Problems for Chapter 16 of 'Ultra Low Power Bioelectronics'

<u>Problem 16.1</u>
In this problem, we will study series-to-parallel and parallel-to-series impedance transformations. Assume that the circuits shown in Figure P16.1 operate at 6.785 MHz.

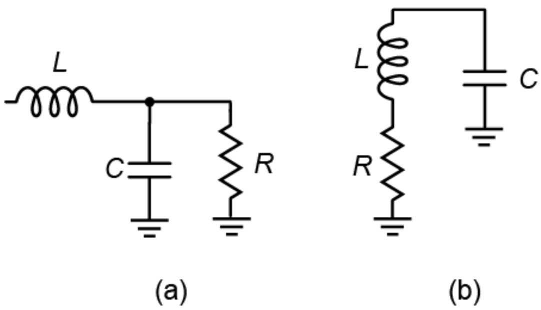

Figure P16.1 Impedance transformation: (a) parallel-to-series; (b) series-to-parallel.

a) Let $L = 2\ \mu$H, $C = 10\ \mu$H, and $R = 2.2$ kΩ in Figure P16.1 (a). Transform the parallel resistance into a series resistance.
b) Let $L = 3\ \mu$H, $C = 15\ \mu$m, and $R = 1\ \Omega$ in Figure P16.1 (b). Transform the series resistance into a parallel resistance.

<u>Problem 16.2</u>
Explain why the frequency transfer function shown in Figure 16.7 (a) has two peaks for small values of coil separation and only one peak for large values of coil separation.

<u>Problem 16.3</u>
Prove Equation (16.37).

<u>Problem 16.4</u>
In this problem we will design a power link to deliver 5 V to a 2 kΩ load at a resonant frequency of 1 MHz. Assume that $Q_1 = 50$, $Q_2 = 25$, and $k = 0.1$ (with respect to Figures 16.1 and 16.2). Follow the procedure described in section 16.2 in order to determine the values of all components. Draw a schematic and label the values of all parameters. You may ignore the Class-E amplifier (ignore C_s in Figure 16.10) and you may also assume that $L_1 = L_2$.

<u>Problem 16.5</u>
In this problem we will design a coil to be used in a power link. Assume that you have a No. 36 AWG copper wire. For this problem, you should use the self inductance formulas provided by Equation (16.6).

a) Design a circular coil with a total inductance of 3 μH and a maximal diameter of 20 mm. What is the least number of turns that this coil can have?
b) Repeat part a) for a coil with 32 AWG copper wire.

Problem 16.6
Use the data shown in Figure 16.7 and Table 16.1 to determine the coil distance that will yield ω_{lft} = 4.25 MHz and ω_{rght} = 4.84 MHz.

Problem 16.7
Based on the information provided by Figure 16.18 and the knowledge acquired in this chapter, explain the pros and cons of running a power link at a higher frequency. Also, explain the pros and cons of running it at a lower frequency. What factor(s) would likely dictate the lower-frequency bound and the upper-frequency bound?

Problem 16.8
Prove Equation (16.42).

Problem 16.9

a) Show that the piezo-electret circuit model of Figure 26.2 (a) leads to the feedback loop of Figure 26.2 (b).
b) Derive Equations (26.5) and (26.6) by making an analogy between the series mutual-inductance circuit of Figure 16.2 and the parallel piezo-electret circuit of Figure 26.2(a).
c) Why are the feedback loops in Figure 16.3 (a) and in Figure 26.2 (b) similar? Is there any difference between these loops and the loop that characterizes the feedback loop of an electric motor (Figure 26.7 (b))?

Problem 16.10
This problem requires the use of a circuit simulator such as SPICE. In this problem we will study how the skin affects the output voltage of a power link.

a) Using the data provided in Figure 16.18, create a two-parameter lumped-circuit approximation of the skin that is valid at 6.785 MHz. Evaluate how the parameters of the lumped circuit vary as the skin thickness varies from 1 mm to 10 mm, which corresponds to a variation in k from 0.04 to 0.17, respectively. You can assume that the primary and secondary coils' radii are both 14 mm.
b) Using the circuit shown in Figure 16.2, plot the voltage transfer function of v_2 for $k = 0.04$, $k = 0.1$, and $k = 0.17$. The following parameters are given: $L_1 = L_2 = 10\ \mu$H, $Q_{L1} = Q_{L2} = 90$, $C_1 = C_2 = 55$ pF, and v_1 is a 1 V sine wave at 6.785 MHz.
c) Now combine your skin model with the circuit shown in Figure 16.2 and plot the voltage transfer function v_2/v_1 for different values of k.
d) Compare the results from part c) with the results from part b).