1 Problem 1

1.1 (a)

$$A_v = -\sqrt{\frac{\mu_n(W/L)_1}{\mu_p(W/L)_2}}$$

$$-5 = -\sqrt{\frac{350(x/2)}{100(5/2)}}$$

$$x = 35.7\mu m$$

$$V_{TH} = 0.7V$$

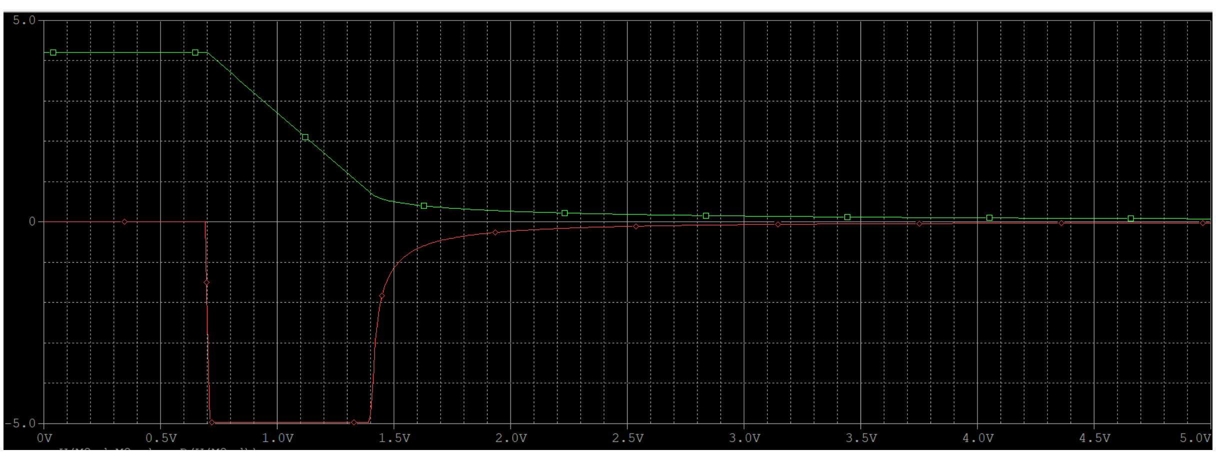
$$\mu_n C_{ox}(\frac{W}{L})_1(V_{in1} - V_{TH1})^2 = \mu_p C_{ox}(\frac{W}{L})_2(V_{DD} - (V_{in1} - V_{TH1}) - V_{TH2})^2$$

$$0.035 * \frac{35.7}{2 - 2 * 0.08} * (V_{in1} - 0.7)^2 = 0.01 * \frac{5}{2 - 2 * 0.09} * (5 - (V_{in1} - 0.7) - 0.8)^2$$

$$V_{in1} = 1.4V$$

The range for V_{in} is (0.7, 1.4)V.

1.2 (b)



This is the plot of V_{out} and A_v vs V_{in}, when V_{in} is about 1V, A_v is very close to the calculated value, and the the V_{out} is in saturation region when V_{in} is in my calculated region.

1.3 (c)

