Aalto University
School of Electrical
Engineering

# ELEC-C9610 Basics in Electronics

## Lecture 1: Kirchhoff's laws

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# Voltage and current

*No electricity without charge.*

- **Current** is movement of charges. DC current has constant magnitude.
- A flow of charges means a flow of the energy. When charge flows, it arises **potential** (energy per unit charge).
- **Voltage** is difference in potential between two points.
- **Circuit** consists of branches, where currents travel and nodes having potential between them.

power $\boldsymbol{P}$ [W], voltage $\boldsymbol{U}$ [V], current $\boldsymbol{I}$ [A]


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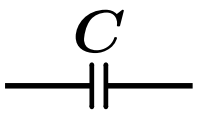
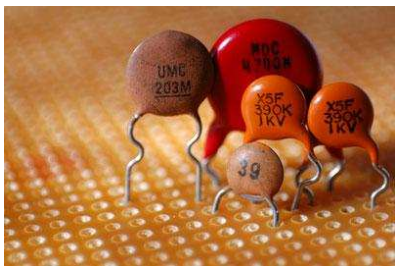
# Passive components

| graphic symbol | component | property |
|---|---|---|
|  | resistance | resistance $\boldsymbol{R}$ [$\boldsymbol{\Omega}$] |
|  | condensator | capacitance $\boldsymbol{C}$ [F] |
|  | coil | inductance $\boldsymbol{L}$ [H] |




Instead of resistance, we can also use conductance $\boldsymbol{G = 1/R}$ [S]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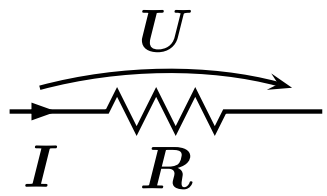
# Ohm's law

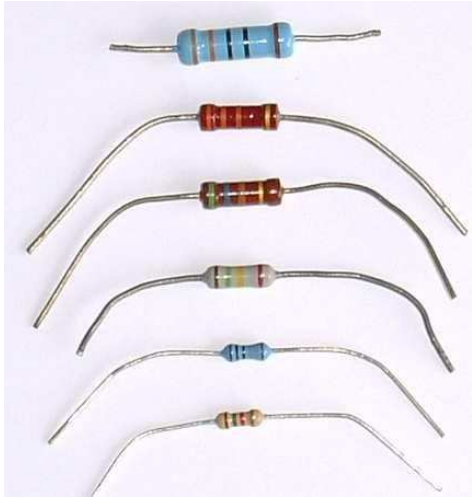



$$U = RI$$

Voltage over the resistor depends linearly on current through the component.

With conductance:

$$I = GU,\ G = \frac{1}{R}$$

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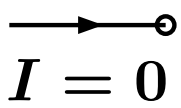
# Open circuit and short circuit

Current in capacitance depends on the change of the voltage:

$$i = C\frac{du}{dt}$$

In DC, current is zero and capacitance corresponds to an open circuit.

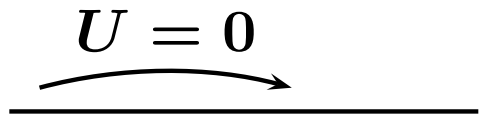



$R = \infty$ $U = ?$

Voltage over inductance depends on the change of the current:

$$u = L\frac{di}{dt}$$

In DC, voltage is zero and inductance corresponds a short circuit.




$R = 0$ $I = ?$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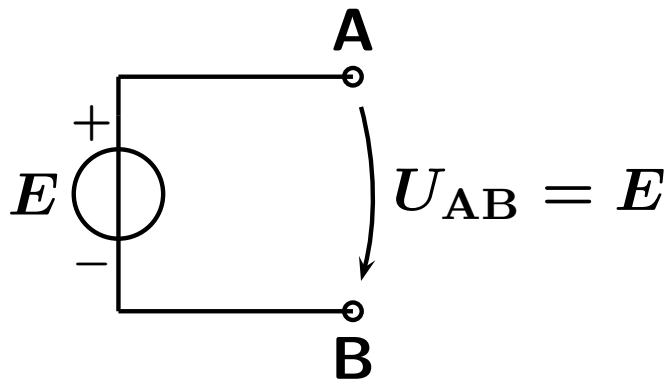
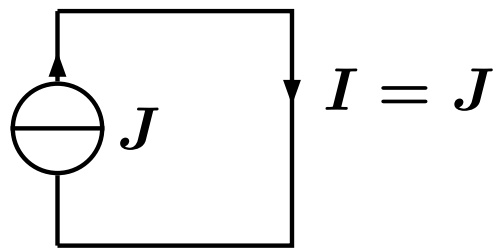
# Ideal sources

Ideal voltage source $E$ determines voltage $U_{AB}$ between nodes (**A** and **B**).




