1 (a)

1.1 (i)

When the nmos is in the saturation region, $I_x = \frac{1}{2}\mu_n C_{ox}(\frac{W}{L_{eff}})_1(V_a - V_{TH})^2$

$$R_{out} = \frac{\mathrm{d}V_x}{\mathrm{d}I_x} = r_{01} = \frac{1}{I_x * \lambda} = \frac{1}{\frac{1}{2}\mu_n C_{ox}(\lambda\frac{W}{L_{eff}})_1(V_a - V_{TH})^2}$$

1.2 (ii)

$$R_{out} = \frac{\mathrm{d}V_x}{\mathrm{d}I_x} = r_{o1} + r_{o2} + gm_2 r_{o1} r_{o2}$$

Assume the voltage between the two nmos is V_D, then

$$R_{out} = \frac{1}{I_{d1}\lambda_1} + \frac{1}{I_{d2}\lambda_2} + \frac{2I_x}{I_{d1}I_{d2}\lambda_1\lambda_2(V_b - V_D - V_{TH})}$$

$$I_x = \frac{1}{2}\mu_n C_{ox}(\frac{W}{L_{eff}})_1(V_a - V_{TH})^2(1+\lambda V_D) = \frac{1}{2}\mu_n C_{ox}(\frac{W}{L_{eff}})_2(V_b - V_D - V_{TH})^2(1+\lambda(V_X - V_D))$$

$$I_{d1} = \frac{1}{2}\mu_n C_{ox}(\frac{W}{L_{eff}})_1(V_a - V_{TH})^2$$

$$I_{d2} = \frac{1}{2}\mu_n C_{ox}(\frac{W}{L_{eff}})_2(V_b - V_{TH} - V_D)^2$$

2 (b)

2.1 (i)

$$R_{out} = \frac{1}{0.5 * 0.035 * \frac{3.9*8.85*10^{-12}}{9*10^{-9}} * \frac{20}{2-2*0.08} * (1.2-0.7)^2 * 0.1} = 54833\Omega$$

2.2 (ii)

$$20 * (1.2-0.7)^2 * (1 + 0.1 * V_D) = 100 * (2.2 - 0.7 - V_D)^2 * (1 + 0.1 * (2 - V_D))$$

$$V_D = 1.271V$$

$$I_{d1} = 0.5 * 0.035 * \frac{3.9 * 8.85 * 10^{-12}}{9 * 10^{-9}} * \frac{20}{2 - 2 * 0.08} * (1.2 - 0.7)^2 = 1.824 \times 10^{-4}A$$

$$I_{d2} = 0.5 * 0.035 * \frac{3.9 * 8.85 * 10^{-12}}{9 * 10^{-9}} * \frac{100}{2 - 2 * 0.08} * (2.2 - 0.7 - 1.271)^2 = 1.913 \times 10^{-4} A$$

$$I_x = I_{d1} * (1 + 0.1 * 1.271) = 2.06 \times 10^{-4} A$$

$$R_{out} = \frac{1}{0.1 \times 1.824 \times 10^{-4}} + \frac{1}{0.1 \times 1.913 \times 10^{-4}} + \frac{2 \times 2.06 \times 10^{-4}}{0.01 \times 1.824 \times 1.913 \times 10^{-8} \times (2.2 - 1.27 - 0.7)}$$

$$R_{out} = 5240688\Omega$$

3 (c)

3.1 (i)

$V_X > V_A - V_{TH} = 1.2 - 0.7 = 0.5V$

3.2 (ii)

