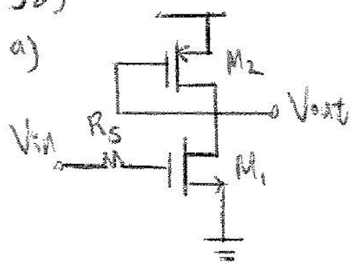
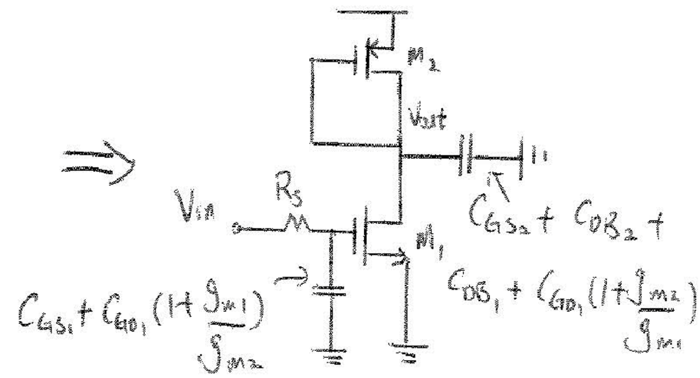
38)

a)



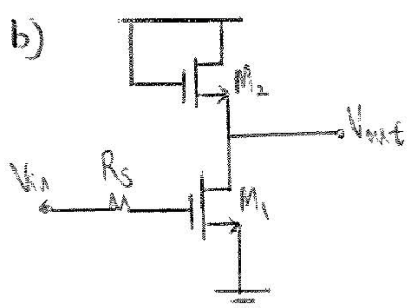
$\Longrightarrow$



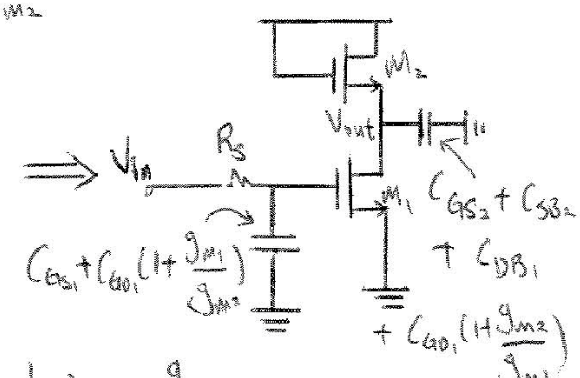
$$\text{DC gain} = -g_{m_1}\left(r_{o_1} \parallel r_{o_2} \parallel \frac{1}{g_{m_2}}\right) \approx -\frac{g_{m_1}}{g_{m_2}}$$

$$\omega_{p_{in}} = \frac{1}{R_S\left(C_{GS_1} + C_{GD_1}\left(1+\frac{g_{m_1}}{g_{m_2}}\right)\right)} \qquad \omega_{p_{out}} = \frac{g_{m_2}}{\left(C_{GS_2} + C_{DB_2} + C_{DB_1} + C_{GD_1}\left(1+\frac{g_{m_2}}{g_{m_1}}\right)\right)}$$

b)



$\Longrightarrow$



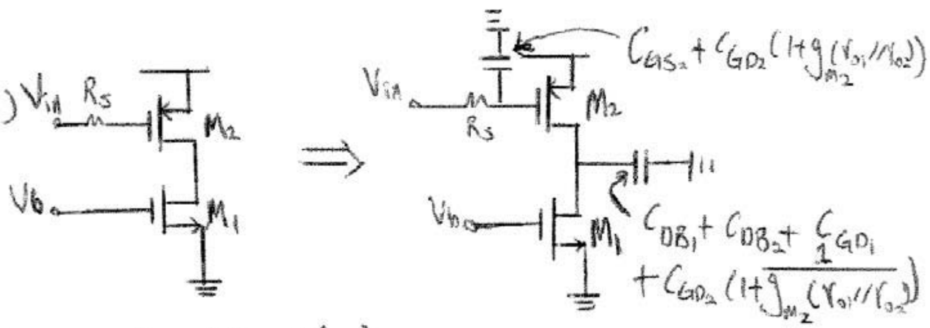
$$\text{DC gain} = -g_{m_1}\left(r_{o_1} \parallel r_{o_2} \parallel \frac{1}{g_{m_2}}\right) \approx -\frac{g_{m_1}}{g_{m_2}}$$

