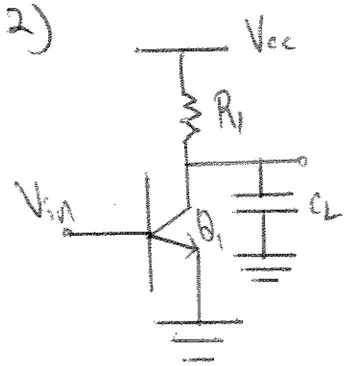
2)



$-3dB$ bandwidth $= 1\ GHz$

$C_L = 2pF$

Power $= 2mW$

Low freq gain ?

Power $= 2.5V\, I_c$, $I_c = 0.8\,mA$

Dominant Pole at the output $= \dfrac{1}{R_1 C_L} = 2\pi\,(1GHz)$

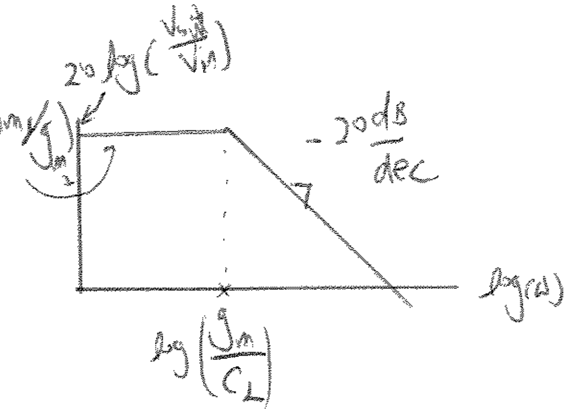
$R_1 = 79.58$ Ohm.

Low Freq gain : $-g_m R_1 = \dfrac{-I_c R_1}{V_T} = \dfrac{(79.58)(0.8)}{26}$

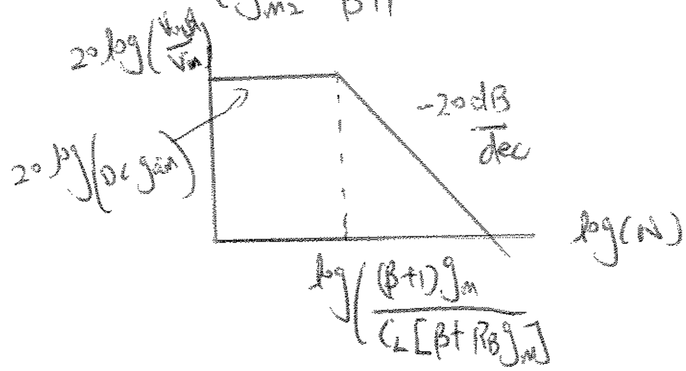
$A_v\big|_{low\,freq} = -2.45$

4)

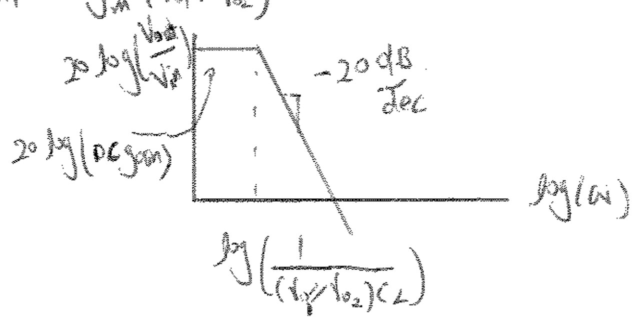
a) $|\text{DC gain}| = \dfrac{g_{m1}}{g_{m2}}$



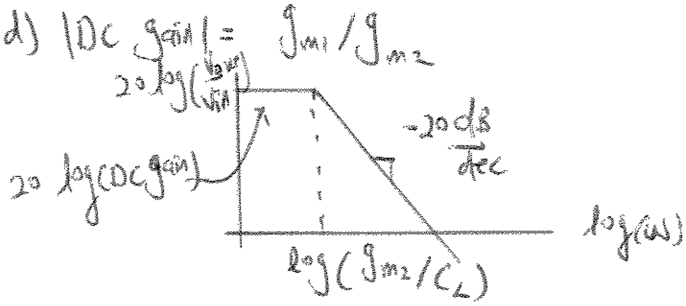
b) $|\text{DC gain}| = g_{m1}\left(\dfrac{1}{g_{m2}} + \dfrac{R_B}{\beta+1}\right)$



c) $|\text{DC gain}| = g_m (r_{o1} // r_{o2})$



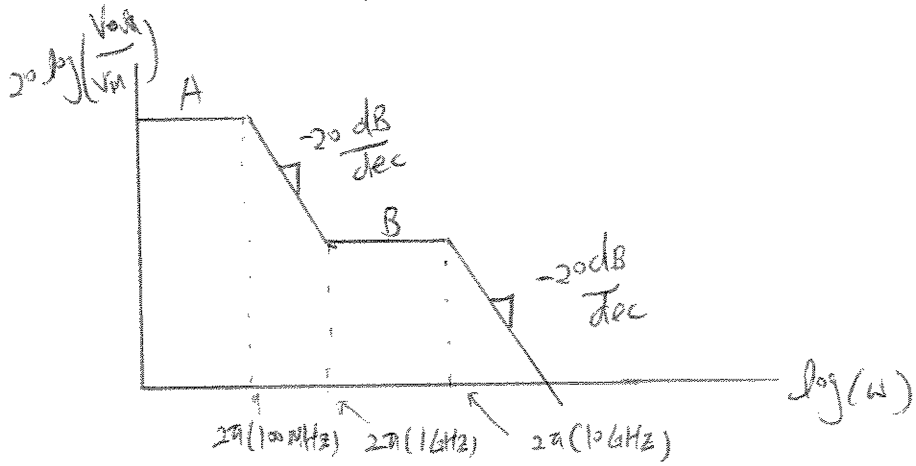
d) $|\text{DC gain}| = g_{m1}/g_{m2}$



6)

Poles at 100 MHz, 10 GHz

Zero at 1 GHz.

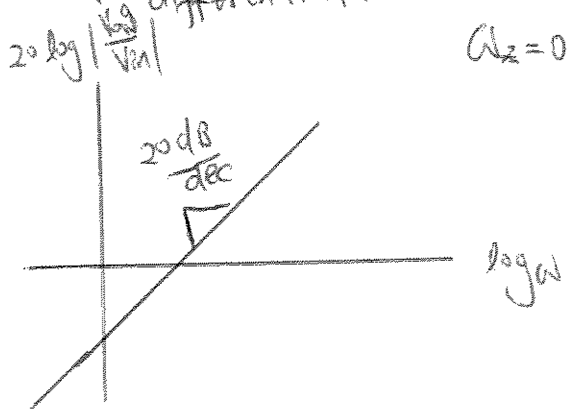


$A(100\,MHz) = B(1\,GHz)$

$B = 0.1A$

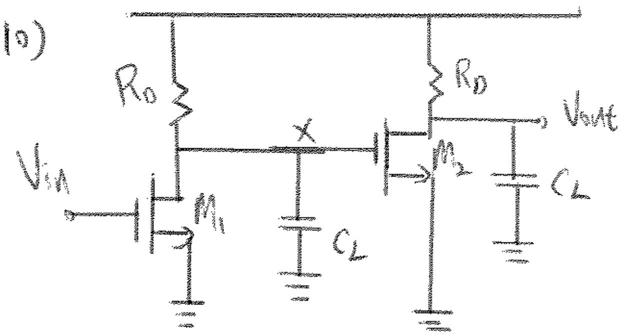
8) Ideal differentiator: $s = \frac{V_{out}}{V_{in}}$, $\left|\frac{V_{out}}{V_{in}}(j\omega)\right| = \omega$

$\omega_z = 0$



For an ideal differentiator, gain at arbitrary high freq approaches infinity.

