6.1 Ignoring other capacitors, calculate the input impedance of the circuit in Figure 6.1(**λ=0**)

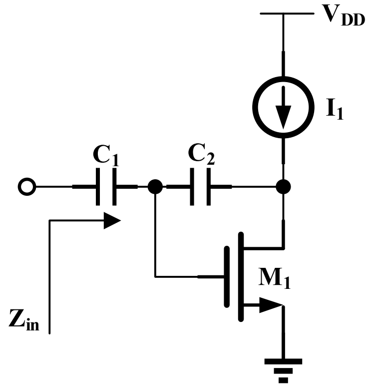
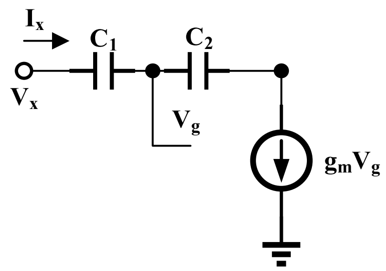


Figure 6.1

解：



$$Ix = g_m V_g$$

$$Vx - \frac{g_m V_g}{SC_1} = V_g$$

$$\therefore Z_{in} = \frac{V_x}{I_x} = \frac{g_m + SC_1}{g_m SC1}$$

6.2 Calculate the input impedance and transfer function of the circuit in Figure 6.2. (**λ=γ=0**)

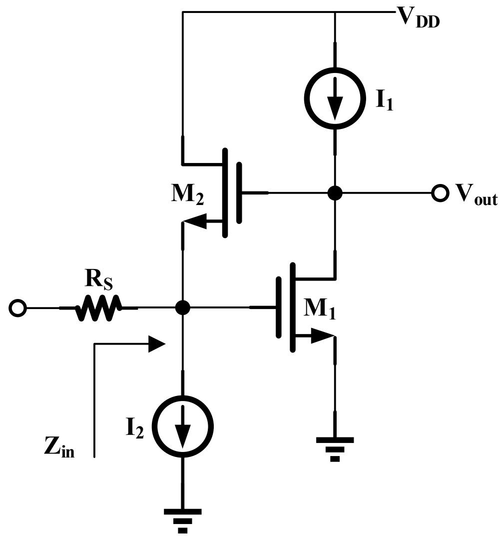
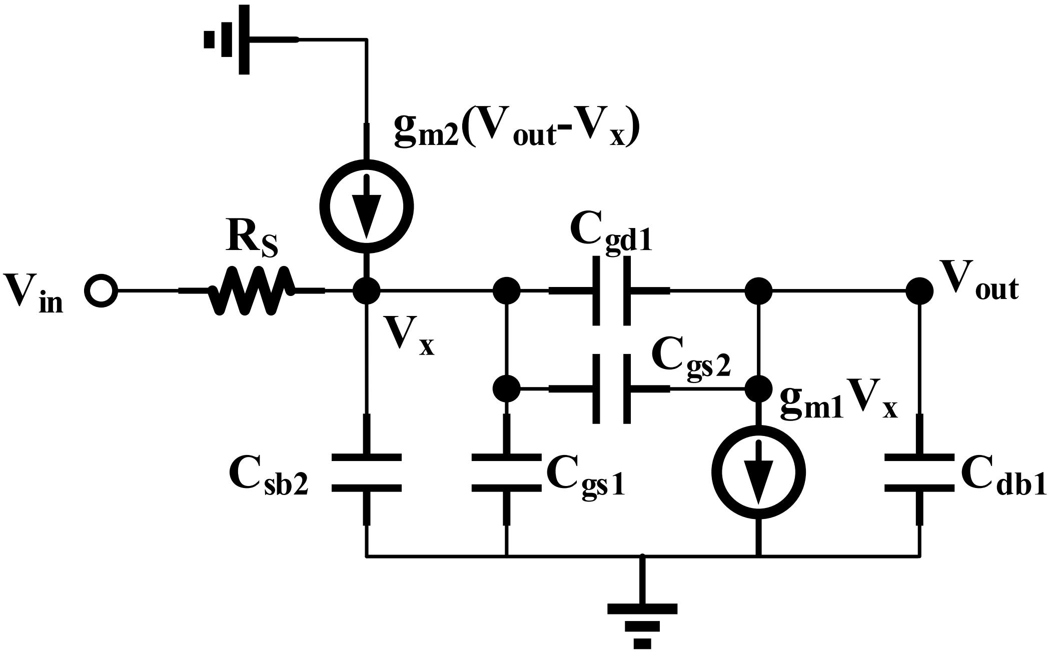
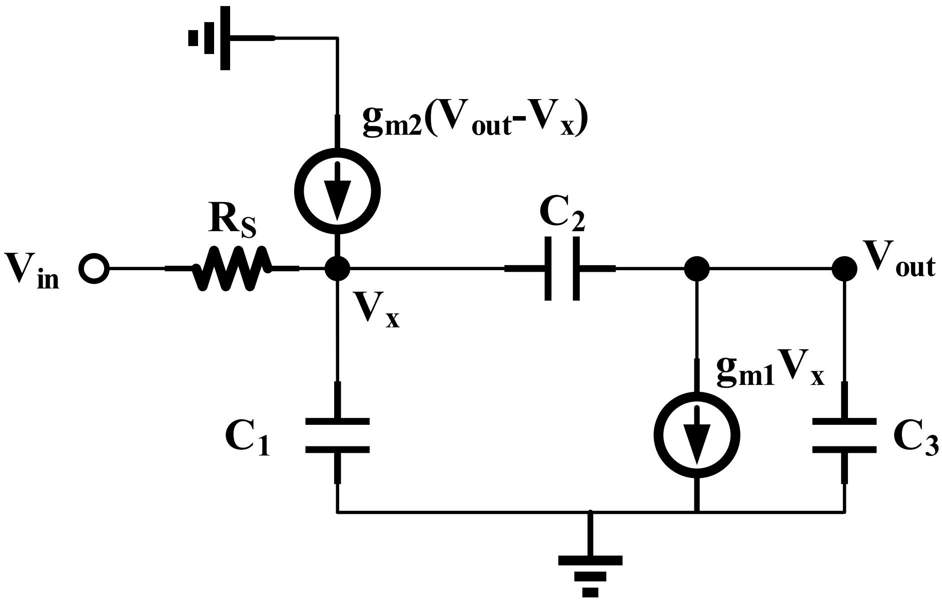


