Parallel and series connection of capacitors

Measuring the charge with the electrometer amplifier

Objects of the experiments

- Determining the total capacitance of two capacitors in parallel connection and comparing with the capacitances of the individual capacitors.
- Determining the total capacitance of two capacitors in series connection and comparing with the capacitances of the individual capacitors.

Principles

The capacitance C of a capacitor is the proportionality coefficient between the charge Q on the capacitor and the applied voltage U:

$$Q = C \cdot U \qquad \text{(I).}$$

When two capacitors with the capacitances C_1 and C_2 are parallel-connected, they take the total charge

$$Q = Q_1 + Q_2 \qquad \text{(II)}$$

Q_1, Q_2: individual charges

because the voltage U is applied to both capacitors (see Fig. 1). Because of Eq. (I), the capacitance of the parallel connection is

$$C = C_1 + C_2 \qquad \text{(III).}$$

In a series connection, both capacitors take the same charge Q. The applied voltage U is the sum of the individual voltages U_1 and U_2:

$$U = U_1 + U_2 \qquad \text{(IV).}$$

The capacitances of the series connection therefore fulfil the equation

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} \qquad \text{(V).}$$

In the experiment, these relations are studied by means of two plate capacitors with different capacitances C_1 and C_2. The capacitors are set up side by side, and both parallel or series connection can be chosen. An insulating plate between the two capacitors ensures that the charges on the capacitors cannot influence each other through electrostatic induction. Charges are measured with an electrometer amplifier operated as a coulombmeter. Any voltmeter may be used to display the output voltage U_A. From the reference capacitance C_A

$$Q = C_A \cdot U_A \qquad \text{(VI).}$$

is obtained. For example, at C_A = 10 nF, U_A = 1 V corresponds to the charge Q = 10 nAs. In this case, the capacitance to be measured is C =200 pF, if the voltage U = 50 V has been applied.

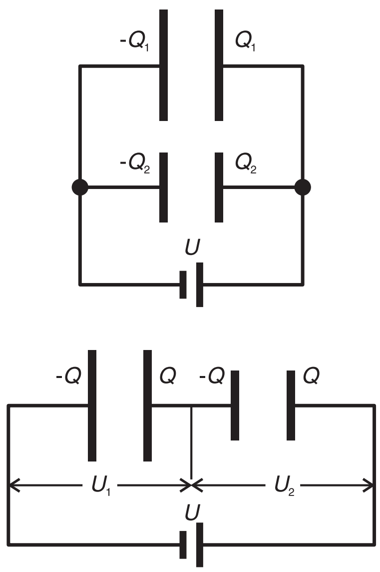

Fig. 1 Parallel (above) and series connection (below) of capacitors

1009-Wei

Apparatus

1 demountable capacitor	544 23
1 power supply 450 V –	522 27
1 two-way switch	504 48
1 Voltmeter, DC, range $U = \pm 8$ V e.g.	531 100
1 Voltmeter, DC, range $U \leq 300$ V e.g.	531 100
1 electrometer amplifier	532 14
1 STE capacitor 100 nF	578 31
1 STE capacitor 10 nF	578 10
1 connection rod	532 16
connection leads	

Setup

The experimental setup is illustrated in Fig. 2.

– Mount the pairs of large and small plates (as a distance between the plates choose 6 mm for both pairs), and put the polystyrene plate between them.
– Connect the voltmeter to the output of the power supply.
– Connect the positive pole of the power supply to socket B of the two-way switch.
– Connect the negative pole of the power supply to the earth socket of the electrometer amplifier.
– Connect the connection rod to the earth socket of the electrometer amplifier with a connection lead.
– Connect socket C of the two-way switch to the input of the electrometer amplifier.
– Plug the reference capacitor C_A = 10 nF in at the electrometer amplifier.
– Supply the electrometer amplifier with voltage from the plug-in unit.
– Connect the voltmeter to the output of the electrometer amplifier.