10)



$$\frac{V_x}{V_{in}}(s) = -g_m\left(R_D \,/\!/\, \frac{1}{C_L s}\right), \quad \frac{V_{out}}{V_x}(s) = -g_m\left(\frac{R_D}{R_D C_L s + 1}\right)$$

$$= -g_m\left(\frac{R_D}{R_D C_L s + 1}\right)$$

$$H(s) = \frac{V_x}{V_{in}}(s)\,\frac{V_{out}}{V_x}(s) = \left(\frac{g_m R_D}{R_D C_L s + 1}\right)^2$$

$$s \to \omega j, \quad H(j\omega) = \left(\frac{g_m R_D}{1 + R_D C_L j\omega}\right)^2$$

$$|H(j\omega)| = \frac{(g_m R_D)^2}{1 + (R_D C_L \omega)^2}$$

$-3dB$ Band Width:

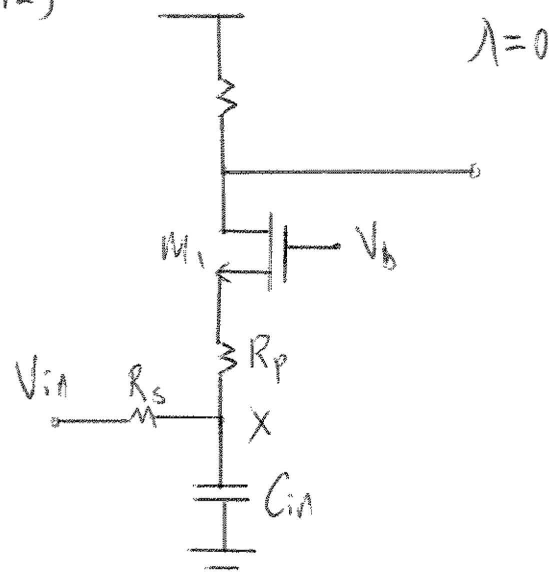
$$\frac{(g_m R_D)^2}{1 + (R_D C_L \omega)^2} = \frac{(g_m R_D)^2}{\sqrt{2}}$$

$$\Rightarrow (R_D C_L \omega)^2 + 1 = \sqrt{2}$$

$$\Rightarrow \omega = \frac{\sqrt{\sqrt{2} - 1}}{R_D C_L} = \frac{0.6436}{R_D C_L} \; (rad/s)$$

$$2\pi f = \frac{0.6436}{R_D C_L} \Rightarrow f = \frac{0.10243}{R_D C_L} \; (Hz)$$

12)



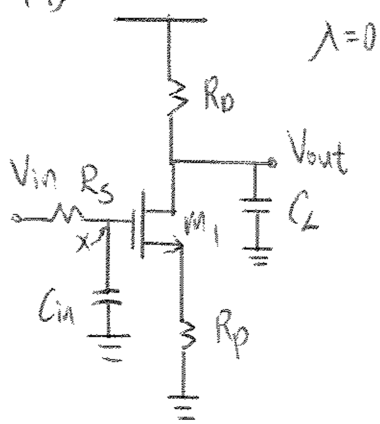
To find input pole, let $V_{in}=0$ and find the equivalent resistance and capacitance from node X to ground.

$$R_X = R_S \,//\, \left(R_P + \frac{1}{g_{m_1}}\right), \quad C_X = C_{in}$$

$$\omega_{p,in} = \frac{1}{C_{in}\left[R_S \,//\, \left(R_P + \frac{1}{g_m}\right)\right]}$$

$$\omega_{p,out} = \frac{1}{R_D C_L}$$

14)



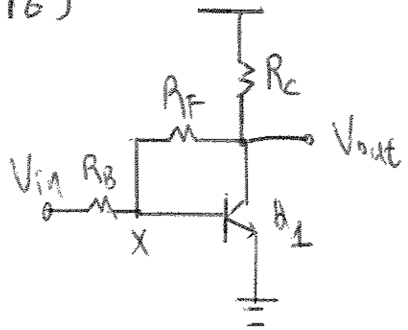
$R_X = R_S$, $R_{out} = R_D$

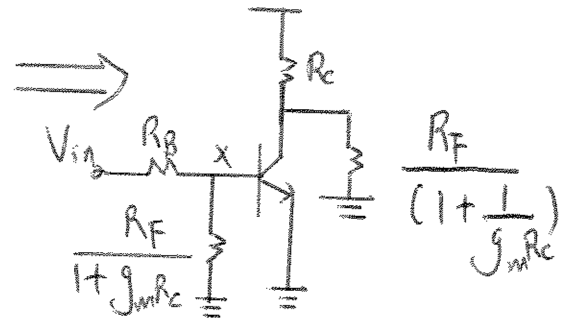
$C_X = C_{in}$, $C_{out} = C_L$

$$\omega_{pin} = \frac{1}{R_S C_{in}} , \quad \omega_{pout} = \frac{1}{R_D C_L}$$

16)

$V_A = \infty$, R_F is large

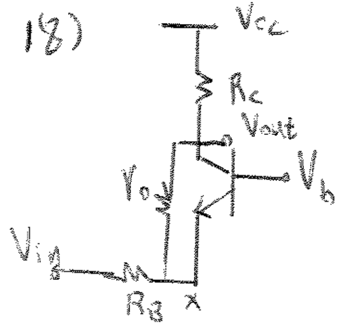


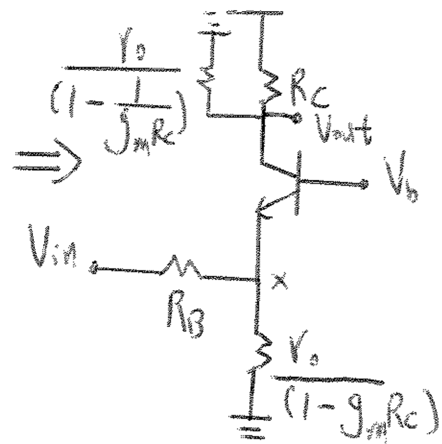


$$R_X = R_B \parallel \left(\frac{R_F}{1+g_m R_C} \right), \quad R_{out} = R_C \parallel \left(\frac{R_F}{1+\frac{1}{g_m R_C}} \right)$$

$$\frac{V_{out}}{V_{in}} = \frac{-R_{out}}{\frac{1}{g_m} + \frac{R_X}{\beta+1}} = \frac{-R_C \parallel \left(\frac{R_F}{1+1/g_m R_C} \right)}{\frac{1}{g_m} + \frac{R_B \parallel \left(R_F/(1+g_m R_C) \right)}{\beta+1}}$$

1(8)



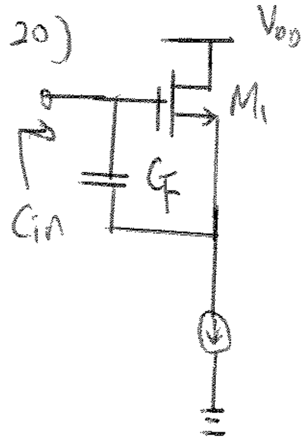


$$R_{out} = R_C \,//\left(\frac{r_o}{1-\frac{1}{g_m R_C}}\right)$$

$$R_X = R_B \,//\left(\frac{r_o}{1-g_m R_C}\right)$$

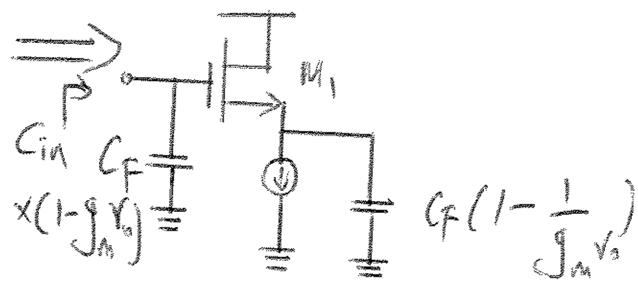
$$\frac{V_{out}}{V_{in}} = \frac{R_{out}}{R_X + \frac{1}{g_m}} = \frac{R_C \,//\left(\frac{r_o}{1-\frac{1}{g_m R_C}}\right)}{R_B \,//\left(\frac{r_o}{1-g_m R_C}\right) + \frac{1}{g_m}}$$

20)



$\lambda > 0$, DC gain $= g_m r_o$

$\Longrightarrow$

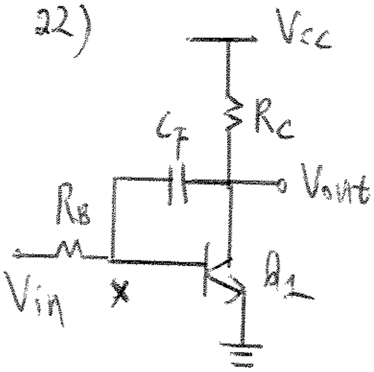


$$C_{in} = C_F(1 - g_m r_o)$$

As $\lambda \to 0$, $r_o \to \infty$, $g_m r_o \to \infty$, $C_{in} = -\infty$

When $C \to$ negative in value, we have inductive activity. So right here, we have an effective infinite inductor.

