

# Charging curve of a capacitor

## Related topics

Charging, discharging, time constant, exponential function, half life.

## Principle

A capacitor is charged by way of a resistor. The current is measured as a function of time and the effects of capacitance, resistance and the voltage applied are determined.

## Equipment

|  |          |   |
|--|----------|---|
| Connection box                               | 06030.23 | 2 |
| Two-way switch, single pole                  | 06030.00 | 1 |
| Capacitor, $2 \times 32 \mu\text{F}$         | 06219.32 | 1 |
| Carbon resistor 1 W, 100 Ohm                 | 39104.63 | 1 |
| Carbon resistor 1 W, 1 MOhm                  | 39104.52 | 4 |
| Connect. plug white 19 mm pitch              | 39170.00 | 2 |
| Capacitor (case 2) $1 \mu\text{F}$           | 39113.01 | 1 |
| Capacitor (case 2) $4.7 \mu\text{F}$         | 39113.03 | 1 |
| Power supply 0-12 V DC/6 V, 12 V AC          | 13505.93 | 1 |
| Stopwatch, digital, 1/100 sec.               | 03071.01 | 1 |
| Digital multimeter                           | 07134.00 | 1 |
| Connecting cord, $l = 250 \text{ mm}$ , red  | 07360.01 | 3 |
| Connecting cord, $l = 250 \text{ mm}$ , blue | 07360.04 | 4 |

## Tasks

To measure the charging current over time:

1. using different capacitance values  $C$ , with constant voltage  $U$  and constant resistance  $R$

2. using different resistance values ( $C$  and  $U$  constant)

3. using different voltages ( $R$  and  $C$  constant).

To determine the equation representing the current when a capacitor is being charged, from the values measured.

## Set-up and procedure

Set up the experiment as shown in Fig. 1 and Fig. 2.

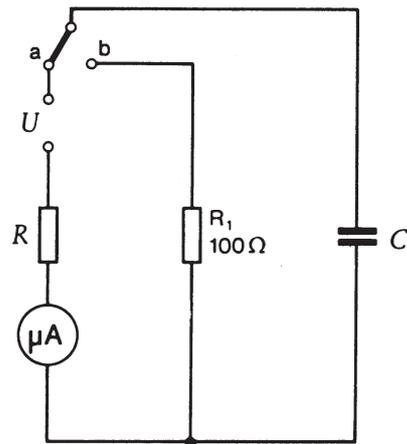


Fig. 2: Capacitor charging circuit  
a) charging      b) discharging

Fig. 1: Experimental set-up for measuring the current when a capacitor is being charged.



## Charging curve of a capacitor

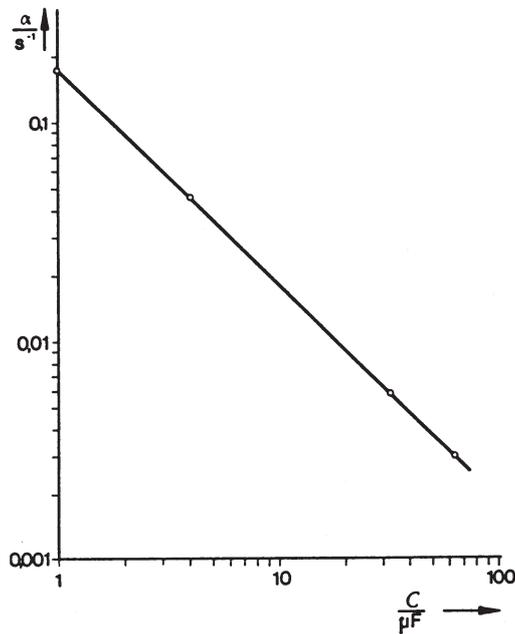


Fig. 3: Exponent  $\alpha$  as a function of capacitance  $C$ .

Various resistance values  $R$  are established by series connection. The internal resistance of the digital multimeter and the setting time can be disregarded.

$R_1$  is a protective resistor which limits the current when discharging (switch setting b).

