Circuits and Signals

Signals, Devices, Circuits, Kirchhoff's Laws — continuation

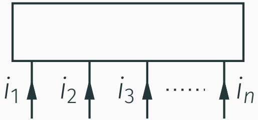
Marek Rupniewski

2022 spring semester

Faculty of Electronics and Information Technology
WARSAW UNIVERSITY OF TECHNOLOGY

Recap

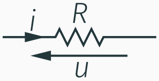
Lumped Device



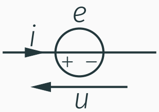
We assume that $i_1 + i_2 + \cdots + i_n = 0$ (the total charge stored in the device is preserved).

The device is described by a set of relations (equations) that relates terminal currents and inter-terminal voltages.

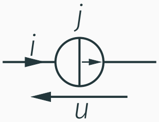
Basic devices



$u = Ri$, equivalently: $i = Gu$.

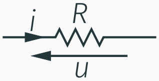


$u = e$ e may be a constant or a function of time.



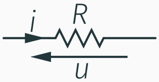
$i = j$ j may be a constant or a function of time.

Symmetry of device's terminals

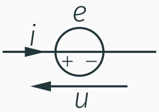


$u = Ri$

rotated by 180°:

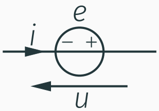


$u = Ri$



$u = e$

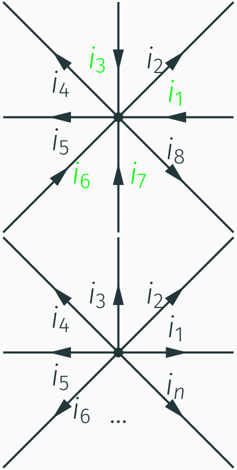
rotated by 180°:



$u = -e.$

Kirchhoff's Current Law (KCL)

The total sum of the currents converging to a node equals the sum of all the currents diverging from the node.

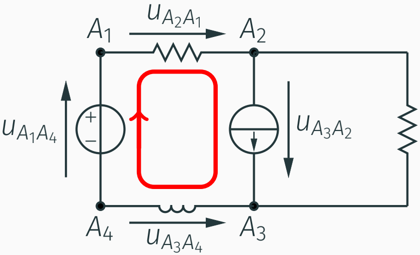


$$i_1 + i_3 + i_6 + i_7 = i_2 + i_4 + i_5 + i_8.$$

$$i_1 + i_2 + \cdots + i_n = 0.$$

Kirchhoff's Voltage Law (KVL)

The algebraic sum of the voltage drops along any directed loop equals zero.



$$u_{A_1A_4} + u_{A_2A_1} + u_{A_3A_2} - u_{A_3A_4} = 0.$$

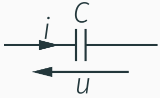
Equivalent formulation: The voltage between any two nodes does not depend on the (oriented) path along which it is computed.

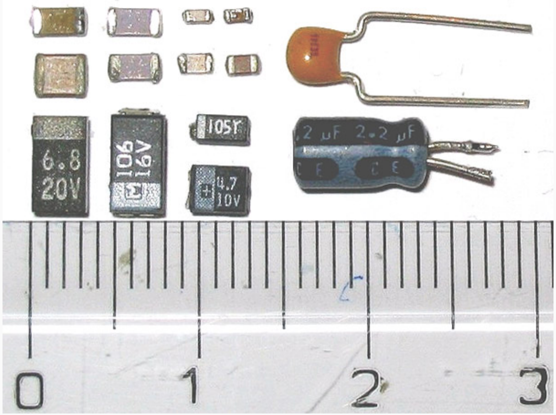
$$u_{A_1A_4} = u_{A_3A_4} - u_{A_3A_2} - u_{A_2A_1}.$$

Some more basic devices

Capacitor

real-life...
... and its symbol





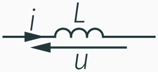
$$q = Cu, \quad \boxed{i = Cu'}.$$

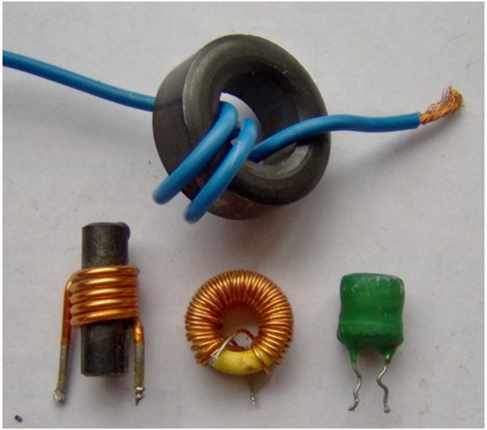
C [F] is called capacitance.

Alternative symbols:

Inductor

real-life...
... and its symbol

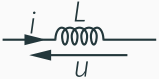




$$\psi = Li, \quad \boxed{u = Li'}.$$

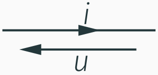
L [H] is called inductance.

