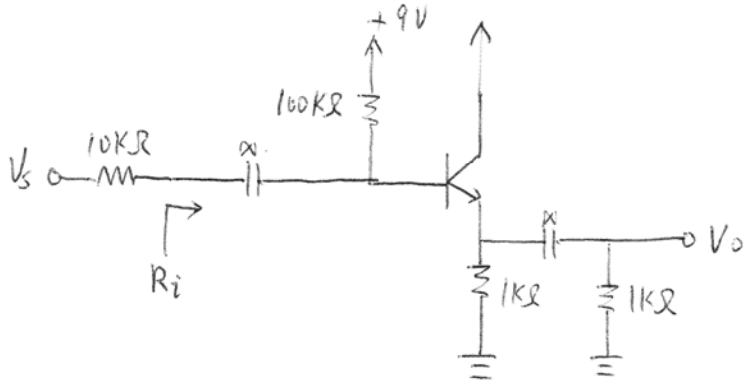
4.91



(a)

For $\beta = 20$
$$I_E = \frac{(9-0.7)V}{\frac{100K\Omega}{\beta+1} + 1K\Omega} = 1.44\,mA$$

$$V_E = I_E \cdot 1K\Omega = 1.44\,V$$

$$V_B = V_E + 0.7 = 2.14\,V$$

For $\beta = 200$
$$I_E = 5.54\,mA$$
$$V_E = 5.54\,V$$
$$V_B = 6.24\,V$$

(b)
$$R_i = 100K\Omega \,//\, [r_\pi + (\beta+1)(1K\Omega // 1K\Omega)] = 100K\Omega // (\beta+1)[r_e + 0.5K\Omega]$$

For $\beta = 20$, $I_E = 1.44\,mA$, $r_e = \frac{V_T}{I_E} = 17.4\,\Omega$, $r_\pi = \frac{V_T}{I_B} = (\beta+1)r_e = 365.4\,\Omega$

$$R_i = 100K\Omega // 21 \cdot [0.0174\,K\Omega + 0.5\,K\Omega]$$
$$= 9.8\,K\Omega$$

For $\beta = 200$, $I_E = 5.54\,mA$, $r_e = 4.51\,\Omega$, $r_\pi = (\beta+1)r_e = 906.51\,\Omega$

$$R_i = 100 // 201\ (0.0045 + 0.5)\ K\Omega.$$
$$= 50.3\,K\Omega$$

(c) $$\frac{V_o}{V_s} = \frac{R_i'}{R_i + R_s} \cdot \frac{1K\Omega // 1K\Omega}{1K\Omega // 1K\Omega + r_\pi / \beta + 1}$$

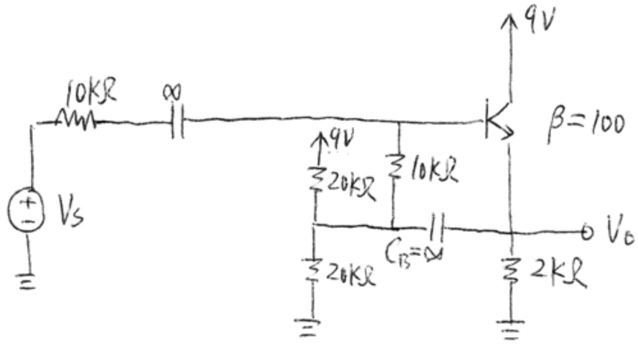
For $\beta = 20$

$$\frac{V_o}{V_s} = \frac{9.8}{9.8 + 10} \cdot \frac{0.5K\Omega}{0.5K\Omega + 0.0174K\Omega} = 0.478$$

For $\beta = 200$

$$\frac{V_o}{V_s} = \frac{50.3K\Omega}{50.3K\Omega + 10K\Omega} \cdot \frac{0.5K\Omega}{0.5K\Omega + 0.0045K\Omega} = 0.827$$