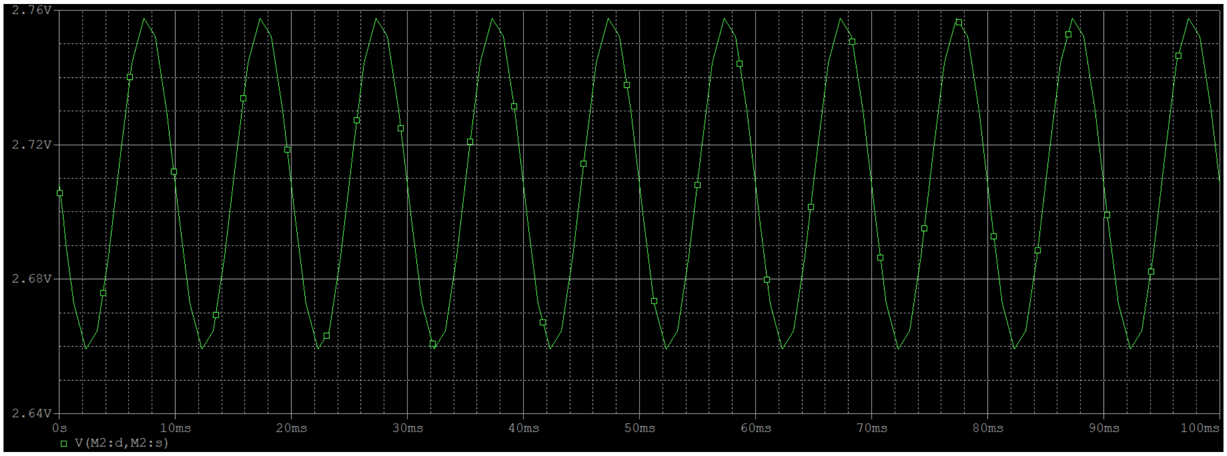


Figure 1: V_{in} has amplitude 0.01V

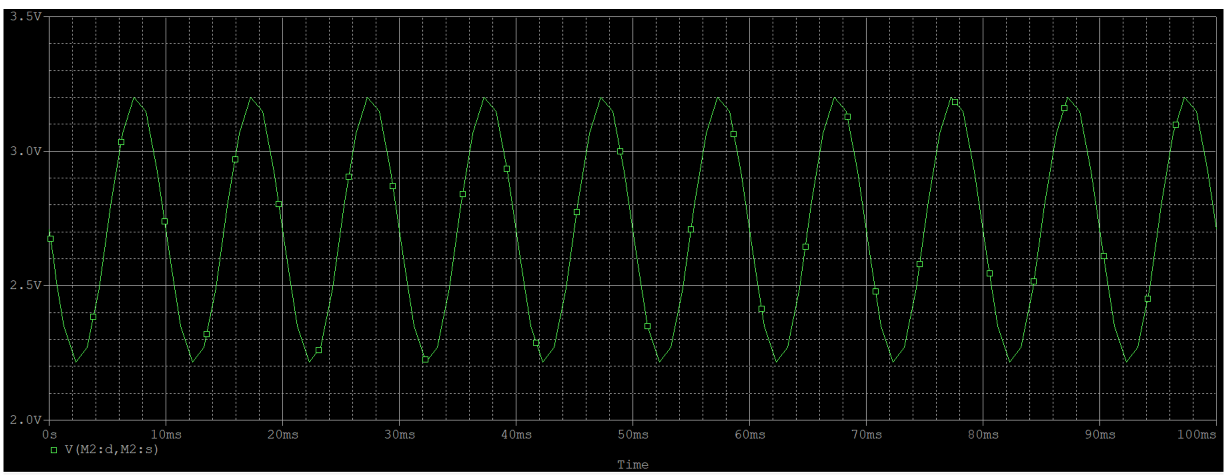


Figure 2: V_{in} has amplitude 0.1V

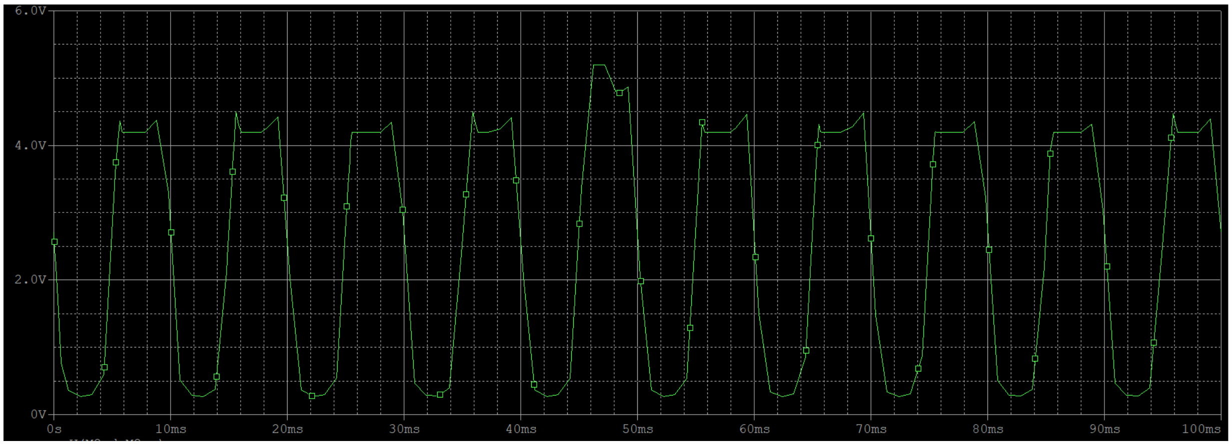


Figure 3: V_{in} has amplitude 1V

In Figure 3, the V_{in} is so large so that the nmos is no longer in saturation region, then it seems the upper part of the plot has been cut off

2 Problem 2

2.1 (a)

For the circuit, assume $V_{out} > V_{in} - V_{TH}$

$$V_{out} = V_{DD} - I_c R_D = 5 - 100000 I_c$$

$$I_c = \frac{1}{2}\mu_n C_{ox}(\frac{W}{L})_1(V_{in1} - V_{TH1} - I_c R_s)^2 = 7.3 \times 10^{-3} * (V_{in} - 0.7 - 20000 I_c)^2$$

$$A_v = \frac{\mathbf{dV_{out}}}{\mathbf{dV_{in}}} = \frac{\frac{\mathbf{dV_{out}}}{\mathbf{dI_c}}}{\frac{\mathbf{dV_{in}}}{\mathbf{dI_c}}} = \frac{-100000}{20000 + 5.85 * I_c^{-0.5}}$$

