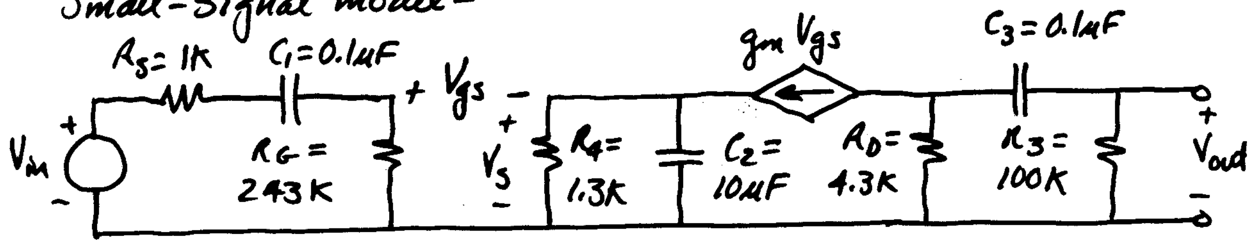
MOSFET Low Frequency Example – Cont'd

Small-signal model –

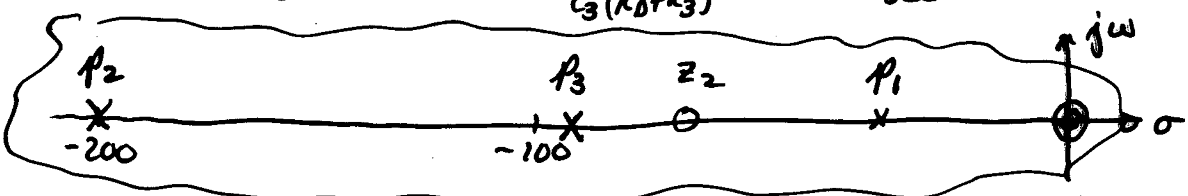


1.) Direct analysis

$$\frac{V_{out}(s)}{V_{in}(s)} = \frac{-g_m R_D R_3 R_G}{(R_D+R_3)(R_G+R_S)}\left[\frac{s^2(s+z_2)}{(s+p_1)(s+p_2)(s+p_3)}\right]$$

$$p_1 = \frac{-1}{C_1(R_G+R_S)} = -41\frac{\text{rads}}{\text{sec}}, \quad z_2 = \frac{-1}{R_4C_2} = -76.9\frac{\text{rads}}{\text{sec}}, \quad p_2 = (1+g_m R_4)z_2$$

$$p_2 = -200\frac{\text{rads}}{\text{sec.}} \quad \text{and} \quad p_3 = \frac{-1}{C_3(R_D+R_3)} = -95.9\frac{\text{rads}}{\text{sec.}}$$

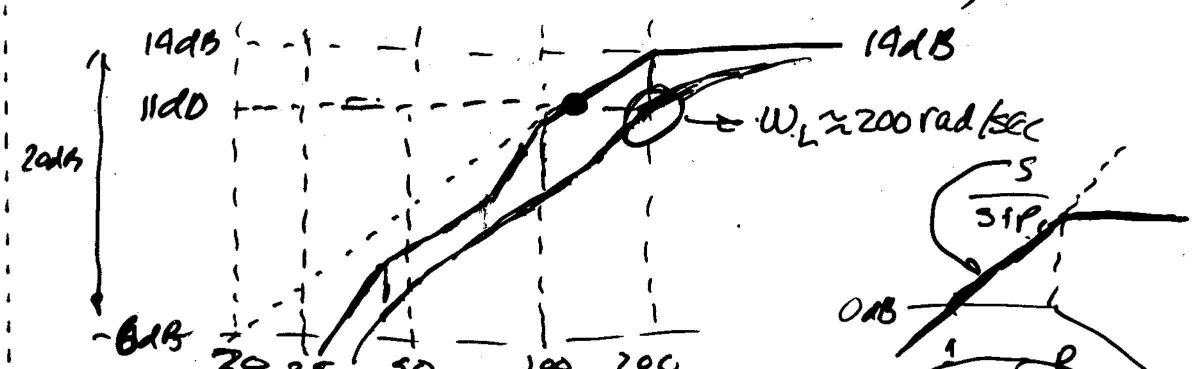


$\omega_L = ? = \omega_{-3dB}$ (lower) LF Roots

a.) $f_L = \frac{1}{2\pi}\sqrt{\sum \text{poles}^2 - 2\sum \text{zeros}^2} = \frac{1}{2\pi}\sqrt{(200)^2+(95.9)^2+(41)^2-2(76.9)^2}$

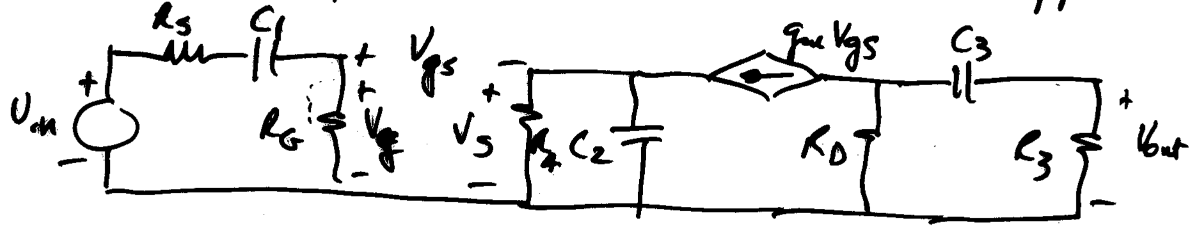
$= 31.5\,Hz$

b.) Bode Plot (Midband Gain = 14dB)



$\omega_L \cong 200 \rightarrow \frac{200}{2\pi} \simeq 31.8\,Hz$

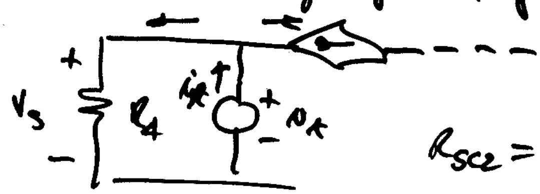
2.) Find ω_L by the short-circuit time constant approach



C_1: $R_{SC1} = R_S + R_G = 244\,K\Omega$

$$\frac{1}{C_1 R_{SC1}} = \frac{1}{(0.1\mu F)(244\,K\Omega)} = -41 \text{ rad/sec} = P_1$$

C_2: R_{SC2} $\quad g_m V_{gs}$ $\quad (V_g = 0) \rightarrow g_m V_{gs} = -g_m V_s$



$$R_{SC2} = \frac{V_x}{I_x}$$

$$I_x = \frac{V_x}{R_4} + g_m V_x = V_x\left(\frac{1}{R_4} + g_m\right)$$

$$\therefore R_{SC2} = \frac{1}{g_m + \frac{1}{R_4}} = \frac{1}{g_m} \| R_4 = \frac{R_4}{1 + g_m R_4}$$

$$\frac{1}{C_2 R_{SC2}} = \frac{1 + g_m R_4}{R_4 C_2} = |P_2| = 200 \text{ rad/sec}$$

C_3: $R_{SC3} = R_D + R_3 \rightarrow \dfrac{1}{C_3 R_{SC3}} = |P_3| = +95.9$

$$\omega_L \cong \frac{1}{R_{SC1} C_1} + \frac{1}{R_{SC2} C_2} + \frac{1}{R_{SC3} C_3} = 337 \text{ rad/sec.}$$

$f_L = 53.6\text{ Hz}$???

Note: You would have been better off to use this method to find the poles and zeros (I need to show you how to do this) and use the methods used on the last page for finding ω_L.