{V_T - V_{t0}}{\sqrt{|V_{SB}| - 2\Phi_f} - \sqrt{-2\Phi_f}} = -\frac{.099}{\sqrt{.11} - \sqrt{.6}} = .223\ V^{\frac{1}{2}}$
- *Find* λ
  - *Use 2 points from same V_GS with differ V_DS {.5 and .8} values and formula.*
  - *Using VGS: -0.7 , Points 7 and 3 : |Currents| of 53.21 and 88.98 uA*
  - $\lambda = \frac{I_B - I_A}{V_B I_A - V_A I_B} = \frac{53.21 + 88.98}{-0.2(88.98) + 0.7(53.21)} = 1.84\ V^{-1}$

2C

PMOS -> Vmax() , Vgt = Vsg + Vt -> Sat

Vgt	Vds	Vdsat	Op Rgn
-.11	-.7	-.4	SAT
-	-	-	Off
-.51	-.7	-.4	Vel SAT
-.21	-.6	-.4	SAT
-.11	-.6	-.4	SAT
-.51	-.4	-.4	Cutoff or Lin/Vel Sat
-.51	-.2	-.4	Linear

3

Use the following table (replacing TABLE 3-5 in the textbook).

Assumptions:

$|V_{TH}| = 0.2V$ for both NMOS and PMOS

For the purpose of capacitance calculation (only), treat velocity saturation as saturation

Param.	**C_{ox} [fF/µm²]**	**C_o [f/µm]**
NMOS	15	0.27
PMOS	14	0.25

3A What is the tox (nm) of the NMOS transistor?

3B Consider a PMOS biased with $V_G = V_D = V_S = V_B = 0V$
Assume W = 360 nm, L = 120nm, $L_D = L_S = 240nm$
Calculate the following capacitances:
(B1) Gate-to-Channel capacitance (C_{GC})
(B2) Gate-to-Source capacitance (C_{GS})

3C Consider an NMOS biased with $V_G = V_D = 0.8V$, $V_S = V_B = 0V$
Assume W = 120 nm, L = 120nm, $L_D = L_S = 240nm$
Calculate the following capacitances:
(C1) Gate-to-Channel capacitance (C_{GC})
(C2) Gate-to-Source capacitance (C_{GS})

Clearly indicate your final formulas and circle/highlight your answers.

3A:

$$t_{ox} = \frac{e_{ox}}{c_{ox}} \to 3.5 * \frac{10^{-13}}{15} = 2.33nm = t_{ox}$$

3B: Cutoff region

$C_{GC} = WLC_{ox} = .36 * .12 * 14 = .6048\, fF = C_{GC}$

$C_{GS} = C_{GCS} + C_{GCO} \rightarrow 0 + C_{GSO} = WC_o = .36 * .25 = .09\, fF = C_{GS}$

3C: Vel Sat Region

$C_{GC} = \frac{2}{3WLC_{ox}} = \frac{2}{3} * .12 * .12 * 15 = .144\, fF = C_{GC}$

$C_{GS} = C_{GCS} + C_{GCO} \rightarrow C_{GC} + C_{GSO} = .144 + WC_o = .144 + (.12 * .25) = .174\, fF = C_{GS}$