$$\omega_{p_{in}} = \frac{1}{R_S\left(C_{GS_1} + C_{GD_1}\left(1+\frac{g_{m_1}}{g_{m_2}}\right)\right)}$$

$$\omega_{p_{out}} = \frac{g_{m_2}}{C_{SB_2} + C_{GS_2} + C_{DB_1} + C_{GD_1}\left(1+\frac{g_{m_2}}{g_{m_1}}\right)}$$

38)

c)



DC gain: $-g_{m_2}(r_{o1} // r_{o2})$

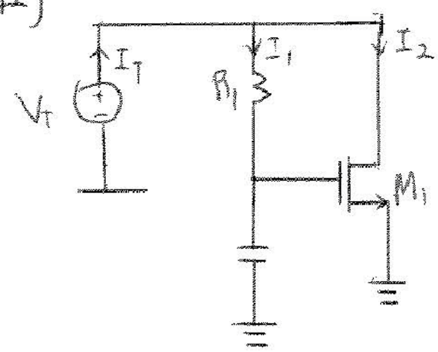
$$\omega_{pin} = \frac{1}{R_S\left(C_{GS_2} + C_{GD_2}\left(1 + g_{m_2}(r_{o1} // r_{o2})\right)\right)}$$

$$\omega_{pout} = \frac{1}{(r_{o1} // r_{o2})\left[C_{DB_1} + C_{DB_2} + C_{GD_1} + C_{GD_2}\left(1 + \frac{1}{g_{m_2}(r_{o1} // r_{o2})}\right)\right]}$$

$$\omega_{pout} \approx \frac{1}{(r_{o1} // r_{o2})\left[C_{DB_1} + C_{DB_2} + C_{GD_1} + C_{GD_2}\right]}$$

Since $g_{m_2}(r_{o1} // r_{o2}) >> 1$

42)



$\lambda = 0$, and neglect other capacitances.

$$I_T = I_1 + I_2$$

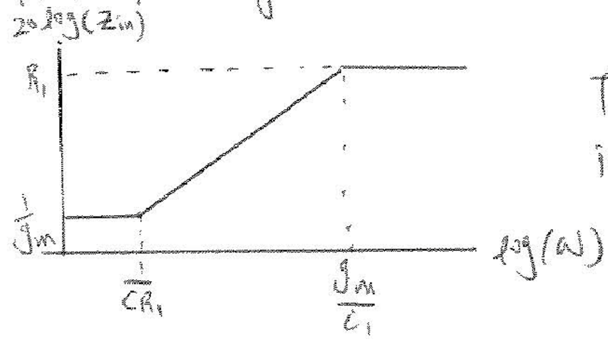
$$I_1 = \frac{V_T}{\left(R_1 + \frac{1}{C_1 S}\right)}, \quad I_2 = \frac{g_{m_1} V_T}{C_1 R_1 S + 1}$$

$$I_T = \frac{C_1 S V_T}{C_1 R_1 S + 1} + \frac{g_{m_1} V_T}{C_1 R_1 S + 1} \Rightarrow \frac{V_T}{I_T} = \frac{C_1 R_1 S + 1}{C_1 S + g_{m_1}}$$

$$S \to j\omega \Rightarrow \frac{C_1 R_1 (j\omega) + 1}{C_1 j\omega + g_{m_1}} = Z_T(j\omega)$$

$$|Z_T| = |Z_{in}| = \frac{\sqrt{(C_1 R_1 \omega)^2 + 1}}{\sqrt{(C_1 \omega)^2 + g_{m_1}^2}} = \frac{\sqrt{(C_1 R_1 \omega)^2 + 1}}{g_m \sqrt{\left(\frac{C_1 \omega}{g_{m_1}}\right)^2 + 1}}$$

