Budapest University of Technology and Economics
Faculty of Transportation Engineering and Vehicle Engineering
Department of Control for Transportation and Vehicle Systems

Electronics - electronic measuring systems

Electronics basics

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Charge

•Symbol: Q

•Unit: Coulomb (C)

- The fundamental electric quantity is charge.
- Atoms are composed of charge carrying particles: **electrons** and **protons**, and neutral particles, **neutrons**.
- Electrons and protons have **equal** and opposite **charges**.
- **Electrons** have more freedom of movement.

- Charge in an electron:

$$Q_e = -1.602\text{x}10^{-19}\ \text{C}$$

- Charge in a proton:

$$Q_p = 1.602\text{x}10^{-19}\ \text{C}$$

Current

- Symbol: I
- Unit: Ampere

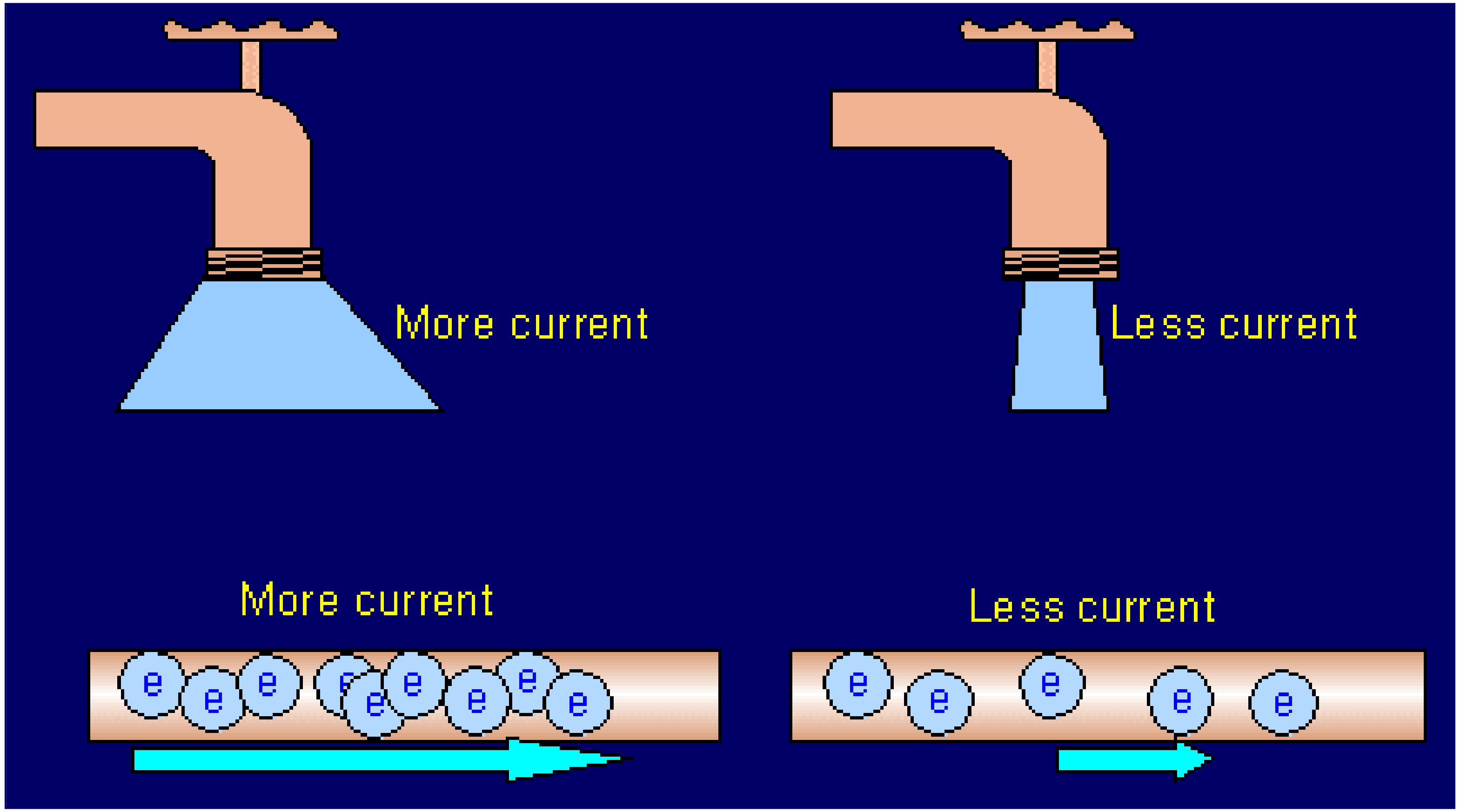
- Current moves through a closed circuit.
- Current is rate of flow of negatively-charged particles, electrons, through a conductor.
- Like water flow.

