Building a Circuit

Learning Goals:

1. The main learning goal of this lab is to understand how to build a circuit as well as to calculate and measure circuit parameters.

2. You will learn how to determine the equivalent capacitance and the equivalent resistance of a circuit.

3. By the end of this lab you will know how to use a breadboard, an ohmmeter, and a capacitance meter and how to connect circuit components to a functional circuit.

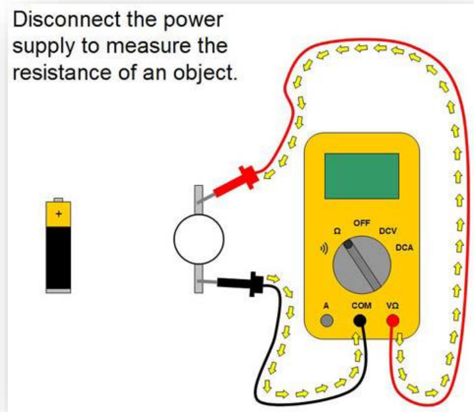


Figure 1: Resistance measurement

Materials:

Capacitor; Resistor; Digital Multimeter; Cables; Timer; Excel.

References:

Giancoli, Physics 7th Edition: Chapter 19, Section 2, 5

Introduction:

Capacitors and resistors are passive circuit devices used in electric circuits. They can be connected in series and in parallel. To anticipate the overall capacitance or resistance of a circuit we need to measure capacitance or resistance of each device and then use the measured values to calculate total capacitance or resistance value of the circuit.

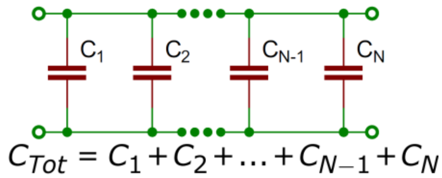
The overall capacitance for capacitors connected in series is given as (equation derived in the book):

$$\frac{1}{C_{Tot}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots + \frac{1}{C_{N-1}} + \frac{1}{C_N}$$

Figure 2: Capacitors in series

$$\boldsymbol{C_{total}} = \left(\frac{\mathbf{1}}{\boldsymbol{C_1}} + \frac{\mathbf{1}}{\boldsymbol{C_2}} + \frac{\mathbf{1}}{\boldsymbol{C_3}} + \cdots + \frac{\mathbf{1}}{\boldsymbol{C_n}}\right)^{-\mathbf{1}} \qquad (1)$$

The overall capacitance of a parallel circuit is given as:



$$C_{total} = (C_1 + C_2 + C_3 + \cdots + C_n) \qquad (2)$$

Figure 3: Capacitors in parallel

How do resistors in series and parallel differ from capacitors? Capacitors store energy; resistors dissipate energy in an active circuit. An active circuit is a combination of devices connected to a battery or another power source. We should anticipate that resistive elements behave differently than capacitors in the same configuration.

In a series circuit the total resistance can be calculated as:

$$R_{total} = R_1 + R_2 + R_3 + \cdots + R_4 \qquad (3)$$

In a parallel circuit the total resistance is given by:

$$R_{total} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_4}\right)^{-1} \qquad (4)$$

Experiment:

This experiment consists of three activities. In the first one, you will evaluate the different ranges of the capacitance meter for two different capacitors. In the second activity you will predict and measure the overall capacitance of a series-parallel circuit. In the third and last activity, you will predict and measure the total resistance of a series-parallel circuit. The apparatus you will use, consists of a breadboard, circuit devices, cables and a multimeter.

Activity 1:

Experimental Procedure and Data Taking:

1. Place the capacitor on the circuit board and connect a multimeter (DVM) to measure its capacitance. On the DVM select the range as shown in the table and record what you see on the display. The uncertainties can be calculated from the error provided by the manufacturer (see appendix B).

