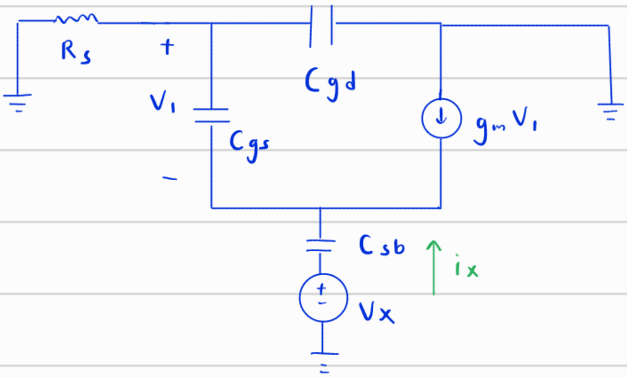
4.1

(a)



$$C_{ov} = C_{ox} L_D$$

$$C_{gd} = C_{gdo} W$$

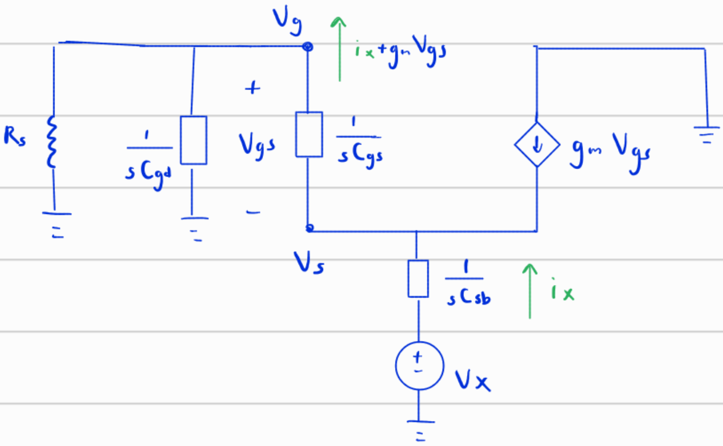
$$C_{gs} = \frac{2}{3} W (L - 2L_D) C_{ox} + W C_{ov}$$

$$C_{db} = C_{bo} W L_j + C_{sw}(2W + 2L_j)$$

$$L_j = 1.5\ \mu m$$

$$C_{bo} = \frac{C_j}{\left(1 + \frac{V_R}{PB}\right) MJ}$$

$$C_{sw} = \frac{C_{jsw}}{\left(1 + \frac{V_R}{PB}\right) MJSW}$$



$V_{DD} = 3V$

$$C_{ox} = 3.9 \frac{\epsilon_o}{t_{ox}} = 3.83673 \times 10^{-7}\ F/cm^2 = 3.83673 \times 10^{-15}\ F/\mu m^2$$

$\mu_n = 350\ cm^2/V/s$ $\quad V_{t_n} = 0.7$

$\mu_p = 100\ cm^2/V/s$ $\quad V_{t_p} = -0.8$

$k'_n = 0.13428\ mA/V^2$ $\quad k'_p = 0.03837\ mA/V^2$

$C_{jn} = 0.56m$ $\quad \lambda_n = 0.1$

$C_{jp} = 0.94m$ $\quad \lambda_p = 0.2$

$L_{Dn} = 0.08\mu$

$L_{Dp} = 0.09\mu$

$$V_g = (i_x + g_m V_{gs}) \left(R_s \parallel \frac{1}{sC_{gd}} \right)$$

$$= (i_x + g_m V_{gs}) \frac{R_s}{sR_s C_{gd} + 1}$$

$$V_{gs} = -(i_x + g_m V_{gs}) \frac{1}{sC_{gs}}$$

$$= -i_x \frac{1}{sC_{gs}} - g_m V_{gs} \frac{1}{sC_{gs}}$$

$$\left(1 + \frac{g_m}{sC_{gs}}\right) V_{gs} = -i_x \frac{1}{sC_{gs}}$$

$$V_{gs} = \frac{-i_x}{sC_{gs}\left(1 + \frac{g_m}{sC_{gs}}\right)} = -\frac{i_x}{sC_{gs} + g_m}$$

$$V_s = V_g - V_{gs}$$

$$= (i_x + g_m V_{gs}) \left(\frac{R_s}{sR_s C_{gd} + 1} - \frac{1}{sC_{gs}} \right)$$

