AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
ELECTROMAGNETIC FIELDS | EPM212s

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Project Report

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Introduction

In this project, as a way to apply what we learned in our curriculum, we were tasked with designing an inductor and connecting it with a capacitor and a resistor to create an RLC circuit.

This report demonstrates the steps taken from start to finish, from theory to application along with the problems that arose and how we tackled them.

Components

1- A 1 mH inductor : this is the component of the circuit that we were tasked to design. It will allow us to see the effects of self-inductance and how the inductor shows reluctance to changing currents.
2- A 22 μF film capacitor : similar to the inductor, this will allow us to see the effects of capacitance in electric circuits and how the capacitor shows reluctance to changing voltages.
3- A 220/24 - 2A transformer : this is the power source of the circuit, it provides AC voltage so the effects of the inductor and capacitor can be seen.
4- A 100 Ω - 5 W resistor : this will control the current from being too large which will damage the components.

Design

The Inductor

For the design of the inductor, we decided to go with a toroid rather than a solenoid for the following reason:

- The equation of a toroid is much simpler than that of the solenoid, since when deriving the magnetic field strength formula inside the toroid:

$$H = \frac{NI}{2\pi r}$$

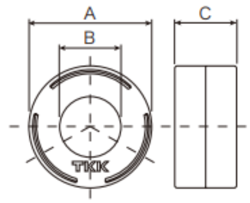
No special assumptions were made. Unlike the solenoid where we have to assume an infinite length, which considering the scale we were working with wouldn't make sense so numerical approximations would need to be made.

As for the ferrite core, we used the Mn-Zn ferrite core "*TCC251512B*" by *TKK*, for the specifications of this core, we used its datasheet.

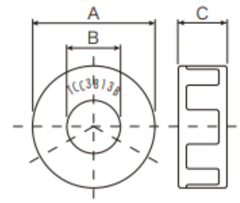
ケース材質 /Case material........PA66（UL94V-0）

色（ケース）/Color (case)......... クロ /Black

<Fig. 1>



<Fig. 2>



品番表 *Product list*

[単位 Unit:mm]

品 番 Product code	寸 法 Dimensions			最低インピーダンス（Ω）Min. impedance (Ω)			適応ケーブル径 Compatible cable diameter	外観図 General view	最低包装単位 Min. packaging quantity
	A	B	C	1MHz	100MHz	500MHz			
TCC201010B	22.0	8.6	12.0	35	-	125	φ 8.2以下 8.2 or less	Fig. 1	168ヶ/pcs
TCC251512B	26.5	13.5	14.2	25	-	125	φ13.0以下 13.0 or less	Fig. 1	120ヶ/pcs

However, we encountered a problem, the permeability was not explicitly stated. Instead, the impedance of the core was listed at various frequencies, which allowed us to calculate a theoretical mean value for μ, assuming that these test were done at 1 turns of wire we got that

$$\mu_r \approx 5000$$

Then using this and the dimensions found in the data sheet and knowing the inductance equation:

$$L = \frac{\mu_r \mu_\circ N^2 h}{2\pi} \, ln\left(\frac{b}{a}\right)$$

We can plug in the values $(where\ a = 25\ mm, b = 15\ mm, h = 12\ mm)$ and solve for the number of turns, which gives us that N ≈ 13. We then wound the turns and measured the inductance, which we found to be 800 mH which suggests that the value for μ is lower than calculated (but still comparable), so we used the relation

$$\frac{N_2}{N_1} = \sqrt{\frac{L_2}{L_1}}$$

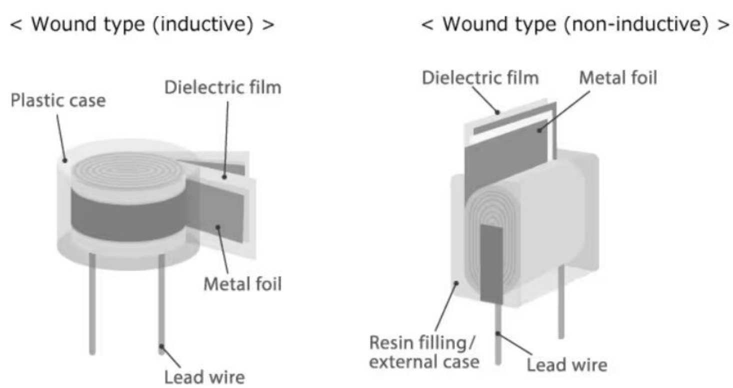
And this gave us that we should have about 15 turns. We adjusted the number of turns and measured the new inductance, which was 1.02 mH, which is within the 10% required error. This also suggests that the actual value for μ_r is closer to 4000.