- Essentially, flow of electrons in an electric circuit leads to the establishment of current.

$$I(t) = \frac{dq}{dt}$$

  - q : relatively charged electrons (C)
  - Amp = C/sec
  - Often measured in milliamps, mA

Current-Water Analogy

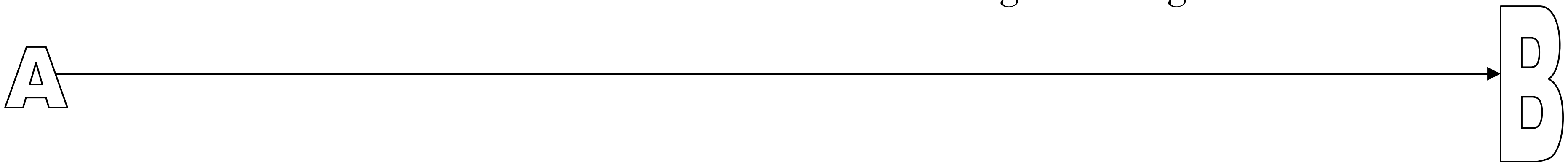


Voltage

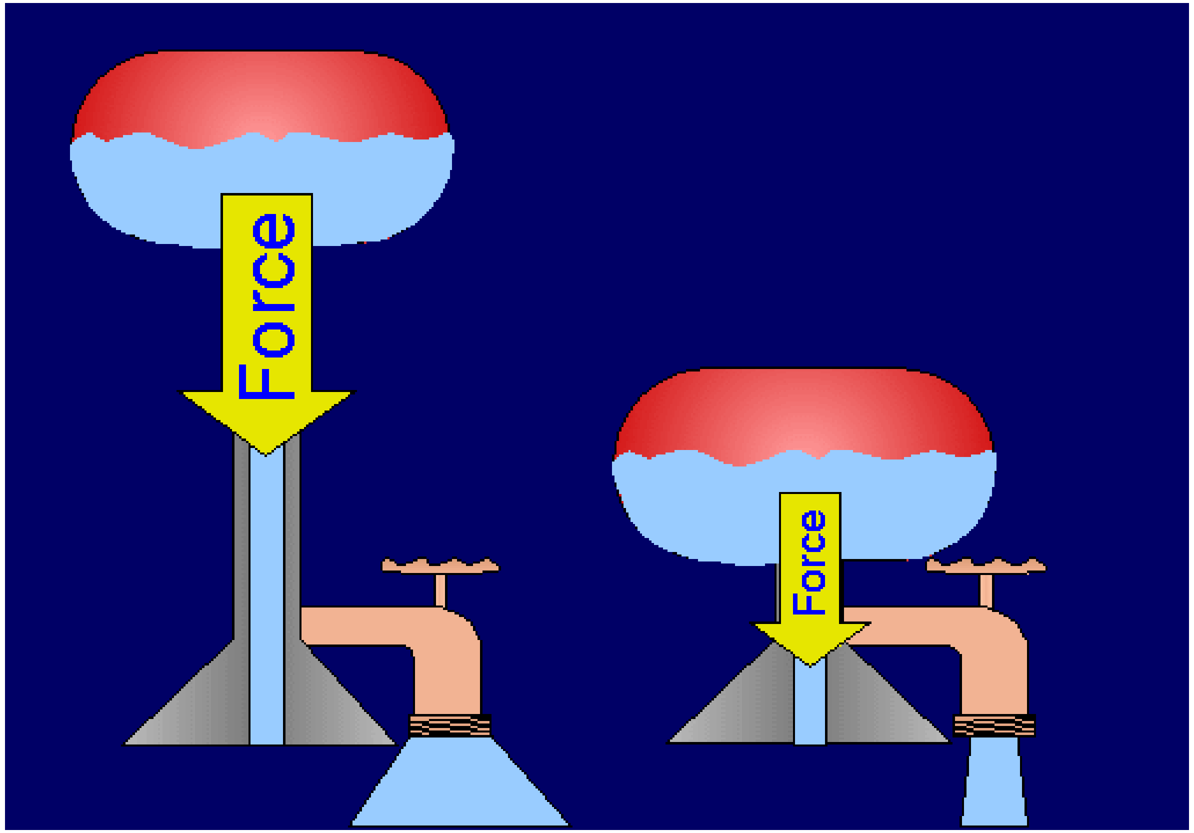
- Symbol: V (U)
- Unit: Volt

