CRAFT #3

Mechatronics

Introduction

André Araújo, andre@ingeniarius.pt
Miguel Araújo, miguel@ingeniarius.pt

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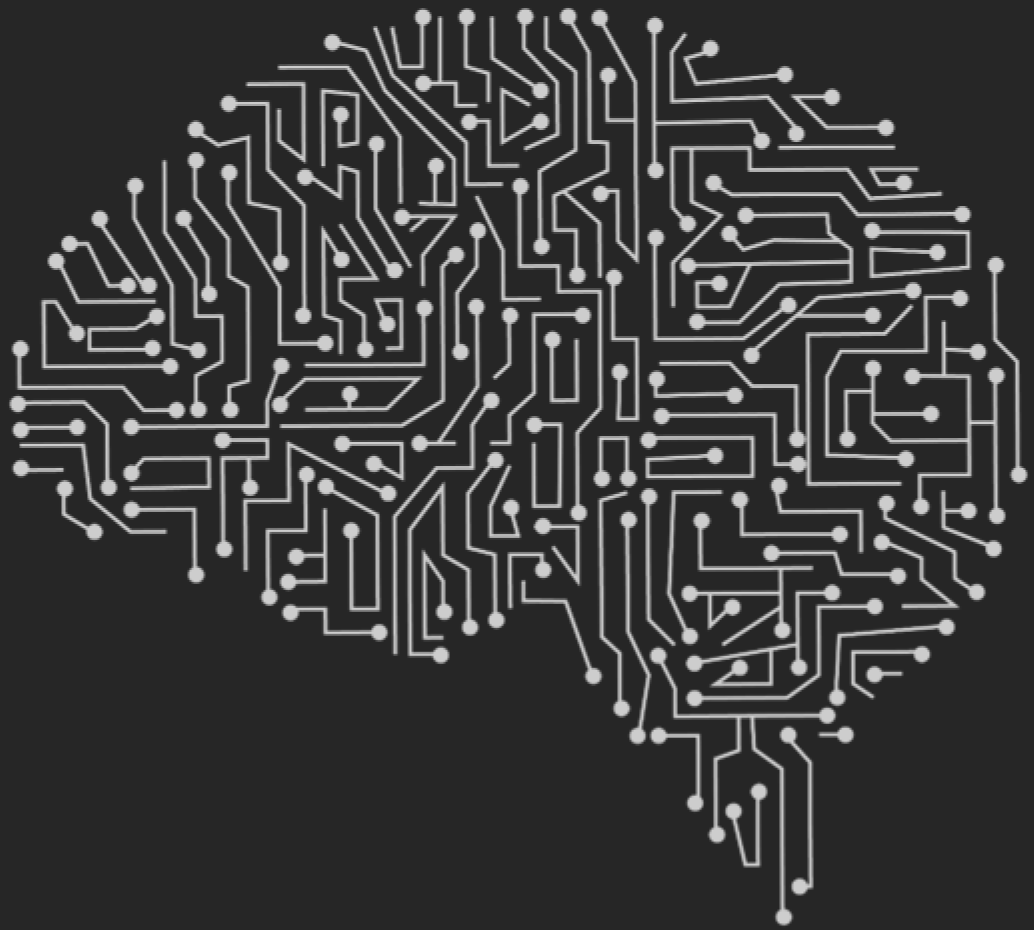
OBJECTIVES