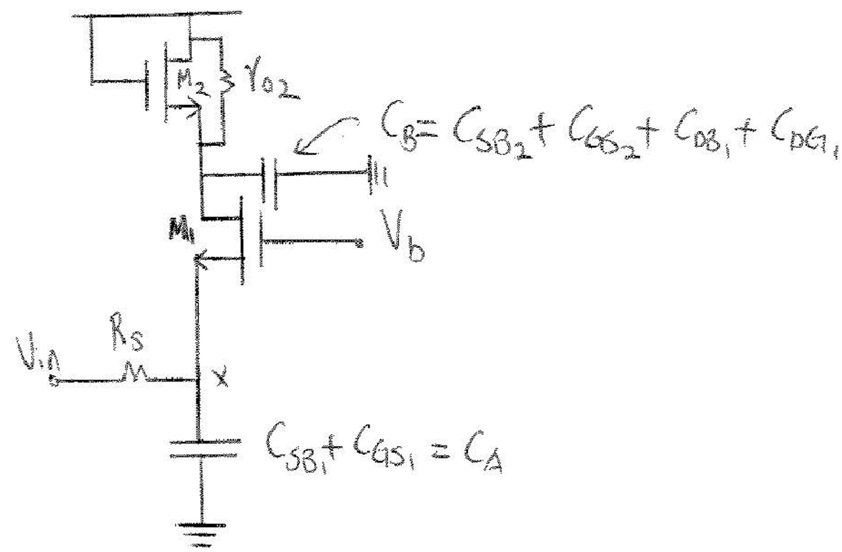
At $\omega = \frac{1}{C_1 R_1}$, we have a zero, at $\omega = \frac{g_{m_1}}{C_1}$, we have a pole. If $R_1 > \frac{1}{g_{m_1}}$, the zero is at a lower frequency than the pole, and the bode-plot for magnitude would look like the following.



The bode-plot shows an impedance that increases with frequency, an inductive behavior.

4b)

a)



$$V_{out} = -(0 - V_x) g_{m_1} \left[\frac{1}{g_{m_2}} \parallel \frac{1}{C_B s}\right] = V_x g_{m_1} \left[\frac{1}{g_{m_2}} \parallel \frac{1}{C_B s}\right]$$

Node equation at X, $\quad \dfrac{V_x - V_{in}}{R_s} + V_x C_A s - g_m(0 - V_x) = 0$

$$V_x\left(\frac{1}{R_s} + C_A s + g_m\right) = \frac{V_{in}}{R_s} \Rightarrow V_x = \frac{V_{in}}{(1 + R_s C_A s + R_s g_m)}$$

subsitute in V_x and solving for $V_{out}/V_{in} \Rightarrow$

$$\frac{V_{out}}{V_{in}} = \frac{g_{m_1}\left[1/g_{m_2} \parallel \frac{1}{C_B s}\right]}{(1 + R_s C_A s + R_s g_m)}$$

