類比積體電路設計概論 HW7, due date: 12 Dec.

HW7.1 (20 points)

Calculate the close-loop input and output resistance ($R_{in,CL}$ and $R_{out,CL}$) using small-signal parameters and assuming that $\gamma = 0$.

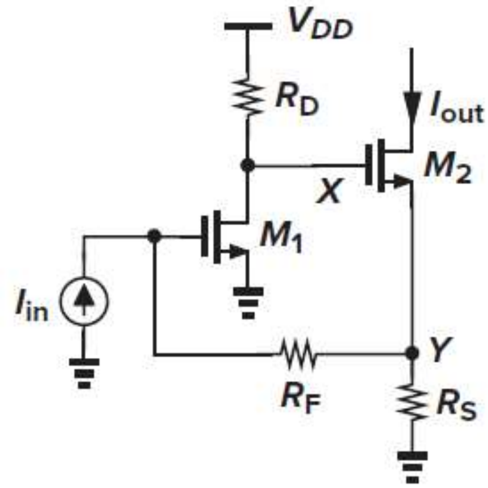
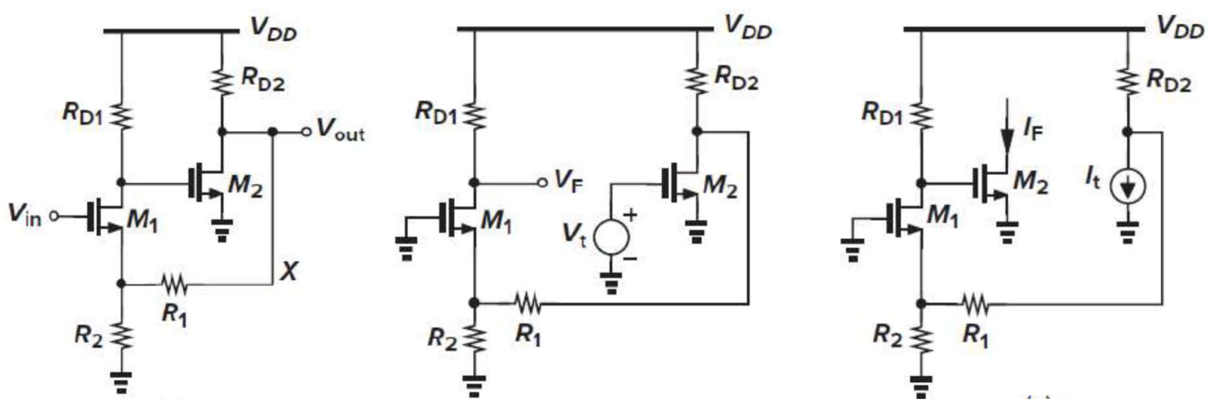


Fig. 7.1

HW7.2 (20 points)

As shown in Fig. 7.2(a), please prove that the loop gain, I_F/I_t (shown in Fig. 7.2(c)), is the same as that using V_F/V_t (shown in Fig. 7.2(b)).



(a) (b) (c)

Fig. 7.2

HW7.3 (40 points)

Using feedback techniques, calculate the input and output impedance and voltage gain of each circuit in Fig. 7.3. Using small-signal parameters to represent your solutions.

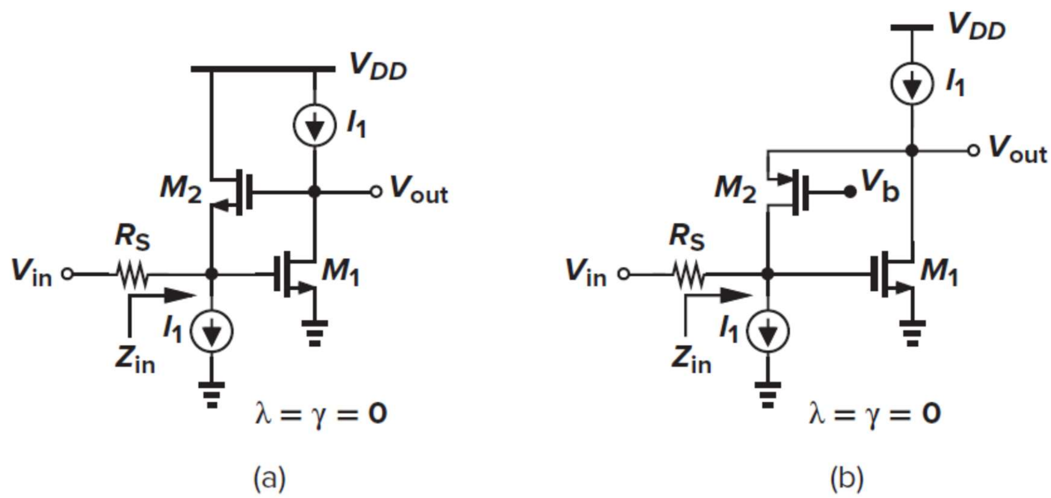


Fig. 7.3

HW7.4 (20 points)

In the circuit of Fig. 7.4, assuming that $\lambda = \gamma = 0$, calculate the closed-loop gain and output impedance. Using small-signal parameters to represent your solutions.