Ideal current source $J$ determines current $I$. For this reason, current through the current source is always equal the value of the source.





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# Power

**Power produced in the circuit = power consumed in the circuit**

$$P = UI$$

By substituing Ohm's law, we can write also

$$P = RI^2 = \frac{U^2}{R} = GU^2$$

If power is positive, element consumes power.


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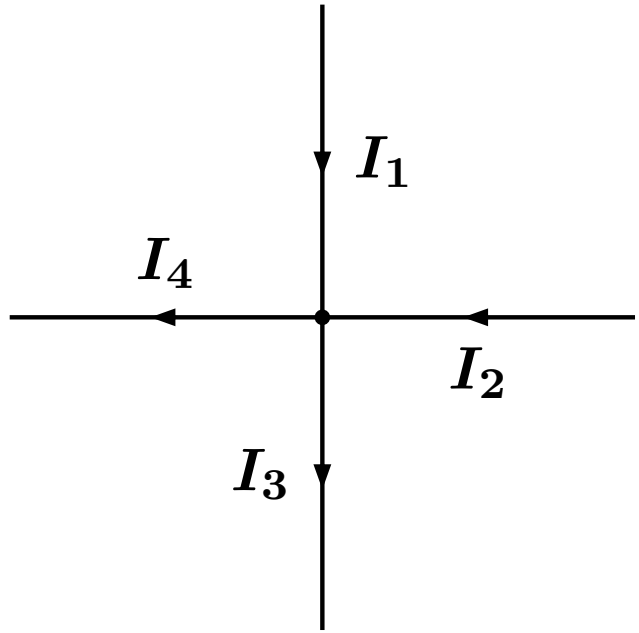
# Kirchhoff's current law




$$I_1 + I_2 = I_3 + I_4$$

The sum of the current coming to the node is same as the sum of the currents going out of the node.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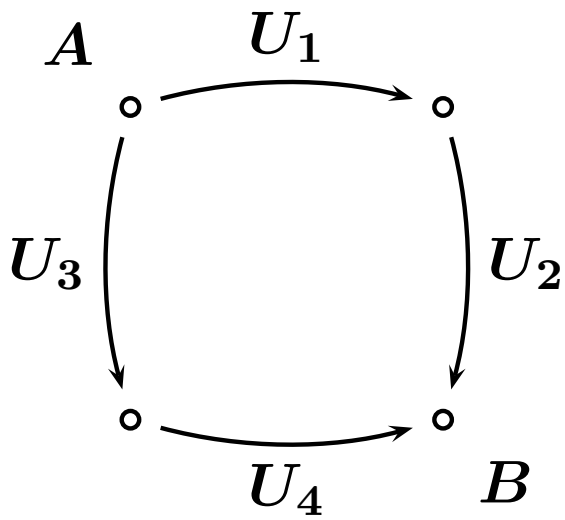
# Kirchhoff's voltage law




$$U_1 + U_2 = U_3 + U_4$$

Voltage between two points is same via all routes.
OR Voltage in closed path is zero.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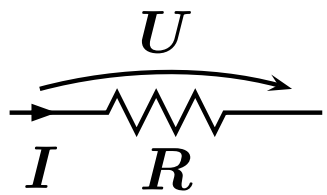
# Important issues

Especially, note direction of currents and voltages and signs.

**If current and voltage have the same direnction $\Longrightarrow$ positive sign**




$$U = RI$$

If current and voltage are in opposite direction $\Longrightarrow$ negative sign

- Currents and voltages drawn to the circuit are 'auxiliary variables'. The real currents and voltages in the circuit might be to the opposite direction. - Then you see a negative sign in your answer!
- Lines can be drawn at several ways, but the circuit doesn't change, if nodes doesn't change.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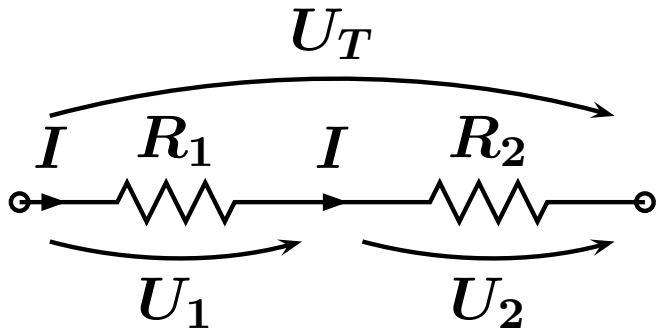
# Resistors in series




