

## Determining capacitive reactance with a Wien measuring bridge

### Objects of the experiments

- Determining the capacitances of capacitors by adjusting a Wien measuring bridge.
- Demonstrating that the balance condition is independent of the frequency of the AC voltage.

### Principles

The Wheatstone measuring bridge is used to determine ohmic resistance in DC and AC circuits. In an analogue bridge circuit, the Wien measuring bridge (see Fig. 1), capacitive reactance can be determined. This measuring bridge, too, consists of four passive bridge arms, which are connected to one another in a square, an indicator arm with a balance indicator and a supply arm with the voltage source. The current in the indicator arm is made zero by adjusting variable elements in the bridge arm. Then the involved complex reactances fulfil the fundamental balance condition

$$Z_1 = Z_2 \cdot \frac{Z_3}{Z_4} \quad (\text{I}),$$

from which the quantity to be measured

$$Z_1 = \frac{1}{i \cdot 2\pi \cdot f \cdot C_1} \quad (\text{II})$$

$C_1$ : capacitance

$f$ : frequency of the applied AC voltage  
can be determined.

$Z_2$  is a capacitive reference reactance,  $Z_3$  is a fixed ohmic resistance and  $Z_4$  is a variable ohmic resistance. Therefore,

$$Z_2 = \frac{1}{i \cdot 2\pi \cdot f \cdot C_2} \quad (\text{III})$$

and

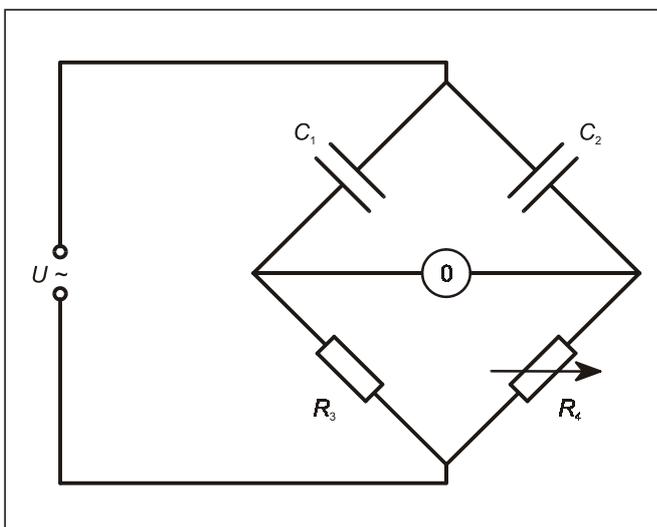
$$Z_3 = R_3 \text{ and } Z_4 = R_4 \quad (\text{IV}).$$

In the case of zero balance, the relation

$$C_1 = C_2 \cdot \frac{R_4}{R_3} \quad (\text{V})$$

holds regardless of the frequency  $f$ . In this experiment an earphone, an oscilloscope or a Sensor-CASSY can be used as a balance indicator.

Fig. 1 Diagram of a Wien measuring bridge for determining a capacitive reactance  $Z_1$



