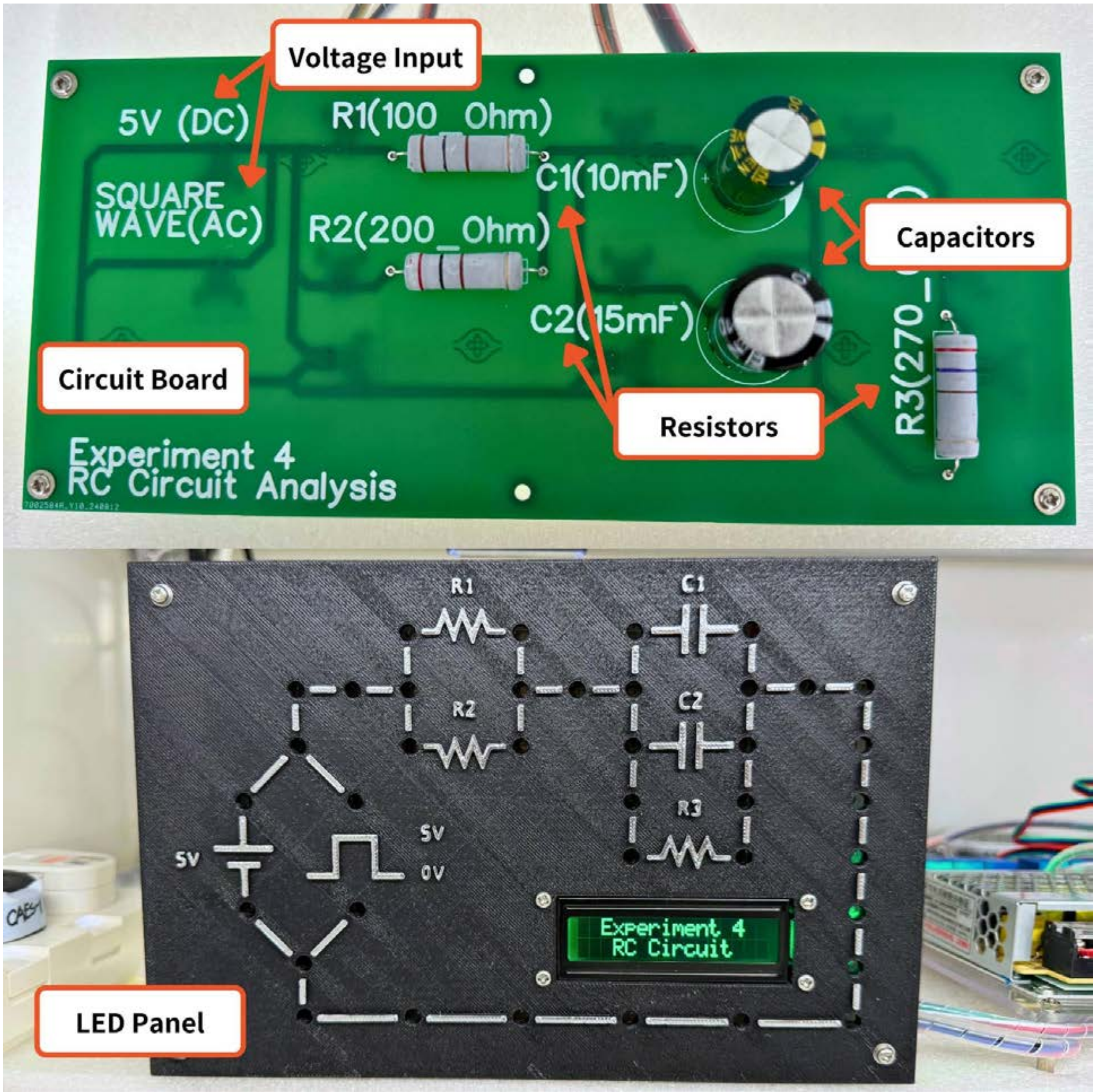
The Hong Kong Polytechnic University
College of Professional and Continuing Education
Hong Kong Community College

HKCC Remote Laboratory System*
Electric Circuit Experiment: *RC* (resistor-capacitor) circuit

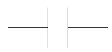


*HKCC Remote Laboratory is a web-based service to enable remote off-campus access to experimental sets for science and engineering students. The Remote Lab was financially supported by the Quality Enhancement Support Scheme of the Hong Kong Special Administrative Region Government (QESS, HKSAR) and Hong Kong Community College of The Hong Kong Polytechnic University (PolyU HKCC), under the project title, “Development of a Web-based Remote Laboratory for Science and Engineering Education”, and project no.: 04/QESS/2021.

