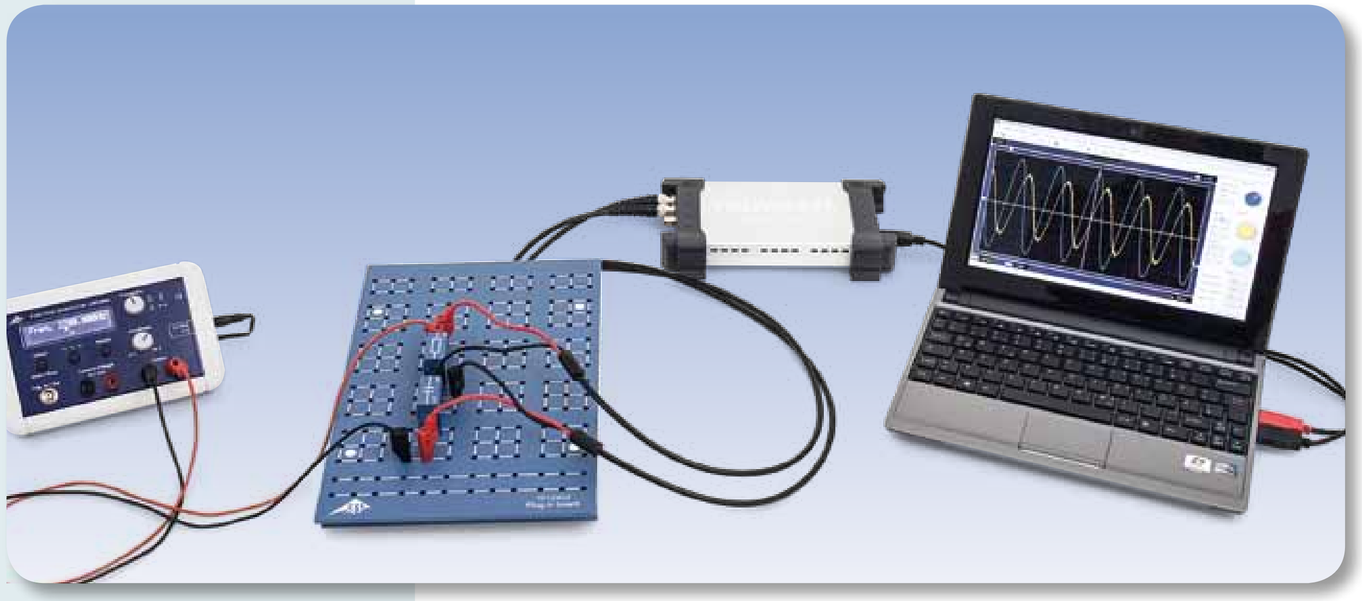
IMPEDANCE OF A CAPACITOR IN AN AC CIRCUIT



EXPERIMENT PROCEDURE

- **Determine the amplitude and phase of capacitive impedance as a function of the capacitance.**
- **Determine the amplitude and phase of capacitive impedance as a function of the frequency.**

OBJECTIVE

Determine the impedance of a capacitor as a function of capacitance and frequency

SUMMARY

Any change in voltage across a capacitor gives rise to a flow of current through the component. If an AC voltage is applied, alternating current will flow which is shifted in phase with respect to the voltage. In this experiment, a frequency generator supplies an alternating voltage with a frequency of up to 3 kHz. A dual-channel oscilloscope is used to record the voltage and current, so that the amplitude and phase of both can be determined. The current through the capacitor is given by the voltage drop across a resistor with a value which is negligible in comparison to the impedance exhibited by the capacitor itself.

REQUIRED APPARATUS

Quantity	Description	Number
1	Plug-In Board for Components	**1012902**
1	Resistor 1 Ω, 2 W, P2W19	**1012903**
1	Resistor 10 Ω, 2 W, P2W19	**1012904**
3	Capacitor 1 µF, 100 V, P2W19	**1012955**
1	Capacitor 0.1 µF, 100 V, P2W19	**1012953**
1	Function Generator FG 100 (230 V, 50/60 Hz)	**1009957 or**
	Function Generator FG 100 (115 V, 50/60 Hz)	**1009956**
1	USB Oscilloscope 2x50 MHz	**1017264**
2	HF Patch Cord, BNC/4 mm Plug	**1002748**
1	Set of 15 Experiment Leads, 75 cm 1 mm²	**1002840**

GENERAL PRINCIPLES

Any change in voltage across a capacitor gives rise to a flow of current through the component. If an AC voltage is applied, alternating current will flow which is shifted in phase with respect to the voltage. In mathematical terms, the relationship can be expressed most easily if current, voltage and impedance are regarded as complex values, whereby the real components need to be considered.