Electrical Signals

Measuring Instruments

- Multimeter
- Oscilloscope
- Resistor Color Code

Kirchhoff's Law



ELECTRICAL SIGNALS

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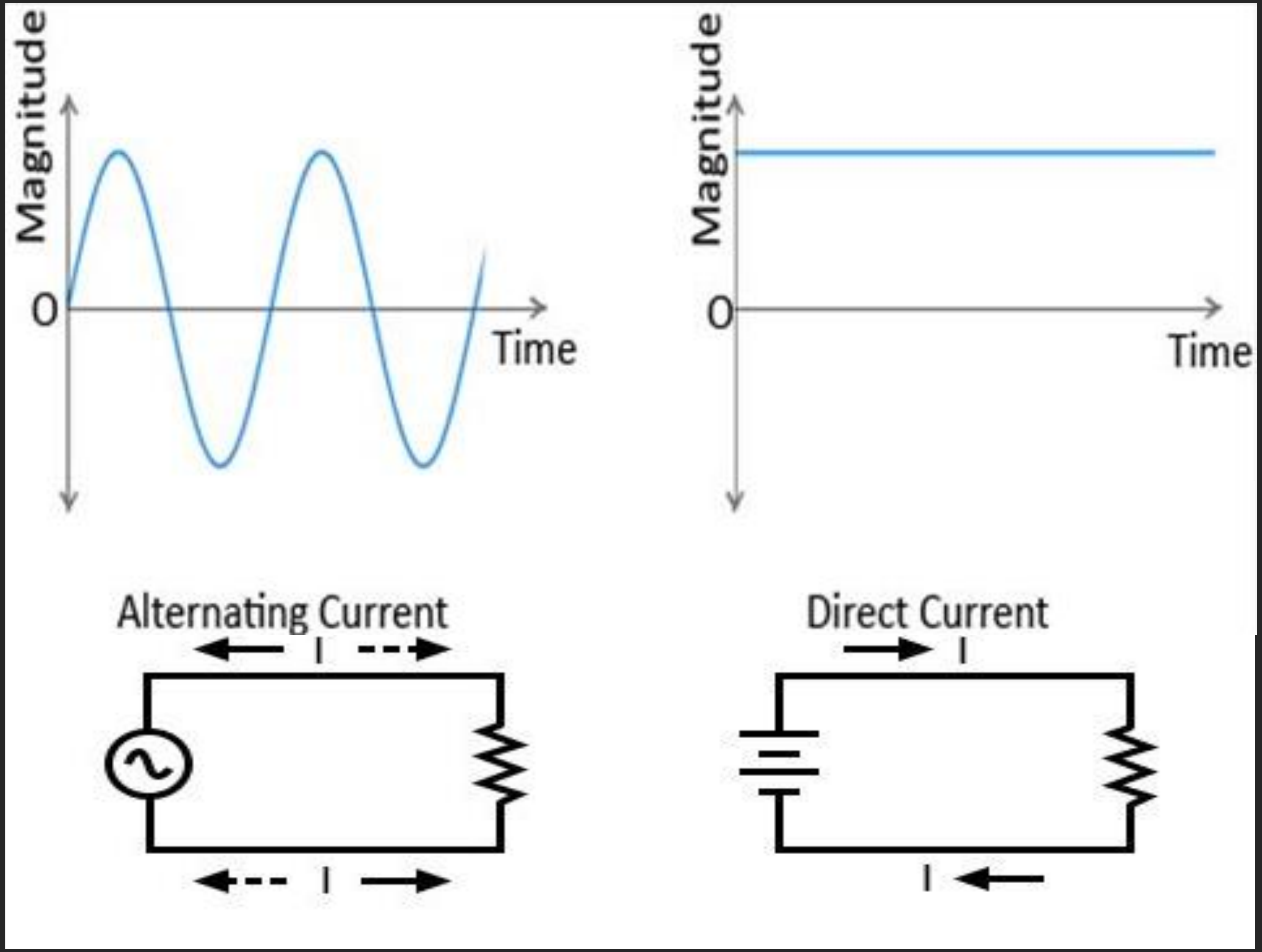
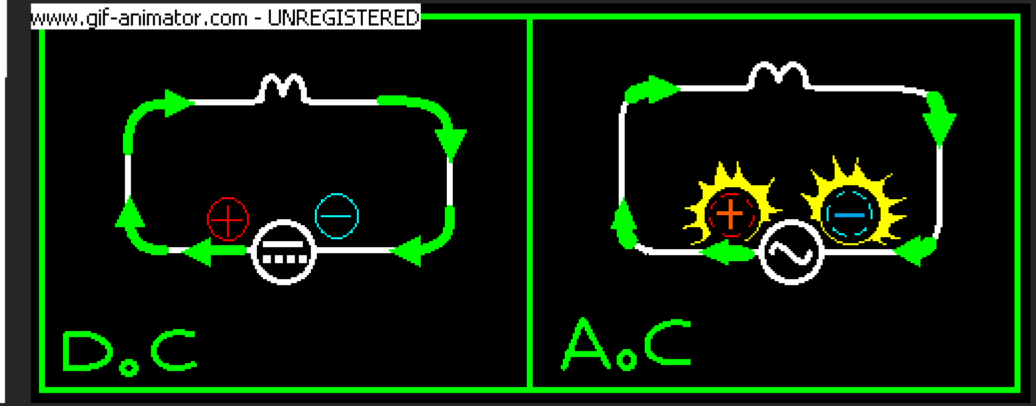
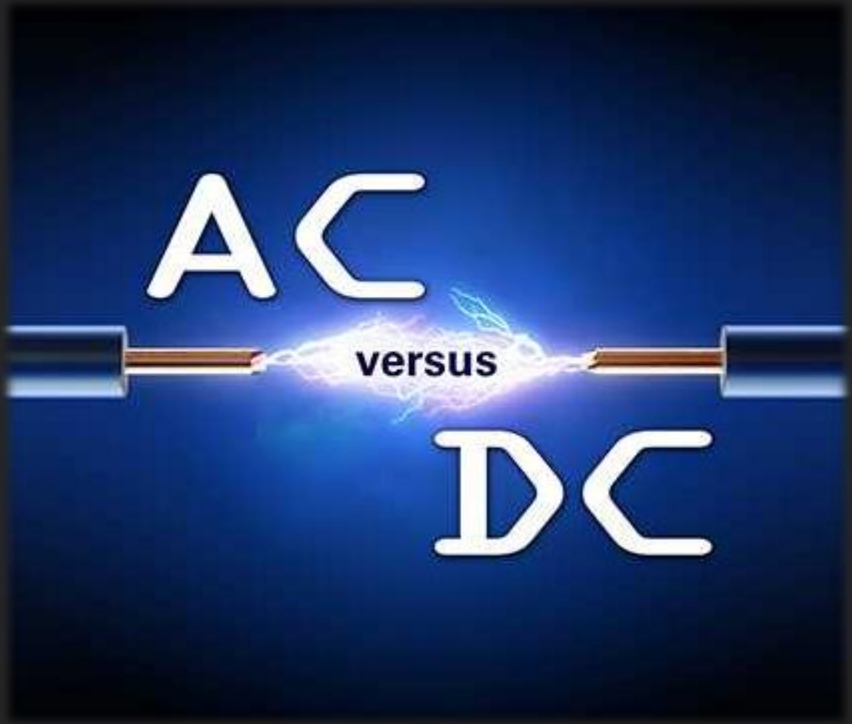