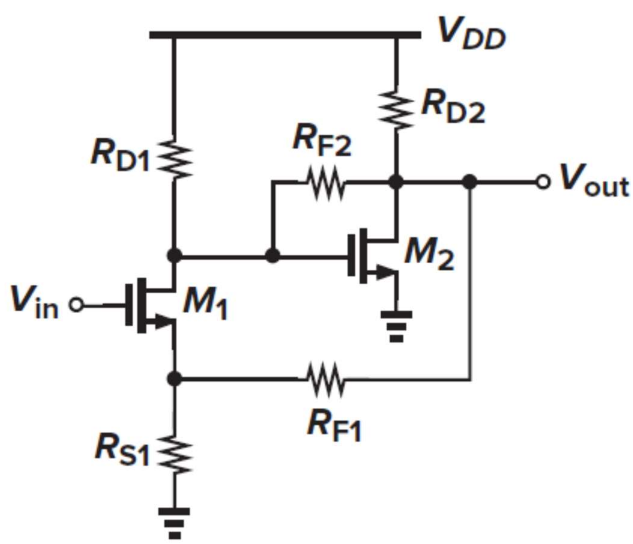


Fig. 7.4

HW 7.1

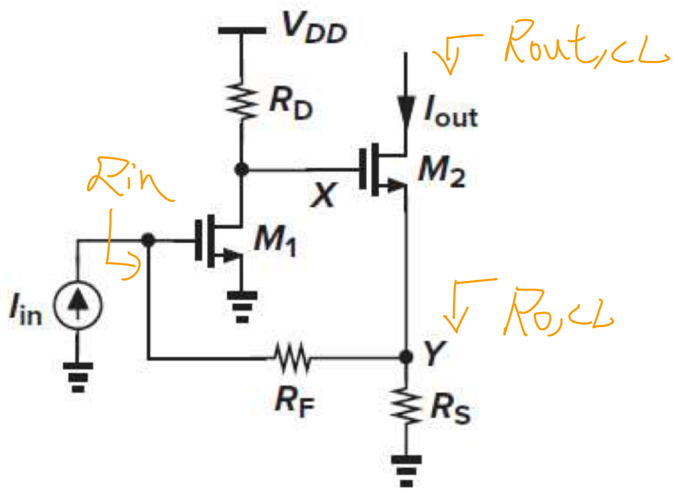
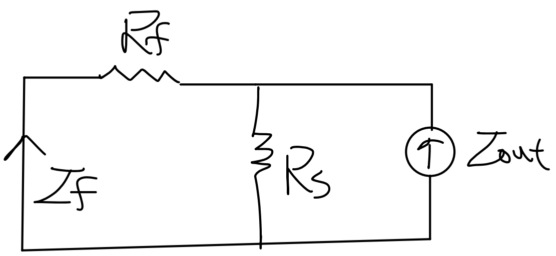


Fig. 7.1

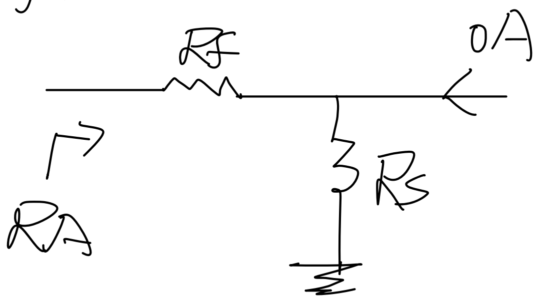
I-I feedback

Find β_I



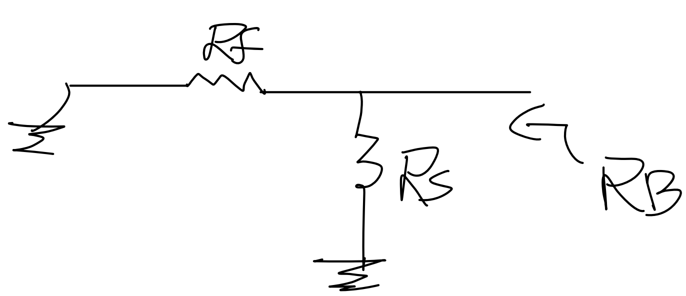
$$\beta_I = \frac{I_f}{I_{out}} = \frac{-R_s}{R_f + R_s}$$