- Potential difference across two terminals in a circuit.
  - fancy word for a piece of metal to which you can hook up wires
- Like potential energy at a water fall.

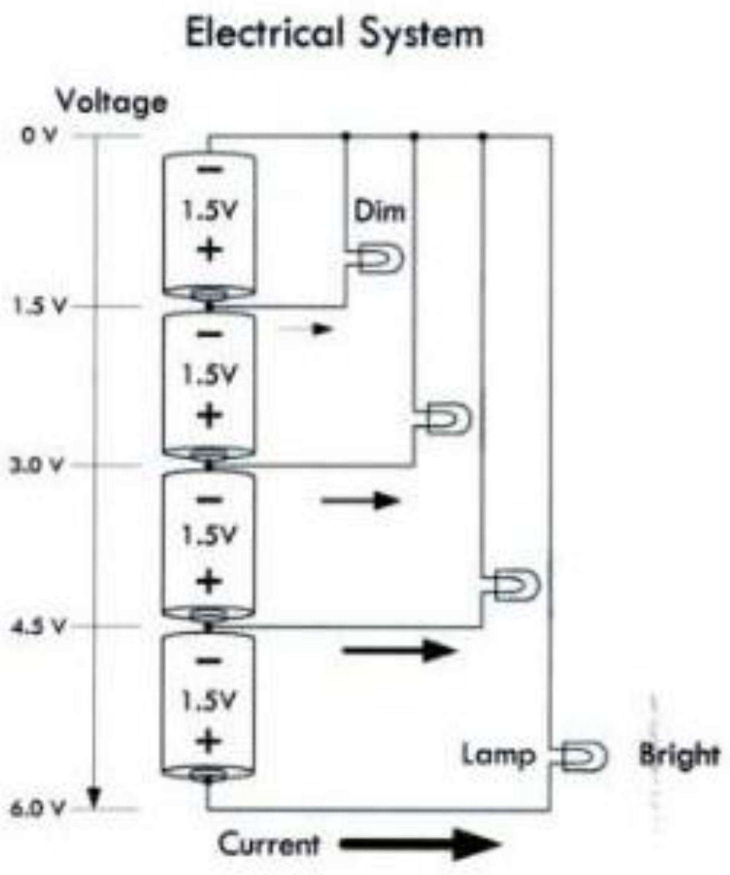
- Let A be the lower potential/voltage terminal
- Let B be the higher potential/voltage terminal
  - Then, voltage across A and B is the cost in energy required to move a unit negative charge from A to B.

