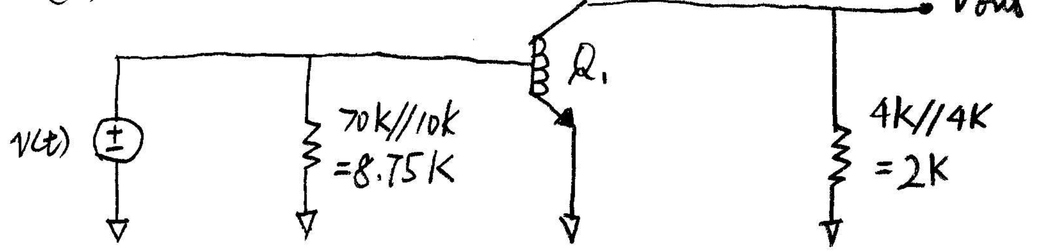
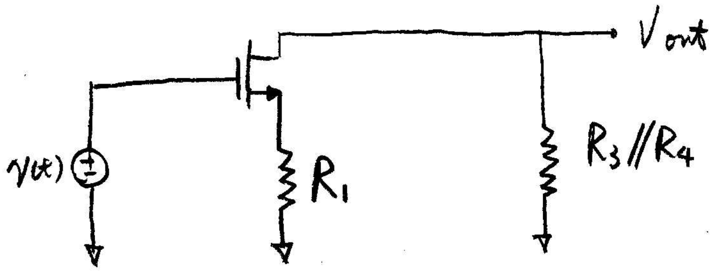
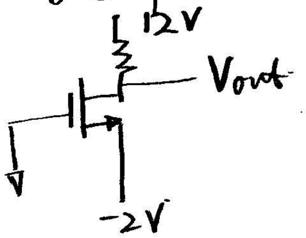
P1 (a)



(b)



P2 DC equivalent



Assume in Saturation.

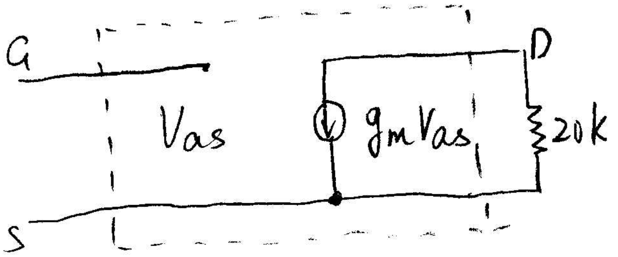
$$I_{DQ} = \frac{uC_{ox}W}{2L}(V_{GSQ} - V_T)^2$$

$$= 0.2mA$$

$$V_{outQ} = 12 - 20k \cdot 0.2mA = 12 - 4 = 8V$$

Hence $V_{DS} = 8 - (-2) = 10V > V_{GS} - V_T$, assumption holds

small signal model.

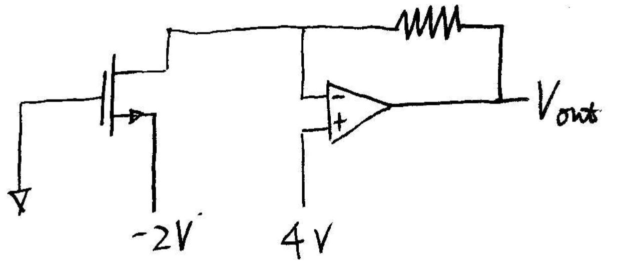


$$g_m = uC_{ox}\frac{W}{L}(V_{GSQ} - V_T)$$

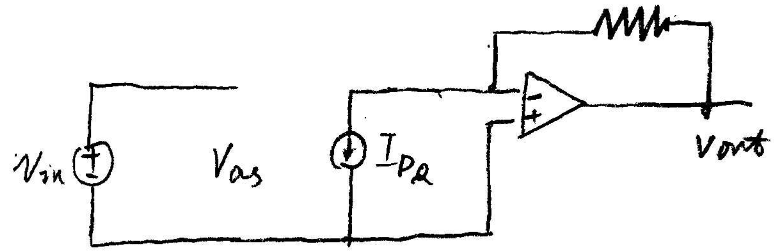
$$= 4\times10^{-4}$$

$$\text{gain} = \frac{V_{out}}{V_{in}} = -g_m \cdot 20k = -8$$

P3 DC equivalent:



Small Signal:



assume saturation

$$I_{DQ} = \frac{\mu C_{ox} W}{2L} (V_{GSQ} - V_T)^2$$
$$= 0.2\,mA$$

$V_{out} = 4V + 0.2 \cdot 20k = 8V$

assumption holds

$$gain = \frac{I_{DQ} \cdot R}{V_{GS}} = 8 \qquad \Rightarrow V_{out} = V_{outQ} + 8 \cdot V_{in}(t)$$
$$= 8 + 0.8 \sin(2000\pi t)$$

P4. (a) $I_{DQ} = \frac{\mu C_{ox} W}{2L} (V_{GSQ} - V_T)^2 = 1\,mA$

$$\Rightarrow V_{GSQ} - V_T = \sqrt{2}\ V$$

$$\therefore R = \frac{\partial V_{DS}}{\partial I_D} = \frac{1}{\left(\frac{\partial I_D}{\partial V_{DS}}\right)} = \frac{1}{g_m}$$

$$g_m = \frac{\partial I_D}{\partial V_{DS}} = \mu C_{ox} \frac{W}{L} (V_{GSQ} - V_T) = \frac{\mu C_{ox} W}{2L} (V_{GS} - V_T)^2 \cdot \frac{2}{V_{GS} - V_T} = \frac{2m}{\sqrt{2}}$$

$$\therefore R = \frac{\sqrt{2}}{2} \cdot 1000 \approx 707\,\Omega$$

(b) $R = \dfrac{V_{CE}}{i_B + i_C}$ $\because V_{CE} = V_{BE}$. $g_\pi = \dfrac{I_{CQ}}{\beta V_T}$, $g_m = \dfrac{I_{CQ}}{V_T}$

$$\Rightarrow R = \frac{V_{BE}}{g_\pi V_{BE} + g_m V_{BE}} = \frac{1}{g_\pi + g_m} = \frac{1}{\left(\frac{1m}{100} + 1m\right)} \approx 990\,\Omega$$

P5 (a)

$$i_1 = y_{11} v_1 + y_{12} v_2 \qquad \text{where } v_1 = V_1 - V_{1Q}$$
$$i_2 = y_{21} v_1 + y_{22} v_2. \qquad v_2 = V_2 - V_{2Q}.$$

$$y_{11} = \left.\frac{\partial I_1}{\partial V_1}\right|_{\substack{V_1 = V_{1Q} \\ V_2 = V_{2Q}}} = V_{2Q}^3 \qquad y_{12} = \left.\frac{\partial I_1}{\partial V_2}\right|_{\substack{V_1 = V_{1Q} \\ V_2 = V_{2Q}}} = 3V_{1Q} V_{2Q}^2$$

$$y_{21} = \left.\frac{\partial I_2}{\partial V_1}\right|_{\substack{V_1 = V_{1Q} \\ V_2 = V_{2Q}}} = 0 \qquad y_{22} = \left.\frac{\partial I_2}{\partial V_2}\right|_{\substack{V_1 = V_{1Q} \\ V_2 = V_{2Q}}} = 0.02 e^{0.2 V_{2Q}}$$

$$\therefore i_1 = V_{2Q}^3 (V_1 - V_{1Q}) + 3 V_{1Q} V_{2Q}^2 (V_2 - V_{2Q})$$
$$i_2 = 0.02 e^{0.2 V_{2Q}} (V_2 - V_{2Q})$$

(b) $y_{11} = 1$, $y_{12} = 15$
$y_{21} = 0$, $y_{22} = 0.02 e^{0.2}$

(c) $I_1 = V_{1Q} V_{2Q}^3 = 5A$, $I_2 = 0.1 \cdot e^{0.2 V_{2Q}} = 0.1 \cdot e^{0.2} \approx 122mA$