ELECTRICAL SIGNALS



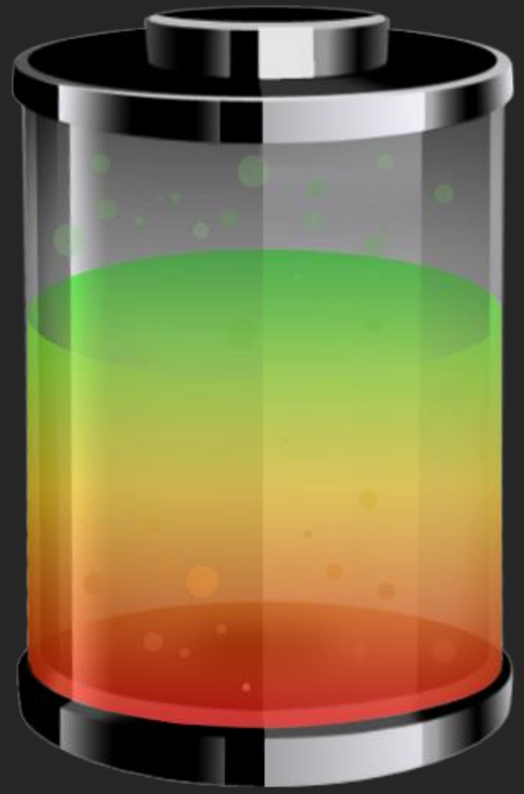
More complex construction
Heavier for the same capacity
Requires extra mechanism for creating a rotating magnetic field
Larger losses and less efficiency

ELECTRICAL SIGNALS

Then why are we building DC robots instead of AC robots?

ELECTRICAL SIGNALS

- Batteries produce DC energy
- Transforming to AC would require a power inverter – any transformation leads to losses
- AC motors, despite being generally more efficient, they are also harder to control
- The maths are quite simpler in DC than AC…



