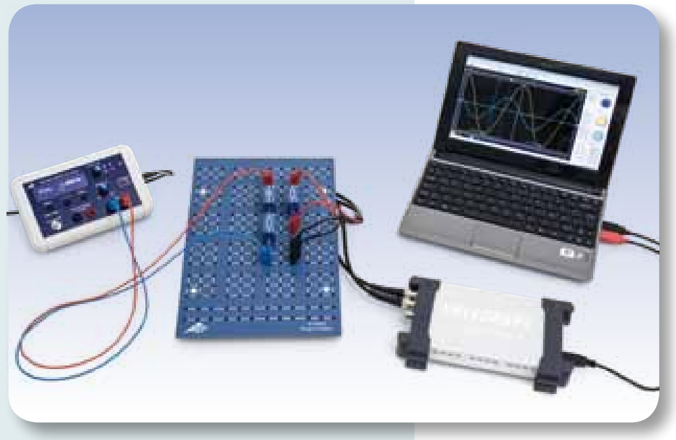
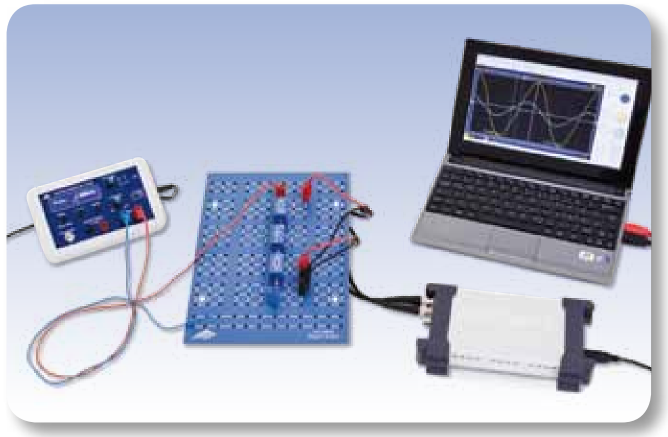
AC RESISTANCE





EXPERIMENT PROCEDURE

- **Determine the amplitude and phase of the overall resistance as a function of frequency for a series circuit.**
- **Determine the amplitude and phase of the overall resistance as a function of frequency for a parallel circuit.**

OBJECTIVE

Determine the AC resistance in a circuit with capacitive and resistive loads

SUMMARY

In AC circuits, not only ohmic resistance needs to be taken into account but also the resistance due to capacitive loads. The combination of the two may be connected in series or parallel. This has an effect on both the amplitudes and phase of the current and voltage. In the experiment, this will be investigated using an oscilloscope and a function generator supplying alternating current with frequencies between 50 and 2000 Hz.

REQUIRED APPARATUS

Quantity	Description	Number
1	Plug-In Board for Components	1012902
1	Resistor 1 Ω, 2 W, P2W19	1012903
1	Resistor 100 Ω, 2 W, P2W19	1012910
1	Capacitor 10 µF, 35 V, P2W19	1012957
1	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

In AC circuits, it is common to use complex numbers to describe the resistance in circuits with capacitors because this actually makes calculation easier. This is because not only the amplitude of the current and voltage is a factor, but also the phase relationships between the two need to be taken into account (this complex resistance is usually called impedance). Series and parallel circuits with both ohmic and capacitive resistance can then be described quite easily, although in each case, only the real component is measurable).

The complex resistance (impedance) of a capacitor with capacitance C in a circuit with an alternating current of frequency f is as follows:

(1) $$X_C = \frac{1}{i\cdot\omega\cdot C}\ ,$$

Angular frequency $\omega = 2\pi\cdot f$

Therefore series circuits containing a capacitor and an ohmic resistor R will have the following overall resistance:

(2) $$Z_S = \frac{1}{i\cdot\omega\cdot C} + R\ ,$$

A parallel circuit can be assigned the following overall resistance

(3) $$Z_P = \frac{1}{i\cdot\omega\cdot C + \frac{1}{R}}$$

The usual way of expressing this is as follows:

(4) $$Z = Z_0\cdot\exp(i\cdot\varphi)$$

This becomes

(5) $$Z_S = \frac{\sqrt{1+(\omega\cdot C\cdot R)^2}}{\omega\cdot C}\cdot\exp(i\cdot\varphi_S)$$

where $$\tan\varphi_S = -\frac{1}{\omega\cdot C\cdot R}$$

and

(6) $$Z_P = \frac{R}{\sqrt{1+(\omega\cdot C\cdot R)^2}}\cdot\exp(i\cdot\varphi_P)$$

where $$\tan\varphi_P = -\omega\cdot C\cdot R\ .$$

In this experiment a function generator supplies an AC voltage with a frequency f, which is adjusted between 50 and 2000 Hz. Voltage U and current I are recorded on an oscilloscope, whereby, I is displayed in the form of the voltage drop across a small auxiliary resistor. This allows the real components of the voltage across the relevant resistance Z.