Carrying out the experiment

Remarks:

Hold the connection rod in your hand during charge measurements.

a) large plate capacitor:

– Set the output voltage U of the power supply to 50 V.
– Connect the "inner" plate of the large plate capacitor to socket A of the two-way switch and the "outer" plate to the earth as shown in Fig. 3a.
– Establish the connection AC with the two-way switch, and discharge the large plate capacitor with the connection rod.
– Hold the connection rod in your hand, and change the two-way switch to the connection AB to charge the plate capacitor.
– Set the two-way switch back to the connection AC, measure the charge Q on the capacitor with the electrometer amplifier, and calculate the capacitance C from it.

b) small plate capacitor:

– Connect the small plate capacitor as shown in Fig. 3b.
– Establish the connection AC with the two-way switch, and discharge the plate capacitor with the connection rod.
– Hold the connection rod in your hand, and charge the small plate capacitor.
– Measure the charge Q, and calculate the capacitance C from it.

c) parallel connection:

– As shown in Fig. 3c, connect the two inner plates to each other and to socket A of the two-way switch; connect the two outer plates to the earth.
– Discharge the parallel-connected capacitors, then charge them, measure the charge Q, and calculate the capacitance C.

d) series connection:

– Set the series connection up as shown in Fig. 3d.
– Discharge the series-connected capacitors, then charge them, measure the charge Q, and calculate the capacitance C.

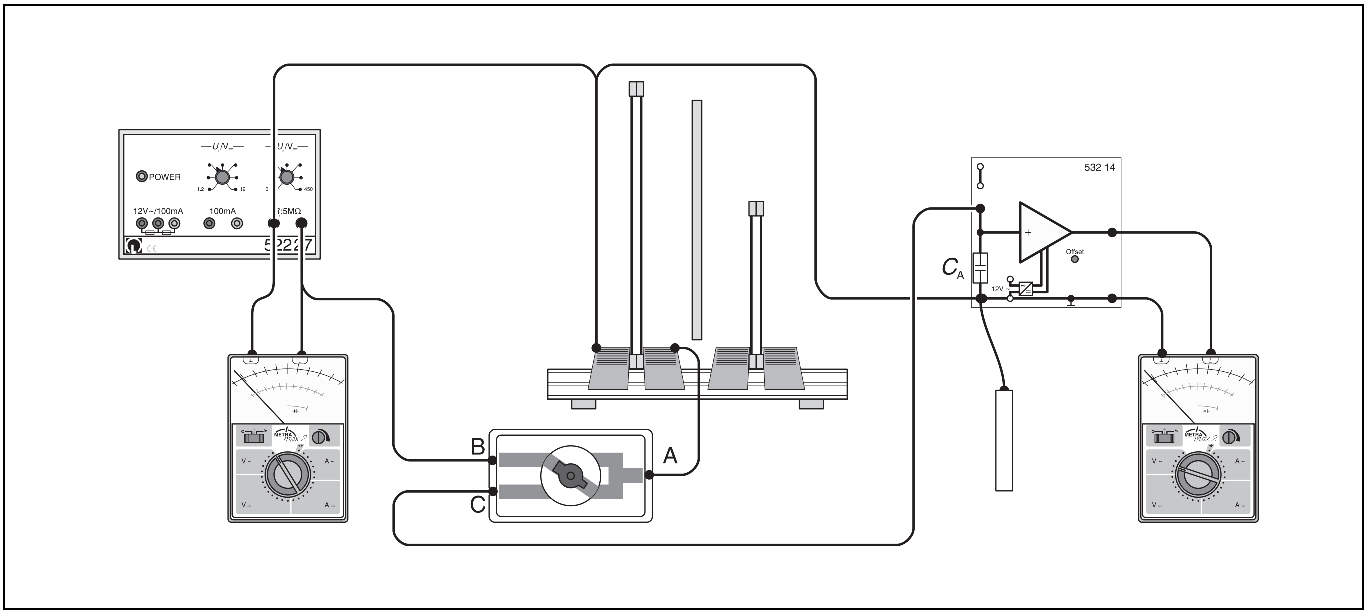

Fig. 2 Experimental setup for measuring the capacitance of parallel- and series-connected capacitors.