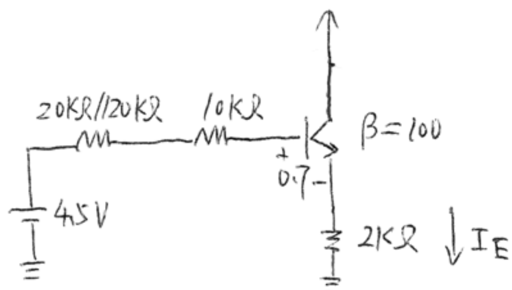
4.95



boot-strapped Follower

(a) DC Analysis

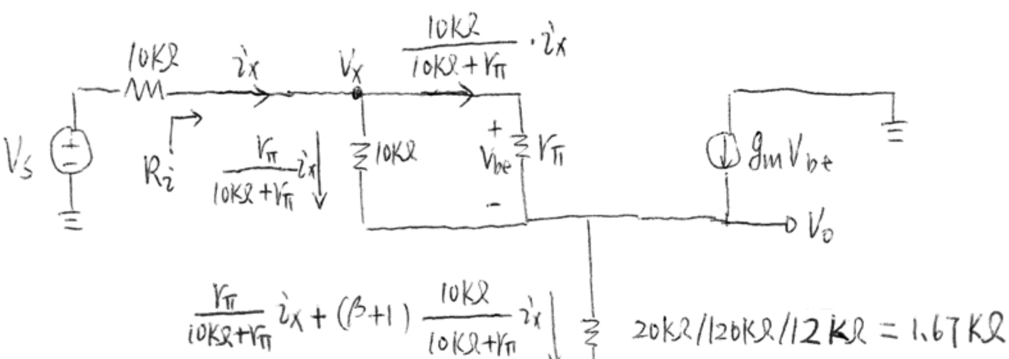
Oringinal Circuit can be simplified as:



$$I_E = \frac{4.5V - 0.7V}{2K\Omega + \dfrac{20K\Omega//20K\Omega + 10K\Omega}{\beta+1}} = 1.73\,mA \qquad I_C = 0.99 I_E = 1.71mA$$

$$g_m = \frac{I_C}{V_T} = 68.5\ mA/V \qquad r_e = \frac{V_T}{I_E} = 14.5\,\Omega \qquad r_\pi = \frac{\beta}{g_m} = 1.46\,K\Omega$$

(b)



input Resistance :

$$V_x = \frac{10K\Omega}{10K\Omega + r_\pi} i_x \cdot r_\pi + \left[(\beta+1)\frac{10K\Omega}{10K\Omega + r_\pi} i_x + \frac{r_\pi}{10K\Omega + r_\pi} \cdot i_x\right] \cdot 1.67K\Omega$$

$$R_i = \frac{V_x}{i_x} = \frac{10K\Omega}{10K\Omega + r_\pi} \cdot \left(r_\pi + (\beta+1) \cdot 1.67K\Omega\right) + \frac{r_\pi}{10K\Omega + r_\pi} \cdot 1.67K\Omega$$

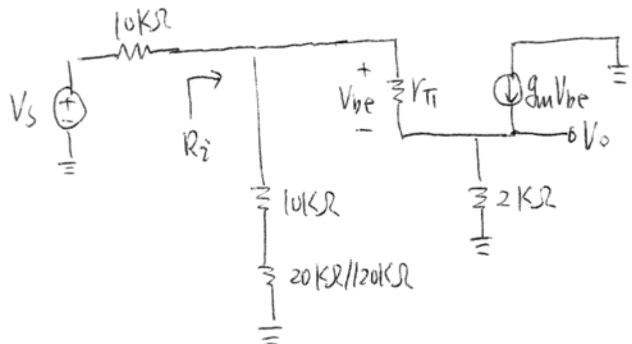
$$= 148.2\ K\Omega$$

$$\frac{V_o}{V_s} = \frac{V_o}{V_x} \cdot \frac{V_x}{V_s}$$

$$= \frac{R_i}{R_i + 10K\Omega} \cdot \frac{\left[(\beta+1)\frac{10K\Omega}{10K\Omega + r_\pi}\cancel{i_x} + \frac{r_\pi}{10K\Omega + r_\pi}\cancel{i_x}\right] \cdot 1.67K\Omega}{\frac{10K\Omega}{10K\Omega + r_\pi}\cancel{i_x} r_\pi + (\beta+1)\frac{10K\Omega}{10K\Omega + r_\pi}\cancel{i_x} \cdot 1.67K\Omega + \frac{r_\pi}{10K\Omega + r_\pi}\cancel{i_x} \cdot 1.67K\Omega}$$

$$= 0.93$$

(c) with C_B open-circuit so that boot-strapping is eliminated, we obtain following equivalent model



$$R_i = (10K\Omega + 20K\Omega // 20K\Omega) \,//\, (r_\pi + (\beta+1) 2K\Omega) = 18.21 K\Omega$$