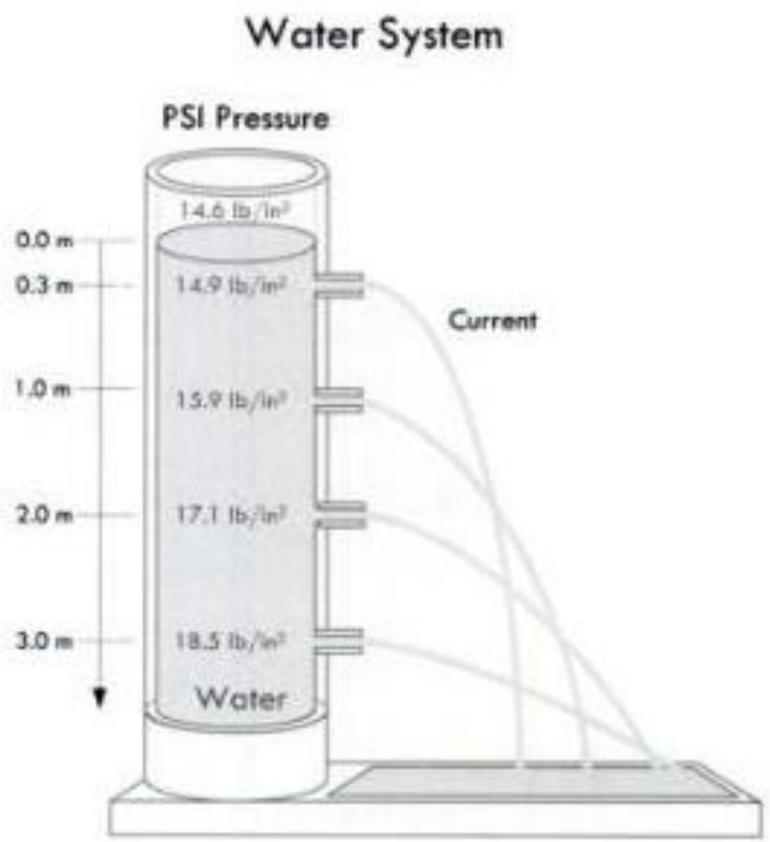


Voltage-Water Analogy



Voltage/Current-Water Analogy





Resistors (1)

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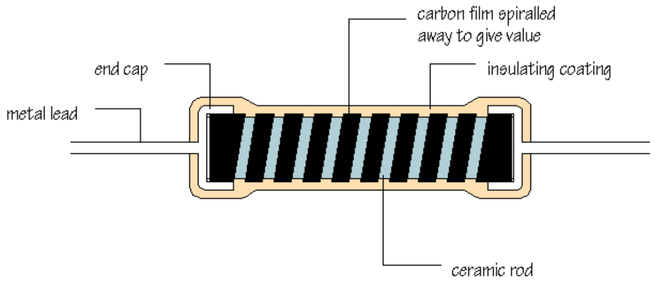
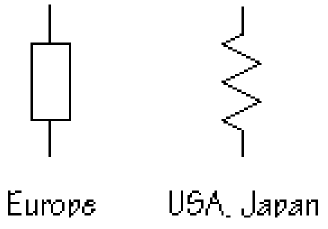
- Flow of electric current through a conductor experiences a certain amount of resistance.
- The resistance, expressed in ohms, kilo-ohms (kΩ, 1000Ω), or mega-ohms (MΩ, 10^6Ω) is a measure of how much a resistor resists the flow of electricity.
- The magnitude of resistance is dictated by electric properties of the material and material geometry.
- This behavior of materials is often used to control/limit electric current flow in circuits.
- Henceforth, the conductors that exhibit the property of resisting current flow are called resistors.





Resistor Symbols

Resistors (2)

- A resistor is a dissipative element. It converts electrical energy into heat energy.
- When electrons enter at one end of a resistor, some of the electrons collide with atoms within the resistor. These atoms start vibrating and transfer their energy to neighboring air molecules. In this way, a resistor dissipates electrical energy into heat energy.
- Resistors can be thought of as analogous to water carrying pipes. Water is supplied to your home in large pipes, however, the pipes get smaller as the water reaches the final user. The pipe size limits the water flow to what you actually need.
- Electricity works in a similar manner, except that wires have so little resistance that they would have to be very thin to limit the flow of electricity. Such thin wires would be hard to handle and break easily.