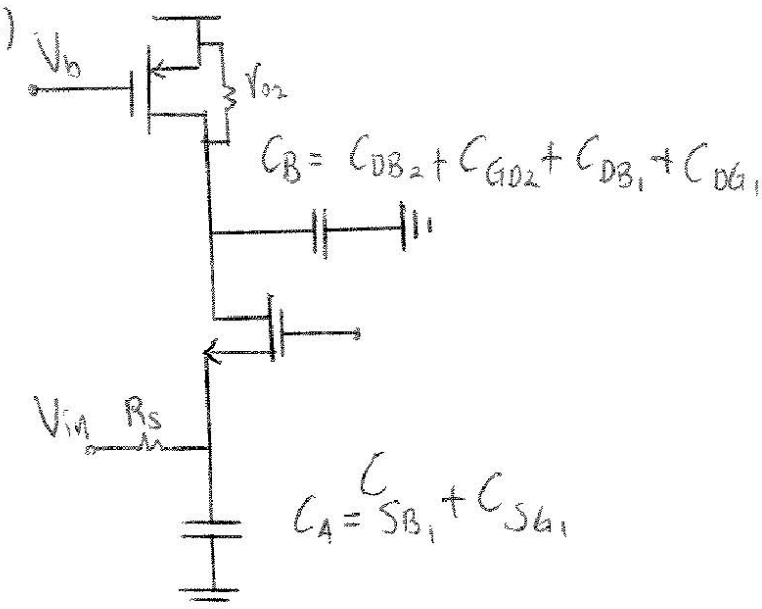
$$\frac{V_{out}}{V_{in}} = \frac{g_{m_1}(1/g_{m_2})}{(C_B(1/g_{m_2})s + 1)(1 + R_s C_A s + R_s g_{m_1})}$$

Where $C_B = C_{SB_2} + C_{GS_2} + C_{DB_1} + C_{DG_1}$

$C_A = C_{SB_1} + C_{GS_1}$

4b)

b)



Similar to part a), with $\frac{1}{g_{m_2}}$ replaced by r_{o2},

and different C_B.

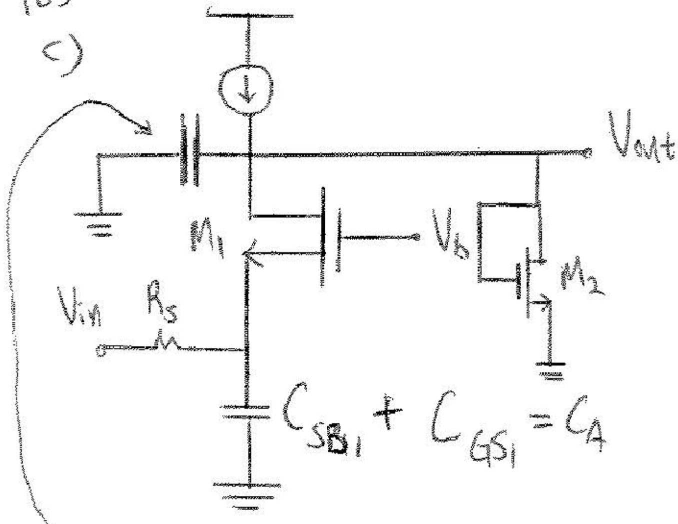
So $$\frac{V_{out}}{V_{in}} = \frac{g_{m_1} r_{o2}}{(C_B r_o s + 1)(1 + R_s C_A s + R_s g_{m_1})}$$

Where $C_B = C_{DB_2} + C_{GD2} + C_{DB_1} + C_{DG_1}$

$C_A = C_{SB_1} + C_{SG_1}$

4b)

c)



$C_B = C_{DB_1} + C_{GD_1} + C_{DB_2} + C_{GS_2}$

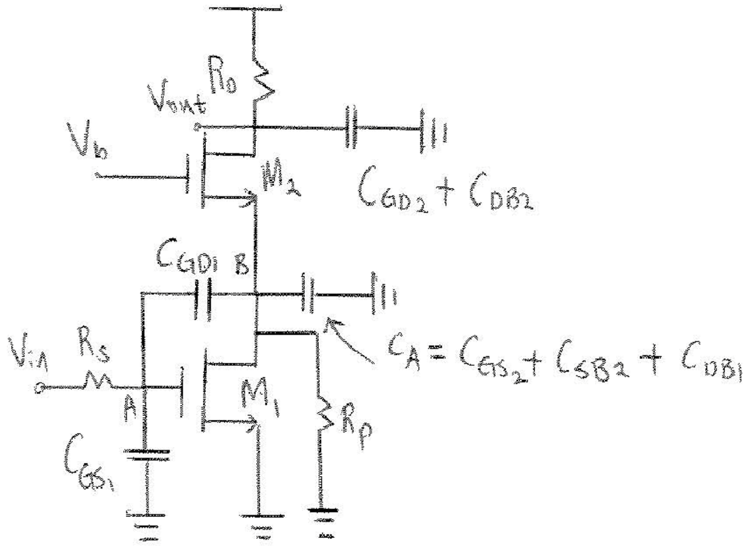
AC-wise, this circuit is very similar to part a). Its transfer function is the same as part a), except for C_B.

