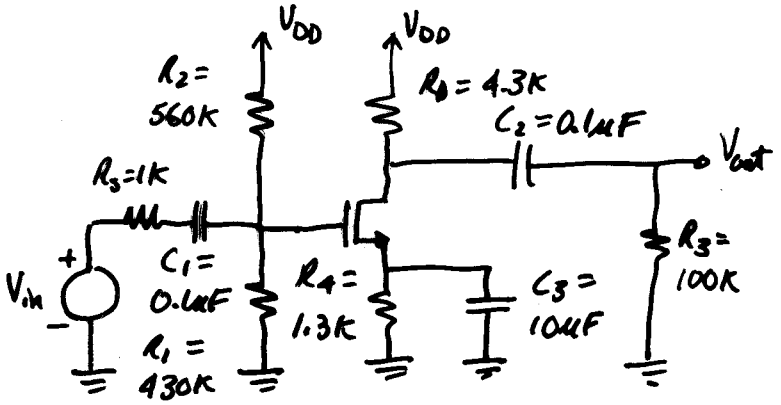
MOSFET High-Frequency Example



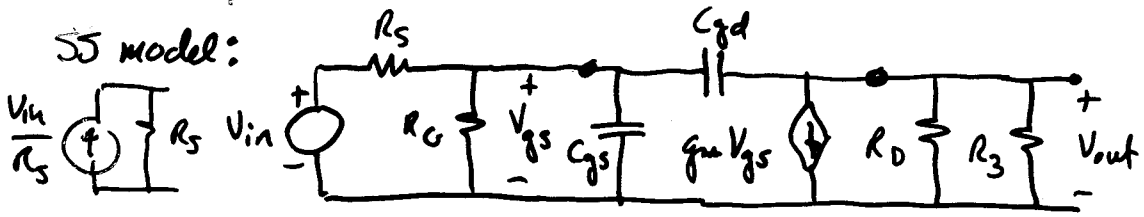
$g_m = 1.23$ ms

$C_{gs} = 10$ pF

$C_{gd} = 2$ pF

(1.) Direct Analysis —

SS model:



Nodal eqs.

$$\left(\frac{1}{R_s} + \frac{1}{R_G} + sC_{gs} + sC_{gd}\right)V_{gs} - sC_{gd}V_{out} = \frac{V_{in}}{R_s} \quad (1)$$

$$sC_{gd}(V_{out} - V_{gs}) + g_m V_{gs} + \left(\frac{1}{R_D} + \frac{1}{R_3}\right)V_{out} = 0 \quad (2)$$

↓ A page of algebra

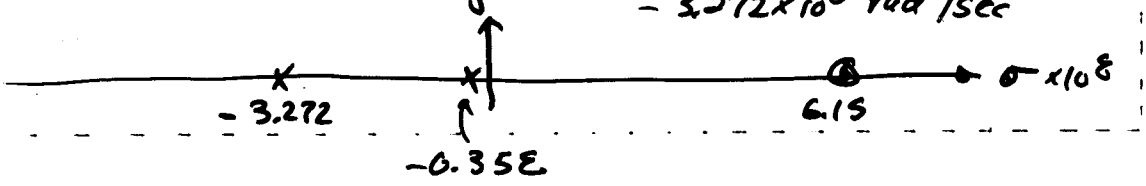
$$\frac{V_{out}}{V_{in}} = \frac{-G_s(g_m - sC_{gd})}{(G_s + G_G)(G_D + G_3) + s\left[C_{gs}(G_D + G_3) + C_{gd}(G_D + G_3 + G_s + G_G) + g_m C_{gd}\right] + s^2 C_{gd} C_{gs}}$$

↓ Substitute the values

$$\frac{V_{out}}{V_{in}} = \frac{-10^{-3}(1.23\times10^{-3} - s2\text{pF})}{20\times10^{-24}\left[s^2 + 3.628\times10^8 s + 1.165\times10^{16}\right]}$$

($-10^{-3}(1.23\times10^{-3} - s2\text{pF})$ → 6.15×10^8)

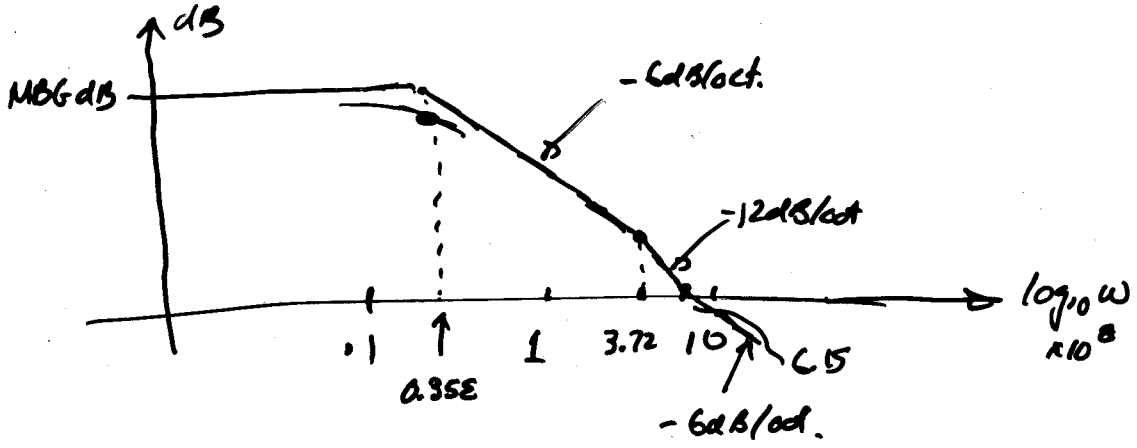
Roots of [ ] → $P_1, P_2 = -0.358\times10^8$ rads/sec, -3.272×10^8 rad/sec