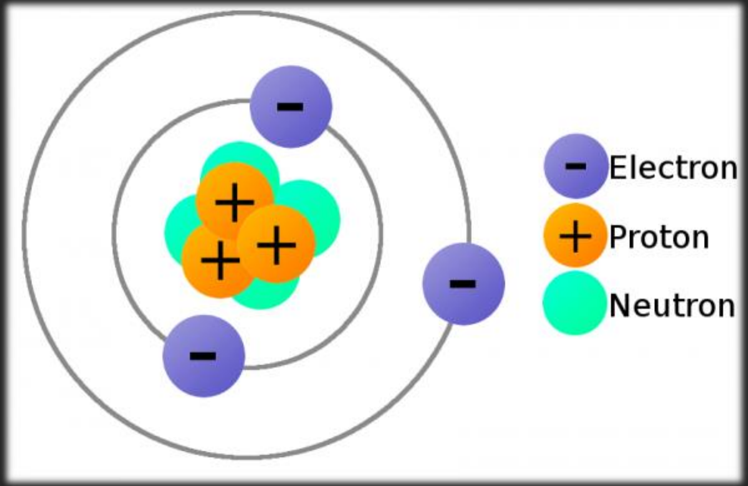
ELECTRICAL SIGNALS

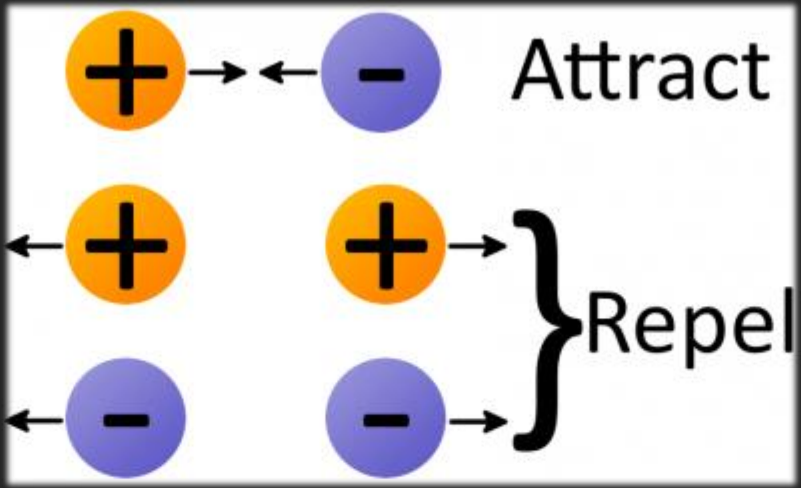
Electrical Charge

Electricity can be defined as the **flow of electric charge**.

Charge can come in two types: **positive (+) or negative (-)**.

Electrons always carry a negative charge, while protons are always positively charged.





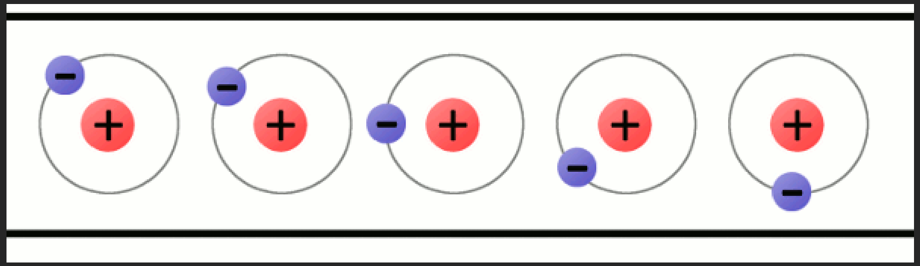
ELECTRICAL SIGNALS

Current

Symbol: I

Units: Amperes (A)

Definition: When an electric current flows through a conductor; the electrons move from one atom to another- in the case of a copper wire, from one copper atom to the next. If the number of electrons flowing through a conductor increases, then the amperage (current) increases. When electrons flow, carrying a current, they can be called charge carriers.



A very simplified model of charges flowing through atoms to make current.

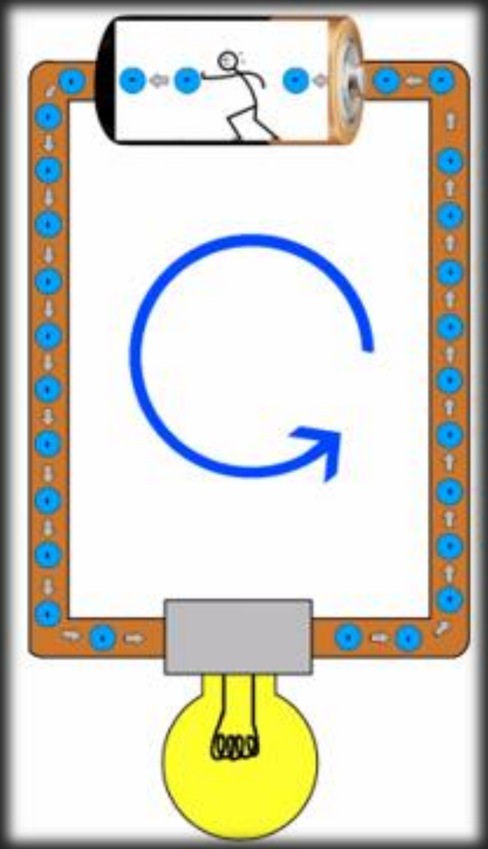
ELECTRICAL SIGNALS

Voltage

Symbol: V

Units: Volts (V)

Definition: The amount of current flowing through a circuit will partly depend on the electromotive force (EMF) of the electrical supply, which is measured in volts (V), and is generally called voltage. The voltage depends on the 'strength' of the electrical supply.



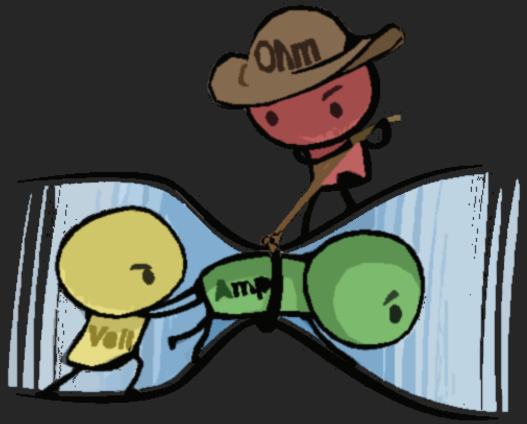
ELECTRICAL SIGNALS

Resistance

Symbol: R

Units: Ohms (Ω)

Definition: The amount of current will also depend on electrical resistance, which is a measure of how easily current can flow through the conductors and components in a circuit. Resistance also depends on the materials used as conductors. For example, copper has a low resistance and so is a good conductor.