$$= \left(1 - \frac{1}{sC_{gs} + g_m}\right) i_x \left(\frac{R_s}{sR_s C_{gd} + 1} - \frac{1}{sC_{gs}} \right)$$

$$V_x = \left(1 - \frac{1}{sC_{gs} + g_m}\right) i_x \left(\frac{R_s}{sR_sC_{gd}+1} - \frac{1}{sC_{gs}}\right) - (-i_x)\frac{1}{sC_{sb}}$$

$$= i_x\left[\left(1 - \frac{1}{sC_{gs}+g_m}\right)\left(\frac{R_s}{sR_sC_{gd}+1} - \frac{1}{sC_{gs}}\right) + \frac{1}{sC_{sb}}\right]$$

$$\frac{V_x}{i_x} = R_{out} = \left(1 - \frac{1}{sC_{gs}+g_m}\right)\left(\frac{R_s}{sR_sC_{gd}+1} - \frac{1}{sC_{gs}}\right) + \frac{1}{sC_{sb}}$$

#

$$C_{ov} = 0.08\,\mu m \cdot 3.83673\times10^{-15}\ F/\mu m^2 = 306.9384\times10^{-18}\ F/\mu m$$

$$C_{gs} = \frac{2}{3}\cdot 50\,\mu m\cdot(0.5\mu - 2\cdot 0.08\mu)m\ 3.83673\times10^{-15}\ F/\mu m^2 + 50\,\mu m\cdot 306.9384\times10^{-18}\ F/\mu m$$

$$= 58.8299\ f$$

$$C_{gd} = 0.4\,nF/m \times 50\,\mu m$$

$$= 20\ f$$

$$k_1 = 0.13428\,mA/V^2 \times \frac{50\mu}{0.5\mu - 2\times0.08\mu}$$

$$= 19.74706\ mA/V^2$$

$$g_m = \sqrt{2kI} = 6.28443\,m$$

$$R_s = 20k$$

After some simplification

$$R_{out} = \frac{R_sC_{gs}s + 1}{g_m + C_{gs}s}$$

When V_{in} is low freq., $s \to 0$

$$R_{out} \approx \frac{0+1}{g_m+0} = \frac{1}{g_m} = 159.1233\ \Omega$$

When V_{in} is high freq., $s \to \infty$

$$R_{out} \approx R_s = 20k$$

Inductive impedance has the form sL, and therefore increases with freq.

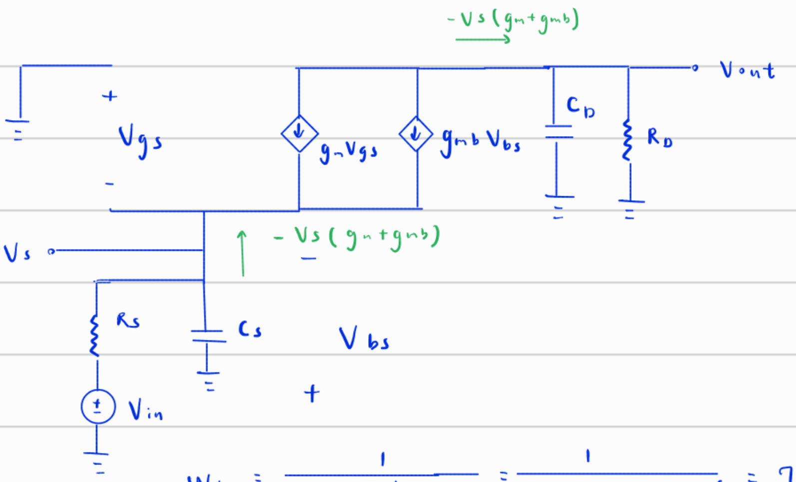
Capacitive impedance has the form $\frac{1}{sC}$, and therefore decreases with freq.