Objective

In this experiment, you will investigate the performance of a *RC* circuit with different resistors and capacitors under DC and AC power supply.

Theory

Resistor is a common electrical component for limiting the current flows in electric circuits. Its unit and symbol are ohms (Ω) and  respectively. Capacitor is an electrical component for storing electrical energy by accumulating electric charges (q) on two closely spaced conducting surfaces. Its unit and symbol are Farad (F) and  respectively. The equations of resistor and capacitor are: $v = ir$ and $q = cv$.

A *RC* (resistor-capacitor) circuit is an electric circuit consisting of resistors and capacitors. Figure 1 shows a typical RC circuit.

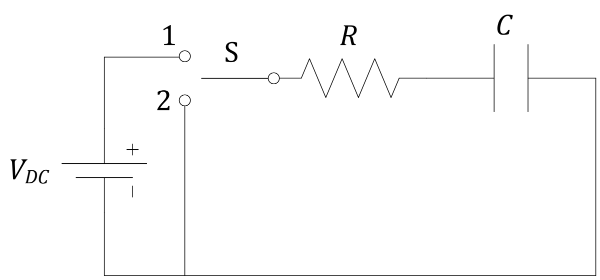


Figure 1. A typical *RC* circuit.

Charging a Capacitor

When switch S is connected to point 1, the (charging) current, i, flows in the circuit (Figure 2) and positive charges are accumulated on the left surface of the conducting surface of the capacitor (C).

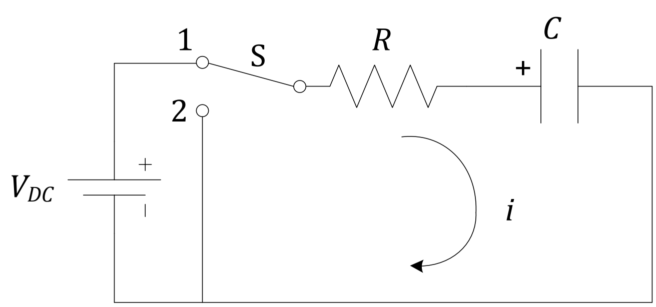


Figure 2. Charging process.

Applying loop rule to the circuit (same direction of the current), we have

$$V_{DC} - iR - \frac{q}{C} = 0.$$

Since $i = \frac{dq}{dt}$ and substitute into the above equation, we have

$$R\frac{dq}{dt} + \frac{q}{C} = V_{DC}\,.$$

If the capacitor is initially uncharged, i.e. $q(0) = 0$, separation of variables and integrating we obtain

$$\int_0^q \frac{dq}{CV_{DC} - q} = \frac{1}{RC}\int_0^t dt$$

Hence

$$q(t) = CV_{DC}\left(1 - e^{-\frac{t}{RC}}\right) \quad \text{and} \quad V_c(t) = \frac{q(t)}{C} = V_{DC}\left(1 - e^{-\frac{t}{RC}}\right).$$

They both are equations for charging a capacitor, where $q(t)$ is the charges accumulated in the capacitor and $V_C(t)$ is the voltage across the capacitor.

Discharging a Capacitor

Assume the capacitor is fully charged with potential V_0 and charge q_0 at time $t = 0$. When switch S is now connected to point 2, the (discharging) current, i, flows in the circuit as shown in Figure 3. The capacitor is now discharging through the resistor.