Figure 6.2

解：
小信号模型：



化简电路得：



其中：

$$C_1 = C_{gs1} + C_{sb2}$$

$$C_2 = C_{gd1} + C_{gs2}$$

$$C_3 = C_{db1}$$

计算传输函数：

对 Vout 点使用 KCL 有：

$$SC_2(Vx - Vout) = g_{m1}Vx + SC_3Vout$$

$$\therefore \frac{Vout}{Vx} = \frac{SC_2 - g_{m1}}{S(C_2 + C_3)}$$

对 Vx 点使用 KCL 有：

$$\frac{Vin - Vx}{Rs} + g_{m2}(Vout - Vx) = SC_1Vx + SC_2(Vx - Vout)$$

$$\frac{Vin}{Rs} = Vx(\frac{1}{Rs} + g_{m2} + SC_1 + SC_2) - (g_{m2} + SC_2)\left[\frac{SC_2 - g_{m1}}{S(C_2 + C_3)}\right]Vx$$

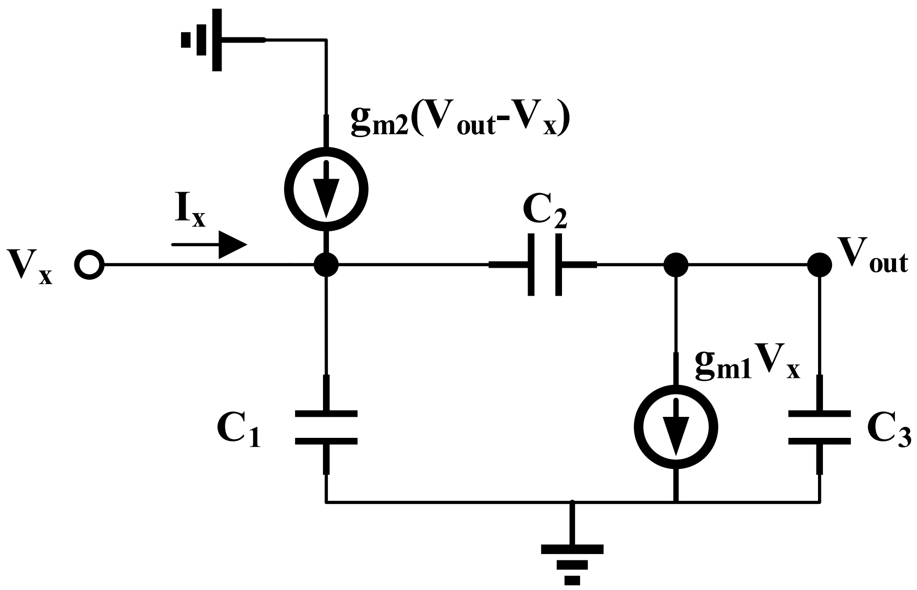
$$= Vx\frac{S^2(C_1C_2 + C_2C_3 + C_1C_3) + S\left[\frac{1}{Rs}(C_2 + C_3) + g_{m1}C_2 + g_{m2}C_3\right] + g_{m1}g_{m2}}{S(C_2 + C_3)}$$

