EE140 HW#7 Solution

1.

There are only two poles because, since we can only specify the initial conditions on at most two capacitors without having specified all capacitor initial conditions. there are only two independent energy storage element.

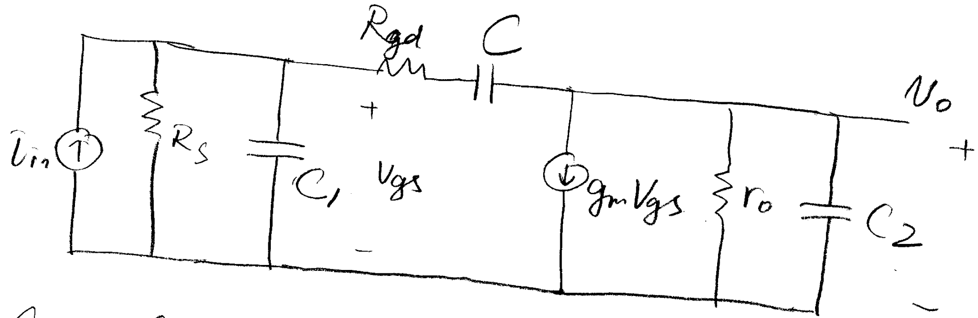
We assume Cgd is large. so we can apply miller approximation here.

$$p_1 \cong -\frac{1}{R_S \cdot (C_{gs} + (1+g_m r_o) C_{gd})}$$

$$p_2 \cong -\frac{1}{r_o (C_{gd} + C_{DB})}$$

Adding a resistor, R_{gd}, adds another degree of freedom since we can now specify the initial conditions on all three capacitors independently. So, there are now three poles.

The equivalent small signal circuit:



$C_1 = C_{gs}$ $\quad C = C_{gd}$ $\quad C_2 = C_{DB} + C_L$

(include load capacitance)

The transfer function can be found:

$$\frac{V_o}{i_{in}} = \frac{g_m R_S r_o \left[1 - sC\left(\frac{1}{g_m} - R_{gd}\right)\right]}{1 + bs + fs^2 + ds^3}$$

$$b = r_o(C_2 + C) + R_S(C_1 + C) + R_{gd}C + g_m R_S r_o C$$

$$f = R_S r_o (C_1 C_2 + C C_1 + C C_2) + R_{gd} C (R_S C_1 + r_o C_2)$$

$$d = R_S r_o R_{gd} C_1 C_2 C$$

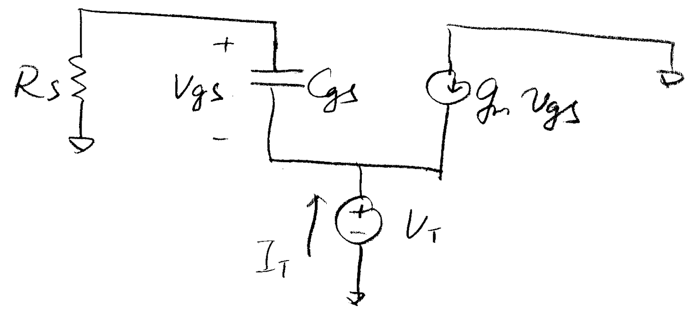
Assume $g_m R_S$, $g_m r_o \gg 1$ and C_{gd} is large.

$$p_1 \approx -\frac{1}{g_m R_S r_o C} \qquad p_2 \approx -\frac{g_m C}{C_1 C_2 + C(C_1 + C_2)} \approx \frac{-g}{C_1 + }$$

$$p_3 \approx -\frac{1}{R_{gd} C_1}$$

2.

a) The equivalent small signal circuit shows below:



$$V_{gs} \cdot S C_{gs} + g_m V_{gs} = -I_T$$

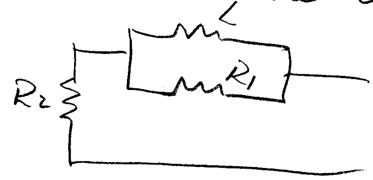
$$V_{gs} \cdot S R_s C_{gs} + V_{gs} = -V_T$$

$$\therefore Z_{out} = \frac{V_T}{I_T} = \frac{1 + S R_s C_{gs}}{g_m + S C_{gs}}.$$

b) when $S \to 0$, $Z_{out} = Z_{dc} = \frac{1}{g_m}$

$S \to \infty$, $Z_{out} = R_s$.

Since $\frac{1}{g_m} < R_s$. Z_{out} shows inductive behavior compared with the circuit



we have:

$$R_1 = R_s - \frac{1}{g_m}$$

$$R_2 = \frac{1}{g_m}$$

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