$$\frac{V_{out}}{V_{in}} = \frac{g_{m_1}(1/g_{m_2})}{\left(C_B(1/g_{m_2})S+1\right)\left(1+R_S C_A S + R_S g_{m_1}\right)}$$

Where $C_B = C_{DB_1} + C_{GD_1} + C_{DB_2} + C_{GS_2}$

$C_A = C_{SB_1} + C_{GS_1}$

5b)



DC gain from A to B is $-g_{m1}(R_P // \frac{1}{g_{m2}})$

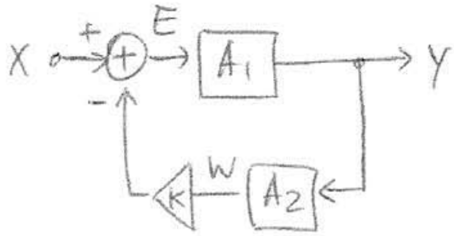
Applying Miller's Theorem:

$$\omega_{pin}(\omega_{pA}) = \frac{1}{R_S(C_{GS1} + C_{GD1}(1 + g_{m1}(R_P // \frac{1}{g_{m2}})))}$$

$$\omega_{pB} = \frac{1}{R_P // \frac{1}{g_{m_2}} [C_{GS_2} + C_{SB2} + C_{DB_1} + C_{GD1}(1 + 1/g_{m1}(R_P // \frac{1}{g_{m2}}))]}$$

$$\omega_{pout} = \frac{1}{R_D(C_{GD_2} + C_{DB2})}$$

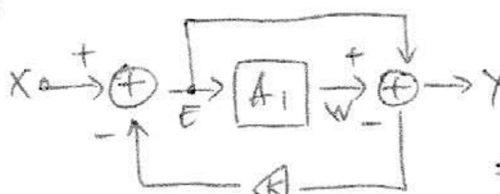
1. (a)



$$Y = A_1 E_1 = A_1[X - YA_2 k]$$

$$\Rightarrow \frac{Y}{X} = \frac{A_1}{1 + kA_1A_2}$$

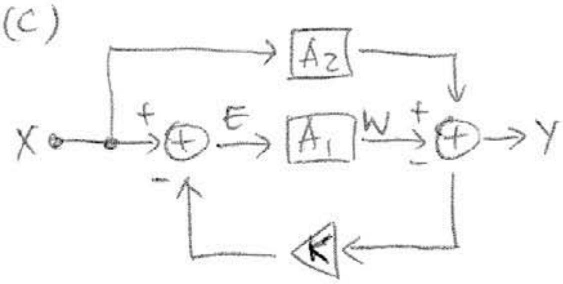
(b)



$$Y = E - A_1 W = (X - kY) - A_1(X - kY)$$

$$\Rightarrow \frac{Y}{X} = \frac{1 - A_1}{1 + (1 - A_1)k}$$

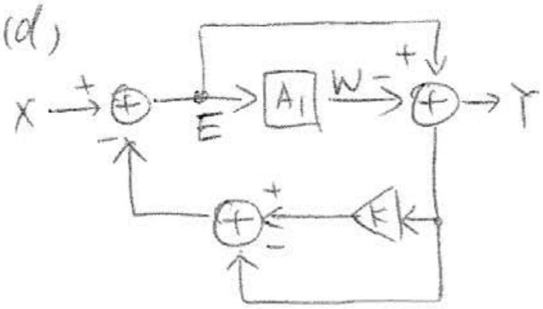
(c)



$$Y = XA_2 - W = XA_2 - A_1(X - YK)$$

$$\Rightarrow \frac{Y}{X} = \frac{A_2 - A_1}{1 - A_1 Y}$$

(d)



