Modeling a 10-mH inductor

Fall 2021

Introduction

The idea of this activity is to gain some understanding and experience of non-ideal behavior of passive components. Component modeling is an important activity in RF engineering. We measure and model a wire-wound, radially leaded 10-mH inductor from Bourns. We use myDAQ, so we have to revert to very low frequencies and thus we cannot use actual "RF frequencies". Because of the low frequency (20 kHz at max), we have to have very high inductance ($L = 10$ mH) for the component to have some reasonable reactance ($2\pi f L$).

Tasks

1. Resistance at DC.
   (a) Measure the resistance of the inductor using myDAQ multimeter. The DC resistance R_{dc} is not necessarily as high as the RF resistance.
   (b) Save this R_{dc} value for later comparison: R_{dc} =_________Ω.
2. Inductance and equivalent series resistance.
   (a) By measuring the impedance (at known frequencies) you can find out the inductance (L) and equivalent series resistance (R_1). See Figure 1.
   (b) Study the document available in Moodle that describes how to use myDAQ Bode Analyzer to measure impedance of a ciruit.
   (c) Build the measurement setup to measure impedance of the inductor.
   (d) Record the impedance Z at (e.g.) 10 kHz. $Z =$ _______ kΩ $\angle$ _______°.
   (e) Calculate R_1 and L using $Z = R + \mathrm{j}2\pi f L$ at 1 kHz.[1]
   (f) Compare R_1 to R_{dc} and L to the nominal inductance 10 mH. Is there a reasonable agreement?

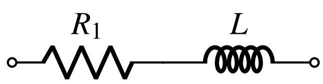

Figure 1: A simple inductor model includes the equivalent series resistance.

3. Simulation with the measured inductance and equivalent series resistance. Simulate in Multisim (preferably using the myDAQ template) the response of the component.

[1]Hint: Convert the impedance to cartesian form. Then the real part is equal to R_1 and the imaginary part is equal to $2\pi f L$. Use the same frequency ($f = 10$ kHz).

(a) Prepare first simulation where only the measured L is included and compare the response with the mesured one. Recall the guidelines on Moodle on the use of the Bode Analyzer.

(b) Prepare then simulation where both the measured L and the equivalent series resistance R_1 are included. Compare this response with the mesured one.

4. Including the parasitic capacitance.

(a) Consider the equivalent circuit in Fig. 2. A capacitor has been added. This capacitor accounts for the self-resonance. The self-resonance frequency f_{sr} is higher than we can measure with myDAQ. Therefore we shall resort to manufacturers information about f_{sr}.

(b) Find the datasheet of the inductor. Search the component at the Mouser web site. The component type number is either RL895-103K-RC or RL187-103J-RC.

(c) Find the typical self-resonance frequency ("SRF") from the datasheet.

(d) Calculate the equivalent parasitic capacitance using $f_{sr} = \frac{1}{2\pi\sqrt{LC_1}}$.

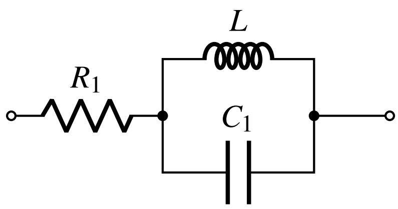

Figure 2: A more complete model includes a capacitor to account for the self-resonance.

5. An advanced problem: Convert your equivalent circuit to the one shown in Figure 3.

(a) Keep the inductance the same but let C and R vary so that both models provide the same impedance at your chosen frequency[2] (such as 10 kHz). In the previous model, $Z_1 = R_1 + L||C_1$. In this model, $Z_2 = R_2||L||C_2$. Choose such new R_2 and C_2 that make $Z_1 = Z_2$.

(b) Should R_1 and R_2 be high or low for a good, low-loss inductor?

(c) R_2 is the impedance of the inductor at the resonance frequency. Note that the impedance is real (a real number) at self-resonance. It is also the highest impedance the component attains at any frequency. Compare R_2 to the peak impedance value of a similar inductor: Mouser web site part number 710-7447211103.

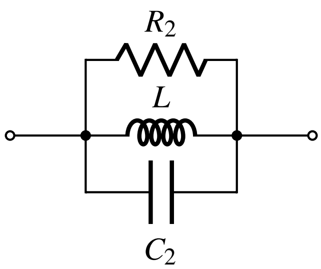

Figure 3: An alternative LRC-equivalent circuit model for inductors. This one works better for real RF inductors, with negligible DC resistance considerable losses at higher frequencies.

[2]Note that the two models can provide exactly the same impedance only at one frequency.