Components are connected one after the other (concatenate) in the same loop. Same current goes through all components.

$$R_{\mathrm{tot}} = \sum_{n=1}^{N} R_n = R_1 + R_2$$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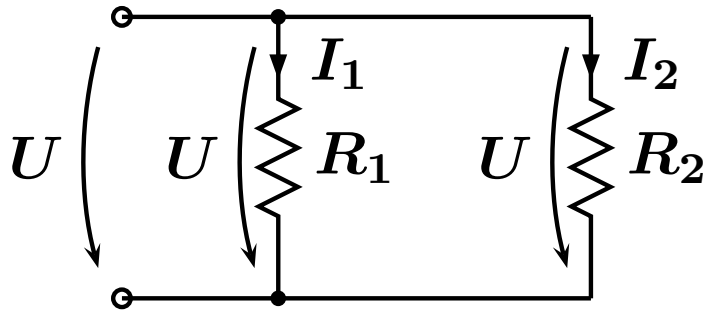
# Resistors in parallel




Components are connected parallel between the same nodes. Same voltage over all components.

$$G_{\mathbf{tot}} = \sum_{n=1}^{N} G_n = G_1 + G_2$$

$$\frac{1}{R_{\mathbf{tot}}} = \sum_{n=1}^{N} \frac{1}{R_n} = \frac{1}{R_1} + \frac{1}{R_2}$$

For two resistors 'product-divided-by-sum-formula':

$$R_{\mathbf{tot}} = \frac{R_1 R_2}{R_1 + R_2}$$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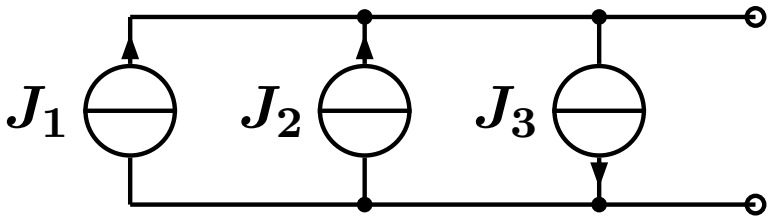
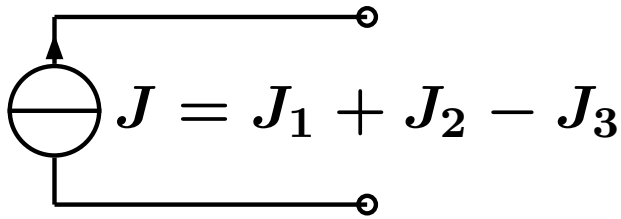
# Sources in series and in parallel

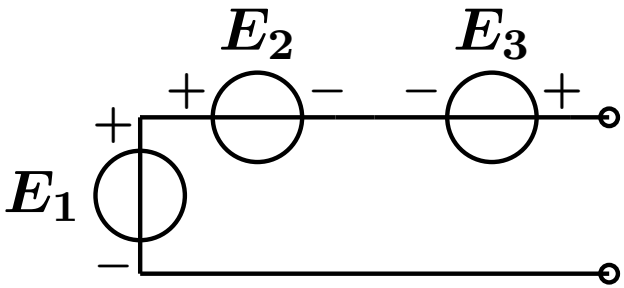
**Current sources in parallel** are added up (taking directions into account)

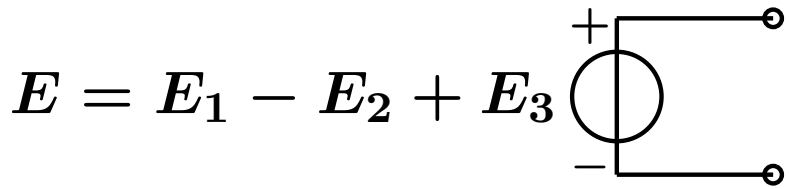



Component in series with ideal current source doesn't affect current!

**Voltage sources in series** are added up (taking directions into account)




Component in parallel with ideal voltage source doesn't affect voltage!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