Resistors (3)

- In a typical resistor, a conducting element displays linear voltage-current relationship. (i.e., current through a resistor is directly proportional to the voltage across it).

$$\mathbf{I \sim V}$$

- Equivalently,

$$V = R*I \quad (\text{or } V = I*R)$$

  – R is termed as the resistance of conductor (ohm, Ω)

Ohm's Law

$$V = R*I$$

- We know the amount of current that the component can withstand without blowing up.
- We also know how much voltage the power source applies.
- So we have to estimate the amount of resistance that keeps the current below the blowing-up level.

- Rearrangements:

$$R = \frac{V}{I} \qquad \text{or} \qquad I = \frac{V}{R}$$

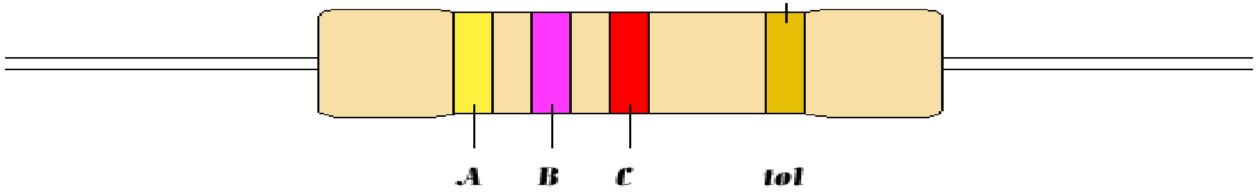
Resistor applications

- Resistors are used for:
  - Limiting current in electric circuits.
  - Lowering voltage levels in electric circuits (using voltage divider).
  - As current provider.
  - As a sensor (e.g., photoresistor detects light condition, thermistor detects temperature condition, strain gauge detects load condition, etc.)
  - In electronic circuits, resistors are used as pull-up and pull-down elements to avoid floating signal levels.

Resistor labels

- A label indicating resistance and power ratings.
- A majority of resistors have color bars to indicate their resistance magnitude.
- There are usually 4 to 6 bands of color on a resistor. Right most color bar indicates the resistor reliability, or tolerance. The color bar immediately left to the tolerance bar (C), indicates the multipliers (in tens). To the left of the multiplier bar are the digits, starting from the last digit to the first digit.

$$\text{Resistor value} = AB \times 10^{C} \pm tol\,\%(\Omega)$$

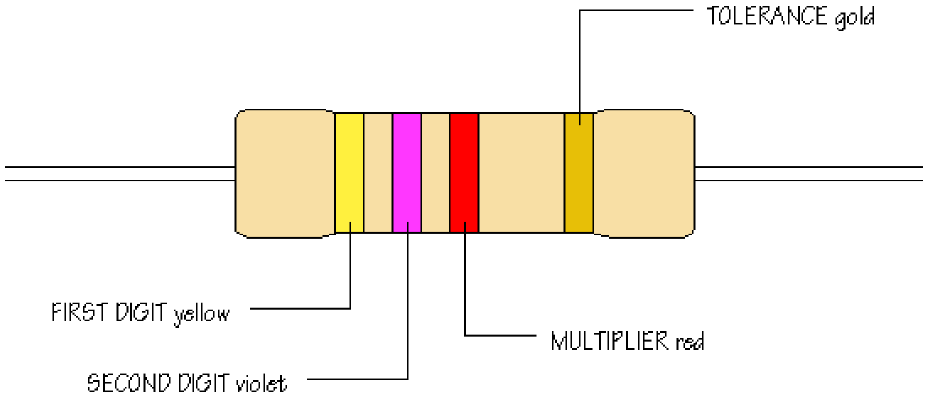


Resistor Color Codes

Color	Tolerance
Brown	±1%
Red	±2%
Gold	±5%
Silver	±10%
None	±20%

Band color	Digit
Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Purple	7
Grey	8
White	9
Silver	-
Gold	-

Example



- The first band is yellow, so the first digit is 4
- The second band is violet, so the second digit is 7
- The third band is red, so the multiplier is 2
- Resistor value is $47\times10^{2}\pm5\%(\Omega)$