Find R_A



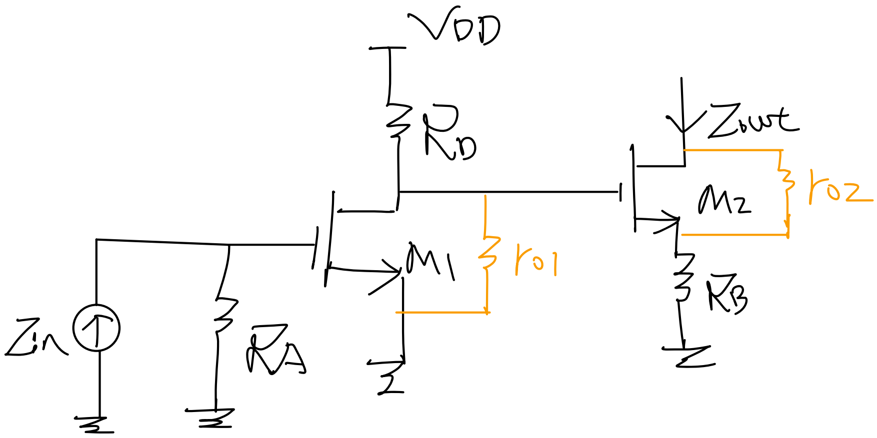
$$R_A = R_f + R_s$$

Find R_B



$$R_B = R_s \,//\, R_f$$

Find open loop gain $A_{Z,OL}$



$$Z_{out} = Z_{in} R_A \times -g_{m1}(R_D // r_{o1}) \times \frac{g_{m2} r_{o2}}{r_{o2} + (1+g_{m2} r_{o2}) R_B}$$

$$A_{Z,OL} = -g_{m1} g_{m2} \frac{R_A (R_D // r_{o1}) r_{o2}}{r_{o2} + (1+g_{m2} r_{o2}) R_B}$$