ELECTRICAL SIGNALS

Power

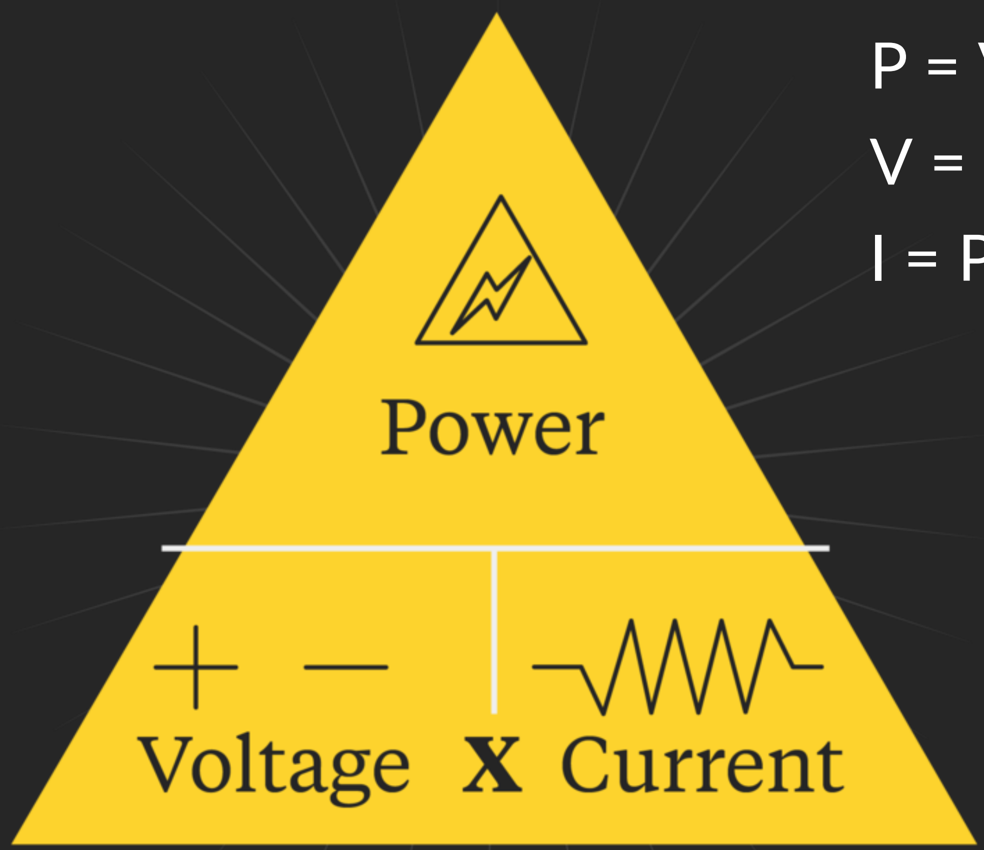
Symbol: P

Units: Watts (W)

Definition: The amount of current required by an electrical appliance depends on the power of the appliance. Energy is measured in terms of joules (J). Power is a measure of energy over a set amount of time, we can measure it in **joules per second**