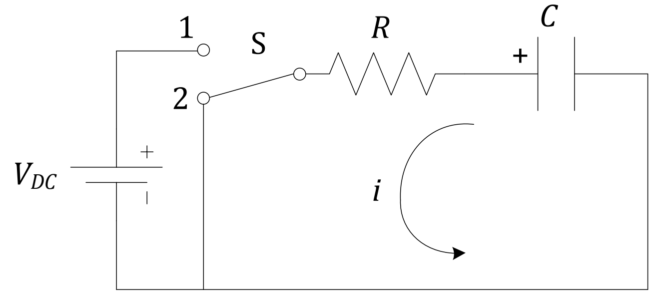


Figure 3. Discharging process.

Apply loop rule to the circuit again, we have

$$R\frac{dq}{dt} + \frac{q}{C} = 0\,.$$

Separation of variables and integrating we obtain

$$\int_{q_0}^q \frac{dq}{q} = -\frac{1}{RC}\int_0^t dt.$$

Hence

$$q(t) = q_0 e^{-\frac{t}{RC}} \quad \text{and} \quad V_c = V_0 e^{-\frac{t}{RC}}$$

They both are equations for discharging a capacitor, where $q(t)$ is the charges remaining in the capacitor and $V_C(t)$ is the voltage across the capacitor.

Time Constant

From the above charging and discharging equations, the product RC is called the capacitive time constant and is represented with the symbol τ :

$$\tau = RC$$

Substitute $t = \tau = RC$ into the charging equation, the charges and voltage on the initially uncharged capacitor will be increased from 0 to 63.2% of its final value.

$$q(t) = CV_{DC}\left(1 - e^{-\frac{RC}{RC}}\right) = CV_{DC}(1 - e^{-1}) = 0.632CV_{DC}$$

$$V_c(t) = V_{DC}(1 - e^{-1}) = 0.632V_{DC}$$

Substitute $t = \tau = RC$ into the discharging equation, the charges and voltage on the initially uncharged capacitor will be decreased from 0 to 36.8% of its final value. The voltage across capacitor during charging and discharging is shown in Figure 4.