Now R_i is much Lower than the value obtained with boot-strapping

$$\frac{V_o}{V_s} = \frac{R_i}{R_i + 10K\Omega} \cdot \frac{(\beta+1) 2K\Omega}{r_\pi + (\beta+1) 2K\Omega} = 0.64$$

Gain is much Lower than the value obtained with boot-strapping Due to Lower R_i. Boot-strapping raises the component of input Resistance due to the base biasing network

5.6 From Table 5.1 $k_n' = 100\,\mu A/V^2$ for $t_{ox} = 20\,nm$

(a) $V_{DS} \leq V_{GS} - V_t \Rightarrow$ triode region

$$i_D = k_n' \frac{W}{L} \left[(V_{GS} - V_t) V_{DS} - \frac{1}{2} V_{DS}^2 \right]$$

$$= 100 \times 10^{-6} \times 10 \left[(5 - 0.8) \times 1 - \frac{1}{2} 1 \right]$$

$$= 5.7\,mA$$

(b) $V_{DS} = V_{GS} - V_t \Rightarrow$ saturation

$$i_D = \frac{1}{2} k_n' \frac{W}{L} (V_{GS} - V_t)^2$$

$$= \frac{1}{2} \times 100 \times 10^{-6} \times 10 (2 - 0.8)^2 = 0.72\,mA$$

(c) $V_{DS} < V_{GS} - V_t \Rightarrow$ triode

$$i_D = 100 \times 10^{-6} \times 10 \left[(5 - 0.8)\, 0.2 - \frac{1}{2} \times 0.2^2 \right]$$

$$= 0.82\,mA$$

(d) $V_{DS} > V_{GS} - V_t \Rightarrow$ saturation

$$i_D = \frac{1}{2} \times 100 \times 10^{-6} \times 10 (5 - 0.8)^2 = 8.82\,mA$$

5.12

V_{GS} constant : $i_D = k_n' \frac{W}{L} \left[(V_{GS} - V_t) V_{DS} - \frac{1}{2} V_{DS}^2 \right]$

At the onset of saturation :

$$I_D = \frac{1}{2} k_n' \frac{W}{L} (V_{GS} - V_t)^2$$

when i_D decreases to $i_D = \alpha I_D$

$$\Rightarrow k_n' \frac{W}{L} \left[(V_{GS} - V_t) V_{DS} - \frac{1}{2} V_{DS}^2 \right] = \frac{\alpha}{2} k_n' \frac{W}{L} (V_{GS} - V_t)^2$$

$$\Rightarrow (V_{GS} - V_t) V_{DS} - \frac{1}{2} V_{DS}^2 = \frac{\alpha}{2} (V_{GS} - V_t)^2$$

$$\Rightarrow V_{DS}^2 - 2 (V_{GS} - V_t) V_{DS} + \alpha (V_{GS} - V_t)^2 = 0$$

$$V_{DS} = (V_{GS} - V_t) - \frac{1}{2}\sqrt{4(V_{GS}-V_t)^2 - 4\alpha(V_{GS}-V_t)^2}$$