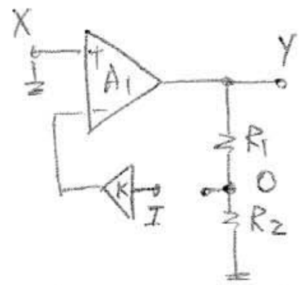
$$Y = E - W = (X - (KY - Y)) - A_1[X - (KY - Y)]$$

$$\Rightarrow \frac{Y}{X} = \frac{(1 - A_1)}{1 + (k - 1)(1 - A_1)}$$

$$(c)\ \frac{Y}{X} = \frac{A_2 - A_1}{1 - A_1 K}$$

4.

(a)

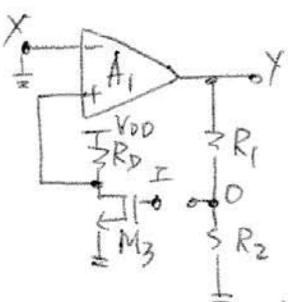


(X is grounded
in loop-gain calculation)

$$O = Y\frac{R_2}{R_1+R_2} = (-Ik)A_1\left(\frac{R_2}{R_1+R_2}\right)$$

$$\Rightarrow -\frac{O}{I} = \text{Loop Gain}$$
$$= +kA_1\left(\frac{R_2}{R_1+R_2}\right)$$

(b)

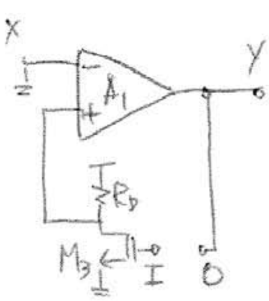


(X is grounded)

$$O = Y\left(\frac{R_2}{R_1+R_2}\right)$$
$$= -Ig_{m3}R_DA_1\left(\frac{R_2}{R_1+R_2}\right)$$

$$\Rightarrow -\frac{O}{I} = \text{Loop Gain}$$
$$= +g_{m3}R_DA_1\left(\frac{R_2}{R_1+R_2}\right)$$

(c)

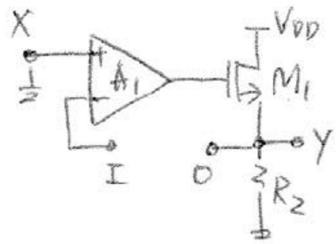


(X is grounded)

$$O = Y = -Ig_{m3}R_DA_1$$

$$\Rightarrow -\frac{O}{I} = \text{Loop Gain}$$
$$= +g_{m3}R_DA_1$$

(d)



(X is grounded)

$$O = Y = -I \times \frac{g_{m_1} R_2}{1 + g_{m_1} R_2} \times A_1$$

$$\Rightarrow -\frac{O}{I} = \text{Loop Gain}$$

$$= +A_1 \frac{g_{m_1} R_2}{1 + g_{m_1} R_2}$$

5.

(a) $$\frac{Y}{X} = \frac{A_{O.L.}}{1 + \text{Loop Gain}} = \frac{A_1}{1 + A_1 K\left(\frac{R_2}{R_1 + R_2}\right)}$$

(b) $$\frac{Y}{X} = \frac{A_1}{1 + g_{m3} R_D A_1 \left(\frac{R_2}{R_1 + R_2}\right)}$$

(c) $$\frac{Y}{X} = \frac{A_1}{1 + g_{m3} R_D A_1}$$

(d) $$\frac{Y}{X} = \frac{A_1}{1 + A_1 \left(\frac{g_{m1} R_2}{1 + g_{m1} R_2}\right)}$$