$$q(t) = q_0e^{-\frac{t}{RC}} = q_0e^{-\frac{RC}{RC}} = q_0e^{-1} = 0.368q_0$$

$$V_C = V_0e^{-1} = 0.368V_0$$

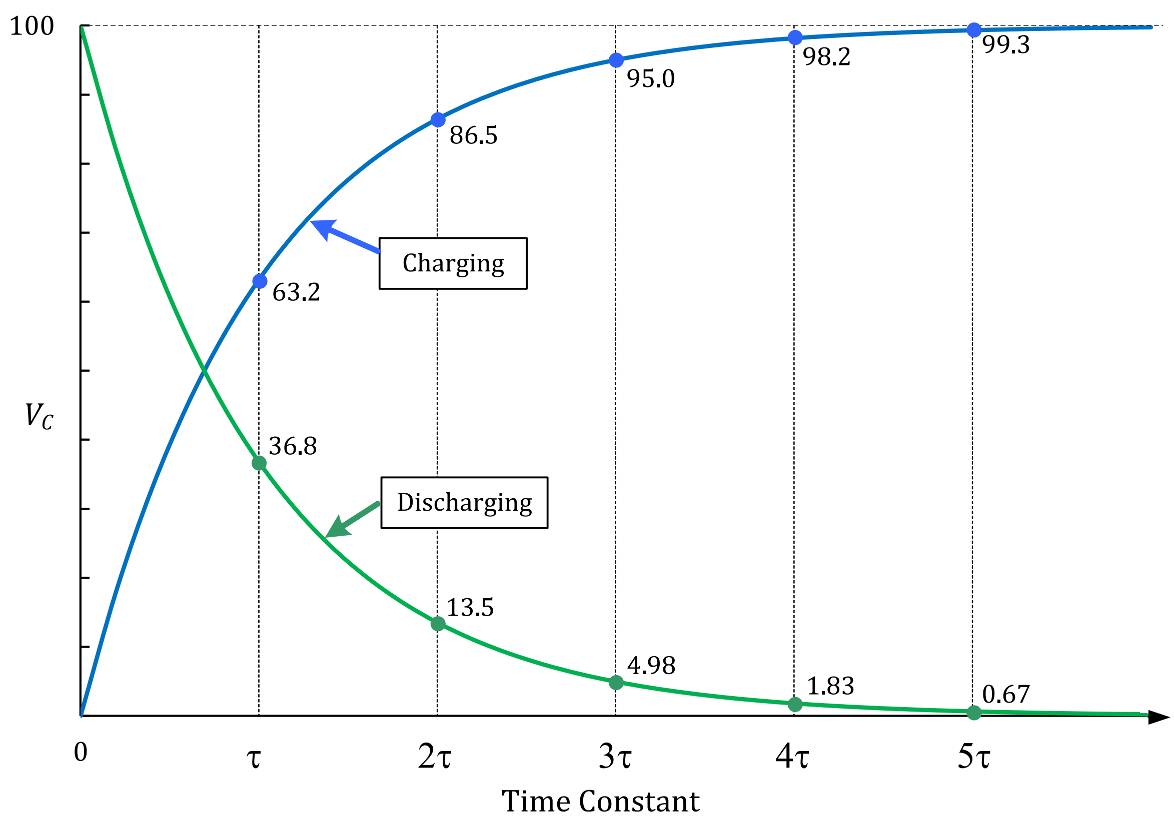


Figure 4. Capacitor voltage changing over time in RC circuit (discharging).

Procedure

1. Select a power source (DC or AC), a resistor (150 Ω or 200 Ω), and a capacitor (10 mF or 15 mF) under the "Controls" tab. Then, click "Start" button to begin the experiment.

