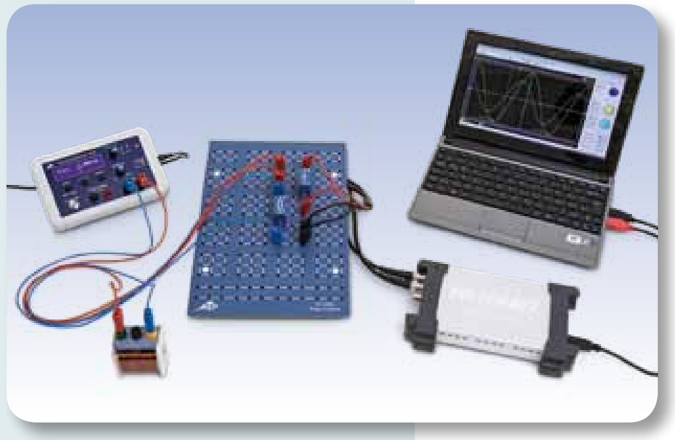

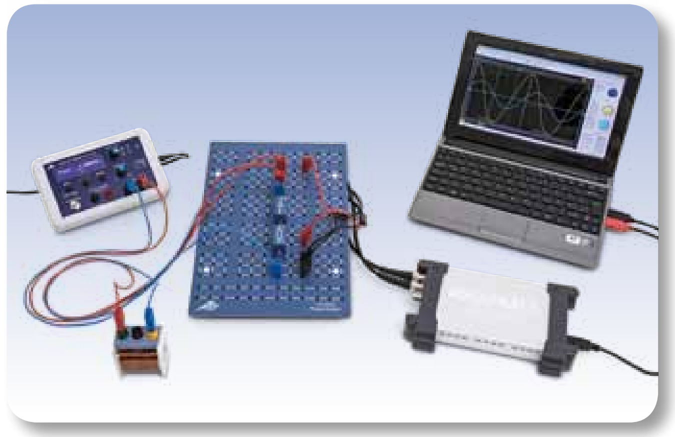

EXPERIMENT PROCEDURE

- **Determining the impedances of series and parallel connections of capacitive and inductive reactances as a function of frequency.**
- **Determining resonant frequency as a function of inductance and capacitance.**
- **Observing changes in phase shift between voltage and current at the resonant frequency.**

OBJECTIVE

Determining impedance in a circuit with an inductive and a capacitive reactance

SUMMARY

AC circuits with inductive and capacitive reactances show resonant behaviour. At the resonant frequency, the impedance of a series connection of an inductive and a capacitive reactance is zero, whereas the impedance of a parallel connection is infinite. This experiment examines this phenomenon with the help of an oscilloscope and a function generator which supplies voltages between 50 Hz and 20,000 Hz.

REQUIRED APPARATUS

Quantity	Description	Number
1	Plug-In Board for Components	**1012902**
1	Capacitor 1 µF, 100 V, P2W19	**1012955**
1	Capacitor 4.7 µF, 63 V, P2W19	**1012946**
1	Coil S with 600 Taps	**1001000**
1	Coil S with 1200 Taps	**1001002**
1	Resistor 10 Ω, 2 W, P2W19	**1012904**
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**

BASIC PRINCIPLES

As the frequency of an AC circuit's current rises, the inductive reactance rises too, while the capacitive reactance drops. Series and parallel connections of capacitive and inductive reactances therefore exhibit resonant behaviour. One speaks here of a resonant circuit, its current and voltage oscillating back and forth between the capacitance and inductance. An additional ohmic resistor dampens these oscillations.

To simplify calculations for series and parallel connections, inductances L are assigned the following complex reactance:

(1) $$X_L = i \cdot 2\pi \cdot f \cdot L$$

f: Alternating current's frequency

Furthermore, capacitances C are assigned the following complex reactance:

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

The total impedance of a series connection without an ohmic resistance therefore is:

(3) $$Z_S = i \cdot \left(2\pi \cdot f \cdot L - \frac{1}{2\pi \cdot f \cdot C}\right),$$

The corresponding calculation for a parallel connection is:

(4) $$\frac{1}{Z_P} = -i \cdot \left(\frac{1}{2 \cdot \pi \cdot f \cdot L} - 2 \cdot \pi \cdot f \cdot C\right)$$

At the resonant frequency

(5) $$f_r = \frac{1}{2 \cdot \pi \cdot \sqrt{L \cdot C}}$$

the impedance Z_S of the series connection comprising inductive and capacitive reactances therefore vanishes, i.e. the voltages across both individual reactances are opposite and equal. By contrast, the value of a parallel connection's impedance Z_P becomes infinite, i.e. the individual currents are opposite and equal. At the resonant frequency, the sign of the phase shift between the voltage and current furthermore changes.