所以传输函数为：

$$\therefore \frac{Vout}{Vin} = \frac{Vout}{Vx} \bullet \frac{Vx}{Vin} = \frac{\frac{1}{Rs}(SC_2 - g_{m1})}{S^2(C_1C_2 + C_2C_3 + C_1C_3) + S\left[\frac{1}{Rs}(C_2 + C_3) + g_{m1}C_2 + g_{m2}C_3\right] + g_{m1}g_{m2}}$$

计算输入阻抗：

等效电路图：



$$Ix = SC_1Vx + SC_2(Vx - Vout) + g_{m2}(Vx - Vout)$$

代入前面 Vx 与 Vout 的公式，得：

$$Zin = \frac{Vx}{Ix} = \frac{S(C_2 + C_3)}{S^2(C_1C_2 + C_2C_3 + C_1C_3) + S(g_{m1}C_2 + g_{m2}C_3) + g_{m1}g_{m2}}$$

6.3 Calculate the poles of the circuit in Figure 6.3. ($\lambda \neq 0$)

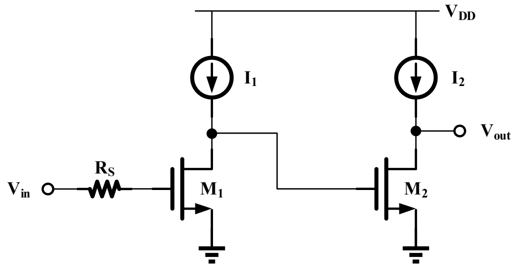
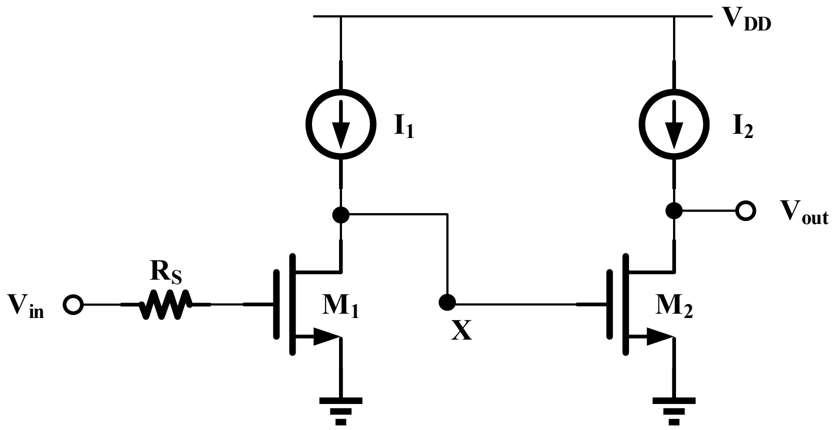


Figure 6.3

解：



电路中一共有三个极点：

第一个极点在 Vout 处：

$$w_{pout}=\frac{1}{r_{o2}(C_{gd2}+C_{db2})}$$

第二个极点在输入端 Vin 处：

$$w_{p\mathrm{in}}=\frac{1}{R_{\mathrm{s}}\left[(1+g_{m1}r_{o1})C_{gd1}+C_{gs1}\right]}$$

第三个极点在端点 X 处：

$$w_{p\mathrm{x}}=\frac{1}{r_{o1}\left[(C_{gd1}+C_{db1}+C_{gs2})+(1+g_{m2}r_{o2})C_{gd2}\right]}$$