$$watt = W = \frac{joule}{second} = \frac{J}{s}$$

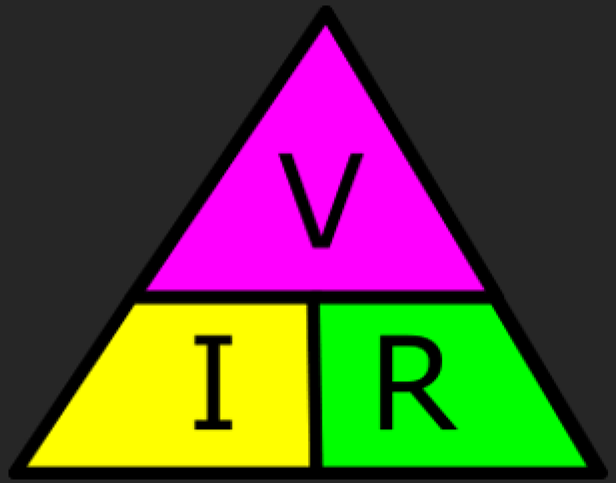
ELECTRICAL SIGNALS



$P = V \times I$

$V = P \div I$

$I = P \div V$

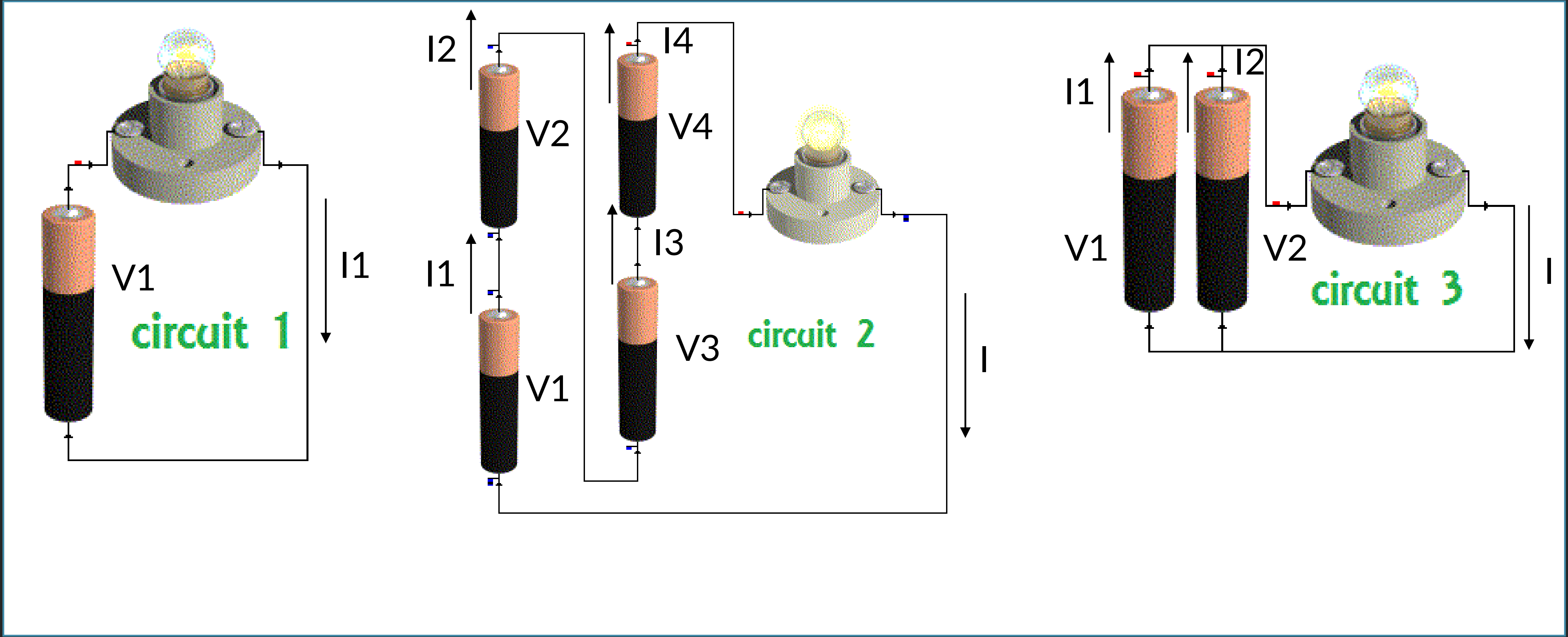