Metric Units and Conversion

Abbreviation	Means	Multiply unit by	Or
p	pico	.000000000001	10^{-12}
n	nano	.000000001	10^{-9}
µ	micro	.000001	10^{-6}
m	milli	.001	10^{-3}
.	Unit	1	10^{0}
k	kilo	1,000	10^{3}
M	mega	1,000,000	10^{6}
G	giga	1,000,000,000	10^{9}

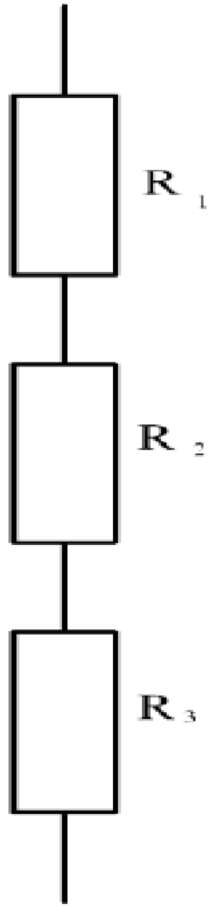
Connecting circuit elements (1)

- Series

$$I_{in} = I_{R1} = I_{R2} = I_{R3}$$

$$U_{in} = U_{R1} + U_{R2} + U_{R3}$$

$$R_s = R1 + R2 + R3$$



Connecting circuit elements (2)