$$R_{in,CL} = \frac{R_A}{1+\beta_Z A_{Z,OL}} \quad \#$$

$$R_{O,CL} = R_B (1+\beta_Z A_{Z,OL})$$

$$R_{out,CL} = (1+g_{m2} r_{o2}) R_{O,CL} + r_{o2} \quad \#$$

HW 7.2

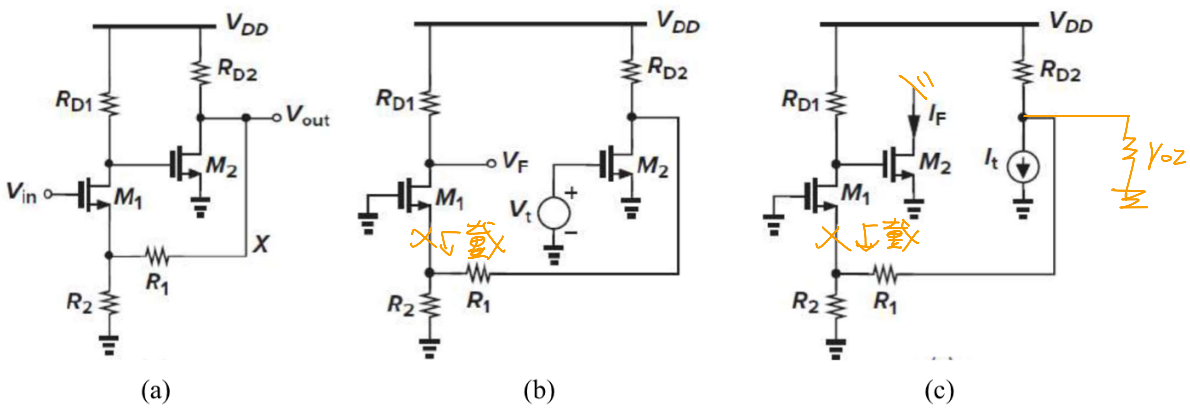


Fig. 7.2

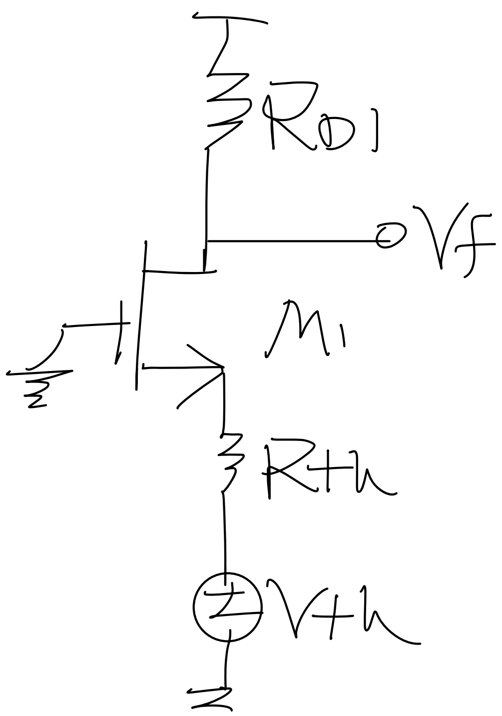
(b)

利用戴維寧等效定理

$$V_{th} = -g_{m2}[R_{D2} // r_{o2} // (R_1+R_2)] \times \frac{R_2}{R_1+R_2}$$

$$R_{th} = R_2 // [R_1 + (R_D // r_{o2})]$$

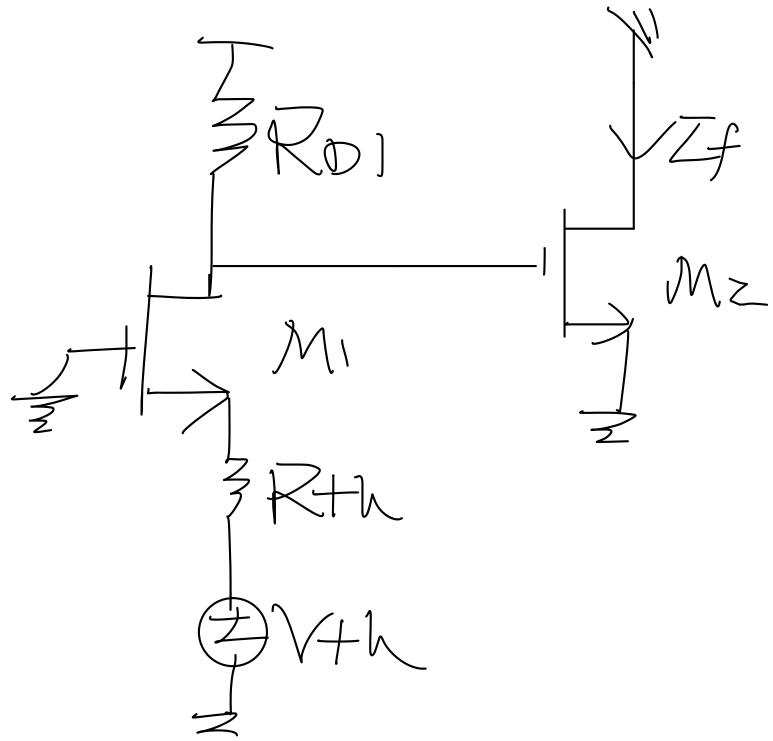
CG放大器增益 A



$$V_f = A \times V_{th}$$

$$= -A \times g_{m2}[R_{D2} // r_{o2} // (R_1+R_2)] \times \frac{R_2}{R_1+R_2} \times V_t$$

(c)



$$V_{th} = I_t \times [R_{D2} // r_{o2} // (R_1 + R_2)] \frac{R_2}{R_1 + R_2}$$

$$R_{th} = R_2 // [R_1 + (R_D // r_{o2})]$$

$$I_f = A \times V_{th} \times g_{m2}$$

$$= A \times g_{m2} [R_{D2} // r_{o2} // (R_1 + R_2)] \frac{R_2}{R_1 + R_2} \times I_t$$

$$\Rightarrow \frac{V_f}{V_t} = \frac{I_f}{I_t} \quad \#$$

HW7.3

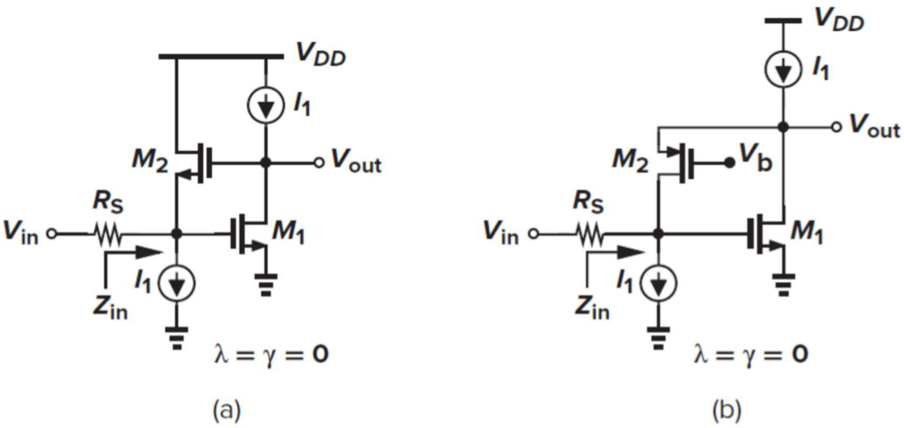
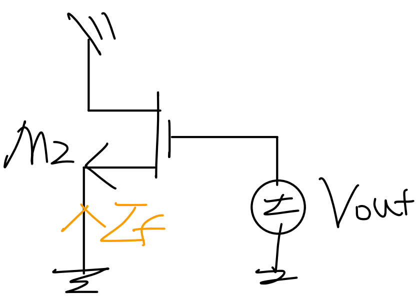