Assume both of the nmos are in saturation region, then $V_D > 0.5V$, $V > 1.5V$

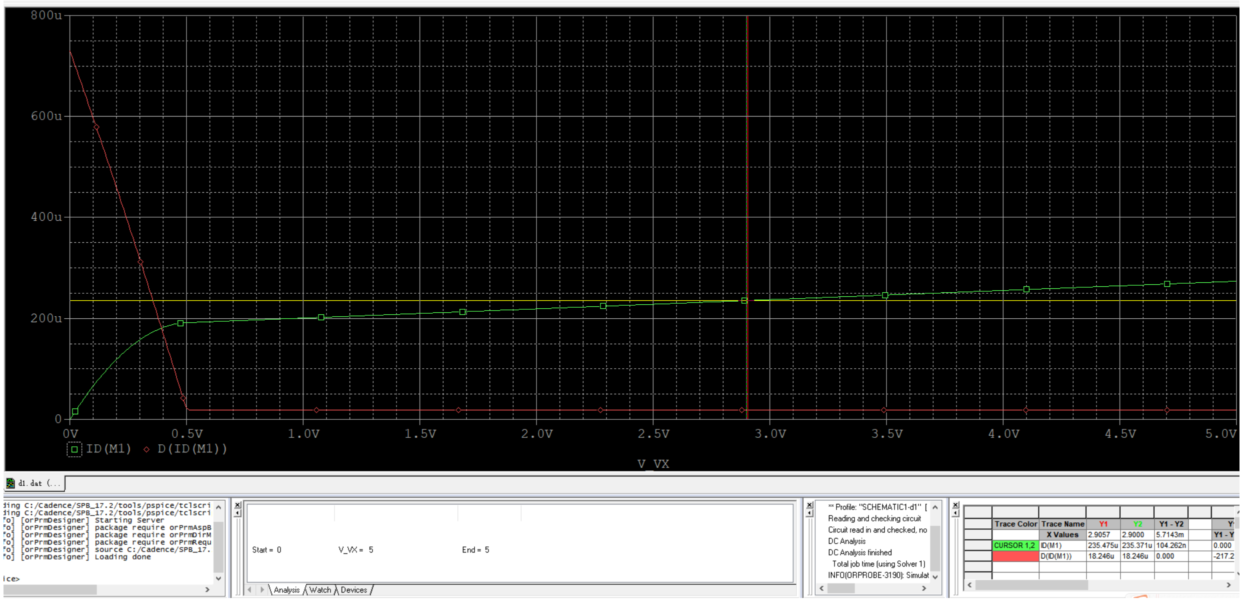
$$I_x = \frac{1}{2}\mu_n C_{ox}(\frac{W}{L_{eff}})_1 (V_a - V_{TH})^2 (1 + \lambda V_D) = \frac{1}{2}\mu_n C_{ox}(\frac{W}{L_{eff}})_2 (V_b - V_D - V_{TH})^2 (1 + \lambda(V_X - V_D))$$

$$20 * 0.5^2 * (1 + 0.1 V_D) = 100 * (1.5 - V_D)^2 (1 + 0.1 * (V - V_D))$$

When $V_D = 0.5V$, $V_x = -9.375V$
When $V_x = 1.5V$, $V_D = 1.265V$
So the minimum voltage for V_x is $1.5V$

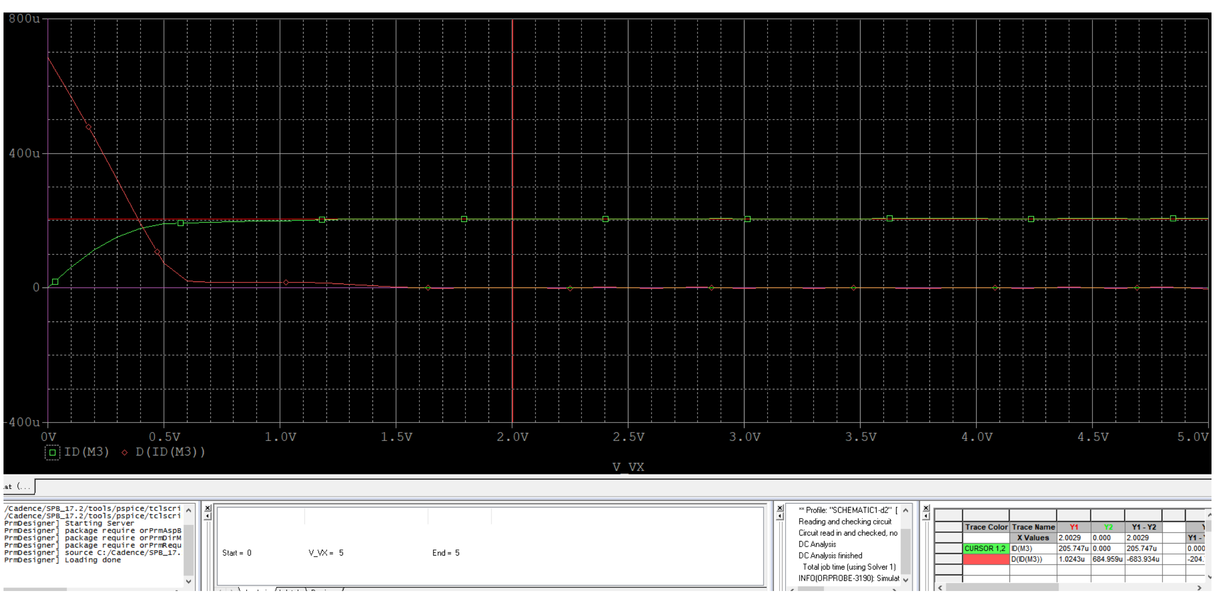
4 (d)

4.1 (i)



The voltage for saturation is about 5V and the output impedance is $\frac{1}{18.246\times10^{-6}} = 54806\Omega$, which is very close to my calculated value.

4.2 (ii)



The voltage for saturation is about $1.5V$ and the output impedance is $\frac{1}{1.024\times10^{-6}} = 976562\Omega$, which is very much smaller than my calculated value.