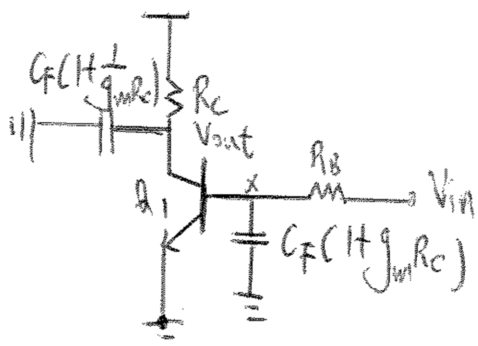
22)



DC gain (from x to out):

$-g_m R_C$

$\Downarrow$



$C_{in} = C_F(1+g_m R_C)$

$R_{in} = R_B // r_\pi$

$C_{out} = C_F(1+\frac{1}{g_m R_C})$

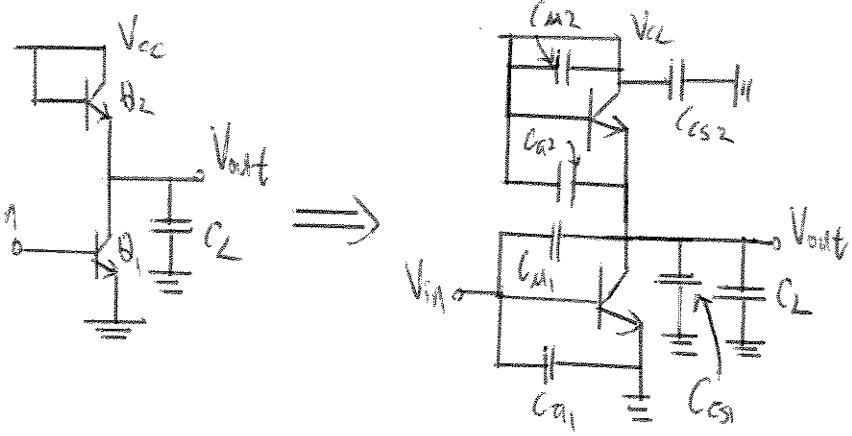
$R_{out} = R_C$

$$\omega_{pin} = \frac{1}{R_B // r_\pi\left[C_F(1+g_m R_C)\right]}$$

$$\omega_{pout} = \frac{1}{R_C C_F(1+\frac{1}{g_m R_C})} \approx \frac{1}{R_C C_F}$$

(If $g_m R_C \gg 1$)

24)
a)

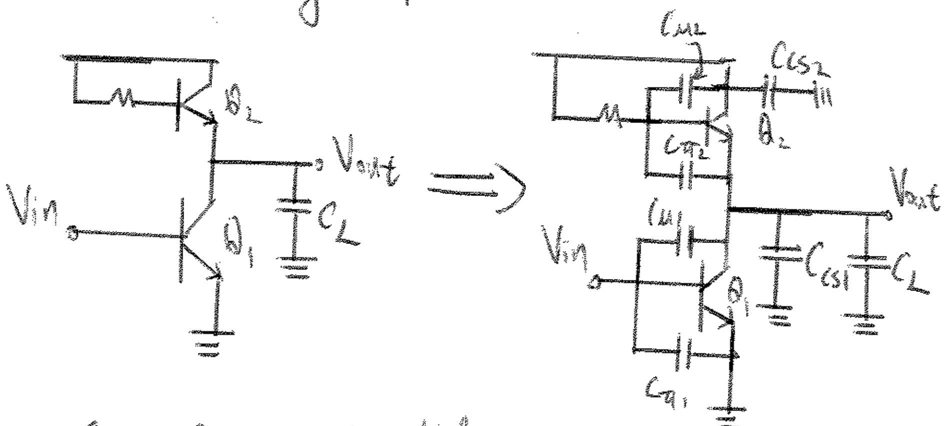


$C_{\pi 2}$, C_{cs1}, C_L are in parallel

$C_{\mu 2}$, C_{cs2} are grounded on both ends.

(and technically in parallel as well)

b)

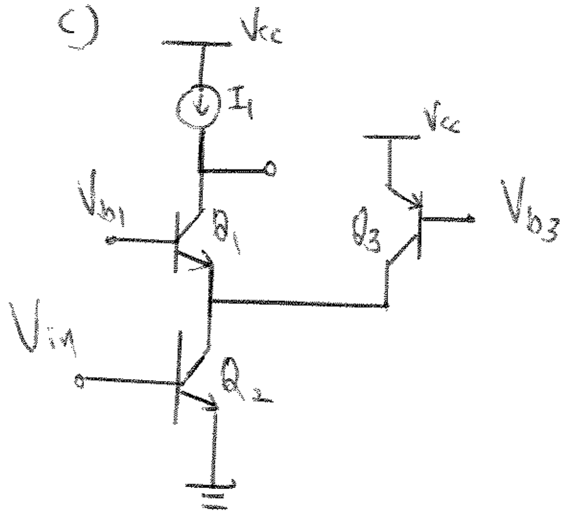


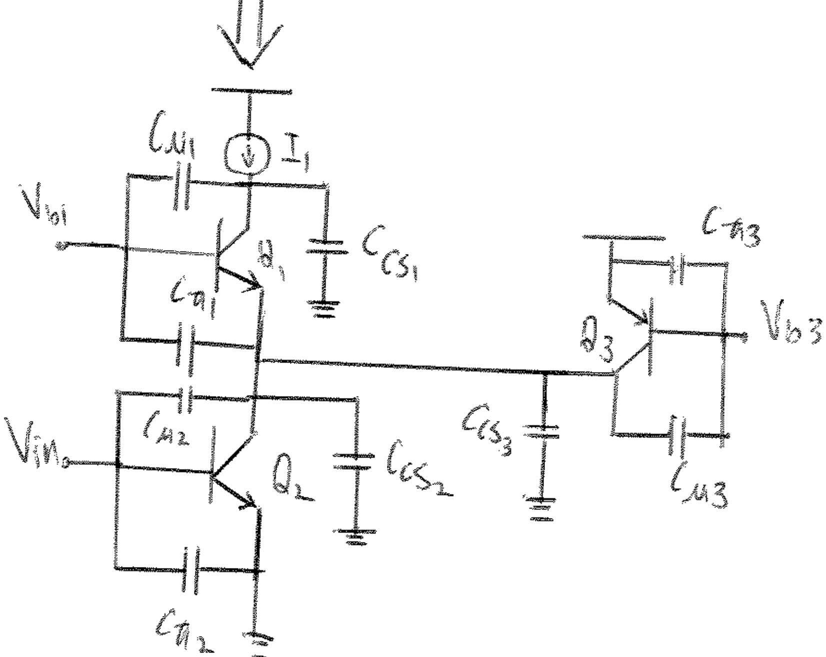
C_{cs1}, C_L are in parallel

C_{cs2} is grounded on both ends

24)

c)





