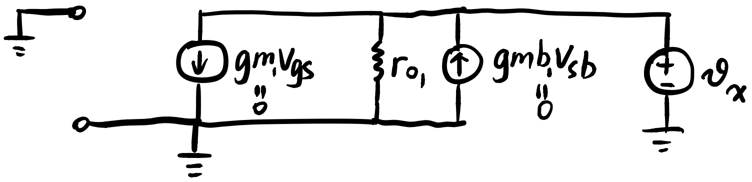
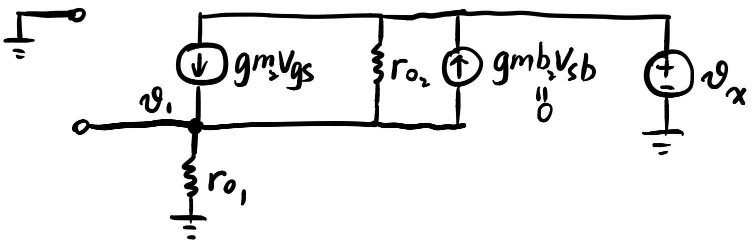
VE311 HW8 周弦凯 518021911039

(a).(i).



$R = r_{o1}$

(ii).



$$\frac{v_1}{r_{o1}} = \frac{v_x - v_1}{r_{o2}} + g_{m2}(0 - v_1)$$

$$v_1 = \frac{r_{o1} v_x}{r_{o1} + r_{o2} + r_{o1} r_{o2} g_{m2}}$$

$$i_x = \frac{v_1}{r_{o1}} = \frac{v_x}{r_{o1} + r_{o2} + r_{o1} r_{o2} g_{m2}}$$

$$R = \frac{v_x}{i_x} = r_{o1} + r_{o2} + r_{o1} r_{o2} g_{m2}$$

(b).(i). $V_{GS} = 1.2V > V_{TH} = 0.7V$

$V_{DS} = 2V > V_{GS} - V_{TH} = 0.5V$

Therefore, M1 is in saturation region.

$$R = r_{o1} = \frac{1}{\frac{1}{2}\mu_n C_{ox} \frac{W}{L_{eff}} (V_{GS} - V_{TH})^2 \cdot \lambda} = 54833.30\ \Omega$$

(ii). $\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L_{eff}}\right)_2 (V_b - V_o - V_{TH2})^2 (1 + \lambda(V_x - V_o)) = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L_{eff}}\right)_1 (V_a - V_{TH1})^2 (1 + \lambda V_o)$

$V_o^3 - 15V_o^2 + 38.3V_o - 26.5 = 0$

$V_o = 11.99V$ or $1.74V$ or $1.27V$

Only $V_o = 1.27V$ can make M1 and M2 both in saturation.

$$r_{o2} = \frac{1}{\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L_{eff}}\right)_2 (V_{GS} - V_{TH})^2 \cdot \lambda} = 51827.32\ \Omega$$

$$g_{m2} = \mu_n C_{ox}\left(\frac{W}{L_{eff}}\right)_2 (V_{GS} - V_{TH})(1 + \lambda V_{DS}) = 1.80 \times 10^{-3}\ \Omega$$