**Apparatus**

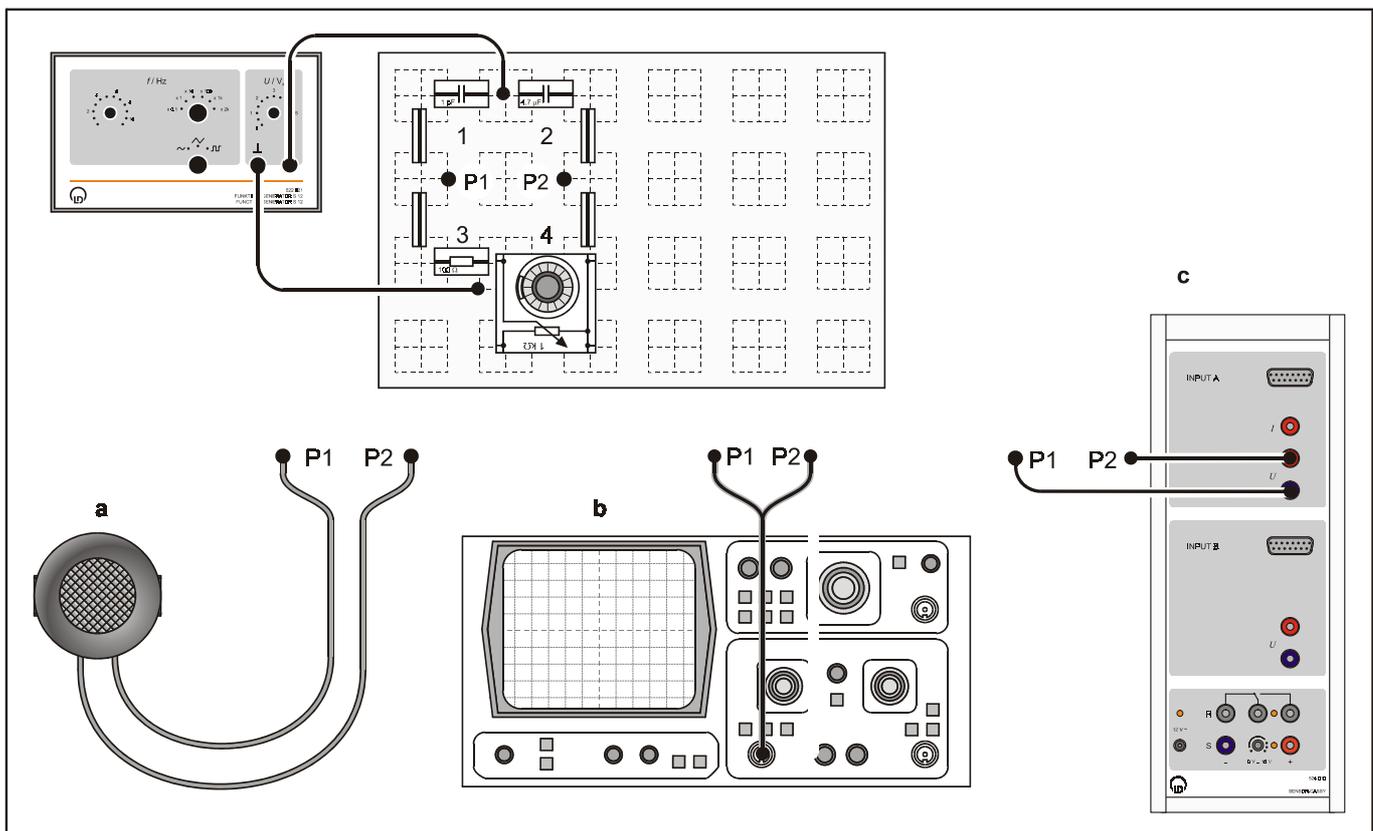
1 capacitor, 1 $\mu\text{F}$ , 100 V, STE 2/19	578 15
1 capacitor 4.7 $\mu\text{F}$ , 63 V, STE 2/19	578 16
1 plug-in board, A4	576 74
1 resistor 100 $\Omega$ , 0.5 W, STE 2/19	577 01
1 potentiometer 1 k $\Omega$ , 2 W, STE 4/50, 10-turn	57793
1 set of 10 bridging plugs	501 48
1 function generator S 12, 0.1 Hz-20 kHz	522 621
Connection leads	
1 earphone 2 k $\Omega$	579 29
or	
1 two-channel oscilloscope 303	575 211
1 screened cable BNC/4 mm	575 24
or	
1 Sensor-CASSY	524 010
1 CASSY Lab	524 200

**Setup**

The experimental setup is illustrated in Fig. 2.