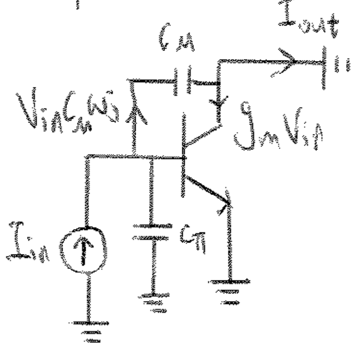
$C_{\pi 1}$, C_{CS_2}, C_{CS_3}, $C_{\mu 3}$ are in parallel

$C_{\mu 1}$, C_{CS_1} are also in parallel

$C_{\pi 3}$ is grounded on both ends

2b)

Bipolar



$$V_{in} = (I_{in})\left(\frac{1}{[C_\mu + C_\pi]\omega j}\right)$$

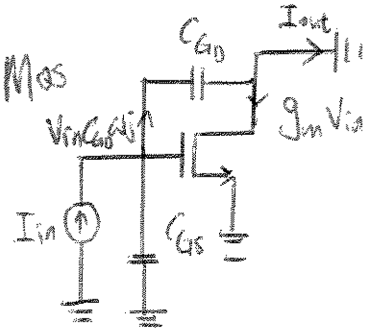
(Assuming we are at freq, and r_π can be neglected)

$$I_{out} = V_{in} C_\mu \omega j - g_m I_{in}\left(\frac{1}{[C_\mu + C_\pi]\omega j}\right)$$

$$\frac{I_{out}}{I_{in}} = \frac{C_\mu \omega j - g_m}{[C_\mu + C_\pi]\omega j} \Rightarrow \left|\frac{I_{out}}{I_{in}}\right| = \frac{\sqrt{(g_m)^2 + (C_\mu \omega_T)^2}}{[C_\mu + C_\pi]\omega_T} = 1$$

$$\omega_T^2 = \frac{g_m^2}{2C_\mu C_\pi + C_\pi^2} \Rightarrow \omega_T = 2\pi f_T = \frac{g_m}{\sqrt{2C_\mu C_\pi + C_\pi^2}}$$

Mos



Similarly for Mos, with C_μ and C_π replaced by C_{GD} and C_{GS} respectively.

$$\omega_T = 2\pi f_T = \frac{g_m}{\sqrt{2C_{GD} C_{GS} + C_{GS}^2}}$$

28)

$$C_{GS} \approx \left(\frac{2}{3}\right) W L C_{ox}$$

$$2\pi f_T = \frac{g_m}{C_{GS}} = \frac{\frac{W}{L}\mu_n C_{ox}(V_{GS}-V_{TH})}{\frac{2}{3} W L \ C_{ox}}$$

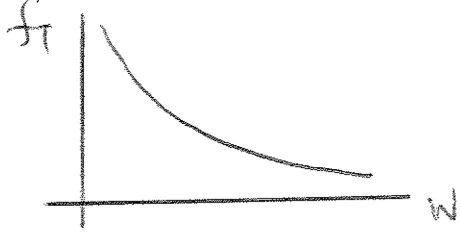
$$2\pi f_T = \frac{3}{2}\frac{\mu_n}{L^2}(\ V_{GS} - V_{TH})$$

3c)

a) As $W \uparrow$, $(V_{GS} - V_{TH})$ has to $\downarrow$ by $\frac{1}{\sqrt{W}}$ in order to maintain I_D constant

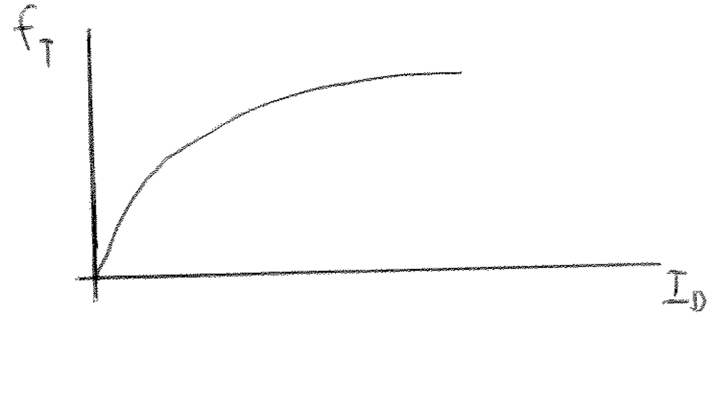
using equation $2\pi f_T = \frac{3}{2} \frac{\mu_n}{L^2} (V_{GS} - V_{TH})$

$2\pi f_T \propto \frac{1}{\sqrt{W}}$



b) $I_D \uparrow$, W constant it means $V_{GS} - V_{TH} \uparrow$ with $\sqrt{I_D}$. Using equation $2\pi f_T = \frac{3}{2} \frac{\mu_n}{L^2} (V_{GS} - V_{TH})$

$2\pi f \propto \sqrt{I_D}$

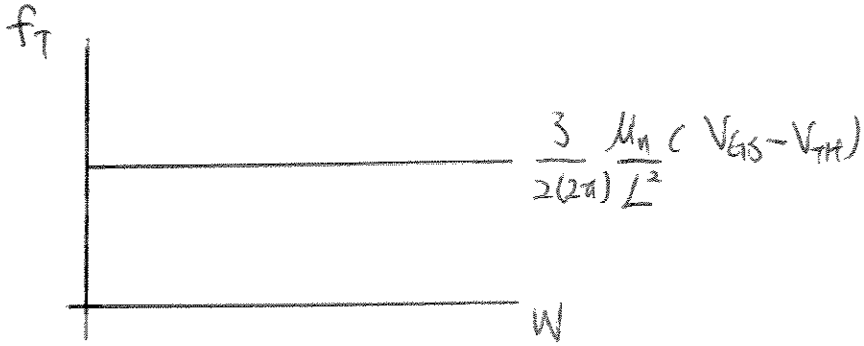


32)

a)

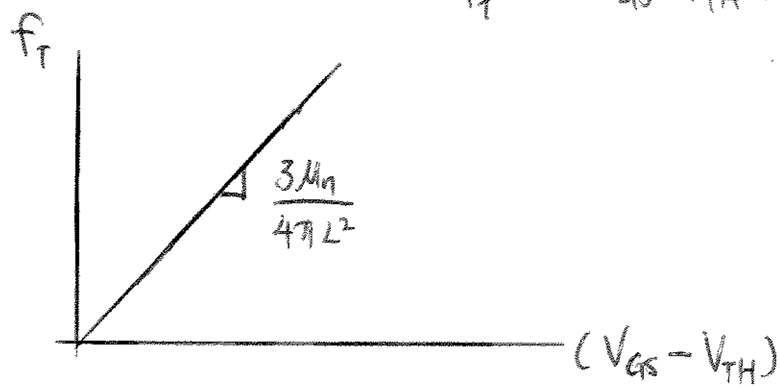
Using equation $2\pi f_T = \frac{3}{2}\frac{\mu_n}{L^2}(V_{GS}-V_{TH})$

we Know that $2\pi f_T$ is constant for all W.



b) Using equation $2\pi f_T = \frac{3}{2}\frac{\mu_n}{L^2}(V_{GS}-V_{TH})$.

we Know that $2\pi f_T \propto (V_{GS}-V_{TH})$.