The capacitor equation leads directly to the following:

(1) $$I = C \cdot \frac{dU}{dt}$$

I: Current, U: Voltage, C: Capacitance

Assume the following voltage is applied:

(2) $$U = U_0 \cdot \exp(i \cdot 2\pi \cdot f \cdot t)$$

This gives rise to a current as follows:

(3) $$I = i \cdot \omega \cdot C \cdot U_0 \cdot \exp(i \cdot 2\pi \cdot f \cdot t)$$

Capacitor C is then assigned the complex impedance

(4) $$X_C = \frac{U}{I} = \frac{1}{i \cdot 2\pi \cdot f \cdot C}$$

The real component of this is measurable, therefore

(5a) $$U = U_0 \cdot \cos\omega t$$

(6a) $$I = 2\pi \cdot f \cdot C \cdot U_0 \cos\left(\omega t + \frac{\pi}{2}\right) = I_0 \cos\left(\omega t + \frac{\pi}{2}\right)$$

(7a) $$X_C = \frac{U_0}{I_0} = \frac{1}{2\pi \cdot f \cdot C}$$

In this experiment, a frequency generator supplies an alternating voltage with a frequency of up to 3 kHz. A dual-channel oscilloscope is used to record the voltage and current, so that the amplitude and phase of both can be determined. The current through the capacitor is related to the voltage drop across a resistor with a value which is negligible in comparison to the impedance exhibited by the capacitor itself.

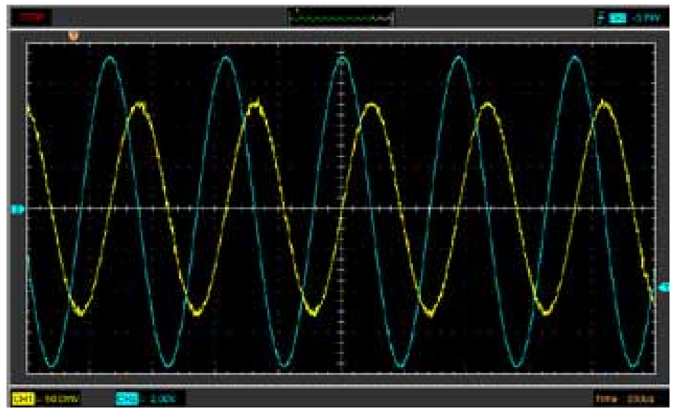


Fig. 1 Capacitor in AC circuit: trace of voltage and current

EVALUATION

The capacitive impedance X_C is proportional to the inverse of the frequency f and the inverse of the capacitance C. In the relevant graphs, the measurements therefore lie along a straight line through the origin within the measurement tolerances.

The phase of the current is 90° ahead of that for the voltage, since charging current (positive sign) and discharge current (negative sign) reach their maxima when the voltage passes through zero.

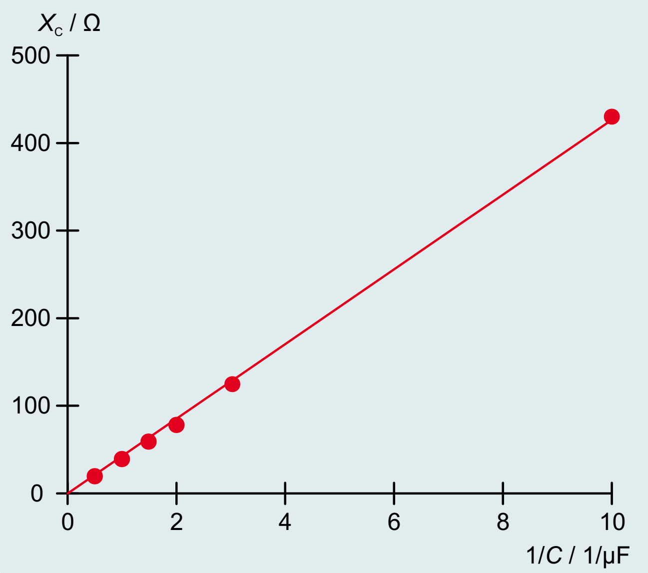


Fig. 2 Capacitive impedance X_C as a function of the inverse of the capacitance C

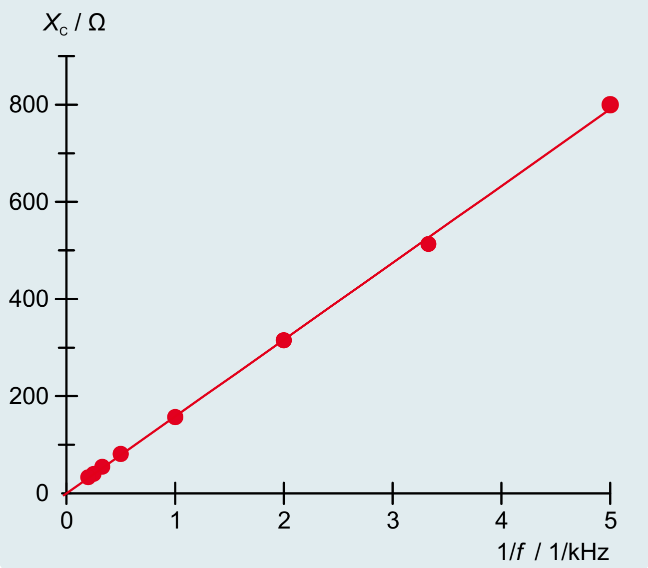


Fig. 3 Capacitive impedance X_C as a function of the inverse of the frequency f