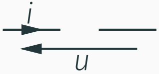
Alternative symbols:



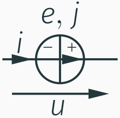
.

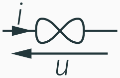
Special one-ports

- short-circuit , equation: 

$\boxed{u = 0}$,
- open-circuit , equation: 

$\boxed{i = 0}$,
- fixator 

, equation: 

$\boxed{u = e,\ i = j}$,
- norator , equation: 

$\boxed{\varnothing}$.

A device port

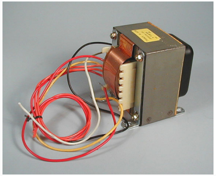
A port of a device is a pair of device terminals such that any current flowing in through one terminal of a port must flow out through the other terminal of the port.

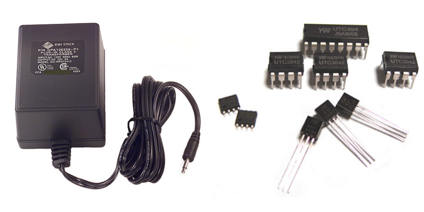
Every 2-terminal device is automatically a one-port!

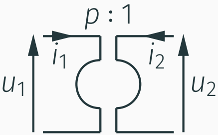
Two-ports

Some basic linear 2-ports

Transformer and DC-DC converters



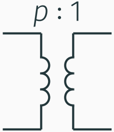




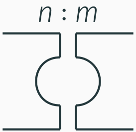
$$\boxed{\begin{aligned} u_1 &= p u_2, \\ i_1 &= -\frac{1}{p} i_2. \end{aligned}}$$

p[ ] is called winding ratio.

Alternative symbols:



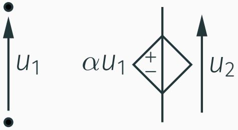
,



$p = \frac{n}{m}$.

Controlled Voltage Sources

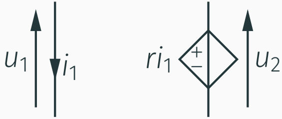
Voltage Controlled V. S.



$$\boxed{u_2 = \alpha u_1,}$$

α is a voltage gain.

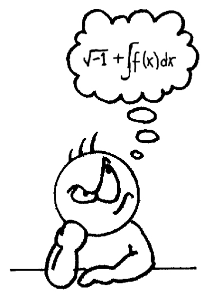
Current Controlled V. S.



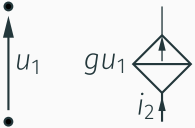
$$\boxed{u_2 = ri_1,}$$

r [Ω] is a transresistance.

Controlled Current Sources



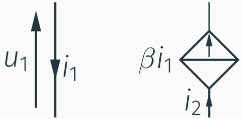
Voltage Controlled C. S.



$$\boxed{i_2 = gu_1,}$$

g [S]=[℧] is transconductance.

Current Controlled C. S.

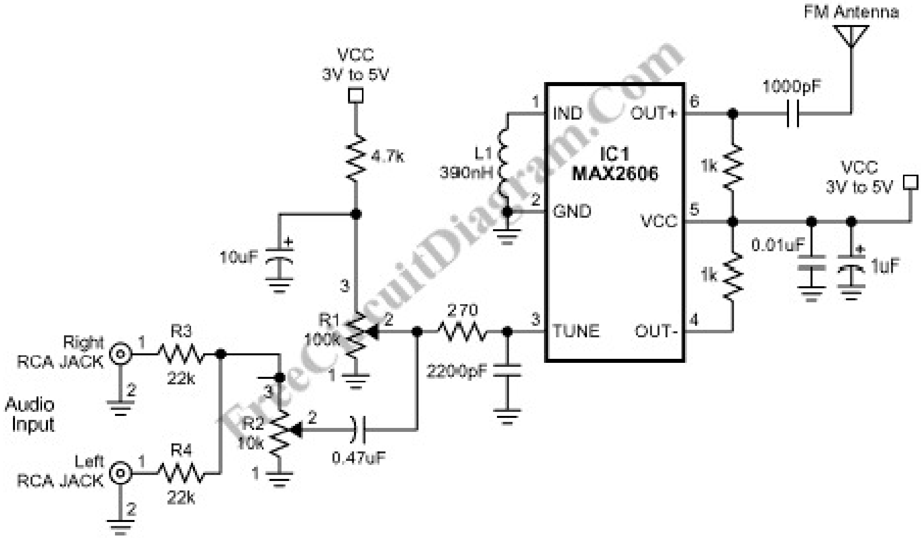


$$\boxed{i_2 = \beta i_1,}$$

β is a current gain.

Circuit diagrams

Circuit Schematic — an example



Circuit Schematic — another example