Experiment 2

Determining the Capacitive Reactance of a Capacitor in an AC Circuit

1- Objects of the experiments:

a- Investigating the voltage and the current at a capacitor in an AC circuit

b- Observing the phase shift between the current and the voltage

c- Determining the capacitive reactance.

2- Principles

In a DC circuit, a capacitor represents an infinite resistance. Only during circuit closing and opening, respectively, a current flows.

However, a current flows in an AC circuit with a capacitor. The current I_{max} flowing in an AC circuit is determined by the capacitive reactance (impedance X_C of the capacitor) and the voltage ΔV_C:

$$I_{\max} = \frac{\Delta V_C}{X_C} \quad or \quad X_C = \frac{\Delta V_C}{I_{\max}} \qquad \text{(Equation 1)}$$

In the case of a sinusoidal voltage, a phase difference arises between the voltage and the current. The voltage takes its maximum when the current is zero, and the voltage is zero at maximum current, i.e. the current is in advance of the voltage by 90°. Due to the power factor ($\cos\Phi$), no power ($P_{av} = (1/2) I_{\max} \Delta V_{\max} \cos\Phi$) is lost in the capacitor, that is no energy is converted.

In the experiment, the current I_{max} is determined via the voltage drop ΔV_R at the resistor R, and the voltage ΔV_C at the capacitor C is measured directly. For this purpose the peak voltages are determined by means of an oscilloscope. The current in Equation 2 is used to calculate the capacitive reactance X_C in Equation 1.

$$I_{\max} = \frac{\Delta V_R}{R} \qquad \text{(Equation 2)}$$

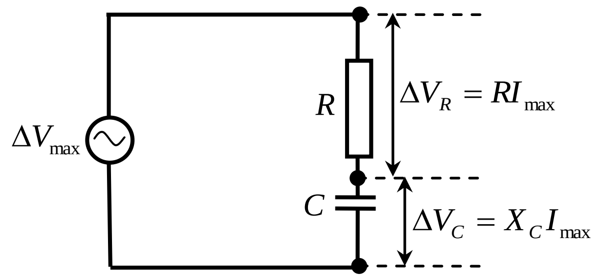

Figure 1: AC circuit with a capacitor and an ohmic resistor in series connection

In order to establish Equation 3, first the dependence of the capacitive reactance on the capacitance ($X_C \propto \frac{1}{C}$) and then on the frequency ($X_C \propto \frac{1}{f}$) is investigated.

$$X_C = \frac{1}{2\pi Cf} \qquad \text{(Equation 3)}$$

3- Apparatus:

1 plug-in board A4; 1 resistor 10Ω, 3 capacitors 1μF; 1 function generator; 1 two-channel oscilloscope; 2 screened cables BNC/4mm; 1 pair of cables, 100cm, blue and red.

4- Setup

- Setup according to Figure 2

- Measure the voltage drop ΔV_R at the resistance with channel 1 (CH1) and the voltage drop ΔV_C at the capacitor with channel 2 (CH2).

- Display both curves on the oscilloscope at the same time (DUAL). Set the coupling and the trigger to AC. For correct reading of the voltages and times (frequency) use the calibrated mode (CAL) for the deflections. Invert (INV) one channel for a correct in-phase representation of the two curves.

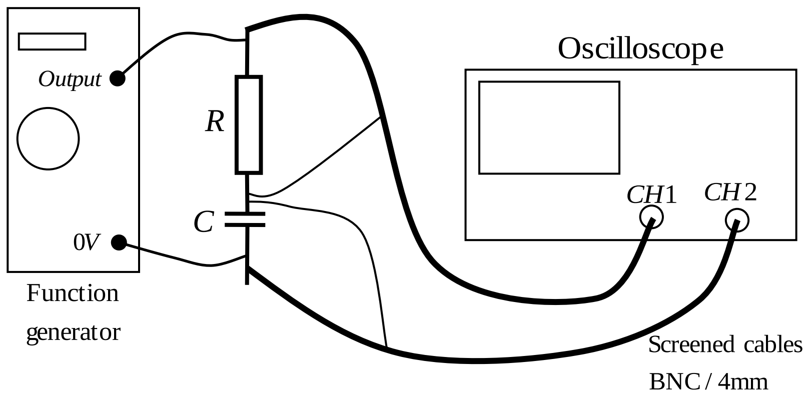

Figure 2: Experimental setup for determining the capacitive reactance with capacitor and Ohmic resistor in series connection.

5- Carrying out the Experiments:

a) Observing the phase shift

- Adjust a sinusoidal voltage with a frequency *f=1kHz* and a voltage $\Delta V_{max} = 4V$ ($\Delta V_{pp} = 8V$) at the function generator.

- Select suitable Y-deflections and time bases at the oscilloscope to observe deflections as large as possible and several oscillations.

- Compare the positions of the maxima and minima, respectively, of the voltage at the capacitor with the position of the zero passages of the current, which is represented by the voltage at the resistor.

b) Dependence of the capacitive reactance on the capacitance

- Adjust the frequency f = 1000-Hz of the function generator precisely, by reading (T=1-ms) on the oscilloscope.

- Implement various capacitance C through parallel and series connection of the capacitors.

- In each case determine the voltage drops (peak voltages) at the resistor ΔV_R and the capacitor ΔV_C using the oscilloscope.

Table 1: R=10-Ω, f = ١000-Hz

C (μF)	ΔV_R (mV)	ΔV_C (V)	$I_{\max}$ (mA)	X_C (Ω)
0.5				
1				
1.5				
2				

- Prepare a sheet of graph paper for plotting X_C versus 1/C. You should make X_C the vertical axis and 1/C the horizontal axis. Each axis should be labelled and appropriate units indicated. The graph should have a title.
- Plot your data on the graph.
- Draw best fit line to the points on your graph.
- Determine the slope of your best fit line.
- Determine the frequency *f* by using Equation 3 and the slope of your best fit line.
- There is any discrepancy between the frequency determined experimentally and that given by the function generator? (For that, calculate the percent error)

$$Percent\ error = \frac{|1000Hz - f_{\exp}|}{1000Hz} \times 100$$

c) Dependence of the capacitive reactance on the frequency

- Set up the experiment with the capacitance C =1μF.
- Adjust various frequencies f at the function generator precisely by reading the period on the oscilloscope.
- In each case determine the voltage drops (peak voltages) at the resistor ΔV_R and the capacitor ΔV_C using the oscilloscope.

Table 2: R=10-Ω, C=1-μF

f (Hz)	ΔV_R (mV)	ΔV_C (V)	$I_{\max}$ (mA)	X_C (Ω)
٢00				
٤00				
٦00				
٨00				
١000				

- Prepare a sheet of graph paper for plotting X_C versus 1/*f*. You should make X_C the vertical axis and 1/*f* the horizontal axis. Each axis should be labeled and appropriate units indicated. The graph should have a title.
- Plot your data on the graph.
- Draw best fit line to the points on your graph.
- Determine the slope of your best fit line.
- Determine the capacitance by using Equation 3 and the slope of your best fit line.
- There is any discrepancy between the capacitance determined experimentally and that given by the constructor? (For that, calculate the percent error)

$$Percent\ error = \frac{\left|1\mu F - C_{\exp}\right|}{1\mu F}\times 100$$