E4215: Analog Filter Synthesis and Design: Final

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150 minutes; 4 problems; 30 pts.; Closed book;

- Clearly show all steps and explanations.
- None of the questions needs complicated calculations involving high order transfer functions.
- It is generally less confusing to carry out the calculations analytically and to substitute numerical values at the end.
- Use judicious approximations to simplify numerical calculations. e.g. $1 + \delta \approx 1$ if δ is small, say 0.01. You can then verify if the approximation is valid by substituting back the answer so obtained.

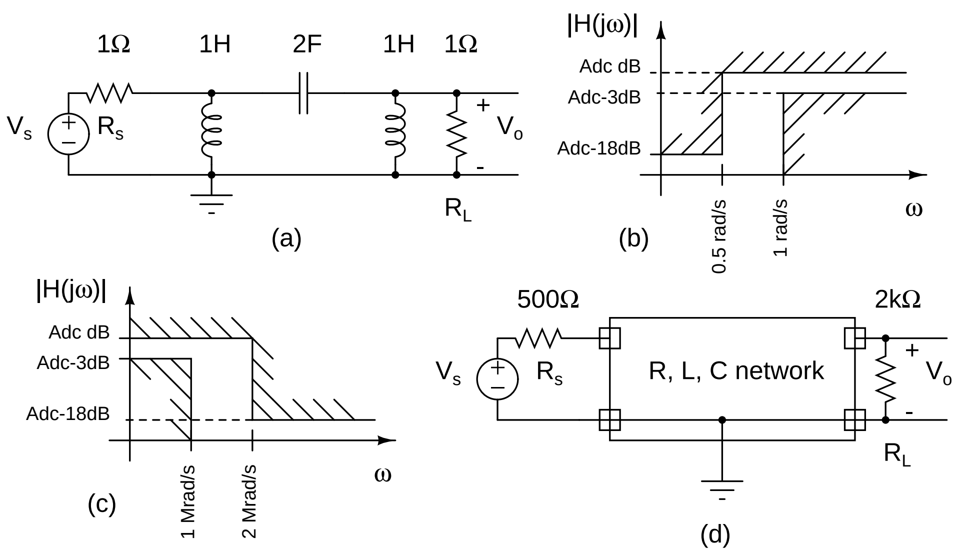

Figure 1: Circuit for problem 1.

1. $H(s) = V_o(s)/V_s(s)$. It is known that the circuit in Fig. 1(a) satisfies the specs in Fig. 1(b).
   (a) (1 pt.) Determine Adc
   (b) (2 pts.) Design a passive RLC circuit with equal termination impedances of $1\,\mathrm{k}\Omega$ that satisfies the specs in Fig. 1(c).

(c) (1 pt.) Calculate the capacitor values corresponding to each inductor in the circuit determined in the previous part if the inductors are realized using capacitively terminated gyrators with gyration resistance of $1\,\mathrm{k\Omega}$,

(d) Fig. 1(d) shows an RLC circuit driven by a voltage source whose resistance is $500\,\Omega$ and driving a $2\,\mathrm{k\Omega}$ load resistance. Include *brief* explanations in the following parts on how you came up with the circuits.

i. (2 pts.) Show the schematic of a passive RLC circuit in a generalized form that can be inserted in Fig. 1(d) and which meets the specs in Fig. 1(c).

ii. (2 pts.) Choose the component values in the RLC circuit for minimum possible current consumption from the source given the resistance values in Fig. 1(d) (while still meeting the specs in Fig. 1(c)). If the source is set to an amplitude of 1 V, what is the peak current drawn from it at very low frequencies?

iii. (2 pts.) Choose the component values for minimum output noise spectral density (while still meeting the specs in Fig. 1(c)). What is the ratio of rms output noise in this case to that in the circuit designed for minimum power dissipation.