The Capacitor

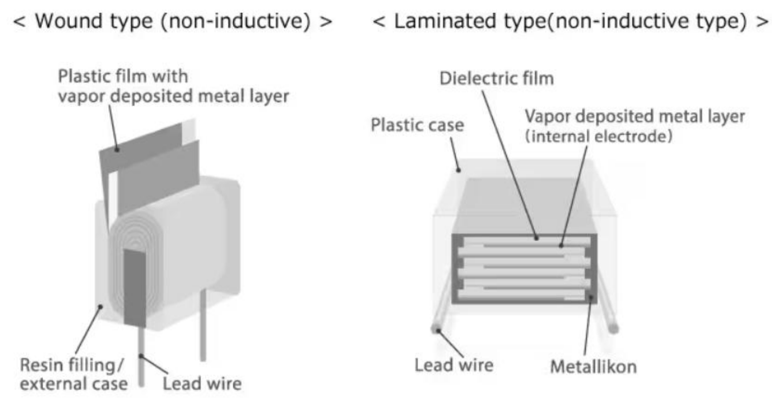
We were asked to use a 22 μF film capacitor for this project. However, we weren't able to find that specific capacitance, so we settled for the closest available option which was a 28 μF capacitor. The reason we needed to use a film capacitor is because we are using an AC source, so we can't use polarized (electrolytic) capacitors which need to be connected to a specific polarity. We also need a relatively high capacitance value, so we can't use ceramic capacitors which reach to ≈ 10% of the required value at most, leaving film capacitors as the best option.

As for the internal design of the capacitor, it uses a polyester film as its dielectric and has two types of electrodes:

1- Foil electrodes: These consist of a metallic foil rolled up and sandwiched between plastic film layers. They come in inductive and non-inductive versions. Inductive types have lead wires attached to the internal electrodes before winding, while non-inductive types have lead wires or terminal electrodes connected to end faces. Compared to inductive types, non-inductive film capacitors have a lower inductance component and exhibit better high frequency characteristics.

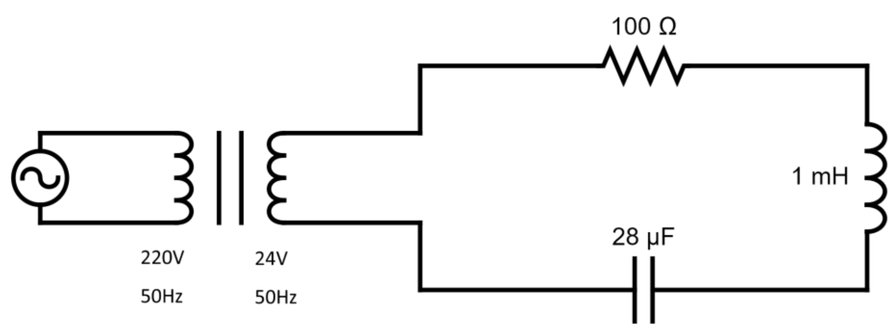


2- Metallized film: Instead of using a metal foil, the electrodes can also be a metallic layer that is deposited on the plastic film. Similar to the foil type, these also come in an inductive and non-inductive versions.



Film capacitors use various plastics and polymers as the dielectrics. In our project, we used a polyester film capacitor.

Circuit Analysis



After designing the inductor, we needed to analyze the circuit to make sure that everything was safe for the components, there are four restrictions we need to consider:

1- The most important limit is that the power dissipated by the resistor does not exceed 5 watts, otherwise it might burn.
2- The current in the circuit doesn't exceed 333 mA, as that's the ferrite core's saturation current, after which the magnetic flux it generates will stay constant and that will affect its inductance.
3- The voltage rating of the capacitor is 250 volts, which isn't a problem since the transformer provides 24 volts RMS.

To start off, we know that the transformer provides an RMS voltage value of 24 volts at a frequency of 50 Hz. Knowing the frequency, we can calculate the reluctances:

$$X_L = 2\pi f L = 0.314\ \Omega$$

$$X_C = \frac{1}{2\pi f C} = 113.7\ \Omega$$

Then we can get the impedance:

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = 151\ \Omega$$

And thus the RMS current is:

$$I_{rms} = \frac{V_{rms}}{Z} = 0.159\ A$$

And the max current is

$$I_{max} = \sqrt{2}\, I_{rms} = 0.225\ A$$

This is less than the saturation current of the toroid, so that's the first check mark.

To get the maximum power dissipated by the resistor:

$$P_{max} = I_{max}^2 R = 5.1\ W$$

This slightly exceeds the 5-watt rating of the resistor. However, this shouldn't be a problem since the RMS power is

$$P_{rms} = \frac{P_{max}}{2} = 2.55\ W$$

Which is lower than the 5-watt rating, so that's also checked.

We also decided to add a switch to the circuit. This was done so that in the case that the inductor is to be measured, it could be done without interference from the other circuit elements.