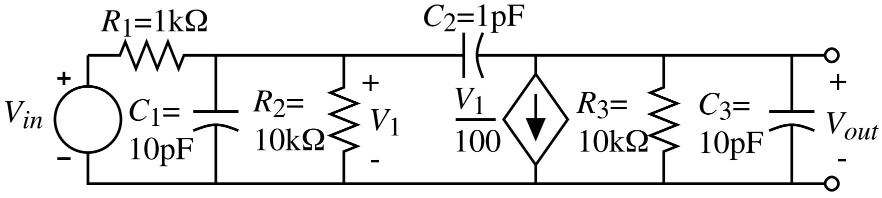
Homework Assignment No. 4 - Solutions

Problem 1

Find the midband voltage gain and the –3dB frequency in Hertz for the circuit shown.



Solution

The midband gain is given as,

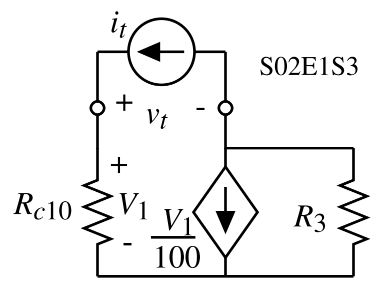
$$\frac{V_{out}}{V_{in}} = -\left(\frac{10\text{k}\Omega}{100}\right)\left(\frac{10\text{k}\Omega}{11\text{k}\Omega}\right) = \underline{\underline{-90.91\text{V/V}}}$$

To find the –3dB frequency requires finding the 3 open-circuit time constants.

R_{C10}:

$R_{C10} = 1\text{k}\Omega \| 10\text{k}\Omega = 0.9091\text{k}\Omega \quad \rightarrow \quad R_{C10}C_1 = 0.9091\cdot 10\text{ns} = 9.09\text{ns}$

R_{C20}:



$$v_t = i_t R_{C10} + R_3(i_t + 0.01V_1)$$
$$= i_t(R_{C10} + R_3 + 0.01R_{C10}R_3)$$
$$\therefore R_{C20} = R_{C10} + R_3 + 0.01R_{C10}R_3$$
$$= 0.9091 + 10(1+0.01\cdot 909.1)\text{k}\Omega = 101.82\text{k}\Omega$$

$$R_{C20}C_2 = 101.82\cdot 1\text{ns} = 101.82\text{ns}$$

R_{C30}:

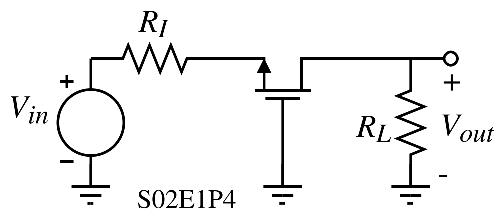
$R_{C30} = 10\text{k}\Omega \quad \rightarrow \quad R_{C30}C_3 = 10\cdot 10\text{ns} = 100\text{ns}$

$\Sigma T_0 = (9.091 + 101.82 + 100)\text{ns} = 210.91\text{ns} \quad \rightarrow \quad \omega_{-3\text{dB}} = \dfrac{1}{\Sigma T_0} = 4.74\text{x}10^6 \text{ rad/s}$

$$f_{-3\text{dB}} = \frac{4.74\text{x}10^6}{2\pi} = \underline{\underline{754.6\text{kHz}}}$$

Problem 2 – (10 points)

Find the midband voltage gain and the exact value of the two poles of the voltage transfer function for the circuit shown. Assume that R_I = 1kΩ, R_L = 10KΩ, g_m = 1mS, C_{gs} = 5pF and C_{gd} = 1pF. Ignore r_{ds}.



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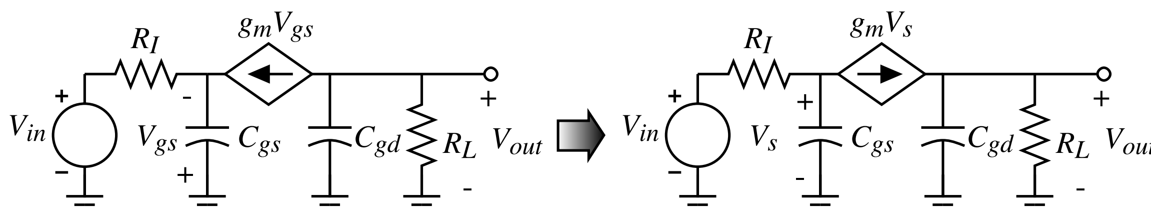
Solution

The best approach to this problem is a direct analysis.

Small-signal model:



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$V_{out} = g_m Z_L V_s$ where $Z_L = \frac{1}{sR_LC_{gd}+1}$ and $\frac{V_{in}-V_s}{R_I} = g_mV_s + sC_{gs}V_s$

Solving for V_s from the second equation gives,

$$V_s = \frac{V_{in}}{1+g_mR_I+sC_{gs}R_I}$$

Substituting V_s in the first equation gives,

$$V_{out} = g_mZ_L\frac{V_{in}}{1+g_mR_I+sC_{gs}R_I} \rightarrow \frac{V_{out}}{V_{in}} = g_m\left(\frac{1}{sR_LC_{gd}+1}\right)\left(\frac{1}{1+g_mR_I+sC_{gs}R_I}\right)$$

$$= \left(\frac{g_mR_L}{1+g_mR_I}\right)\left(\frac{1}{sR_LC_{gd}+1}\right)\left(\frac{1}{\frac{sC_{gd}R_I}{1+g_mR_I}+1}\right) = \text{MBG}\left(\frac{1}{1-\frac{s}{p_1}}\right)\left(\frac{1}{1-\frac{s}{p_2}}\right)$$

$$\therefore \text{ MBG} = \left(\frac{g_mR_L}{1+g_mR_I}\right) = \left(\frac{1\cdot 10}{1+1\cdot 1}\right) = \underline{\underline{5\text{V/V}}}$$

$$p_1 = -\frac{1}{R_LC_{gd}} = -\frac{1}{10\cdot 1\text{ns}} = \underline{\underline{-10^8 \text{ rad/s}}} \text{ and } p_2 = -\frac{1+g_mR_I}{R_IC_{gs}} = -\frac{1+1}{1\cdot 5\text{ns}} = \underline{\underline{-4\text{x}10^8 \text{ rad/s}}}$$