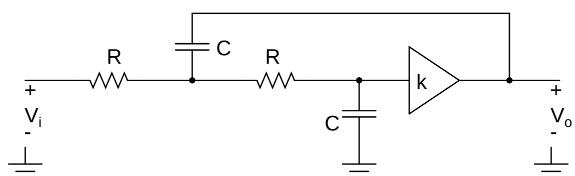

Figure 2: Circuit for Problem 2.

2. (a) (2 pts.) Calculate the transfer function of the circuit in Fig. 2. What is the circuit's function?

(b) (2 pts.) Sketch the magnitude and phase of the transfer function for $C = 1\,\mathrm{nF}$, $R = 1\,\mathrm{k\Omega}$, $k = 2.5$.

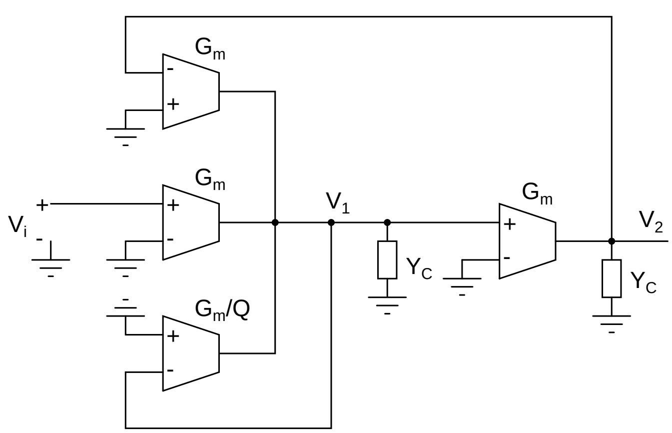

Figure 3: Circuit for Problem 3.

3. The circuit in Fig. 3 comprises transconductors G_m and *admittances* Y_c.

   (a) (2 pts.) Calculate V_1/V_i and V_2/V_i. Arrange the expressions to be in terms of G_m/Y_c.

   (b) (2 pts.) If G_m is a frequency independent transconductor g_m and $Y_C = sC$, a capacitive admittance, what filtering function(s) does the circuit realize? Sketch the magnitude and phase responses of V_1/V_i for $Q = 5$.

   (c) (3 pts.) If $G_m(s) = g_m/(1 + s/p_h)$ is a frequency dependent transadmittance with a high frequency pole p_h, and Y_C is capacitive as before, what do you expect to happen to the frequency responses? Roughly sketch the magnitude response of V_1/V_i with and without the high frequency pole p_h (overlaid on each other).

   (d) (2 pts.) When $G_m(s) = g_m/(1 + s/p_h)$ can you modify Y_C from being just a capacitor to something else that would restore the frequency responses computed in (a)?

   (e) (1 pt.) Is the technique in (d) to restore the original transfer functions applicable to higher order filters? Explain *briefly*.

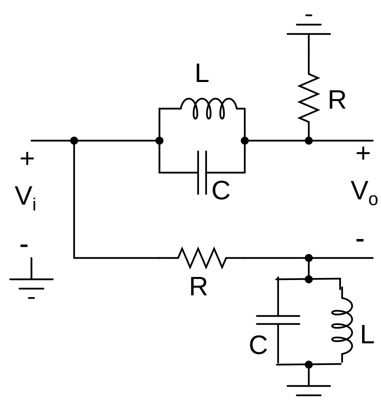

Figure 4: Circuit for Problem 4.

4. (a) (2 pts.) Compute V_o/V_i in Fig. 4.

   (b) (1 pt.) What is the purpose of the circuit?

   (c) (2 pts.) Sketch the magnitude and phase responses of the circuit for $L = 1\,\mu$H, $C = 1\,\mu$F, $R = 1\,\Omega$. Repeat for $R = 10\,\Omega$.

   (d) (1 pt.) Sketch the magnitude and the group delay of the circuit for $R = 1\,\Omega$, $L = 1\mu$H, and $C = 0$.