2. Answer the questions related to activity 1 listed in the analysis section.

Table 1:

Range Value	Manufacturer Capacitance Value (μF)	Measured Capacitance
0-200 pF	0.15	
0-2 nF	0.15	
0-20 nF	0.15	
0-200 nF	0.15	
0-2 μF	0.15	
0-20 μF	0.15	
0-200 μF	0.15	
0-2 mF	0.15	
0-20 mF	0.15	

3. Repeat the procedure with a 2.2 μF capacitor.

Activity 2:

1. Draw the circuit diagram in your notebook and predict the overall capacitance of the following capacitor circuit (C_1 = 0.47 μF, C_2 = 2.2 μF, C_3 = 0.22 μF)

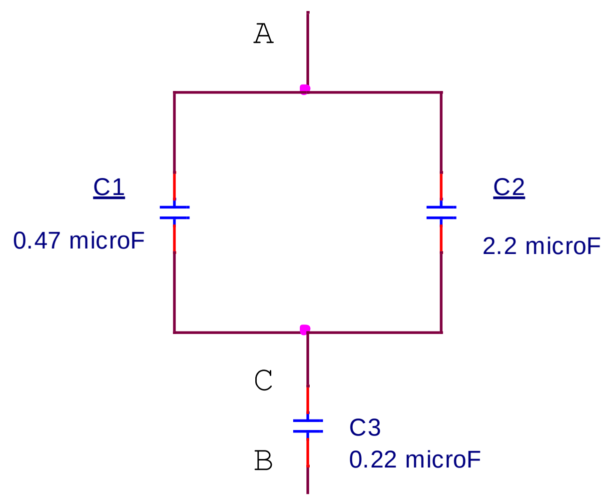


Figure 4: Capacitors in a series-parallel circuit

2. Build the circuit on the breadboard and measure the capacitance between points A and B and points A and C. Record the values in your notebook.

3. In the analysis section answer all questions related to activity 2.

Activity 3:

1. Choose the following resistors: R_1 =5.1 kΩ, R_2 = 220 Ω, R_3 = 100 Ω, R_4 = 1 kΩ, R_5 = 10 kΩ
2. Measure each of them and connect them to the series – parallel circuit shown in figure 5.

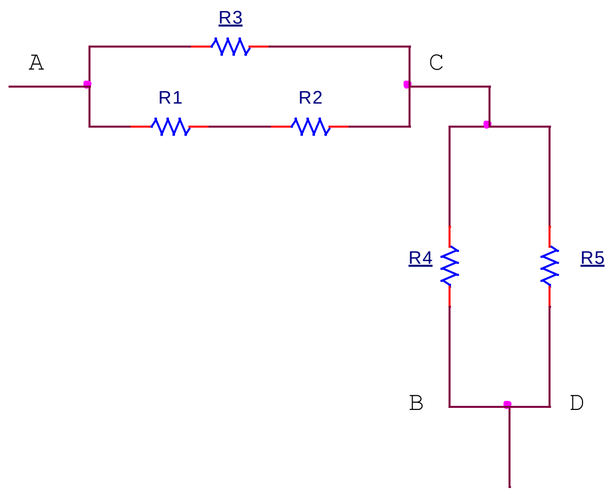


Figure 5: Resistors in a series-parallel circuit

3. Predict the overall circuit resistance (between A and B) and predict the combined resistance values between A and C as well as between C and D.
4. Measure the resistance value between A and B, A and C, and C and D.

Analysis:

1. **Activity 1**: In the first part of the experiment you measured the capacitance values of two different capacitors. You used a Meterman CR-50 DVM for those measurements. Explain why in this experiment the zeroing out of the meter is not essential.

2. What range value offered the best precision for each of the two capacitance values? Explain.

3. What scales were unable to measure the capacitance value? By each scale - include an explanation as to why the scale was unable to provide a measurement value.

4. Which range would be the most precise to measure a capacitor nominally valued at 250 μF?

5. **Activity 2**: In figure 4 examine how the capacitors are connected to each other.