(7) $$U = U_0\cdot\exp(i\cdot\omega\cdot t)$$

The resulting current is as follows:

(8) $$I = \frac{U_0}{Z_0}\cdot\exp(i\cdot(\omega\cdot t-\varphi)) = I_0\cdot\exp(i\cdot(\omega\cdot t-\varphi))\ .$$

The amplitudes I_0 and U_0, plus the phase shift φ can all be read from the oscilloscope.

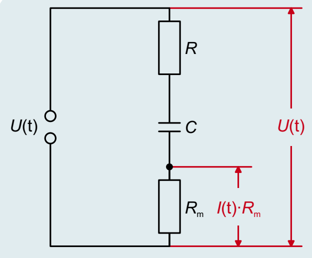


Fig. 1: Measurement set-up for series circuit.

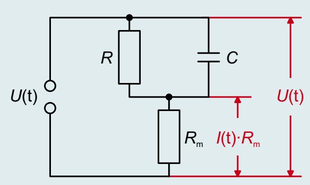


Fig. 2: Measurement set-up for parallel circuit.

EVALUATION

The magnitude of the overall resistance (impedance) $Z_0 = \frac{U_0}{I_0}$ is displayed as a function of frequency f or of the capacitive resistance $X_C = \frac{1}{2\pi\cdot f\cdot C}$.

At low frequencies the resistance of the series circuit corresponds to the capacitive resistance and that of the parallel circuit corresponds to the ohmic resistance. The phase shift is between 0° and 90° and equals 45° if the ohmic and capacitive resistance values are the same.

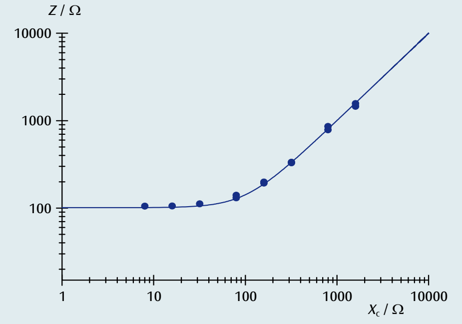


Fig. 3: Overall resistance for series circuit.

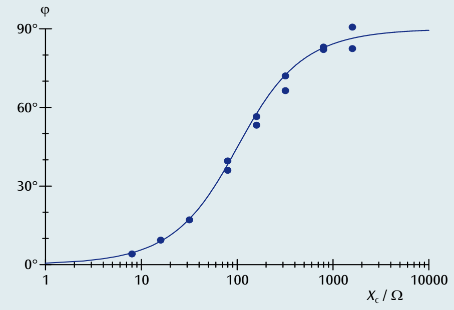


Fig. 4: Phase shift for series circuit.

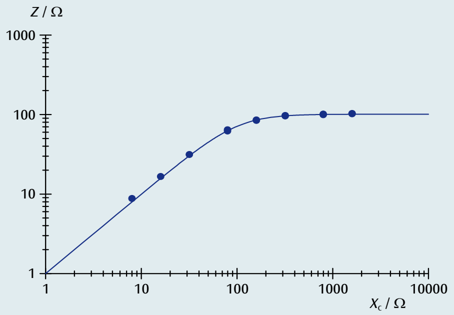


Fig. 5: Overall resistance for parallel circuit.

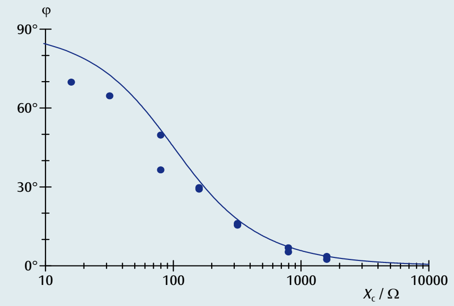


Fig. 6: Phase shift for parallel circuit.