$$R = r_{o1} + r_{o2} + r_{o1} r_{o2} g_{m2} = 5.22 \times 10^6\ \Omega$$

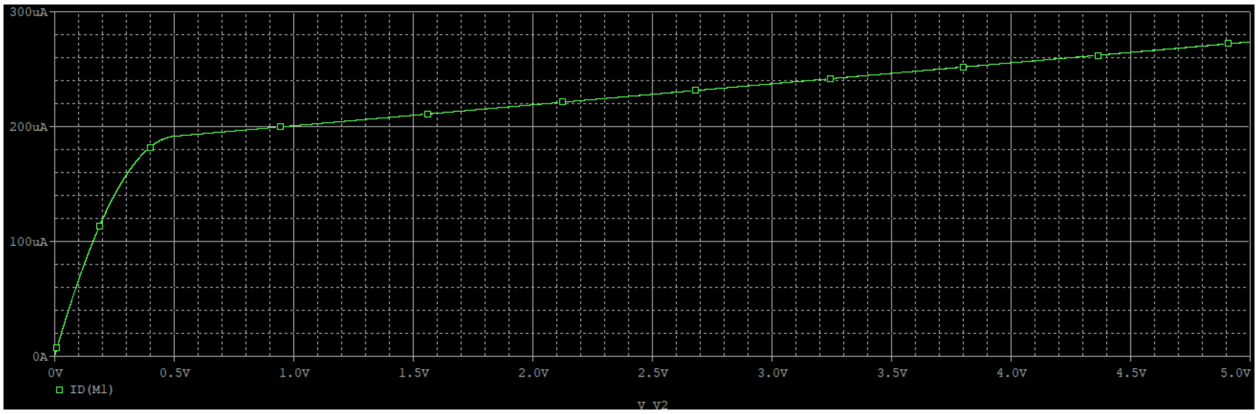
(c). (i). $\begin{cases} V_{GS} > V_{TH} \\ V_{DS} > V_{GS} - V_{TH} \end{cases} \Rightarrow V_x > 0.5\,V$

Therefore, $V_{x\,min} = 0.5\,V$

(ii). $\begin{cases} V_{GS1} > V_{TH} \\ V_{GS2} > V_{TH} \\ V_{DS1} > V_{GS1} - V_{TH} \\ V_{DS2} > V_{GS2} - V_{TH} \end{cases} \Rightarrow V_x > 1.5\,V$

Therefore, $V_{x\,min} = 1.5\,V$

(d). (i).

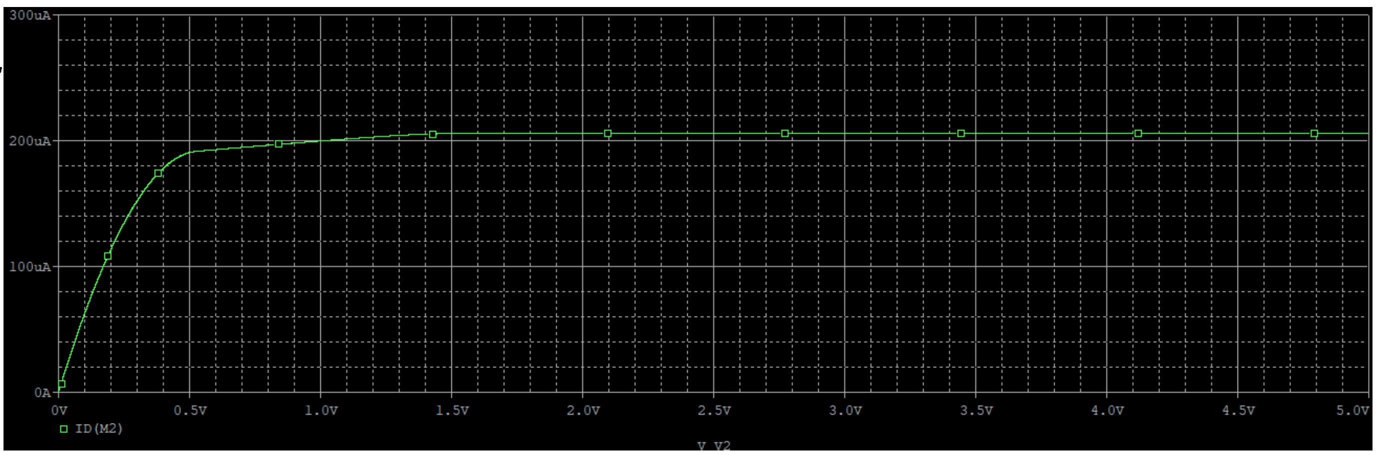


Around 0.5V, the slope becomes almost constant.

We can get $(1.7080, 213.612\times10^{-6})$ $(2.9680, 236.582\times10^{-6})$

$\frac{1}{slope} = 54854.2$, close to the value calculated previously.

(ii).



Around 1.5V, the slope becomes almost constant.

We can get $(1.8641, 205.619\times10^{-6})$ $(4.84, 206.101\times10^{-6})$

$\frac{1}{slope} = 6174066$, close to the value calculated previously.