- Connect the function generator as an AC voltage source, and set the maximum output voltage and the signal shape  $\sim$ .
- Connect the earphone, the oscilloscope or the Sensor-CASSY between the connection points P1 and P2 as a balance indicator.

Fig. 2 Experimental setup for determining capacitive reactance by means of a Wien measuring bridge



## Carrying out the experiment

Remark concerning the selection of the frequency of the AC voltage:

If the Sensor-CASSY is used as a balance indicator, the frequency  $f$  should not exceed 500 Hz because otherwise the r.m.s. value is not determined correctly. If the earphone is used, higher frequencies are recommendable in order to ensure sufficient aural sensitivity.

### Oscilloscope settings:

Coupling: AC  
 Deflection: 10 mV/DIV.  
 Trigger: AC  
 Time base: 5 ms/DIV. ( $f = 100\text{-}500$  Hz)

### Sensor-CASSY settings:

Sensor input settings A1:

Measurement quantity:  $U_{A1}$ , r.m.s. values, measuring range: 0 V ... 0.21 V

Measuring parameters:

automatic recording, repeating measurement

Trigger:  $U_{A1}$  0.0000 V rising

Interval: 1 ms ( $f = 50$  Hz), 500  $\mu$ s ( $f = 100$  Hz), 200 ms ( $f = 250$  Hz), 100  $\mu$ s ( $f = 500$  Hz)

Number: 1000

#### a) Reference capacitance 4.7 $\mu$ F:

- Insert the 1- $\mu$ F capacitor as capacitance  $C_1$  and the 4.7- $\mu$ F capacitor as reference capacitance  $C_2$ .
- Switch the function generator on by connecting the plug-in power supply.
- Set a frequency that fits the balance indicator used.
- Vary the resistance  $R_4$  carefully until the signal at the balance indicator is minimal (zero).
- Vary the frequency in the minimum to check the balance.

#### b) Reference capacitance 1 $\mu$ F:

- Exchange the two capacitors, and repeat the measurement.

## Measuring example

#### a) Reference capacitance 4.7 $\mu$ F:

$$C_2 = 4.7 \mu\text{F}, R_3 = 100 \Omega$$

$$R_4: \text{scale value } 0.225$$

Balance checked for  $f = 50, 100, 200$  and 500 Hz

#### b) Reference capacitance 1 $\mu$ F:

$$C_2 = 1.0 \mu\text{F}, R_3 = 100 \Omega$$

$$R_4: \text{scale value } 4.440$$

Balance checked for  $f = 50, 100, 200$  and 500 Hz

## Evaluation

#### a) Reference capacitance 4.7 $\mu$ F:

$$R_4 = \frac{0,225}{10} \cdot 1 \text{ k}\Omega = 22,5 \Omega$$

$$\text{Eq. (V) gives: } C_1 = 4,7 \mu\text{F} \cdot \frac{22,5 \Omega}{100 \Omega} = 1,06 \mu\text{F}$$

Value imprinted on the capacitor:  $C_1 = 1 \mu\text{F}$

#### b) Reference capacitance 1 $\mu$ F:

$$R_4 = \frac{4,440}{10} \cdot 1 \text{ k}\Omega = 444,0 \Omega$$

$$\text{Eq. (V) gives: } C_1 = 1 \mu\text{F} \cdot \frac{444,0 \Omega}{100 \Omega} = 4,44 \mu\text{F}$$

Value imprinted on the capacitor:  $C_1 = 4.7 \mu\text{F}$

#### c) Comparison of the results with the values imprinted on the capacitors:

In both cases, the deviation of the measuring results from the values imprinted on the capacitors is approximately 6 % and thus somewhat greater than the tolerance indicated by the manufacturer. Note, however, that in either case the reference capacitance is only known within the tolerance of 5 % as well.

## Result

With the aid of a Wien measuring bridge, the capacitance of a capacitor can be determined. The balance parameter is independent of the frequency of the applied AC voltage.