34)

a) $V_{GS} - V_{TH} \longrightarrow \frac{1}{2}(V_{GS} - V_{TH})$

Constant I_D and $W\uparrow$ (L constant)

$$2\pi f_T = \frac{3}{2} \frac{\mu_n}{L^2} (V_{GS} - V_{TH})$$

$$f_{T_{new}} = \frac{f_{T,old}}{2}$$

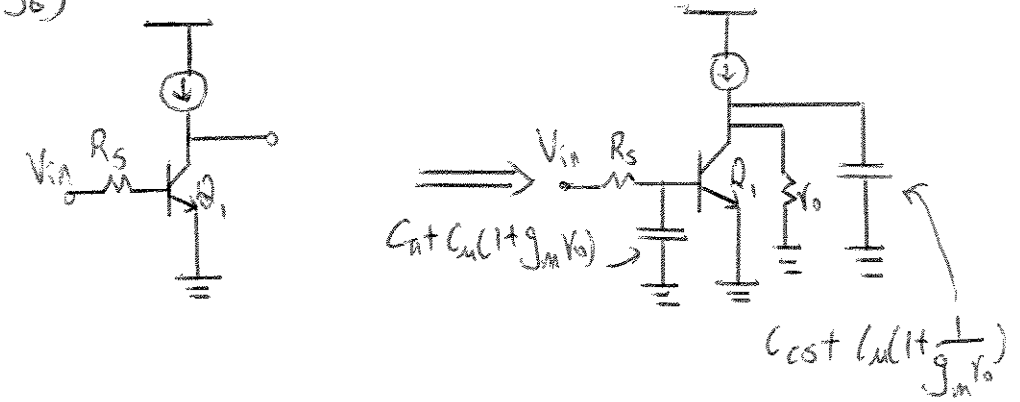
b) $V_{GS} - V_{TH} \longrightarrow \frac{1}{2}(V_{GS} - V_{TH})$

Constant W and $I_D \downarrow$ (L constant)

$$2\pi f_T = \frac{3}{2} \frac{\mu_n}{L^2} (V_{GS} - V_{TH})$$

$$f_{T_{new}} = \frac{f_{T,old}}{2}$$

36)



$$\omega_{p,in} = \frac{1}{(R_S \parallel r_\pi)[C_\pi + C_\mu(1+g_m r_o)]}$$

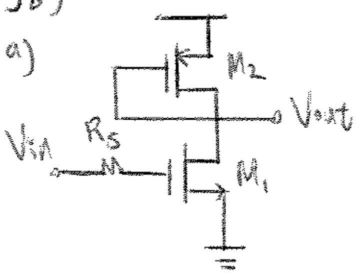
$$\omega_{p,out} = \frac{1}{r_o[C_{cs} + C_\mu(1+1/g_m r_o)]}$$

$$H(s) = \frac{\text{DC gain}}{(1+\frac{s}{\omega_{p,in}})(1+\frac{s}{\omega_{p,out}})}$$

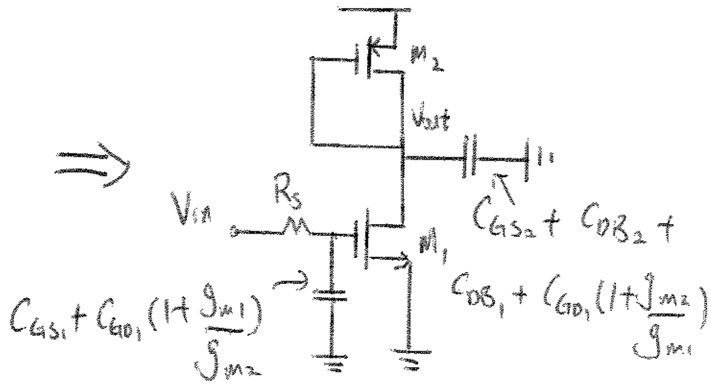
$$H(s) = \frac{g_m r_o (r_\pi/(r_\pi+R_S))}{\left(1+\frac{s}{1/(R_S \parallel r_\pi)[C_\pi+C_\mu(1+g_m r_o)]}\right)\left(1+\frac{s}{1/(r_o[C_{cs}+C_\mu(1+\frac{1}{g_m r_o})])}\right)}$$

3B)

a)



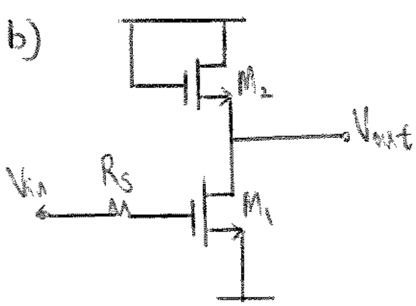
$\Longrightarrow$



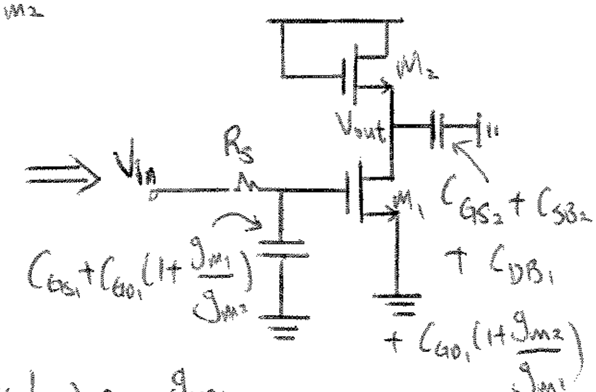
$$\text{DC gain} = -g_{m_1}\left(r_{o_1} \,//\, r_{o_2} \,//\, \frac{1}{g_{m_2}}\right) \approx -\frac{g_{m_1}}{g_{m_2}}$$

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

b)



$\Longrightarrow$



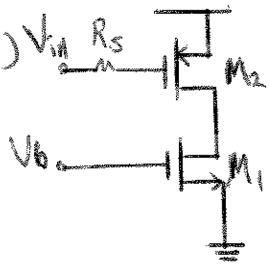
$$\text{DC gain} = -g_{m_1}\left(r_{o_1} \,//\, r_{o_2} \,//\, \frac{1}{g_{m_2}}\right) \approx -\frac{g_{m_1}}{g_{m_2}}$$

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

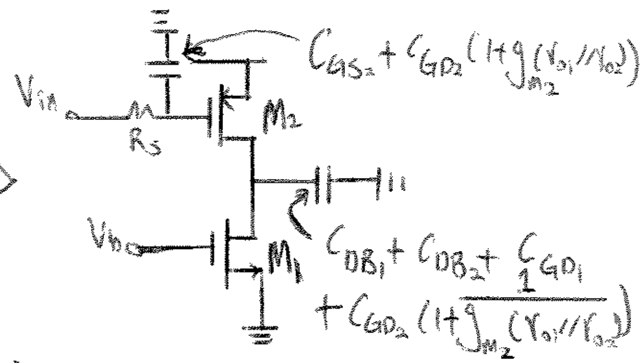
$$\omega_{p_{out}} = \frac{g_{m_2}}{C_{SB_2} + C_{GS_2} + C_{DB_1} + C_{GD_1}\left(1+\frac{g_{m_2}}{g_{m_1}}\right)}$$

38)

c)



$\Longrightarrow$



DC gain: $-g_{m2}(r_{o1}//r_{o2})$

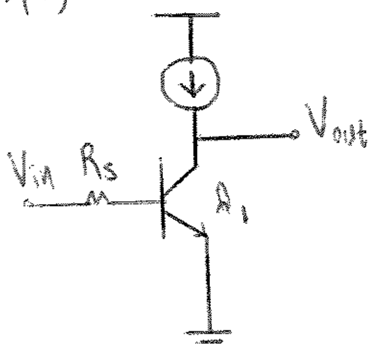
$$\omega_{pin} = \frac{1}{R_S\left(C_{GS_2} + C_{GD_2}(1+g_{m_2}(r_{o1}//r_{o2}))\right)}$$

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

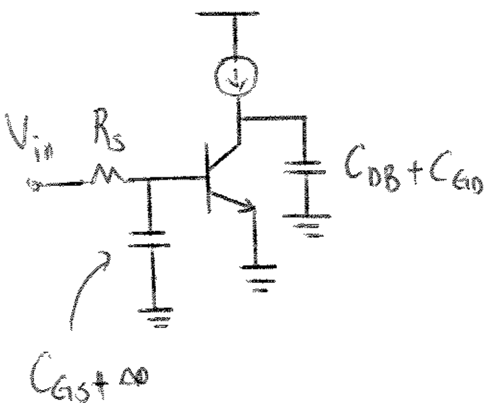
$$\omega_{pout} \approx \frac{1}{(r_{o1}//r_{o2})\left[C_{DB_1} + C_{DB_2} + C_{GD_1} + C_{GD_2}\right]}$$