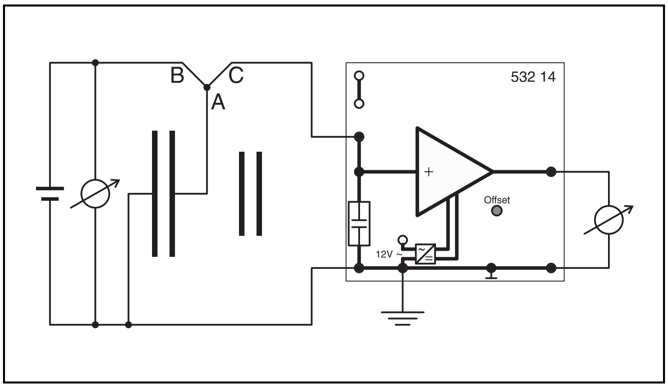

Fig. 3a Connection for measuring the capacitance of the large plate capacitor

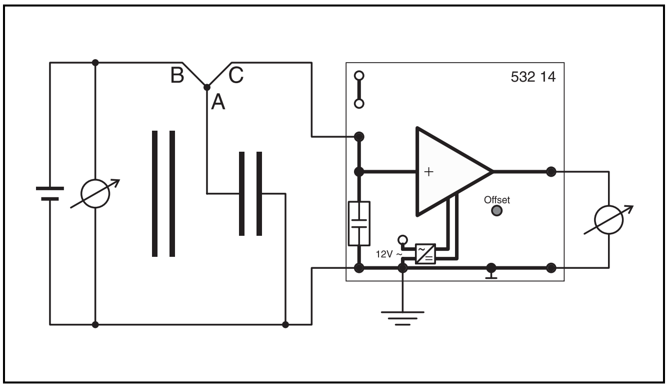

Fig. 3b Connection for measuring the capacitance of the small plate capacitor

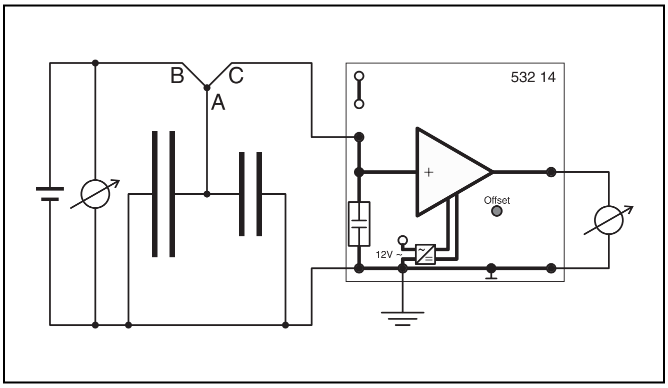

Fig. 3c Connection for measuring the capacitance of the parallel-connected capacitors

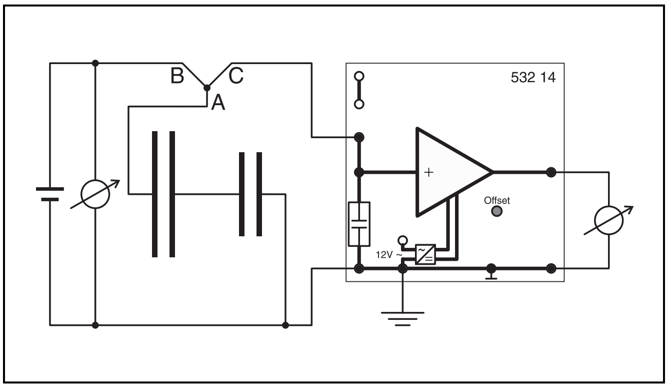

Fig. 3d Connection for measuring the capacitance of the series-connected capacitors.

Measuring example

U = 50 V, d = 6 mm:

Setup	$\frac{Q}{\text{nAs}}$	$\frac{C}{\text{pF}}$
single, large area	12	240
single, small area	6.5	130
parallel connection	18	360
series connection	4.4	88

Evaluation

Parallel connection:

Application of Eq. (II) leads to C = 130 pF +240 pF = 370 pF.

Measuring result: C = 360 pF.

Series connection:

Application of Eq. (IV) leads to

$$\frac{1}{C} = \frac{1}{240\text{ pF}} + \frac{1}{130\text{ pF}} = 0.01186\,\frac{1}{\text{pF}}.$$

From this C = 84.3 pF follows.

Measuring result: C = 88 pF.

Results

The capacitance of parallel-connected capacitors is equal to the sum of the individual capacitances.

The reciprocal of the capacitance of series-connected capacitors is equal to the sum of the reciprocals of the individual capacitances.