When $V_{in} = 1.2V$, $I_c = 2.81 \times 10^{-5}(A)$

$$A_v = \frac{\mathbf{dV_{out}}}{\mathbf{dV_{in}}} = \frac{-100000}{20000 + 1103.5} = -4.7$$

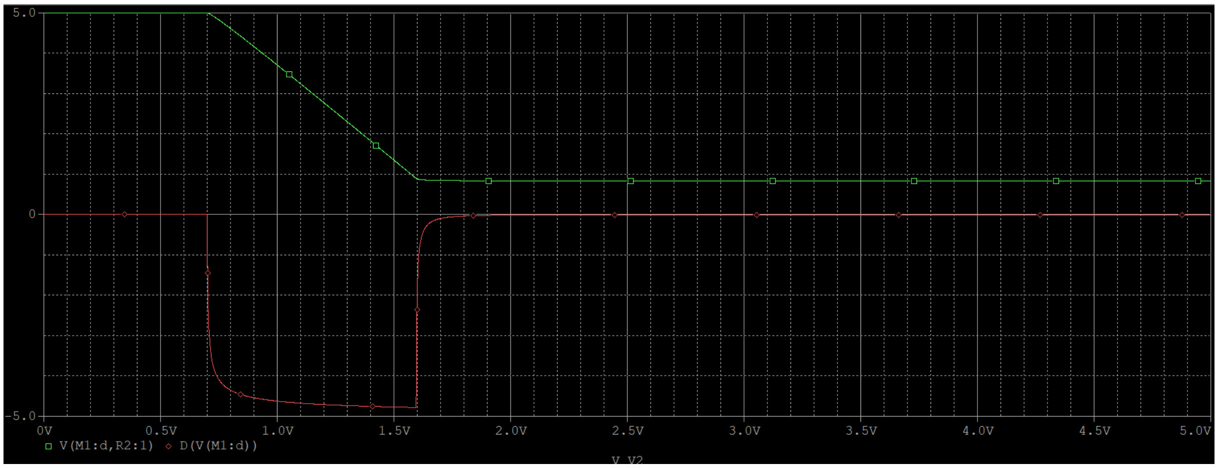
$$gm_1 = \mu_n C_{ox}(\frac{W}{L})_1(V_{in1} - V_{TH1})^2 = 0.035 * \frac{3.9 * 8.85 * 10^{-12}}{9 * 10^{-9}} * \frac{200}{2 - 2 * 0.08} * (1.2 - 0.7)^2 = 3.65 \times 10^{-3}$$

Since $\lambda = 0$, then $r_{o1} = \infty$. Also $\gamma = 0$, then $gm_1 = 0$, so the voltage gain will become

$$A_v = -\frac{R_D}{R_S} = \frac{100}{20} = 5$$

The to A_v are very close to each other.

2.2 (b)



This is the plot of V_{out} and A_v vs V_{in}, when V_{in} is about 1.2V, $A_v = -4.7$, which is very close to the calculated value.

2.3 (c)

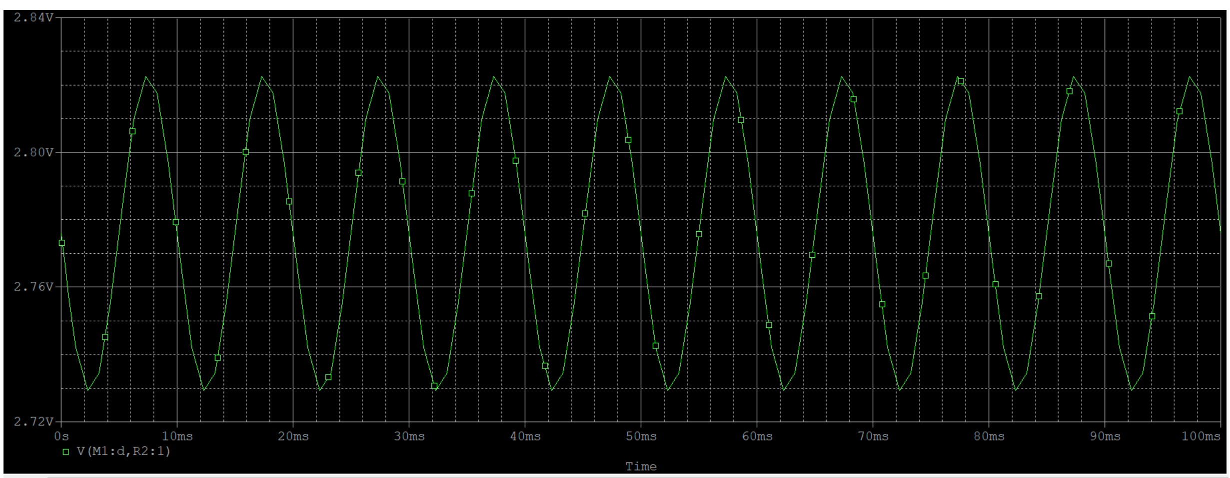


Figure 4: Plot of V_{out} vs t