Chapter 6: Nonideal Capacitors and Inductors

6.1 How can the ESR for a capacitor be measured? Is it the resistance measured across the leads using an ohmmeter?

6.2 Determine a simplified nontrivial model for a capacitor valid for very low frequencies. Define low frequencies as a function of the parameters in the model. Specific numerical values may only be used as a check.

6.3 Determine a simplified nontrivial model for a capacitor valid for very high frequencies. Define high frequencies as a function of the parameters in the model. Specific numerical values may only be used as a check.

6.4 Repeat Problem 6.2 for an inductor.

6.5 Repeat Problem 6.3 for an inductor.

6.6 Improve the series *RLC* model given for a capacitor by adding one additional passive element. Then, determine the expression for its resonant frequency. Under what conditions is this expression approximately equal to the commonly quoted equation

$$\frac{1}{2\pi\sqrt{LC}}\ ?$$

6.7 Repeat Problem 6.6 for an inductor (using the *RLC* model given in this chapter for a real inductor).

6.8EC Determine a better approximation than

$$f \le \frac{R_s}{2\pi L}$$

for the upper frequency limit for where an inductor is mainly resistive.

6.9 Using one R, one L, and one C, which *RLC* model is best for modeling an inductor with high core loss? State all assumptions.

6.10 Using one R, one L, and one C, which *RLC* model is best for modeling a high-value resistor with low internal inductance? State all assumptions.

6.11S Using a data sheet or catalogue, determine the ESR for a real capacitor from its given Q.

6.12 Derive the expressions for the Q of a series *RL* circuit, series *RC* circuit, parallel *RL* circuit, and parallel *RC* circuit.

6.13 Derive the expression for the Q of a capacitor that includes both shunt and series resistance.

6.14 Provide an example (not discussed in this book) where the Q expression for a parallel *RL* circuit would be of value.

6.15 Provide an example (not discussed in this book) where the Q expression for a parallel *RC* circuit would be of value.

6.16 Repeat the entire analysis given in this chapter for the Q of an iron-core inductor for the modified model of a real iron-core inductor given in Figure 1. Assume the frequency is well below the circuit's resonant frequency. Compare the results to those given in this chapter.

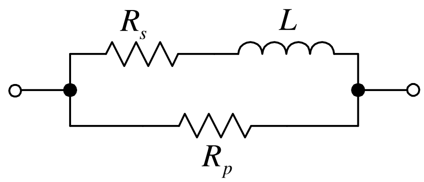

Figure 1

6.17 Using the model given in this chapter, analytically show that the effective inductance of an iron-core inductor, operating well-below its first resonant frequency, decreases as the iron-core losses increase.

6.18 Show that the effective inductance and resistance of a real inductor well below its approximate resonant frequency, f_o, can be approximated by the equations

$$L_{eff} = \frac{L}{1-\left(\frac{f}{f_o}\right)^2} \quad \text{and} \quad R_{eff} = \frac{R_s}{\left[1-\left(\frac{f}{f_o}\right)^2\right]^2} \quad \text{where } f_o = \frac{1}{2\pi\sqrt{LC_{par}}}$$

if the Q of the inductor (ignoring the parasitic capacitance)

$$Q = \frac{\omega L}{R_s}$$

is high. Assume the inductor is modeled as shown in Figure 2. *Sketch* (not plot) the effective inductance and resistance versus frequency. [Everitt]

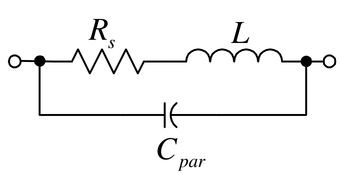

Figure 2

6.19 Determine the resonant frequency(s) of the circuit given in Figure 3.

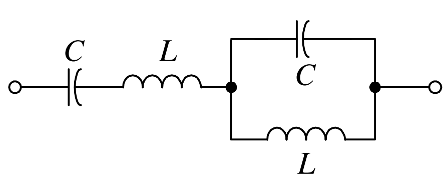

Figure 3

6.20C Repeat the analysis given in this chapter for two capacitors in parallel but assume three real capacitors in parallel. Select reasonable parameters in order to extend the capacitive operating range of the combination.

6.21S In reference the table in this chapter providing several real applications and corresponding potential capacitor types, argue whether the capacitor stated is indeed the best choice for the first five applications. Add any necessary descriptive qualifiers to the original scenarios. Do not assume that the solution given is correct.

6.22S Repeat Problem 6.21 for the sixth to tenth application.

6.23S Repeat Problem 6.21 for the eleventh to fifteenth application.

6.24S Repeat Problem 6.21 sixteenth to twentieth application

6.25S Repeat Problem 6.21 for the last three applications.

6.26 What is the major disadvantage of air capacitors?

6.27 What is the major disadvantage of double layer (supercap) capacitors?

6.28 Why is the resonant frequency of inductors and capacitors not usually provided in the data sheets?

6.29 In reference to the impedance summary table provided in this chapter, verify each impedance expression in the table that involves only resistors and capacitors. Why do these circuits not have a resonant frequency?

6.30 In reference to the impedance summary table provided in this chapter, verify each impedance expression in the table that involves only resistors and inductors. Why do these circuits not have a resonant frequency?

6.31 In reference to the impedance summary table provided in this chapter, verify each impedance expression in the table that has a resonant frequency of $1/\sqrt{LC}$.

6.32 In reference to the impedance summary table provided in this chapter, verify the impedance and resonant frequency expressions provided in the table for the circuit shown in Figure 4.

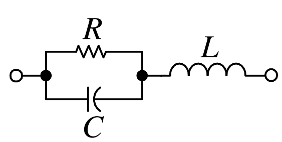

Figure 4

6.33 In reference to the impedance summary table provided in this chapter, verify the impedance and resonant frequency expressions provided in the table for the circuit shown in Figure 5.

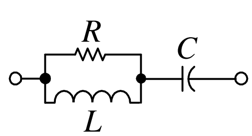

Figure 5

6.34 In reference to the impedance summary table provided in this chapter, verify the impedance and resonant frequency expressions provided in the table for the circuit shown in Figure 6.

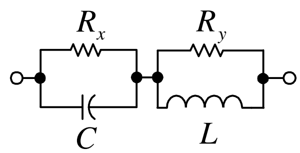

Figure 6

6.35 In reference to the impedance summary table provided in this chapter, verify the impedance and resonant frequency expressions provided in the table for the circuit shown in Figure 7.

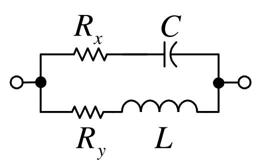

Figure 7