In the experiment, resonant circuits are set up as series / parallel connections of capacitors and inductors. A function generator serves as a voltage source with an adjustable frequency and amplitude. An oscilloscope is used to measure current and voltage as functions of the set frequency. The voltage U and current I are displayed on the oscilloscope; I corresponds to the voltage drop across a small load resistor.

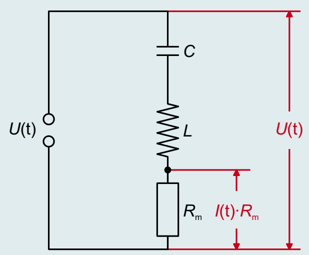

Fig. 1: Measurement setup for a series connection

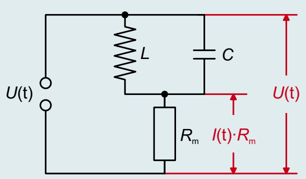

Fig. 2: Measurement setup for a parallel connection

EVALUATION

For each frequency f, the phase shift ϕ as well as the amplitudes I_0 and U_0 are read on the oscilloscope. The readings are used to calculate the total impedance: $Z_0 = \frac{U_0}{I_0}$.

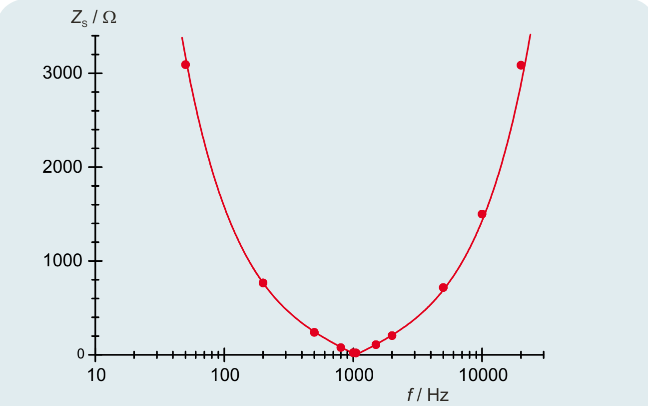

Fig. 3: Impedance of a series connection as a function of frequency

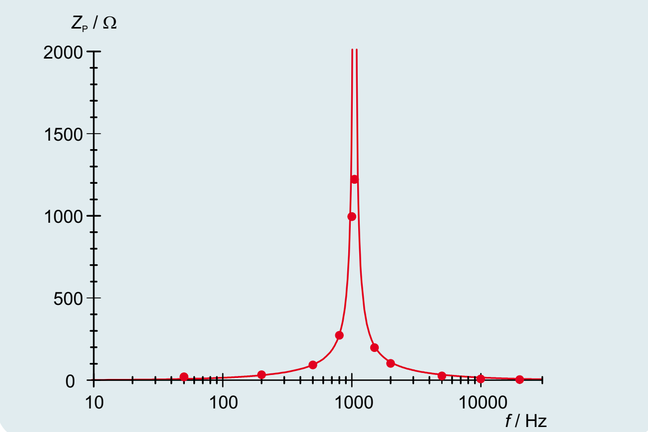

Fig. 4: Impedance of a parallel connection as a function of frequency

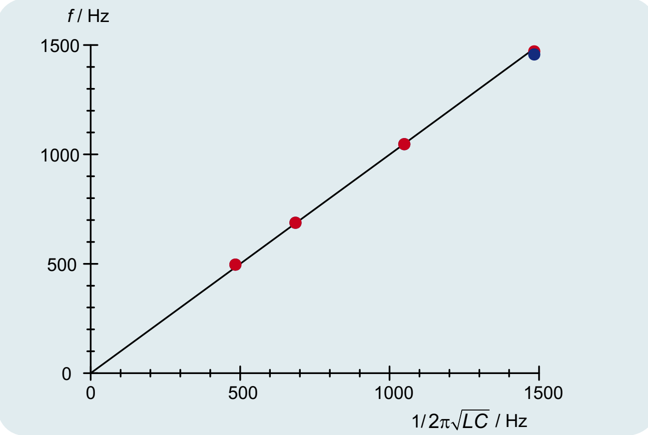

Fig. 5: Comparison between measured and calculated resonant frequencies for a series connection (red) and a parallel connection (blue)