Since $g_{m2}(r_{o1}//r_{o2}) \gg 1$

40)



a) Miller's Approximation: DC gain: $-\infty$



$$\omega_{pin} = \frac{1}{R_S(\infty)} = 0, \quad \omega_{pout} = \frac{1}{\infty(C_{DB}+C_{GD})} = 0$$

b) Transfer Function:

$$\frac{V_{out}}{V_{thev}}(s) = \frac{(C_{XY}s - g_m)R_L}{as^2 + bs + 1}$$

$$a = R_{Thev}R_L(C_{in}C_{XY} + C_{out}C_{XY} + C_{in}C_{out})$$

$$b = (1+g_mR_L)C_{XY}R_{Thev} + R_{Thev}C_{in} + R_L(C_{XY} + C_{out})$$

40)

b) $R_L \to \infty$

$$\frac{V_{out}}{V_{thev}} = \frac{C_{XY}s - g_m}{s[R_{thev}(C_{in}C_{XY} + C_{out}C_{XY} + C_{in}C_{out})s + g_m C_{XY} R_{thev} + (C_{XY} + C_{out})]}$$

So $\omega_{p_1} = 0$

$$\omega_{p_2} = \frac{(g_m C_{XY} R_{thev} + (C_{XY} + C_{out}))}{R_{thev}[C_{in}C_{XY} + C_{out}C_{XY} + C_{in}C_{out}]}$$

$$\omega_{p_2} = \frac{g_m C_\mu R_S /\!/ R_\pi + C_\mu + C_{CS}}{R_S /\!/ r_\pi [C_\pi C_\mu + C_{CS} C_\mu + C_\pi C_{CS}]}$$

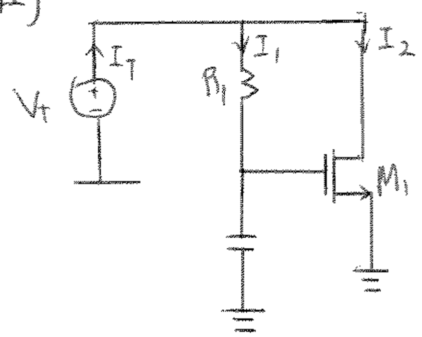
$\omega_{p_1} = \omega_{pin}$, $\omega_{p_2} = \omega_{pout}$.

<u>Miller:</u>

$\omega_{pin} = 0$, $\omega_{pout} = 0$

Again, the output pole predicted by the transfer function is pushed out, and the input poles are similar. (In fact, they are the same this time.)
This shows one of the short-comings of Miller's approximation.

42)



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

$$I_T = I_1 + I_2$$

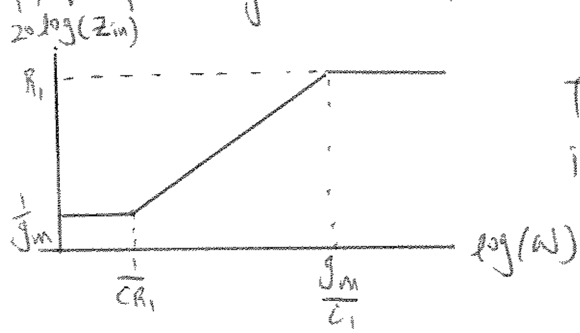
$$I_1 = \frac{V_T}{\left(R_1 + \frac{1}{C_1 s}\right)}, \quad I_2 = \frac{g_{m_1} V_T}{C_1 R_1 s + 1}$$

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

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

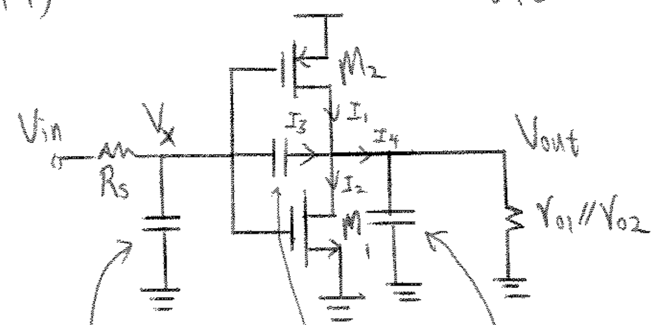
$$|Z_T| = |Z_{in}| = \frac{\sqrt{(C_1 R_1 \omega)^2 + 1}}{\sqrt{(C_1 \omega)^2 + g_{m_1}^2}} = \frac{\sqrt{(C_1 R_1 \omega)^2 + 1}}{g_m \sqrt{\left(\frac{C_1 \omega}{g_{m_1}}\right)^2 + 1}}$$

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.

44) $\lambda > 0$



$C_{GS_2} + C_{GS_1} = C_C$

$C_{GD_1} + C_{GD_2} = C_B$

$C_{DB_2} + C_{DB_1} = C_A$

$$V_{out} = I_4 \underbrace{\left(r_{o1} // r_{o2} // \frac{1}{[C_{DB_2} + C_{DB_1}]s} \right)}_{Z_{out}}$$

$$I_4 = I_1 + I_3 - I_2$$

$$I_1 = (0 - V_x) g_{m_2}$$

$$I_2 = V_x g_{m_1}$$

$$I_3 = (V_x - V_{out}) \left((C_{GD_1} + C_{GD_2}) s \right.$$

$$I_4 = -V_x g_{m_2} + (V_x - V_{out}) C_B s - V_x g_{m_1}$$

$$V_{out} = Z_{out} \left[-V_x (g_{m_2} + g_{m_1}) + (V_x - V_{out}) C_B s \right]$$

Writing a node equation at x.

$$\frac{V_x - V_{in}}{R_s} + V_x C_c s + (V_x - V_{out}) C_B s = 0$$

$$V_x = \frac{V_{out} C_B s + V_{in}/R_s}{(1/R_s + C_c s + C_B s)}$$

44)

Subsitute everything and we get

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

collect all the V_{out}'s on one-side and likewise for V_{in}'s, we will get

$$\frac{V_{out}}{V_{in}} = \frac{\frac{Z_{out}}{R_s}\left(C_B s - (g_{m_1}+g_{m_2})\right)}{1/R_s + (C_c+C_B)s + Z_{out}C_B s(g_{m_1}+g_{m_2}) + Z_{out}C_B s\left(\frac{1}{R_s}+(C_c+C_B)s\right) - Z_{out}C_B^2 s^2}$$

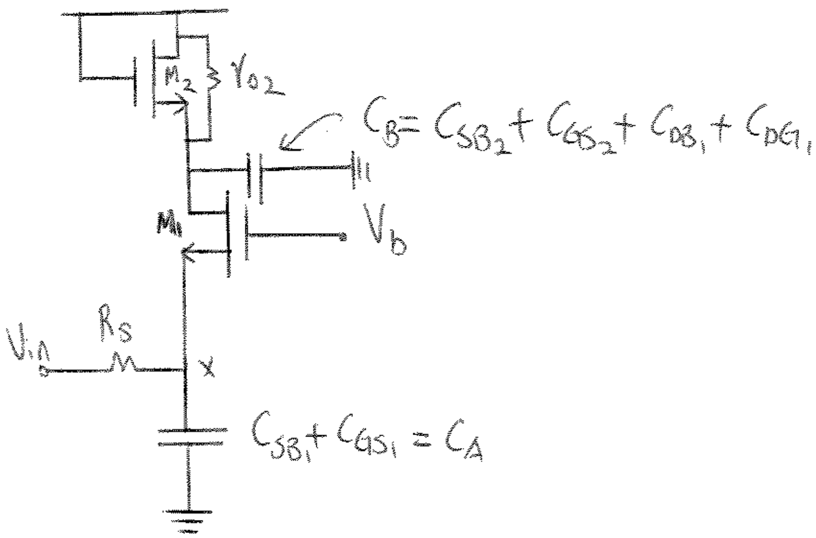
where $Z_{out} = r_{o1} // r_{o2} // \dfrac{1}{[C_{DB_1}+C_{DB2}]s}$