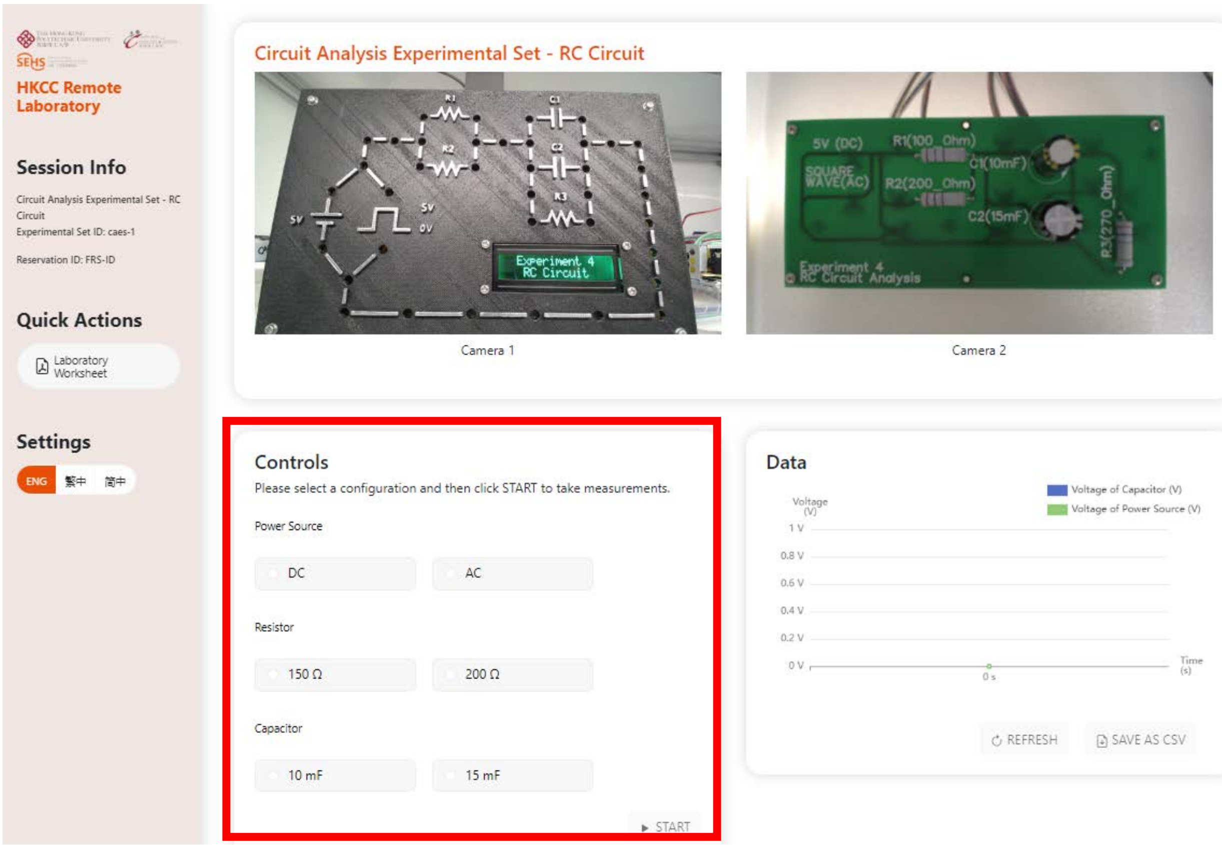


Figure 5. Select the power source, resistor and capacitor for starting the experiment.

2. The charging and discharging processes will be started. The light on the LED panel (Camera 1) shows the direction of the current flows in the circuit. Green lights show the charging process, while red lights show the discharging process. The LCD display on the panel indicates the current status of the experiment (e.g. charging or discharging). You can click on the live Camera 1 to enlarge the view.

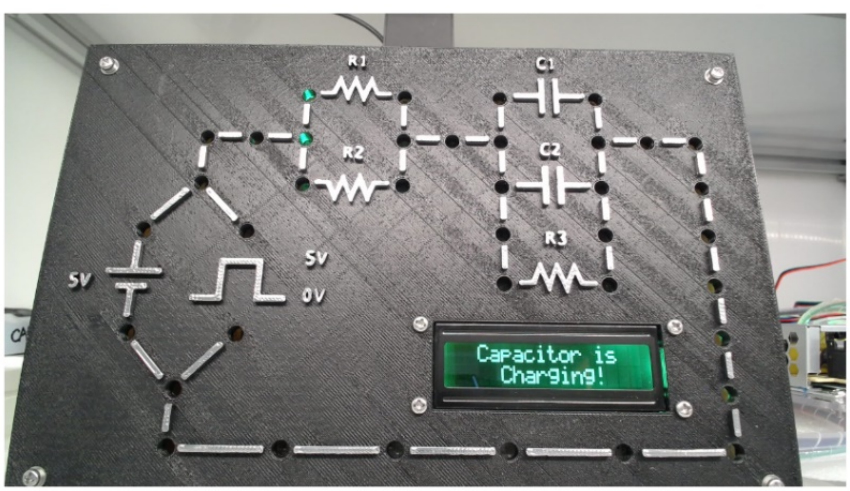


Figure 7. The direction of current flows in the circuit is indicated by the LED lights.