Fig. 7.3

(a)

V-Z feedback

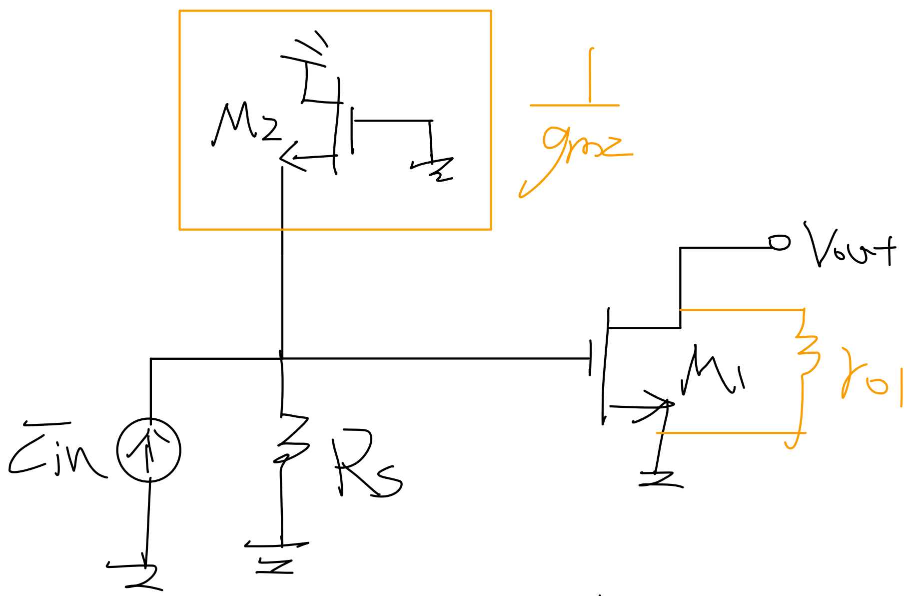
Find β_g



$$Z_f = -g_{m2} V_{out}$$

$$\beta_g = \frac{Z_f}{V_{out}} = -g_{m2}$$

Find $A_{Z,OL}$



$$V_{out,OL} = Z_{in}\left(R_s // \frac{1}{g_{m2}}\right) \times (-g_{m1} r_{o1})$$

$$A_{Z,OL} = -g_{m1} r_{o1} \left(R_s // \frac{1}{g_{m2}}\right)$$

$$R_{in,OL} = R_S \parallel \frac{1}{g_{m2}}$$

$$R_{o,OL} = r_{o1}$$

$$A_{Z,CL} = \frac{A_{Z,OL}}{1 + \beta_g A_{Z,OL}} = \frac{-g_{m1} r_{o1} \left(R_S \parallel \frac{1}{g_{m2}}\right)}{1 + g_{m1} g_{m2} r_{o1} \left(R_S \parallel \frac{1}{g_{m2}}\right)}$$

$$A_{v,CL} = A_{Z,CL} \times \frac{1}{R_S} \quad \#$$

$$R_{in,CL} = \frac{R_{in,OL}}{1 + \beta_g A_{Z,OL}} \quad \#$$

$$R_{o,CL} = \frac{R_{o,CL}}{1 + \beta_g A_{Z,OL}} \quad \#$$

因為 $\lambda = 0 \Rightarrow r_o \to \infty$

$$\Rightarrow A_{v,CL} \simeq -\frac{1}{g_{m2} R_S} \quad \#$$

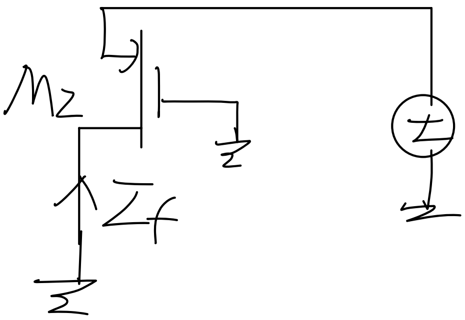
$$R_{in,CL} \simeq 0 \quad \#$$

$$R_{o,CL} \simeq \frac{1}{g_{m1} g_{m2} \left(R_S \parallel \frac{1}{g_{m2}}\right)} = \frac{\frac{1}{g_{m2}} + R_S}{g_{m1} R_S} \quad \#$$

