ELECENG 2CJ4 Lab 5

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a) Assuming that the op-amp is ideal, we can assume that $V_+ = V_-$ and determine these values:

$$\begin{aligned} V_+ &= V_f \frac{Z_3}{Z_2 + Z_3} \\ V_- &= V_o \frac{R_3}{R_3 + R_4} \\ V_+ &= V_- \\ V_f \frac{Z_3}{Z_2 + Z_3} &= V_o \frac{R_3}{R_3 + R_4} \\ V_f &= V_o \frac{R_3}{R_3 + R_4}(1 + \frac{Z_2}{Z_3}) \end{aligned}$$

KCL at node V_f:

$$0 = \frac{V_f - V_i}{Z_1} + \frac{V_f - V_o}{Z_4} + \frac{V_f}{Z_2 + Z_3}$$

We can combine these questions:

$$\begin{aligned} 0 &= \frac{V_f - V_i}{Z_1} + \frac{V_f - V_o}{Z_4} + \frac{V_f}{Z_2 + Z_3} \\ \frac{V_o - V_f}{Z_4} &= \frac{V_f - V_i}{Z_1} + \frac{V_f}{Z_2 + Z_3} \\ \frac{V_o - V_f}{Z_4} &= \frac{(Z_2 + Z_3)(V_f - V_i) + Z_1 V_f}{Z_1(Z_2 + Z_3)} \\ V_o - V_f &= Z_4 \frac{(Z_2 + Z_3)(V_f - V_i) + Z_1 V_f}{Z_1(Z_2 + Z_3)} \\ &\vdots \\ H(s) = \frac{V_o}{V_f} &= \frac{1 + \frac{R_4}{R_3}}{R_1 R_2 C_1 C_2 s^2 + s(R_1 C_1 + R_2 C_1 + R_1 C_2(-\frac{R_4}{R_3})) + 1} \end{aligned}$$

The cutoff frequency f_c is equal to $f_c = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}} = \frac{1}{2\pi 10k \cdot 10n} = 1591$ Hz. The Q-factor Q is equal to $Q = \frac{\sqrt{R_1 R_2 C_1 C_2}}{R_1 C_1 + R_2 C_1 + R_1 C_2(-\frac{R_4}{R_3})} \approx 0.5$.