$C_B = C_{GD_1} + C_{GD2}$

$C_c = C_{GS_1} + C_{GS_2}$

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, $\dfrac{V_x - V_{in}}{R_s} + V_x C_A s - g_m (0 - V_x) = 0$

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

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

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

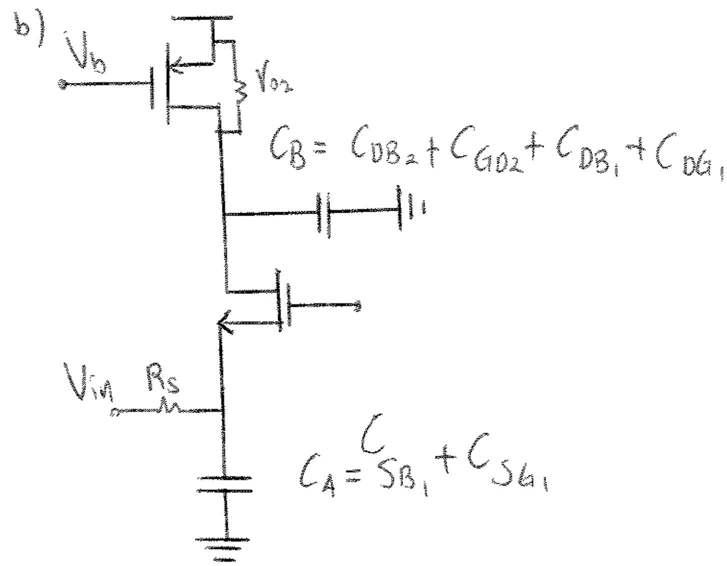
$$\frac{V_{out}}{V_{in}} = \frac{g_{m_1} (1/g_{m_2})}{(C_B (1/g_{m_2}) s + 1)(1 + R_s C_A s + R_s g_{m_1})}$$

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.

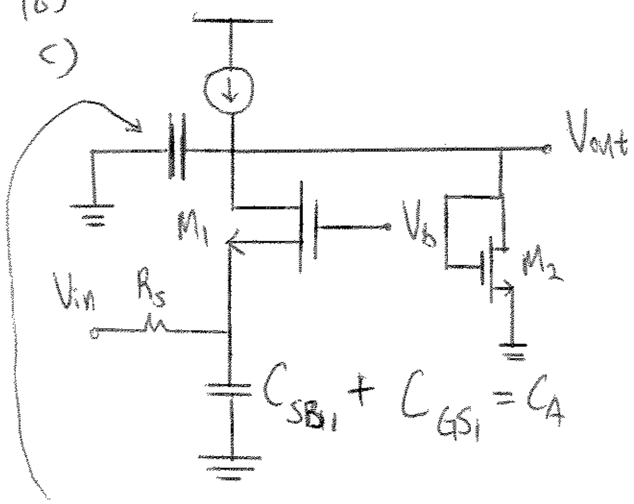
So $$\frac{V_{out}}{V_{in}} = \frac{g_{m_1} r_{o2}}{(C_B r_o s + 1)(1 + R_s C_A s + R_s g_{m_1})}$$

Where $C_B = C_{DB_2} + C_{GD_2} + C_{DB_1} + C_{DG_1}$

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

46)

c)



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

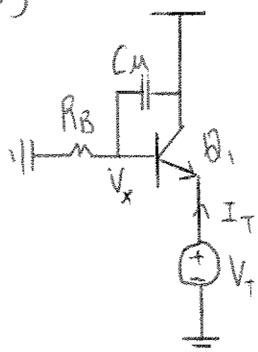
AC-wise, this circuit is very similar to part a). Its transfer function is the same as part a), except for C_B.

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

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

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

48)



$V_A = \infty$,

$\frac{\beta}{\beta+1} \approx 1$, if $\beta >> 1$

$I_T = -(V_x - V_T) g_m \alpha \approx -(V_x - V_T) g_m$

$V_x = \frac{I_T}{\beta}\left(R_B // \frac{1}{C_\mu s}\right)$

$I_T = \left(V_T - \frac{I_T}{\beta}\left(R_B // \frac{1}{C_\mu s}\right)\right) g_m$

$I_T = g_m V_T - \frac{g_m}{\beta}\left(R_B // \frac{1}{C_\mu s}\right) I_T$

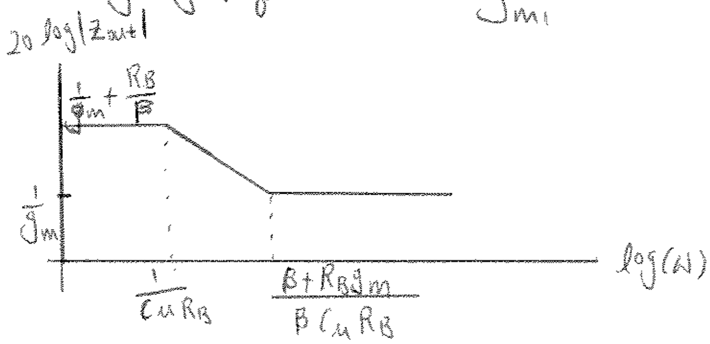
$I_T\left(1 + \frac{g_m}{\beta}\left(R_B // \frac{1}{C_\mu s}\right)\right) = g_m V_T$

$$\frac{V_T}{I_T} = \frac{1}{g_m} + \frac{R_B // \frac{1}{C_\mu s}}{\beta} = \frac{\beta C_\mu R_B \left(s + \frac{\beta + R_B g_m}{\beta C_\mu R_B}\right)}{g_m \beta (1 + C_\mu R_B s)}$$

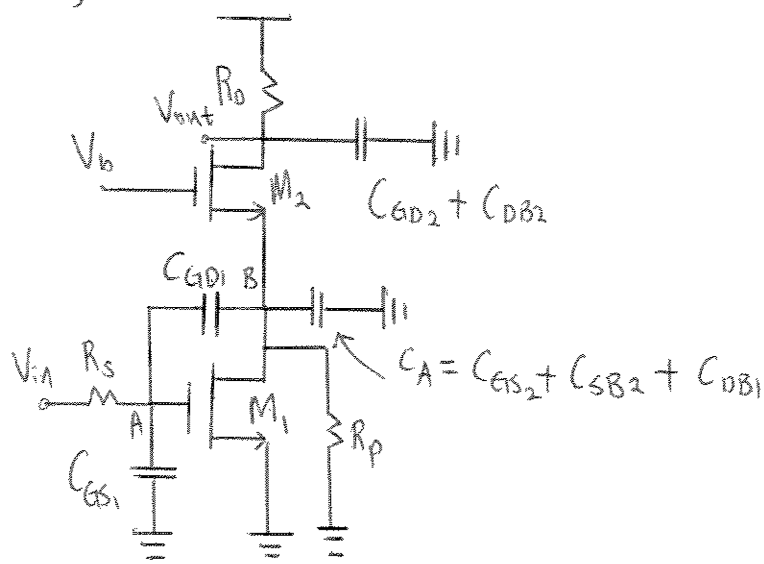
Zero: $\frac{\beta + R_B g_m}{\beta C_\mu R_B}$, Pole: $\frac{1}{C_\mu R_B}$

At DC, $|Z_{out}| = \frac{1}{g_{m1}} + \frac{R_B}{\beta}$

At very high freq: $|Z_{out}| = \frac{1}{g_{m1}}$



50)