(b)

V-I feedback

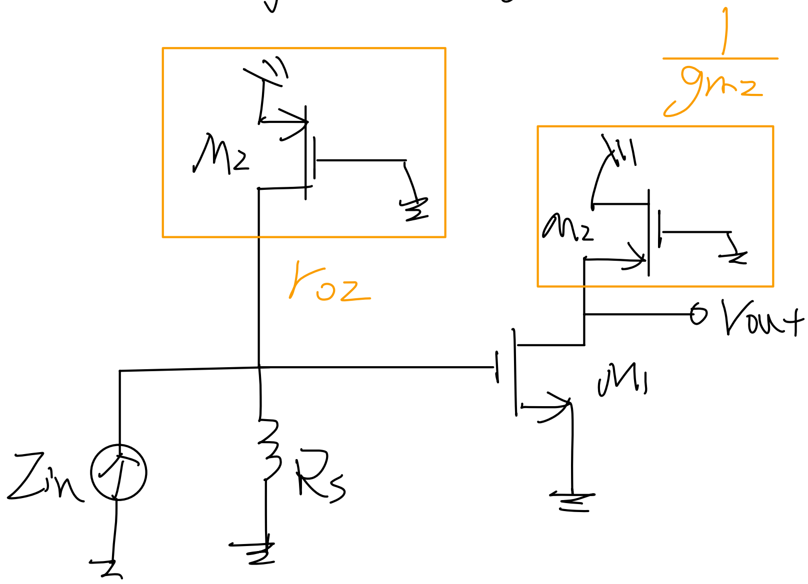
find β_g



$$I_f = -g_{m2} V_{out}$$

$$\beta_g = \frac{I_f}{V_{out}} = -g_{m2}$$

find $A_{Z,OL}$



$$V_{out} = Z_{in}(R_S \,//\, r_{o2}) \times -g_{m1}\left(r_{o1} \,//\, \frac{1}{g_{m2}}\right)$$

$$A_{Z,OL} = \frac{V_{out}}{Z_{in}} = -g_{m1}\left(r_{o1} \,//\, \frac{1}{g_{m2}}\right)(R_S \,//\, r_{o2})$$