3. The supply voltage and voltage across the selected capacitor will be plotted in the "Data" tab as shown in Figure 8.

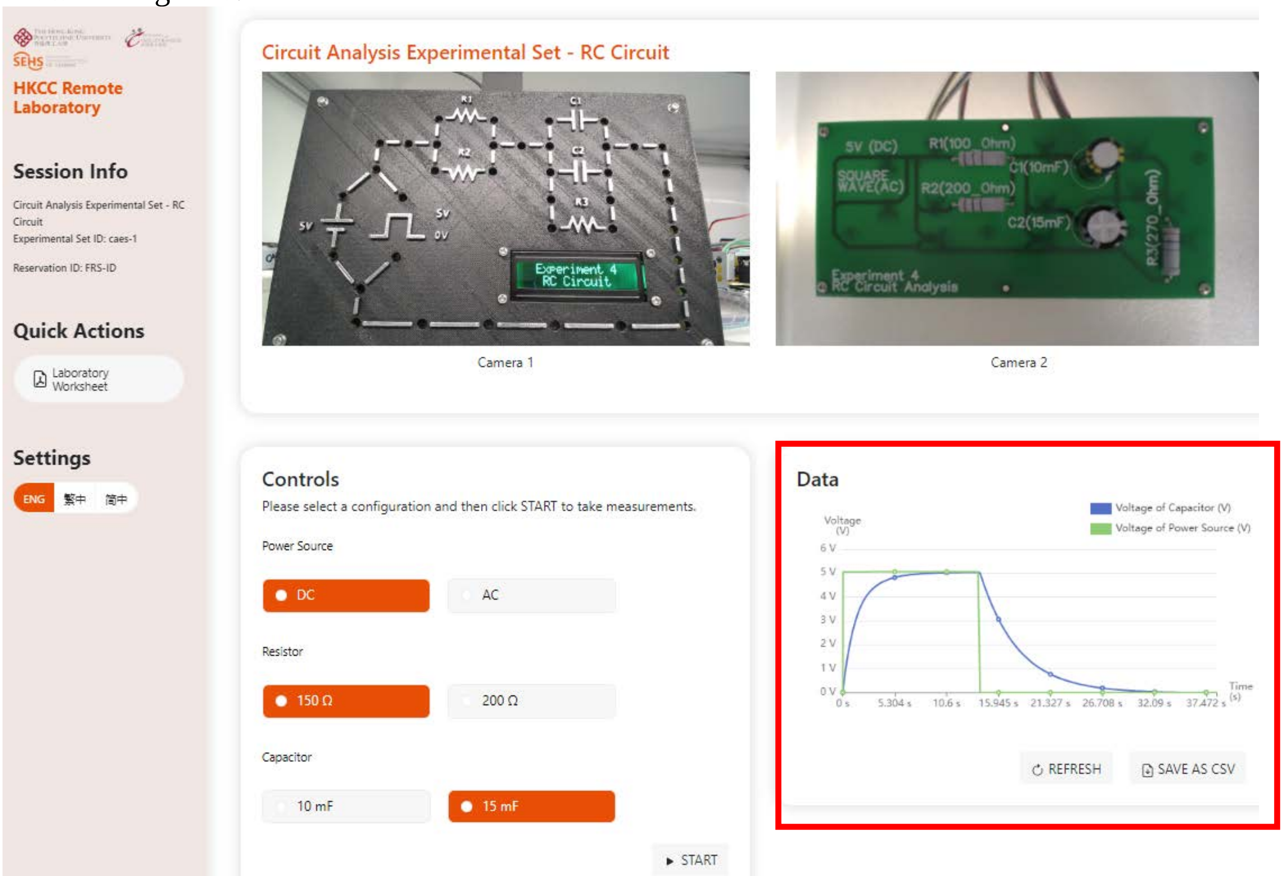


Figure 8. The experimental result.

4. The result can be downloaded in .CSV format for further analysis (Figure 8). Record your selected parameters in the "**Data**" section below.

5. You may start a new trial of the experiment with same or other settings.

Data

Trial	Power Source (AC or DC)	Resistance (Ω)	Capacitance (mF)
1			
2			
3			
4			

Analysis and Discussion

6. Select any ONE of the experimental data (with DC power input) obtained in the "Data" section above. Determine the time constant of the circuit from your experimental data. Is it consistent with the theoretical value? [You may attach the graph of voltages obtained in the experiment to show how you determine the time constants below.]

Trial Number	Time Constant (τ)	
	Experimental (Second)	Theoretical (Second)

7. Select <u>any ONE</u> of the experimental data (<u>with AC power input</u>) obtained in the "Data" section above. Determine the time constant of the circuit from your experimental data. Is it consistent with the theoretical value? [You may attach the graph of voltages obtained in the experiment to show how you determine the time constants below.]

Trial Number	Time Constant (τ)	
	Experimental (Second)	Theoretical (Second)

8. Based on the experimental time constants obtained in Step 8 above and the selected parameters, compute voltage across a capacitor, $V_C(t)$, at time, t = 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 second, under a square wave of 0 – 5V and 0.1 Hz.

Time (s)	$V_C(t)$	Time (s)	$V_C(t)$
1		6	
2		7	
3		8	
4		9	
5		10	

End of Laboratory Worksheet