DC gain from A to B is $-g_{m_1}\left(R_P // \frac{1}{g_{m2}}\right)$

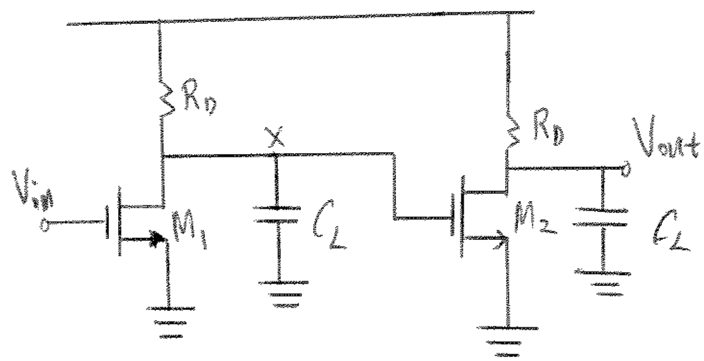
Applying Miller's Theorem:

$$\omega_{pin}\,(\omega_{pA}) = \frac{1}{R_S\left(C_{GS_1} + C_{GD_1}\left(1 + g_{m_1}\left(R_P // \frac{1}{g_{m2}}\right)\right)\right)}$$

$$\omega_{pB} = \frac{1}{R_P // \frac{1}{g_{m_2}}\left[C_{GS_2} + C_{SB2} + C_{DB_1} + C_{GD_1}\left(1 + 1/g_{m_1}\left(R_P // \frac{1}{g_{m2}}\right)\right)\right]}$$

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

52)



Bias Current = 1mA (each stage)

$C_L = 50 fF$

$\mu_n C_{ox} = 100 \mu A/V^2$, $A_V = 20$, $-3dB$: 1GHz

DC gain: $(g_m R_D)^2 = 20$

$-3dB$ bandwidth: $0.10243/(R_D C_L) = 1 GHz$

Since $C_L = 50fF$, $R_D = 2048.6 \Omega$

$(g_m R_D)^2 = 20 \Rightarrow g_m = 0.002183 = \frac{2I_D}{V_{eff}} \Rightarrow V_{eff} = 0.916V$

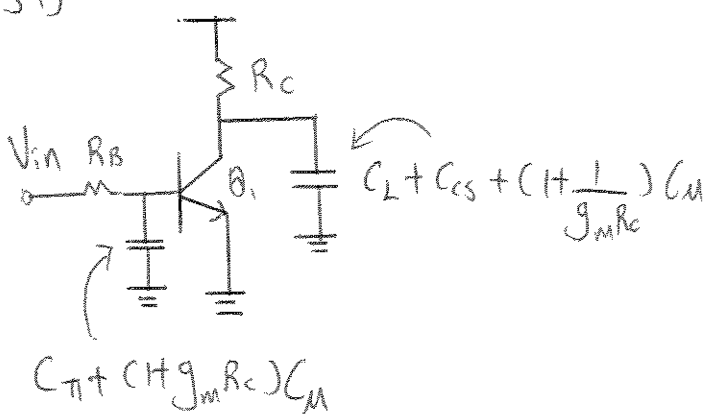
$V_{eff} = V_{GS} - V_{th} = 0.916V$

$g_m = \mu_n C_{ox} \frac{W}{L} (V_{eff}) \Rightarrow \frac{W}{L} = \frac{g_m}{\mu_n C_{ox} (V_{eff})} = 23.83$

So $R_D = 2.05K$, $C_L = 50fF$

$V_{GS} - V_{th} = 0.916V$, $W/L = 23.83$

54)



Low freq voltage gain: $\frac{V_{out}}{V_{in}} = \frac{-R_C}{1/g_m + \frac{R_B}{\beta+1}}$

$$\omega_{pout} = \frac{1}{R_C[C_L + C_{CS} + (1+\frac{1}{g_m R_C})C_\mu]} = (2\pi)(2\,GHz)$$

$$g_m = \frac{I_C}{V_T} = 0.0386\ \frac{1}{\Omega}$$

$$g_m = (2\pi)(2\,GHz)[g_m R_C[C_L + C_{CS}] + g_m R_C C_\mu + C_\mu]$$

$$R_C = \left[\frac{g_m}{(2\pi)(2G)} - C_\mu\right] / (g_m[C_L + C_{CS} + C_\mu])$$

$R_C = 2269.94\Omega \approx 2.27\,K\Omega$

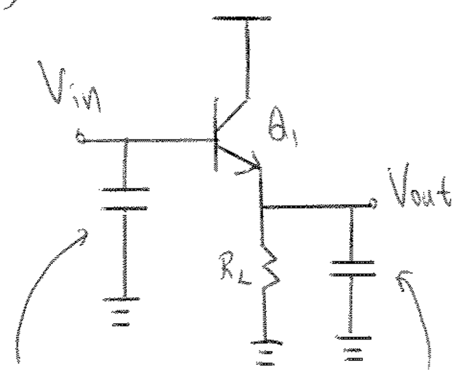
Again, to maximize low freq gain, R_B should be as small as possible, so $R_B // r_\pi \approx R_B$

$$\omega_{pin} \approx \frac{1}{R_B(C_\pi + C_\mu(1+g_m R_C))} = (2\pi)(50 \times 10^6),\ g_m R_C = 87.62$$

$R_B = 687.35\Omega$

So, $R_C = 2.27K\Omega$, $R_B = 687.35\Omega$

56)



DC gain: $\dfrac{R_L}{R_L + 1/g_m}$

$V_A = \infty$

$C_\mu = 10fF$, $C_\pi = 100fF$

$C_\pi\left(1 - \dfrac{R_L + 1/g_m}{R_L}\right)$

$C_\mu + C_\pi\left(1 - \dfrac{R_L}{R_L + 1/g_m}\right)$

$$C_{in} < 50fF \Rightarrow C_\mu + C_\pi\left(1 - \frac{R_L}{R_L + 1/g_m}\right) < 50fF$$

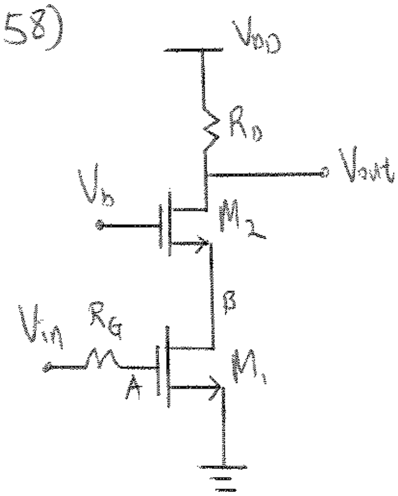
$$10fF + 100fF\left(1 - \frac{R_L}{R_L + 1/g_m}\right) < 50fF$$

$$100fF\left(1 - \frac{R_L}{R_L + 1/g_m}\right) < 40fF$$

$$\left(\frac{\frac{1}{g_m}}{R_L + 1/g_m}\right) < 0.4$$

$$R_L > \frac{3}{2g_m} = 38.85\Omega$$

58)



$\omega_{pin} = 5\text{ GHz}$, $\omega_{pout} = 10\text{ GHz}$

$V_{eff} = 200\text{ mV} \ (V_{GS} - V_{th})$, $I_D = 0.5\text{mA}$

$\lambda = 0$, $C_{GS} = (2/3)\, WL\, C_{ox}$,

$L = 0.18\mu m$, $\mu_n C_{ox} = 100\mu A/V^2$

$C_{GD} = WC_o$, $C_o = 0.2 fF/\mu m$

$C_{ox} = 12 fF/\mu m^2$

DC gain from A to B: $\dfrac{-g_{m1}}{g_{m2}} = 1$

$C_{in} = C_{GS} + C_{GD}(1 + g_{m1}/g_{m2}) = C_{GS} + 2C_{GD}$

$I_D = \frac{1}{2}\frac{W}{L}\mu_n C_{ox}(V_{eff})^2 = 0.5\text{ mA} \Rightarrow \frac{W}{L} = 250$

$L = 0.18\mu$, $W = 45\mu$

$$\omega_{pin} = (2\pi)(5\times10^9) = \frac{1}{R_G\left[\frac{2}{3}(45)(0.18)(12 ff/\mu m^2) + (0.2)(45)(2)\right]}$$

$R_G = 384.43\Omega$

$$\omega_{pout} = \frac{1}{R_D[0.2W]} = (10\times10^9)(2\pi), \ W = 45\mu m$$

$\Rightarrow R_D = 1.8K\Omega$ (1768.4Ω) exact value

$$\text{Gain} = |g_m R_D| = \frac{2I_D}{V_{eff}} R_D = 8.842$$