(d) $i_1 = 1 \cdot 1 + 15 \cdot 2 = 31\ mA$
$i_2 = 0.02 e^{0.2 \cdot 0.002} \approx 48.9\ uA$

P6 ⓐ

$V_{GSA} = 2V$
$V_{DSA} = 0 < V_{GSA} - V_T$ } in triode region

$$R_{FET} = \frac{L}{\mu C_{ox} W (V_{GS} - V_T)} = \frac{1\mu}{100\mu \cdot 16\mu} = 625$$

$$gain = \frac{V_{out}}{V_{in}} = 1 + \frac{R_F}{R_{FET}} = 1 + \frac{R_F}{625}$$

ⓑ $V_{DS} < V_{GS} - V_T$ for $1.5V \le V_{XX} \le 4$

So transistor is always in triode region.

as $V_{XX} \uparrow$, $R_{FET} \downarrow$, gain $\uparrow$

P7. ⓐ

$V_{DS} < V_{GS} - V_T$ ∴ in triode region

$$R_{FET} = \frac{L}{\mu C_{ox} W (V_{GS} - V_T)} = 2500\Omega$$

$$A(s) = 1 + \frac{R_F // C_F}{R_{FET}} = \frac{s + 5000}{s + 1000}$$

$$\therefore |A(j1000)| = \frac{\sqrt{1000^2 + 5000^2}}{\sqrt{2 \times 1000^2}} = \sqrt{13} \approx 3.61$$

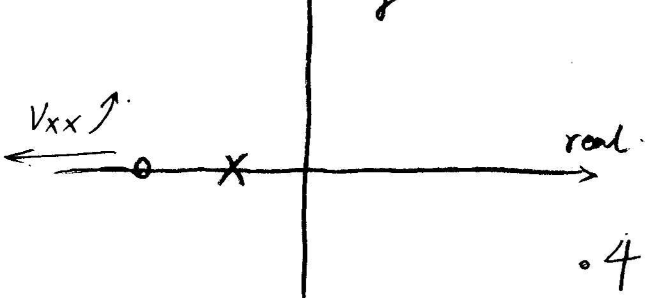
$$\angle A(j1000) = \tan^{-1}\left(\frac{1}{5}\right) - \tan^{-1}(1) = -33.69^\circ$$

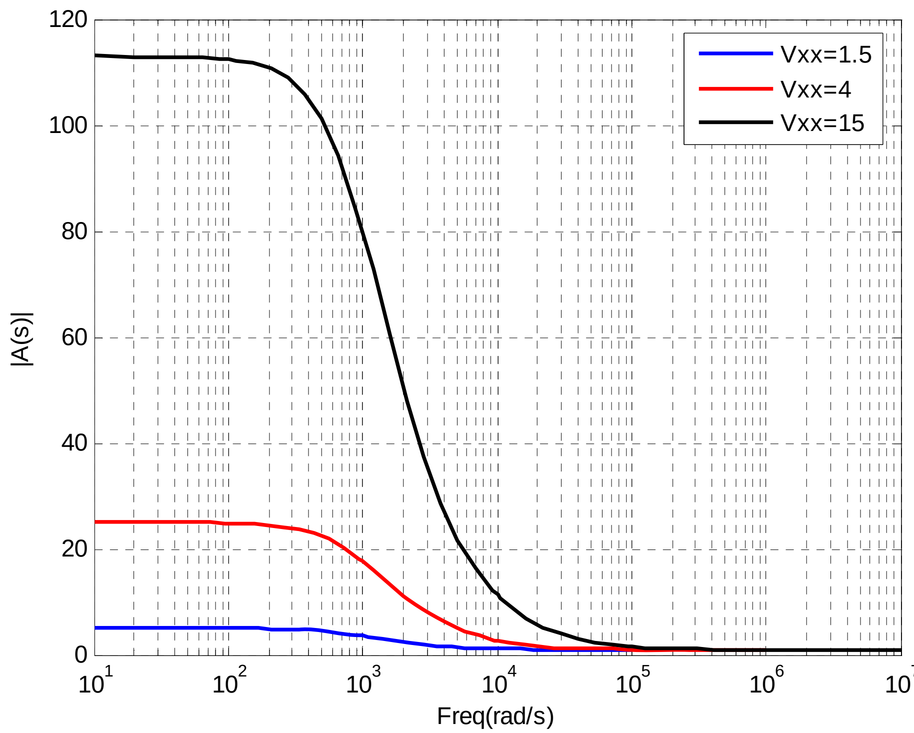
$$\therefore V_{out} = |A(j1000)| \cdot 0.02 \sin(1000t - \angle A(j1000))$$
$$= 0.0722 \cdot \sin(1000t - 33.69^\circ)$$