6. Why is the value of the combined capacitances so close to the 0.22 μF capacitance value? Will this always be true if two capacitors are connected in series and one is much larger than the other?

7. In the series-parallel circuit of capacitors, you measure the total equivalent capacitance between A and B. What changes if you move the multimeter from B to C and measure between A and C? Explain.

8. **Activity 3**: Explain why the resistance is different if you measure between A and B, and then C and D.

9. Is the difference between your predicted and your measured values reasonable? (Reasonable means between 5-10% of the predicted value.

References:
Adapted from a previous handout.

Appendix A: Resistor Color Code

The nominal value is displayed on the resistor body as a color code. The first band is the first digit, the second band is the second digit and the third band is the multiplier. The forth band represents the tolerance given by the manufacturer (4-band code).

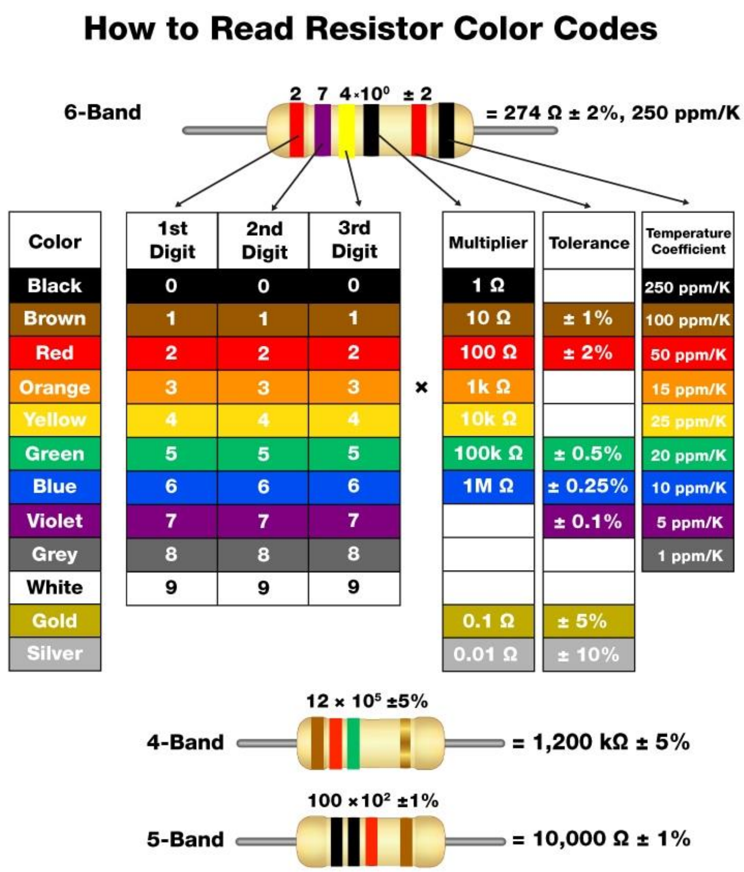


Figure 6: Resistor color code

Appendix B: Meter Uncertainties

The manufacturer of the Meterman CR-50 DVM provided the following uncertainties:

Table 2:

Capacitance	Uncertainty	Test Frequency
200pF	± 0.5% + 0.6pF	820 Hz
2000pF to 2 μF	± 0.5% + 1 lsd*	820 Hz
20 μF	± 0.5% + 1 lsd*	82 Hz
200 μF	± 0.5% + 1 lsd*	8.2 Hz
2mF	± 1.0% + 1 lsd*	8.2 Hz
20 mF	± 1.5% + 1 lsd*	8.2 Hz
Protection: 0.1A/250		

*lsd =least significant digit (place)

Table 4:

Resistance	Uncertainty
20 Ω	± 2 % (Zero adjust)
200 Ω	± (1% + 3 lsd)
2 kΩ – 2 MΩ	± (1.2% +2 lsd)