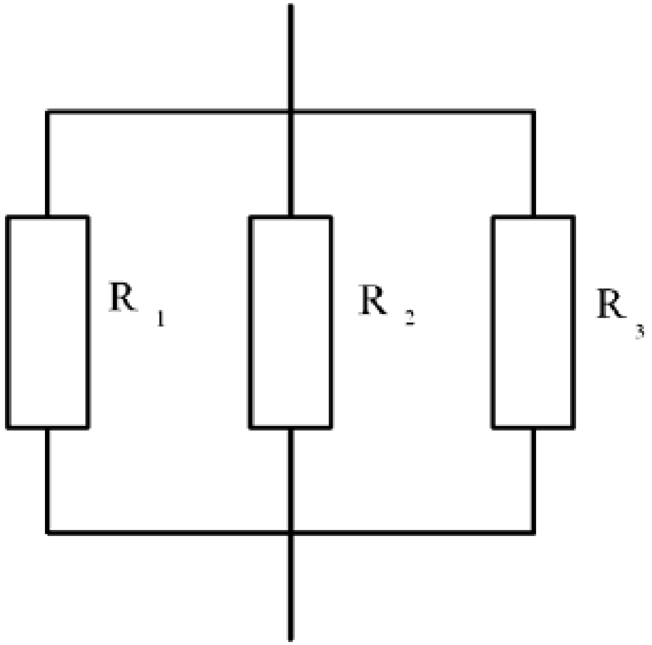
- Parallel

$$I_{in} = I_{R1} + I_{R2} + I_{R3}$$

$$U_{in} = U_{R1} = U_{R2} = U_{R3}$$

$$R_s = R1xR2xR3$$

$$1/R_s = 1/R1 + 1/R2 + 1/R3$$



Kirchoff's Voltage Law

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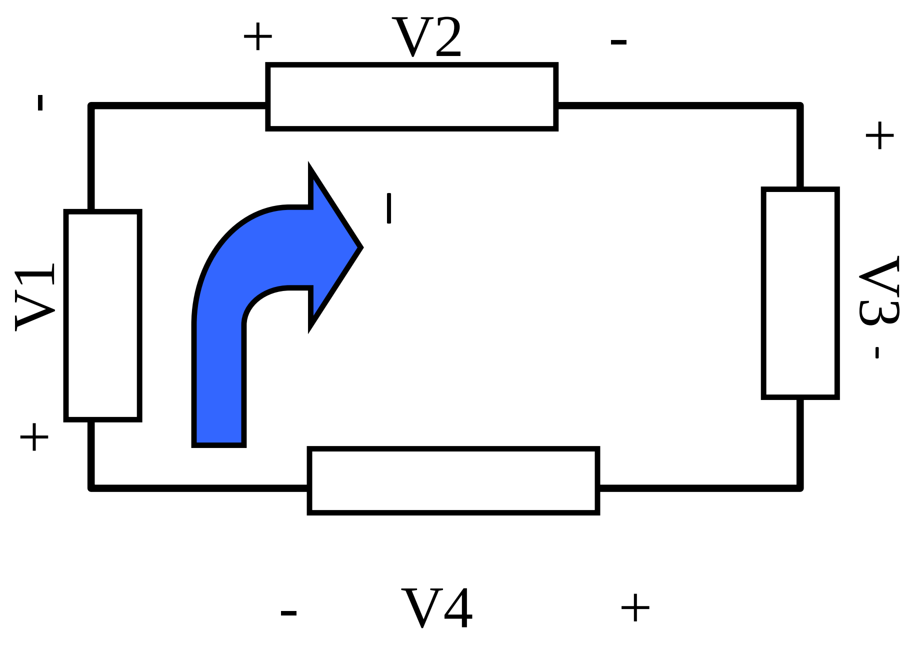
- The algebraic sum of voltage around a closed loop is zero.
- Assumption:
  - Voltage drop across each passive element is in the direction of current flow.

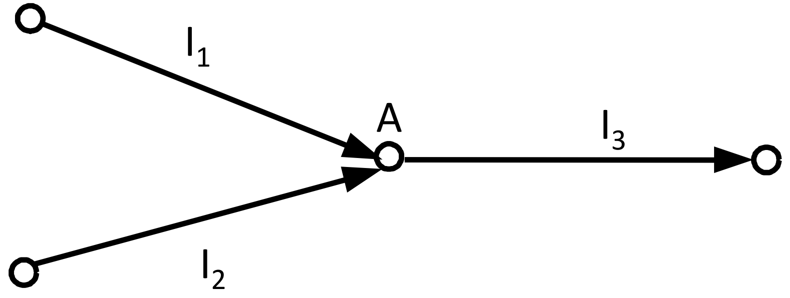


$$V_1 + V_2 + V_3 + V_4 = 0$$

Kirchoff's Current Law

- Algebraic sum of all currents entering and leaving a node is zero.
- At node A:

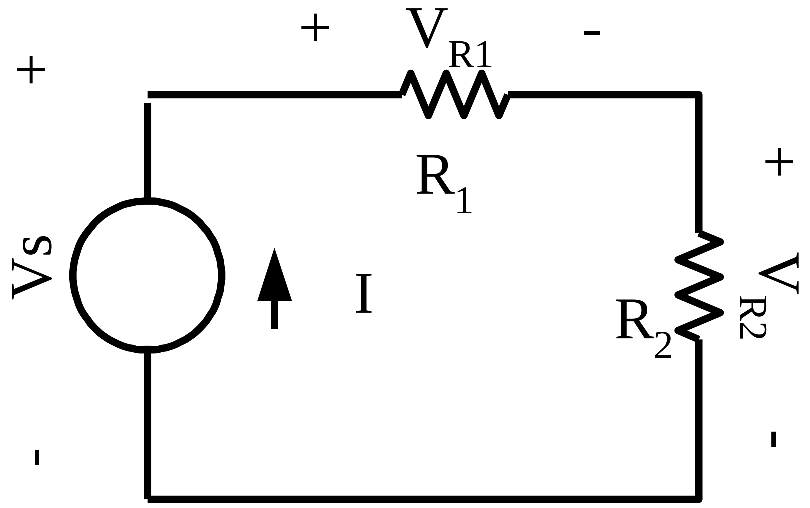
$$I_1 + I_2 - I_3 = 0$$



Law of Voltage division

$$V_{R_1} = \frac{R_1}{R_1 + R_2} V_s$$

$$V_{R_2} = \frac{R_2}{R_1 + R_2} V_s$$



Law of Current Division

$$I_{R_1} = \frac{R_2}{R_1 + R_2} I$$

$$I_{R_2} = \frac{R_1}{R_1 + R_2} I$$