The output impedance of this circuit increases with freq. so it's inductive. #

$$L = \frac{C_{gs}}{g_m}\left(R_s - \frac{1}{g_m}\right)$$

$$= 188.714\,nH \quad \#$$

4.2 $\quad R_s = 1k \quad R_D = 2k \quad C_s = 101.2\,fF \quad C_D = 27.14\,fF$



$$W_{in} = \frac{1}{\left(R_s \| \frac{1}{g_m+g_{mb}}\right)C_s} = \frac{1}{138.5156 \cdot 101.2f} = 71.338\,G \text{ rad/s} \quad \#$$

$$W_{out} = \frac{1}{C_D R_D} = \frac{1}{27.14f \cdot 2k} = 18.4230\,G \text{ rad/s}$$

To determine low freq. gain, treat $C_s \cdot C_D$ as open circuit

$k = 0.13428\,mA/V^2 \times 100$

$= 13.428\,mA/V^2$

$\frac{1}{2}k(V_{gs}-0.7)^2 = 1m$

$V_{gs} = \sqrt{\frac{2m}{k}} + 0.7$

$= 1.08593$

$1.45 - V_s = 1.08593$

$V_s = 0.36407\,V \qquad V_{SB} = 0.36407$

$g_m = \sqrt{2kI}$

$= 5.1823m$

$g_{mb} = g_m \cdot \frac{\gamma}{2\sqrt{|2\phi_f + V_{SB}|}}$

$= 5.1823m \frac{0.45}{2\sqrt{|0.9+0.36407|}}$

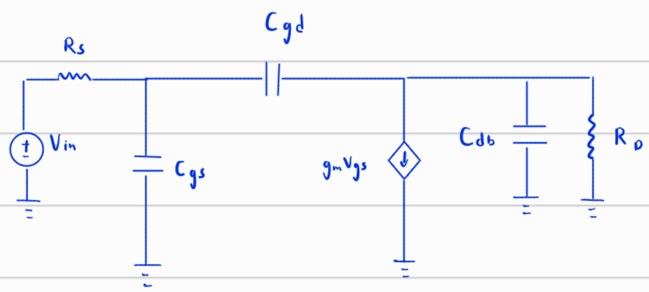
$= 1.03710m$

$g_m + g_{mb} = 6.21940m$

$$A_v = \frac{R_D}{R_s + \frac{1}{g_m+g_{mb}}}$$

$$= 1.730\,V/V \quad \#$$

4.3



$k = 0.13428\,mA/V^2 \times 100$

$= 13.428\,mA/V^2$

$R_S = 2k$

$R_D = 2k$

$g_m = 5.1823\,m$

$A_v = -g_m R_D$

$= -10.3646\ V/V$

$$\omega_{in} = \frac{1}{R_S[C_{gs} + (1+g_m R_D) C_{gd}]}$$

$$\omega_{out} = \frac{1}{R_D[C_{db} + (1+\frac{1}{g_m R_D}) C_{gd}]}$$

$C_{ov} = 0.08\,\mu m \cdot 3.83673 \times 10^{-15}\ F/\mu m^2 = 306.9384 \times 10^{-18}\ F/\mu m$

$C_{gs} = 58.8299\,f$

$C_{gd} = 0.4\,nF/m \times 50\,\mu m$

$= 20\,f$

$$C_{bo} = \frac{C_j}{(1+\frac{V_R}{PB})^{MJ}}$$

$C_j = 0.56\,mF/m^2$ $\quad V_{DB} = 1V$

$PB = 0.9$

$$C_{sw} = \frac{C_{jsw}}{(1+\frac{V_R}{PB})^{MJSW}}$$

$L_j = 1.5\,\mu m$ $\quad W = 50\,\mu m$

$C_{jsw} = 3.5\,pF/m$

$C_{db} = C_{bo} W L_j + C_{sw}(2W + 2L_j)$

$MJ = 0.45$ $\quad MJSW = 0.2$ $\quad$ Exponents

$$= \frac{C_j}{(1+\frac{1}{PB})^{MJ}} W L_j + \frac{C_{jsw}}{(1+\frac{1}{PB})^{MJSW}} (2W + 2L_j)$$

$$= \frac{0.56m}{(1+\frac{1}{0.9})^{0.45}} 1.5\mu\ 50\mu + \frac{3.5\,p}{(1+\frac{1}{0.9})^{0.2}} (100\mu + 3\mu)$$

$= 30.31723\,fF$

$$w_{in} = \frac{1}{R_S\left[C_{gs} + (1+g_m R_o)\, C_{gd}\right]} = 1.748\ G\ \text{rad/s}$$ #

$$w_{out} = \frac{1}{R_D\left[C_{db} + \left(1+\frac{1}{g_m R_o}\right) C_{gd}\right]} = 9.570\ G\ \text{rad/s}$$ #

$$w_z = \frac{g_m}{C_{gd}} = 259.115\ G\ \text{rad/s}$$ #