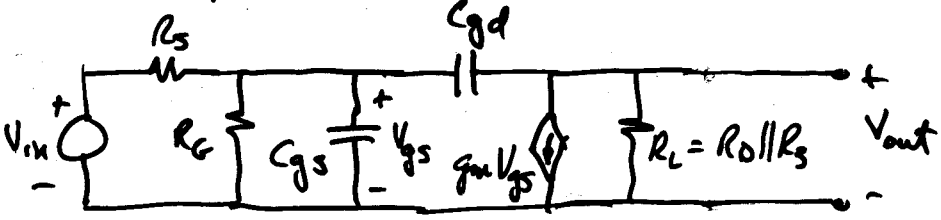
$\omega_H = ?$ $|\text{Dominant pole}| \approx 0.355 \times 10^6$ rad/sec

$f_{3dB(\text{upper})} = 5.67\,MHz$

Bode plot -



(2.) Miller approach

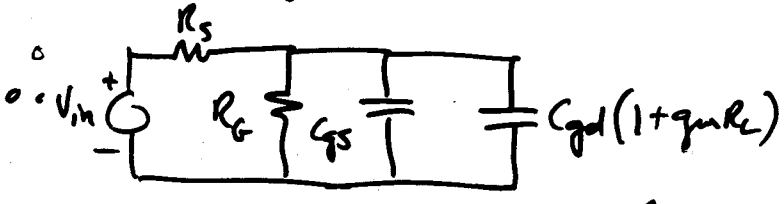


$\frac{V_{out}}{V_{gs}} = K \qquad C_{eq} = C_{gd}(1-K)$

Assume $\frac{1}{\omega C_{gd}} >> R_L \rightarrow K \rightarrow V_{out} \cong -g_m R_L V_{gs}$

$= -1.23(2.3 \| 100)$

$\cong -5\ V/V$



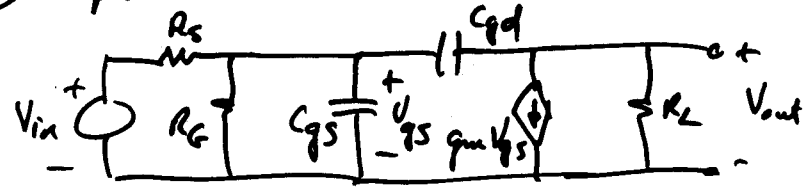
Pole = ? $\frac{1}{R_{eq} C_{eq}}$ $C_{eq} = C_{gs} + C_{gd}(1+g_m R_L)$ $R_{eq} = R_S \| R_G$

$\omega_H \approx \frac{1}{R_{eq} C_{eq}} = \frac{1}{(0.996K)[10pF + 2pF \times 6]} = 45.3 \times 10^6$ rad/sec

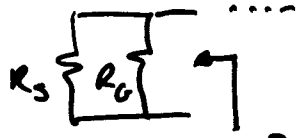
$\frac{1}{45.3 \times 10^6 \times 2 \times 10^{-12}} \cong 10K$

$\therefore \quad f_H = \frac{\omega_H}{2\pi} = 7.22\,MHz$

③ Open-Circuit Time Constant

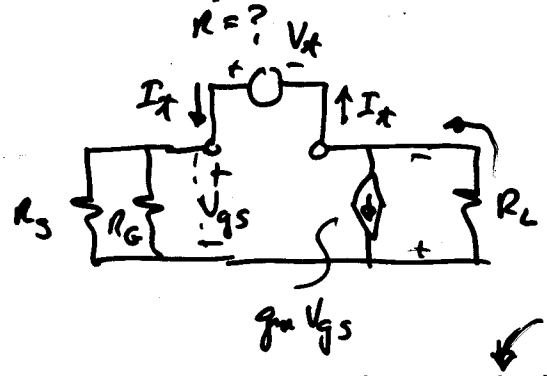


C_{gs}:



$R_{cgso} = R_S \| R_G \rightarrow R_{cgso} C_{gs} = 0.996K \times 2pF$

C_{gd}:



$R_{cgdo} = \frac{V_x}{I_x}$

$I_x(R_S \| R_G)$

$$V_x = I_x(R_S \| R_G) + R_L(I_x + g_m V_{gs})$$

$$V_x = I_x(R_S \| R_G) + I_x R_L + I_x g_m (R_S \| R_G) R_L$$

$$\therefore \frac{V_x}{I_x} = R_{cgdo} = R_S \| R_G (1 + g_m R_L) + R_L$$

$$= 0.996k\,[1+5] + 4.122k = 10.16K$$

$$\omega_H = \frac{1}{R_{cgso} C_{gs} + R_{cdgo} C_{gd}} = \frac{1}{(0.996K)(2pF) + 10.16K(10pF)}$$

$$= 3333 \times 10^6 \text{ rads/sec} \rightarrow \underline{f_H = 5.3 MHz}$$