### Theory and evaluation

The course of current with time,  $I(t)$ , when a capacitor  $C$  is charged through a resistor  $R$  at a fixed voltage  $U$  (Fig. 2) is determined from Kirchhoff's laws:

$$I(t) = \frac{U}{R} e^{-\frac{t}{RC}} \quad (1)$$

The dependence of the current on the capacitance, the resistance and the voltage should be worked out from the measured values obtained by systematically varying the parameters.

## Charging curve of a capacitor

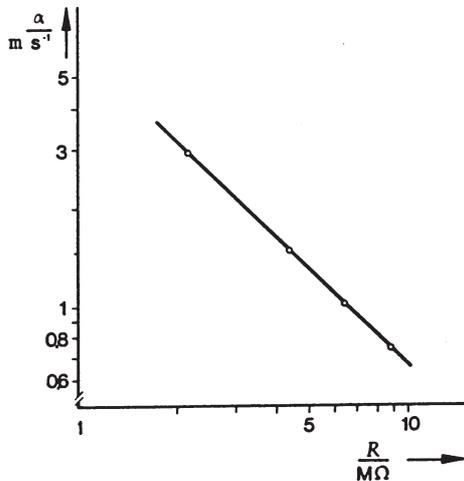


Fig. 4: Exponent  $\alpha$  as a function of resistance  $R$ .

- $I(t) = I_0(U, R) e^{-\alpha(U, R, C) \cdot t}$

$I_0$  is not dependent on  $C$  as all curves begin at the same current values.

To investigate the dependence of the exponent on the capacitance, the slopes of the straight lines in Fig. 3 are plotted against capacitance, on a log-log basis.

A straight line with the slope  $-0.98 \approx -1$  is obtained, so that

$$I(t) = I_0(U, R) e^{-\frac{\alpha'(U, R)}{C} t}$$

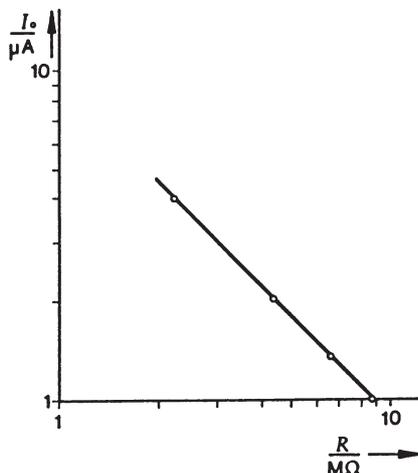


Fig. 5: Starting current  $I_0$  of the measured values as a function of the resistance.

- Straight lines with different slopes and different starting points are obtained. The dependence of the exponent on  $R$  is determined by plotting the log-log of the straight lines.

A straight line with the slope  $-1.00$  is obtained, so that

$$I(t) = I_0(U, R) e^{-\frac{\alpha'(U)}{RC} \cdot t}$$

The straight line has a slope of  $-0.99 \approx -1$ , i.e.

$$I_0 = \frac{\beta(U)}{R}$$

- All the straight lines have the same slope. The exponent is thus independent of the voltage  $U$  (this statement can also be made on the basis of dimensions). The slope of the straight line is

$$0.058 \text{ s}^{-1} = \frac{1}{RC} \rightarrow RC = 17.24 \text{ s}$$

The starting current values  $I_0$  for the measured values are plotted directly against the voltage values  $U$  in this case. (Fig. 5).

A straight line with the slope

$$0.227 \frac{\mu\text{A}}{\text{V}} = \frac{1}{R} \rightarrow R = 4.41 \text{ M}\Omega$$

is obtained.

Taken together, therefore, all the measured values give equation (1).

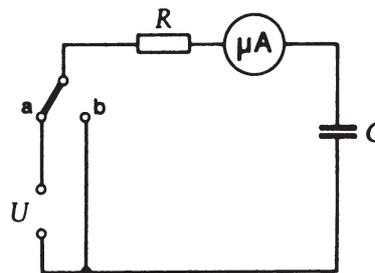


Fig. 6: Circuit for recording charging and discharging curves.

### Note

If discharging curves are to be measured as well, the circuit as shown in Fig. 6 will be used.

Another experiment which could be carried out would be to determine unknown capacitance values from the charging and discharging curves with known resistance and charging function, or conversely to determine large resistance values at known capacitance.