6.4 Calculate the gain of each circuit in Figure 6.4 ignoring all other capacitors. ($\lambda=\gamma=0$)

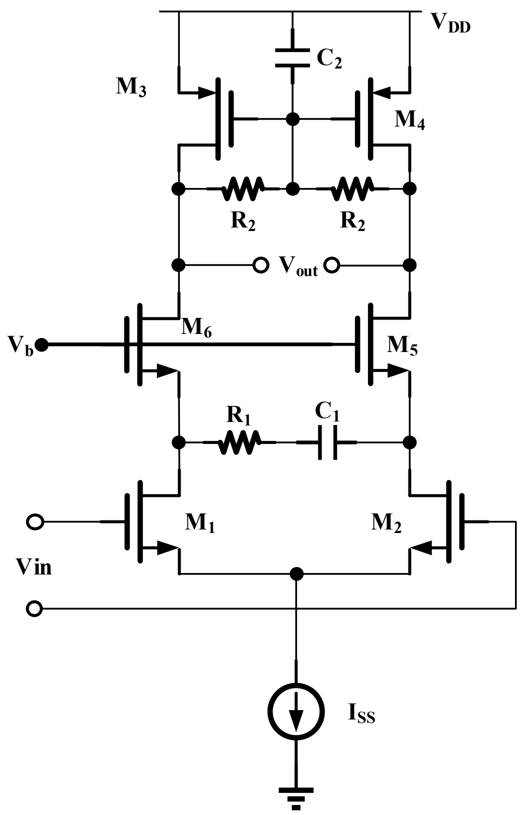
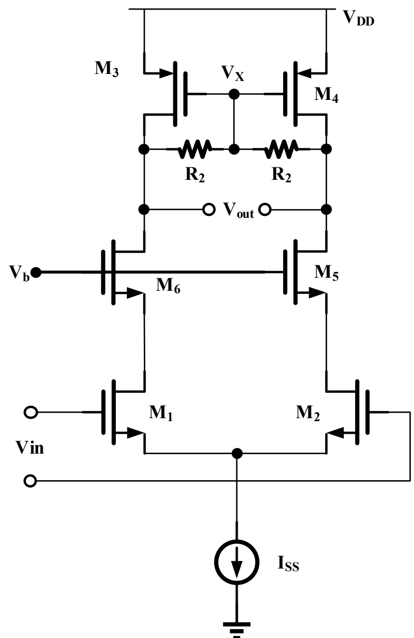