$$\Rightarrow V_{DS} = (V_{GS} - V_t)(1 - \sqrt{1-\alpha})$$

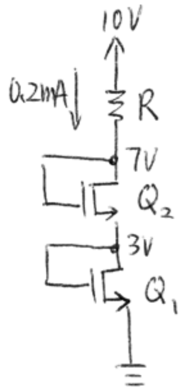
For $V_t = 1V$ and $V_{GS} = 2V$

$$V_{DS} = 1 - \sqrt{1-\alpha}$$

$\alpha = 0.5 \Rightarrow V_{DS} = 0.29\,V$

$\alpha = 0.1 \Rightarrow V_{DS} = 0.05\,V$

5.37



$V_t = 2V \quad \mu_n C_{ox} = 20\,\mu A/V^2$

$\lambda = 0$

$L_1 = L_2 = 10\,\mu m$

$V_{GS_1} = 3V \qquad V_{GS_2} = 7V - 3V = 4V \qquad$ Q Q2 both in sat

① $I_D = 0.2mA = \frac{1}{2}\mu_n C_{ox}\frac{W_1}{L_1}(V_{GS_1} - V_t)^2$

$\Rightarrow W_1 = 200\,\mu m$

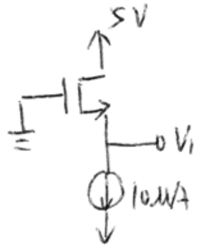
② $I_D = 0.2mA = \frac{1}{2}\mu_n C_{ox}\frac{W_2}{L_2}(V_{GS_2} - V_t)^2$

$\Rightarrow W_2 = 50\,\mu m$

$$R = \frac{(10-7)V}{0.2mA} = 15K\Omega$$

5.41 $\quad V_t = 2V \quad k_n' \frac{W}{L} = 0.5\,mA/V^2$

(a)

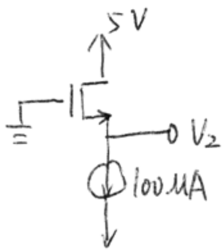


$V_D > V_G \Rightarrow$ saturation

$10 = \frac{1}{2}\, 0.5 \times 10^3\, (V_{GS} - 2)^2$

$V_{GS} = 2.2V \Rightarrow V_1 = -2.2\,V$

(b)

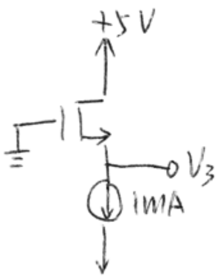


$100 = \frac{1}{2}\, 0.5 \times 10^3 (V_{GS} - 2)^2$

$\Rightarrow V_{GS} = 2.63V$

$\Rightarrow V_2 = -2.63V$

(c)

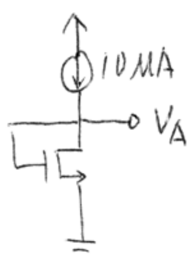


$1 = \frac{1}{2} \times 0.5\, (V_{GS} - 2)^2$

$V_{GS} = 4V$

$V_3 = -4V$

(d)

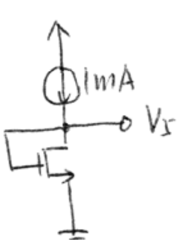


$10 = \frac{1}{2}\, 0.5 \times 10^3\, (V_{GS} - 2)^2$

$V_{GS} = 2.2V$

$V_4 = 2.2V$

(e)

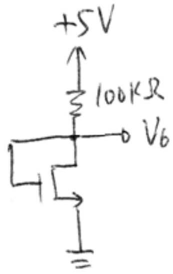


$1 = \frac{1}{2} \times 0.5\, (V_{GS} - 2)^2$

$V_{GS} = 4V$

$V_5 = 4V$

(f)



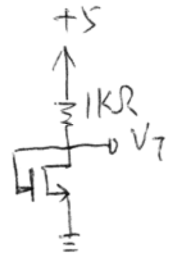
$$\frac{5-V_6}{100} = \frac{1}{2}\, 0.5\, (V_6-2)^2$$

$$\Rightarrow V_6^2 - 4V_6 + 4 = 0.2 - 0.04V_6$$

$$V_6 - 3.96\, V_6 + 3.8 = 0$$

$$\Rightarrow V_6 = 2.33\,V$$

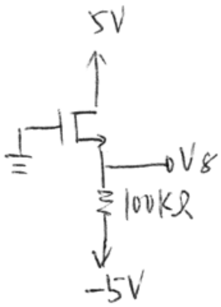
(g)



$$\frac{5-V_7}{1} = \frac{1}{2} \times 0.5 \times (V_7-2)^2$$

$$\Rightarrow V_7 = 4\,V$$

(h)



$$\frac{V_8+5}{100} = \frac{1}{2}\, 0.5\, (-V_8-2)^2$$

$$\Rightarrow V_8^2 + 4V_8 + 4 = 0.04V_8 + 0.2$$

$$\Rightarrow V_8^2 + 3.96\,V_8 + 3.8 = 0$$

$$\Rightarrow V_8 = -2.33\,V$$