1 Objective

Upon successful completion of this lab we will know what capacitors and inductors are and we will know how to measure them. Specifically:

1 Understand the principle of capacitance
2 Read capacitance and tolerance by their body markings
3 Measure capacitance using an LCR meter.
4 Construct series and parallel capacitor circuits and measure the net capacitance

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*This lab is adapted from the original *Capacitance and Capacitors by R. Schaus
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5 Calculate the net capacitance for series and parallel capacitor circuits
6 Understand the principle of inductance
7 Measure inductance using an LCR meter.
8 Construct series and parallel Inductor circuits and measure the net inductance
9 Calculate the net Inductance for series and parallel Inductor circuits

2 Theory

2.1 Capacitors and Inductors

The study of circuits is really a part of the study of electricity and magnetism. All energy in a circuit can be stored in one of two ways: it can be stored in the electric field or it can be stored in the magnetic field. Capacitors store energy in the electric field captured between two parallel plates. Inductors store energy in the magnetic field captured in a coil of wire. These two components make up two important building blocks in electronics and behave in similar fashions even though they are very different in design and use. Let’s start with a discussion of capacitors, then take up their cousin the inductor.

Capacitors are one of the components used in electrical and electronic circuits to accomplish a variety of tasks including storing electric charge, blocking the flow of direct current (DC), shaping circuit response timing and signal filtering. Often we think of capacitors storing charge but more accurately they store separated charges. Capacitance is defined in an electrical sense as the amount of charge $Q$ stored on a single plate of a parallel plate pair when there is a voltage difference maintained between the paired plates. See figure ???. Mathematically in terms of voltage $V$, charge $Q$, capacitance $C$ is given in equation 1

$$C = \frac{Q}{V}$$ (1)

The unit of capacitance are Farads [F], the unit of charge are Coulombs [C]. Like resistors, capacitors may be combined in series, parallel, and series-parallel networks.

- **Parallel Combinations:** Capacitors combined in parallel will all have the same potential difference $[V]$ across their terminals. Parallel capacitors will each carry a charge and the total charge is simply a sum. Because of this the equivalent capacitance is given by equation 2.

$$C_{eq} = \sum C_p = C_1 + C_2 + C_3 + \ldots$$ (2)
Series Combinations: Capacitors combined in series will not all have the same potential difference [V] across their terminals. However, the charge on each capacitor in series will be the same. The consequence is that series capacitors carry less total charge than any one capacitor in the series could carry. It turns out the the formula for equivalent capacitance is similar to parallel resistors. It is given in equation 6

$$C_{eq} = \left( \sum \frac{1}{C_p} \right)^{-1} = \left( \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots \right)^{-1}$$

You might notice that these formulas are exactly the opposite of the way resistors add. When a circuit has networks of capacitors arranged in both series and parallel configurations, the net circuit capacitance is calculated by applying the rules given by 2 & 6 to build simplifying equivalent circuits. Many configurations can be distilled down to one equivalent capacitor, but not all.

Inductors play a role in circuits that in many ways parallels the capacitor, but it act on exactly the opposite features in a circuit. So while capacitors can be used to block DC signals, inductors can block AC signals. Fundamentally inductors are devices that produce their own (self-induced) potential difference when a changing electric current flows through them. A common example it the coil on your cars ignition system. Inductors are very similar to capacitors but they will combine like resistors do rather than the way capacitors do. The unit of inductance is the Henry [H]. The mathematical model for how inductors behave in circuit is given in equation 4.
\[ V = L \frac{\Delta I}{\Delta t} \]  \hspace{1cm} (4)

- **Parallel Combinations:** Inductors combined in parallel will all have the same potential difference \([V]\) across their terminals. Parallel inductors will divide the current in a circuit, much like resistors in parallel do. Inductors basically are reactionary components to current. So because of this the equivalent inductance is given by equation 5.

\[
L_{eq} = \left( \sum \frac{1}{L_p} \right)^{-1} = \left( \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} + \ldots \right)^{-1}
\]  \hspace{1cm} (5)

- **Series Combinations:** Inductors combined in series will all have the same current. Again, since current dictates the reaction of the inductor, this leads to the series formula matching the equivalent resistance formula. It is given in equation 6.

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L_{eq} = \sum L_p = L_1 + L_2 + L_3 + \ldots
\]  \hspace{1cm} (6)

3  **Equipment**

The basic equipment for this experiment is as follows:

1. Protoboard
2. Capacitors
3. Inductors
4. LCR meter

4  **Procedure**

4.1  **Capacitors**

In this section of the lab we will measure various capacitors.

1. Identify the nominal capacitance coded on the body of each of your capacitors. Use the capacitor codes given in figure 3. Record these values in your data table. The tolerance of all capacitors used in this experiment is \( \pm 10\% \). As with resistors, the tolerance of a capacitor is the maximum amount the capacitor should vary from its nominal value.

2. Compute and record the % deviation of each capacitor’s actual value from nominal. Use the nominal value as the basis in these computations.
3. Zero your LCR meter following the instructions in its operating manual.

4. Measure and record the actual (experimental) capacitance of each of your capacitors using the LCR meter.

5. Measure the DC resistance of the capacitors

6. Using the protoboard, connect two capacitors in parallel and then measure the net capacitance.

7. Calculate what the net capacitance should be for the capacitors you just measured. Do the calculations match the measurement?

8. Repeat the last two steps, wiring 2 capacitors in series rather than parallel. Again, do the calculations match the measurement?

9. Connect the capacitor which you wired in parallel in series with the two resistors you connected in series. This is the series-parallel combination. See Figure 2 Uses the LCR meter to measure the net capacitance of the 4 capacitors.

10. Calculate the expected equivalent capacitance using equations 2 & 6. Do the calculations match the measurement?

### 4.2 Inductors

In this section of the lab we will measure various Inductors. The inductors do not have a code on them.

1. Zero your LCR meter following the instructions in its operating manual.

2. Measure and record the actual (experimental) Inductance of each of your Inductors using the LCR meter.
Figure 3: How to read the codes on capacitors
3. Measure the DC resistance of the Inductors

4. Using the protoboard, connect two inductors in parallel and then measure the net Inductance.

5. Calculate what the net Inductance should be for the Inductors you just measured. Do the calculations match the measurement?

6. Repeat the last two steps, wiring 2 Inductors in series rather than parallel. Again, do the calculations match the measurement?

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\% \text{difference} = \left( \frac{V_c - V_m}{V_c} \right) \times 100
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