$$R_{in,OL} = r_{o2}$$

$$R_{o,OL} = \frac{1}{g_{m2}} \,//\, r_{o1}$$

$$A_{v,CL} = \frac{A_{Z,OL}}{1+\beta_g A_{Z,OL}} \times \frac{1}{R_s}$$

$$R_{in,CL} = \frac{R_{in,OL}}{1+\beta_g A_{Z,OL}}$$

$$R_{o,CL} = \frac{R_{o,OL}}{1+\beta_g A_{Z,OL}}$$

因為 $\lambda = 0 \Rightarrow r_o \to \infty$

$\Rightarrow R_{in,CL} \simeq \infty$

$$R_{o,CL} \simeq \frac{1}{g_{m2}(1+g_{m1}R_s)} \quad \#$$

$$A_{v,CL} \simeq \frac{-g_{m1}}{g_{m2}(1+g_{m1}R_s)} \quad \#$$

HW 7.4

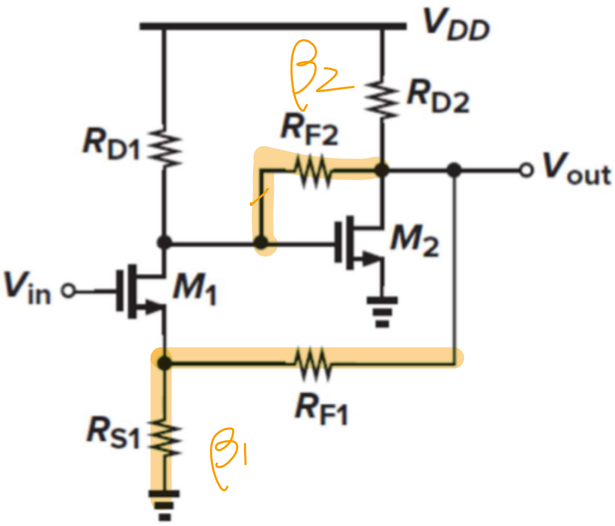
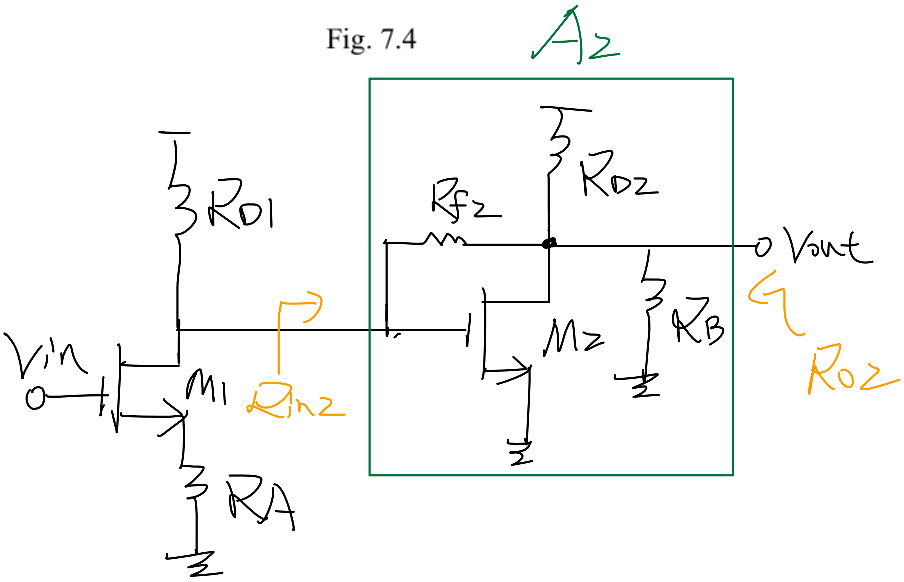


