ECEG 497 **Wireless System Design** **Spring 2025**

Homework Assignment #2 – due via Moodle at 11:59 pm on Monday, Feb. 17, 2025

***Instructions, notes, and hints*:**

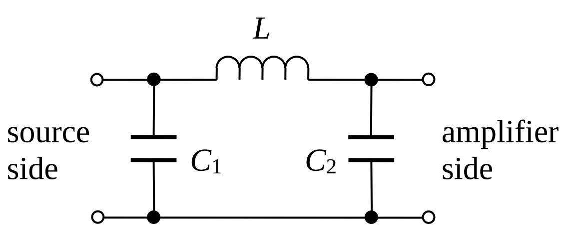
You may make reasonable assumptions and approximations to compensate for missing information, if any. Provide the details of all solutions, including important intermediate steps. You will not receive credit if you do not show your work.

It might be necessary to use reasonable approximations or assumptions to solve some of these problems, especially if critical information is missing. In those cases, your answer might differ from the posted answer by a significant margin. That's okay. If you justify any approximations that you make, you will be given full credit for such answers.

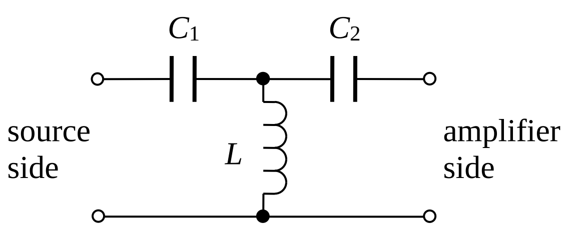
The first set of problems will be graded and the rest will not be graded. Only the graded problems must be submitted by the deadline above. Do not submit the ungraded problems.

***Graded Problems*:**

1. Specify the components (L and C values) required in the pi network depicted below to match a source impedance of 50 Ω to the input port of a common-gate MOSFET amplifier that has an input impedance of 100 Ω. The frequency of operation is 144 MHz (the lower end of the "2-meter" amateur radio band), and the desired impedance matching bandwidth is 18 MHz. Strive for the topology shown below. Assume that the bandwidth in hertz is equal to f_0/Q_{net}, where f_0 is the center (design) frequency and Q_{net} is the quality factor of the full matching network.



2. Repeat the previous impedance matching task, but this time use a T network topology like the one shown below.



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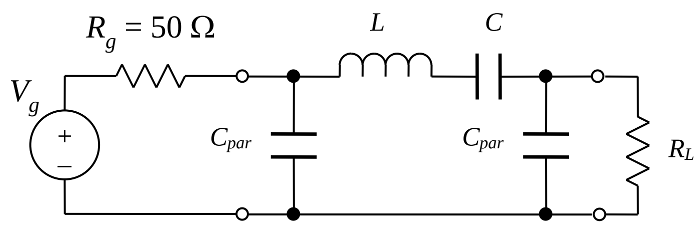
3. Find the capacitor and inductor values for the coupled-resonator filter shown below so that it has cut-off frequencies of 800 and 1000 MHz (to cover the cell phone band). Use an inductive reactance of 150 Ω at the center frequency. The system impedance is 50 Ω. Neglect all stray reactance effects.

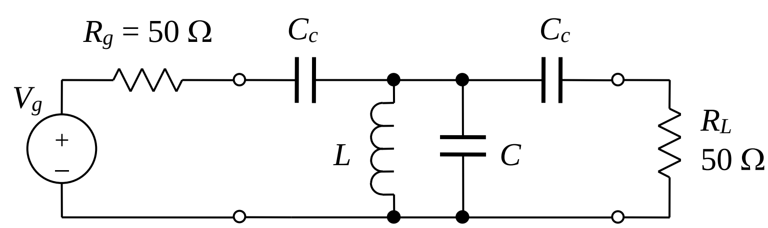


4. Re-design the series-LC coupled-resonator filter in the previous problem so that the parallel element next to the load is an inductor instead of a capacitor.

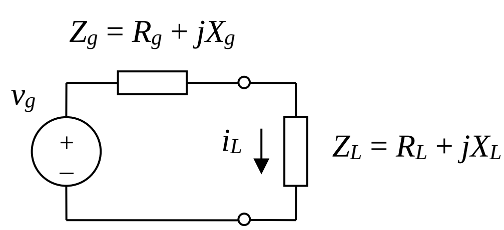
***Ungraded Problems*:**

The following problems will not be graded. However, you should attempt to solve them on your own and then check the solutions. Do not give up too quickly if you struggle to solve any of them. Move on to a different problem and then come back to the difficult one after a few hours.

1. Find the capacitor and inductor values for the coupled-resonator filter shown below so that it has cut-off frequencies of 800 and 1000 MHz (to cover the cell phone band). Use an inductive reactance of 150 Ω at the center frequency. The system impedance is 50 Ω. Neglect all stray reactance effects. Note that this problem is the same as Graded Prob. 3 except that a parallel tuned circuit is used instead of a series circuit.



2. The formulas for attenuation derived in the lecture notes on filters assume that the source and load impedances are pure resistances. In general, however, both impedances can be complex as shown in the figure below left. Show that for the general case (for which $Z_L \neq Z_g^*$, where the asterisk indicates complex conjugation), the fraction of the available power P_A delivered to the load with no filter present is given by the expression shown below right. *Hint*: Find the power P_L delivered to the load in terms of the load current i_L. Remember that v_g and i_L are complex phasors. Available power is defined in one of the supplemental readings.



$$\frac{P_L}{P_A} = \frac{4R_g R_L}{\left|Z_g + Z_L\right|^2}$$

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3. Refer to Graded Problems 3 and 4 above. Use Matlab or other mathematical analysis software to plot the attenuation (in dB) vs. frequency over the 100–2000 MHz range for the filters that you designed in the two problems. Calculate the network Q of the filter (i.e., the Q that determines the bandwidth), and use it to verify that $BW_f \approx f_o/Q$, where BW_f is the 3-dB filter bandwidth in hertz.

4. An RF designer would like to match the 8.0 Ω load shown below left to a higher real impedance at the frequency 7.0 MHz, but the exact value of the higher impedance has not been set yet. The designer knows only that it will range from 50 Ω to 250 Ω. The designer intends to add a variable capacitor in series with the 8.0 Ω load so that the parallel equivalent circuit consists of a resistor in parallel with a capacitor as shown below right. Use the Q method to find the required range of the series capacitor C_s.