ⓒ
$$A(s) = \frac{s + 8000V_{XX} - 7000}{s + 1000}$$

poles $s = -1000$

zeros $s = 7000 - 8000V_{XX}$




Vxx=1.5
Vxx=4
Vxx=15
|A(s)|
Freq(rad/s)
120
100
80
60
40
20
0
10^1
10^2
10^3
10^4
10^5
10^6
10^7

P8 (a) $P_a = \dfrac{KAR}{1+R^2}\Bigg|_{R=1} = \dfrac{KA}{2}$

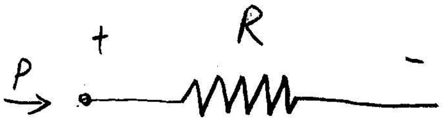
(b) $$P = \frac{KA\,(1+0.1\sin\omega t)}{1+(1+0.1\sin\omega t)^2} \qquad \omega = \frac{2\pi}{30\,year} \ \ldots$$

(c) $$\frac{\partial P}{\partial R}\Bigg|_{R=1} = \frac{KA(1+R^2) - KAR\cdot 2R}{(1+R^2)^2} = \frac{KA(R-1)^2}{(1+R^2)^2} = 0$$

$$P = P_a + \frac{\partial P}{\partial R}\cdot(R-R_a) = \frac{KA}{2}$$

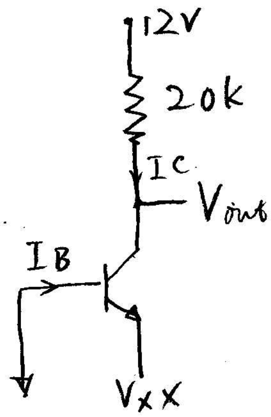
(d) the gain obtained in c is zero, while the gain in b is not zero, they are close, though. This is due to the fact that the small signal model is based on first-order Taylor expansion only.

(e)



$$\frac{\partial P}{\partial R} = \frac{KA(R-1)^2}{(1+R)^2}$$

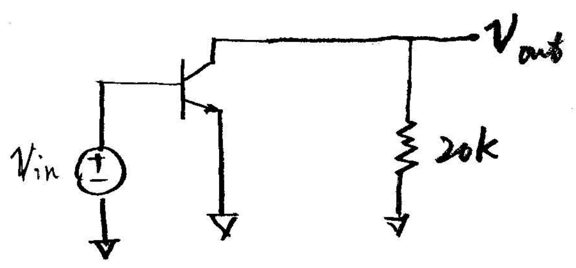
P9. D.C. equivalent

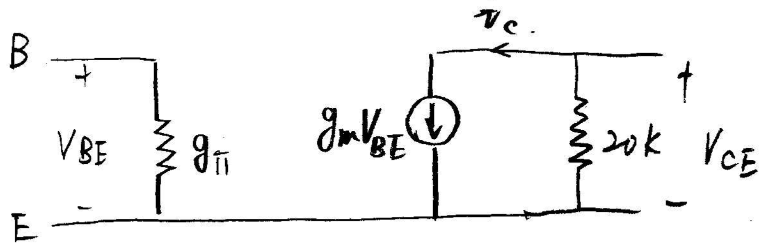


$V_{out} = 12V - I_{CQ} \cdot 20K$

$= 12 - 4 = 8V$

Small Signal





$$\frac{V_{out}}{V_{in}} = \frac{-i_c \cdot R}{V_{BE}} = -g_m R$$

$$= -\frac{I_{CQ}}{V_t} \cdot R$$

$$= -160$$