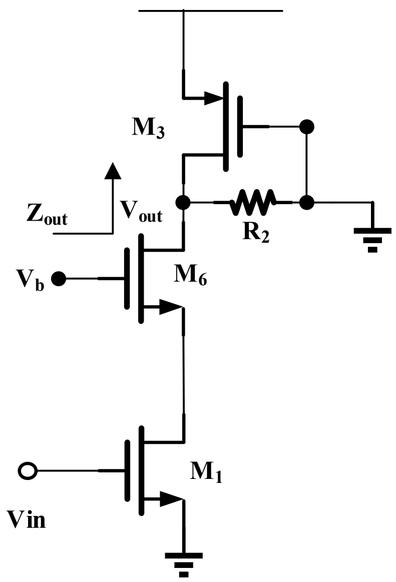
Figure 6.4

解：

低频时电容作为开路，等效电路如图：



在 Vin 变化时认为 Vx 点电压不变，可用半边电路等效：



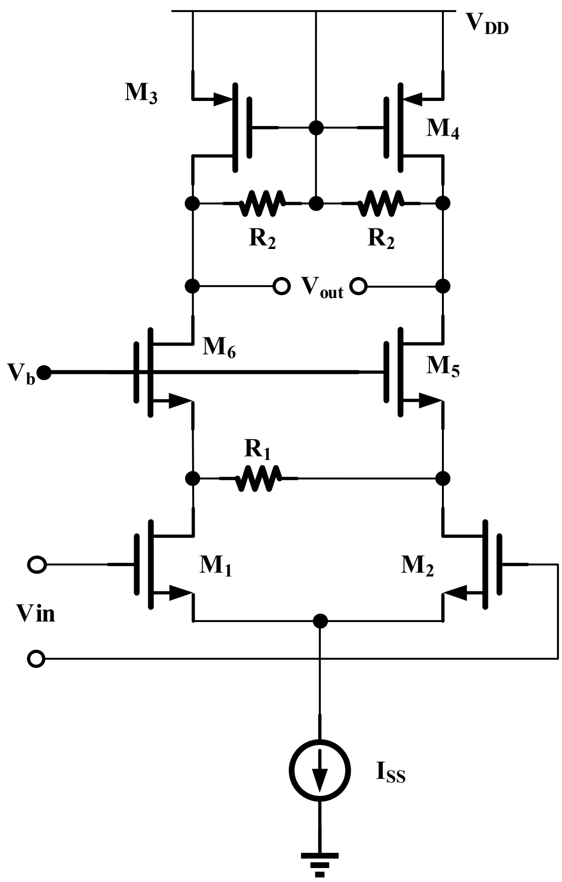
其中，

$$Z_{out} \cong r_{o3} \| R_2 \cong R_2$$

所以，

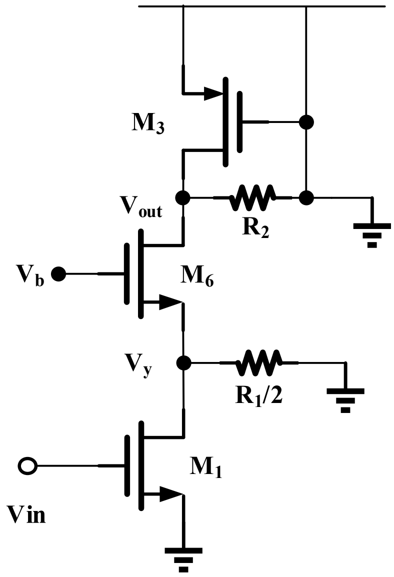
$$Av \cong -g_{m1} R_2$$

高频时认为电容为通路，等效电路如图：



同理，可以用半边电路来做：

解：



$$\frac{V_y}{V_{in}} = -g_{m1}\left(\frac{1}{g_{m6}} \| \frac{R_1}{2}\right), \frac{Vout}{Vy} \cong +g_{m6}R_2$$

$$\therefore \frac{V_{out}}{V_{in}} = -\frac{g_{m1}g_{m6}R_1R_2}{(2+g_{m6}R_1)}$$

6.5 Calculate the zero of the transfer function in figure 6.5. Assume the gate capacitance and transconductance of M_4 is C_E and g_m, the output node capacitance and resistance is C_{out} and r_{op}. (*Please refer to equation (6.43) in Design of Analog CMOS Integrated Circuits 2nd*)

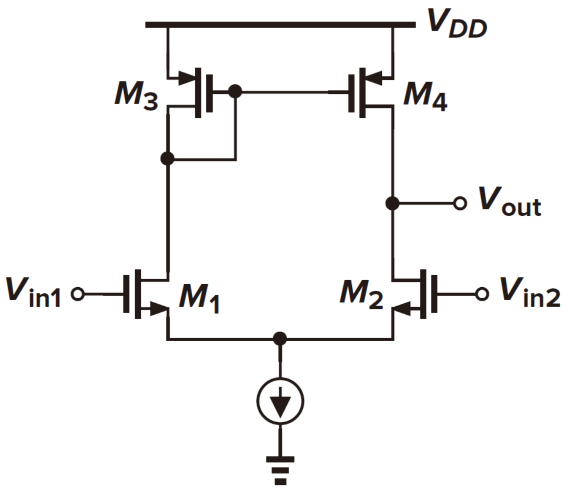
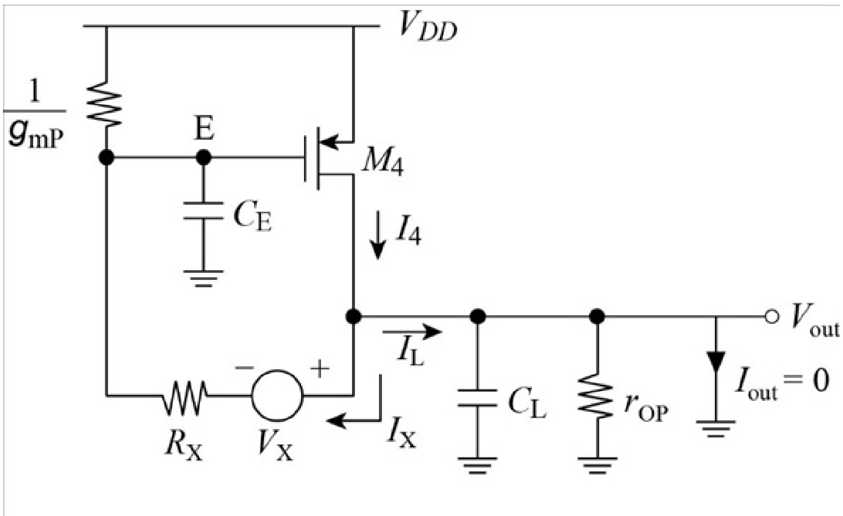


Figure 6.5

解：



As the output is shorted to the ground, the current I_L becomes zero at $s = s_z$, which is equal to I_{out}.

Current I_4 through the device equals to the current I_x .

From the circuit, consider the expression for

$$\begin{aligned} I_4 &= -\frac{V_E}{\left(\frac{1}{g_{mP}}\right)} \\ &= -g_{mP}V_E \end{aligned}.$$

From the circuit, consider the expression for I_x.

$$\begin{aligned} I_X &= \frac{V_E}{\left(\frac{1}{g_{mP}}\right)} + \frac{V_E}{\left(\frac{1}{s_z C_E}\right)} \\ &= g_{mP}V_E + s_z C_E V_E \\ &= (g_{mP} + s_z C_E)V_E \end{aligned}$$

Thus, the zero of the transfer function is $s_z = -\frac{2g_{mP}}{C_E}$.