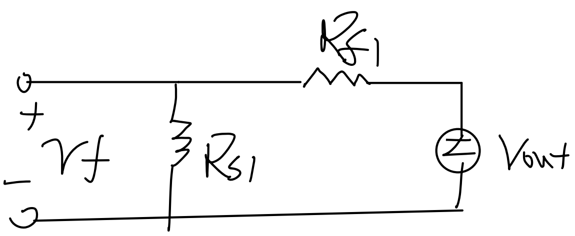
Fig. 7.4



$R_A = R_{f1} + R_{s1}$

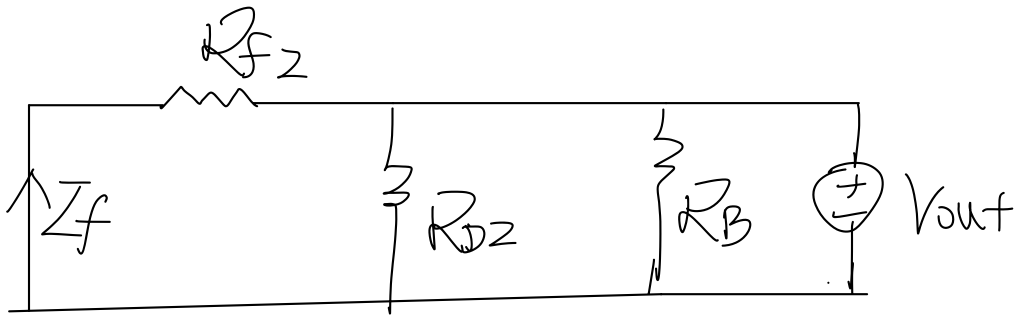
$R_B = R_{f1} \,//\, R_{s1}$

find β_1



$$\beta_1 = \frac{R_{s1}}{R_{f1} + R_{s1}}$$

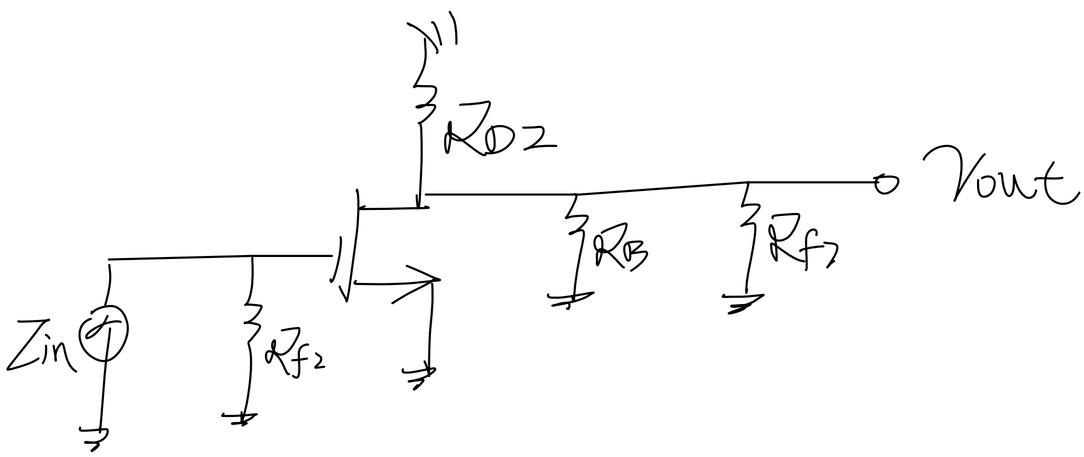
find β_2



$$Z_f = \frac{0 - V_{out}}{R_{f2}}$$

$$\beta_2 = \frac{Z_f}{V_{out}} = \frac{-1}{R_{f2}}$$

find $A_{2,OL}$



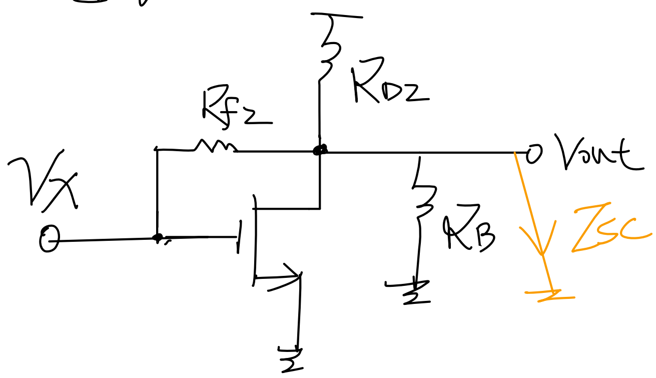
$$A_{2,OL} = \frac{V_{out}}{Z_{in}} = R_{f2} \times -g_{m2}(R_{D2} // R_B // R_{f2})$$

$$\beta_2 A_{2,OL} = g_{m2}(R_{D2} // R_B // R_{f2})$$

$$R_{in2} = \frac{R_{f2}}{1 + g_{m2}(R_{D2} // R_B // R_{f2})}$$

$$R_{o2} = \frac{R_{B2} // R_{f2} // R_{D2}}{1 + g_{m2}(R_{D2} // R_B // R_f)}$$

find A_2

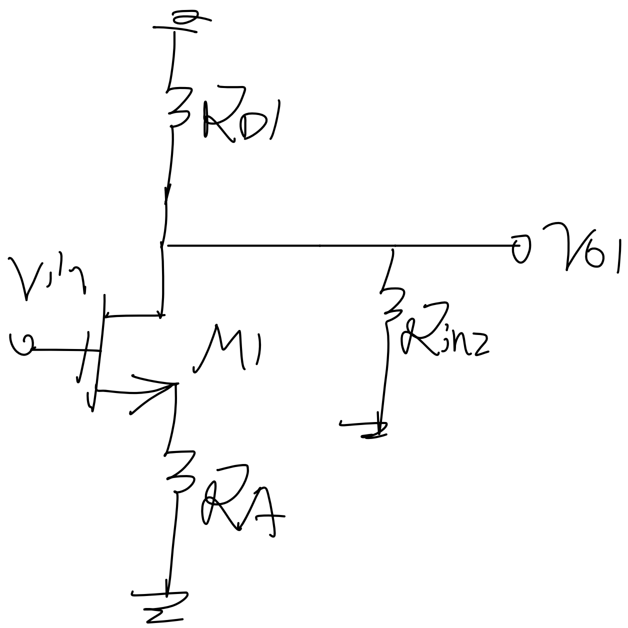


$$G_m = \frac{I_{SC}}{V_x} = \frac{1}{R_{f2}} - g_{m2}$$

$$R_o = R_B // R_{D2} // R_{f2}$$

$$A_2 = \frac{V_{out}}{V_x} = G_m R_o$$

find A_1



$$A_1 = \frac{V_{o1}}{V_{in}} = \frac{-g_{m1}(R_{D1} // R_{in2})}{1 + g_{m1} R_A}$$

$$A_{VT,OL} = A_1 \times A_2$$

$$R_{O,OL} = R_{O2}$$

$$A_{VT,CL} = \frac{A_{VT,OL}}{1 + \beta_1 A_{VT,OL}} \quad \#$$

$$R_{O,CL} = \frac{R_O}{1 + \beta_1 A_{VT,OL}} \quad \#$$

$R_{in,CL} \to \infty$ 直接看到Gate

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