$V = I \times R$

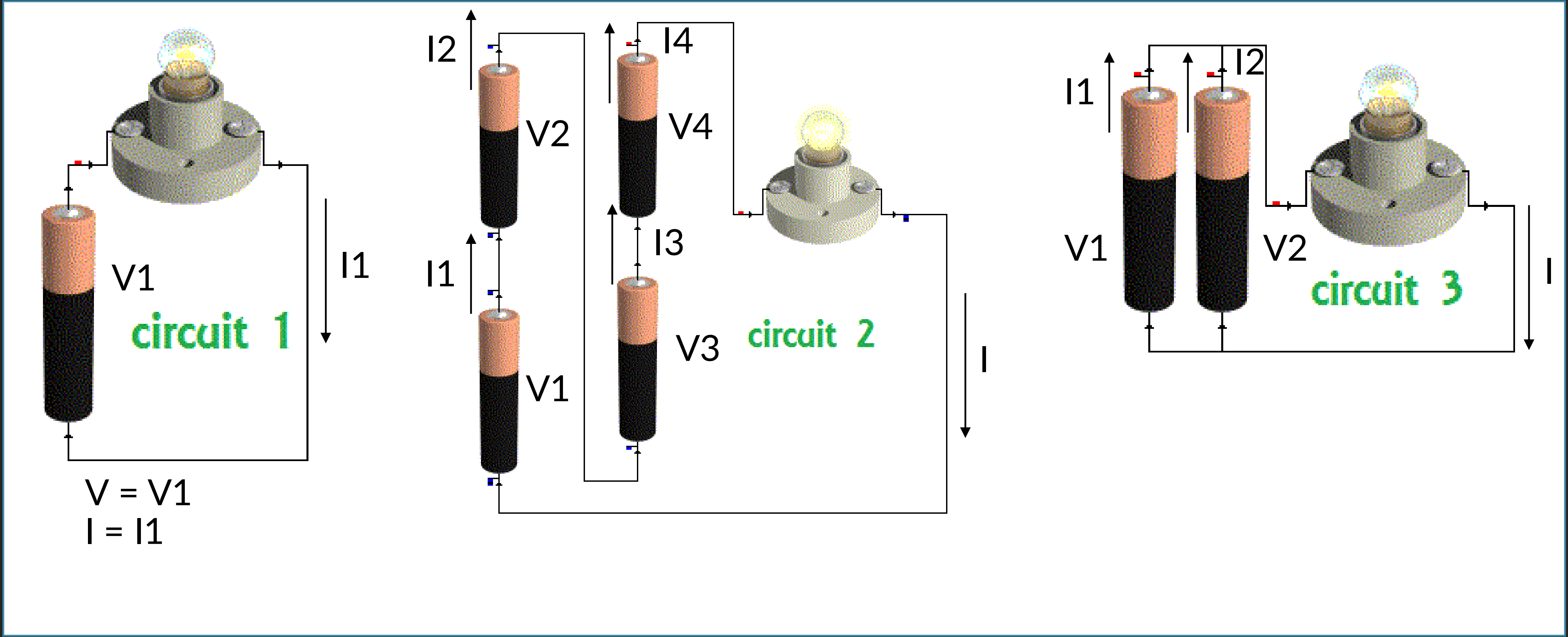
$I = V \div R$

$R = V \div I$

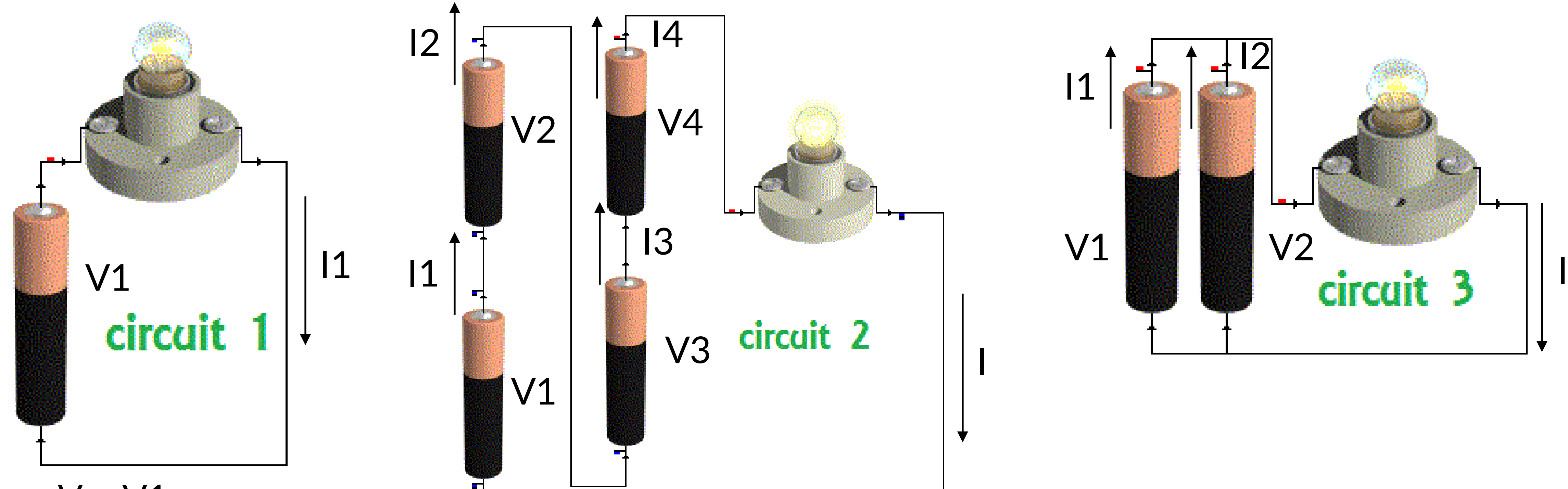
ELECTRICAL SIGNALS



ELECTRICAL SIGNALS



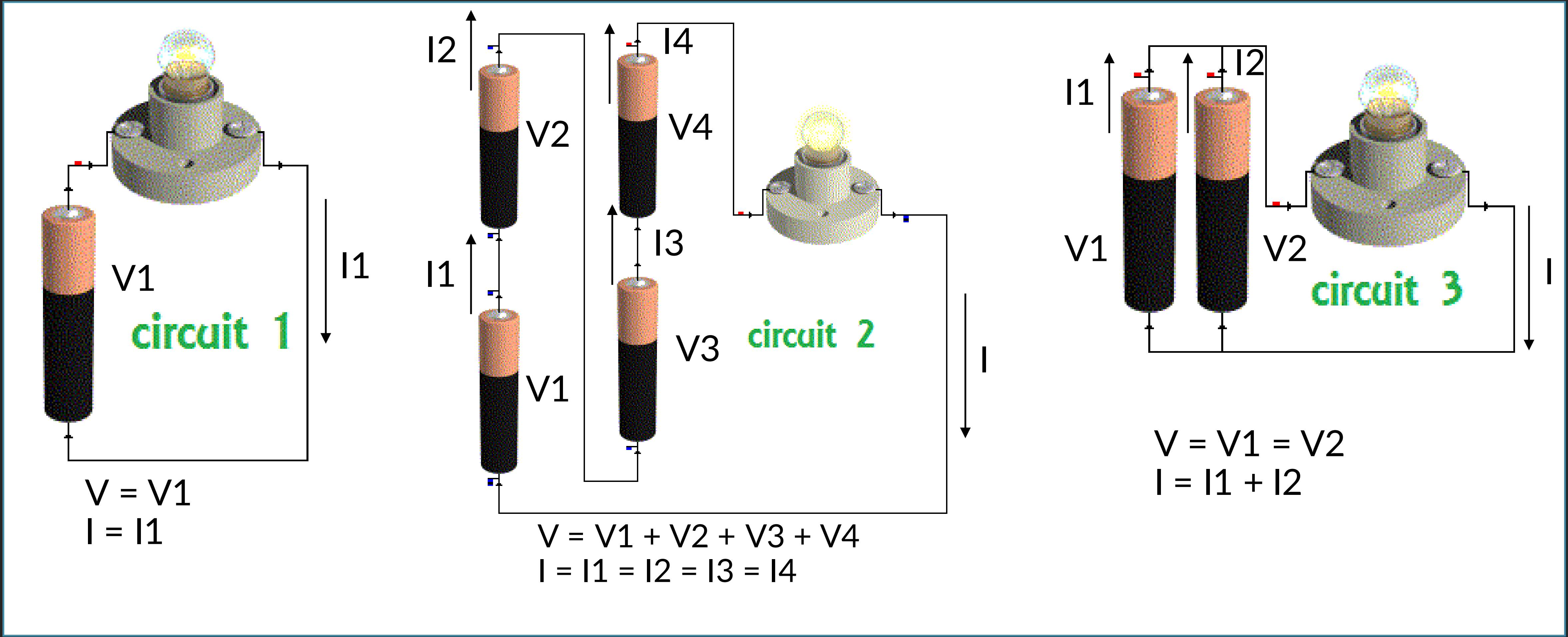
ELECTRICAL SIGNALS



V = V1
I = I1

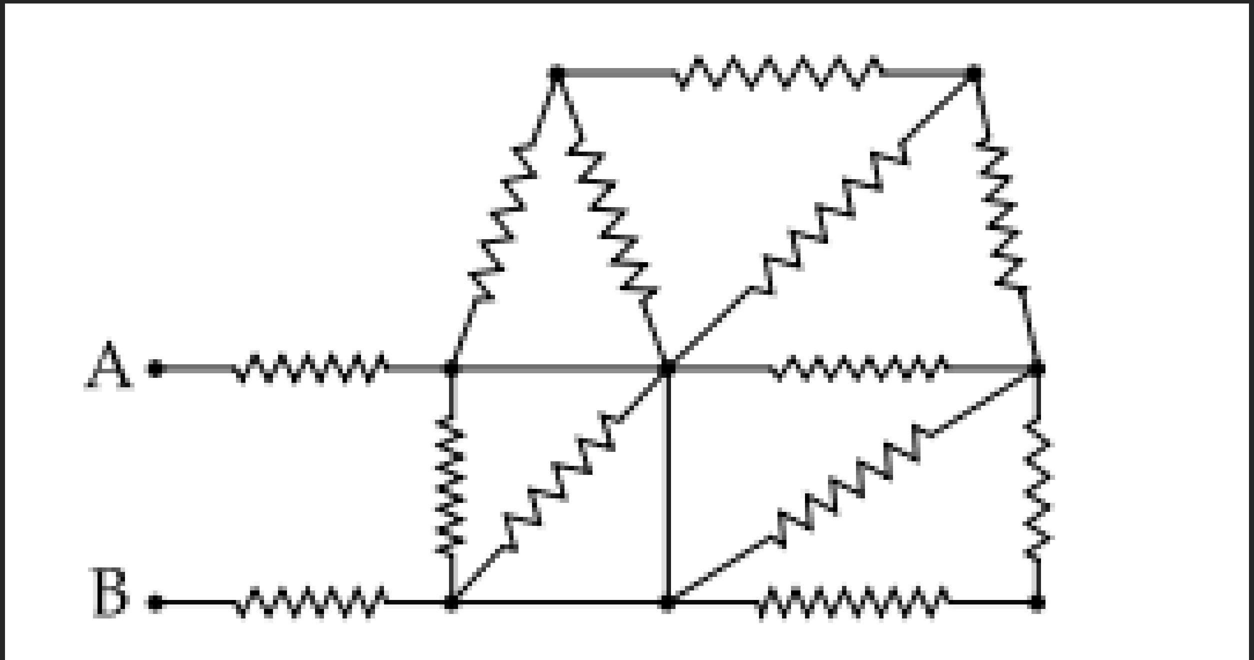
V = V1 + V2 + V3 + V4
I = I1 = I2 = I3 = I4

ELECTRICAL SIGNALS

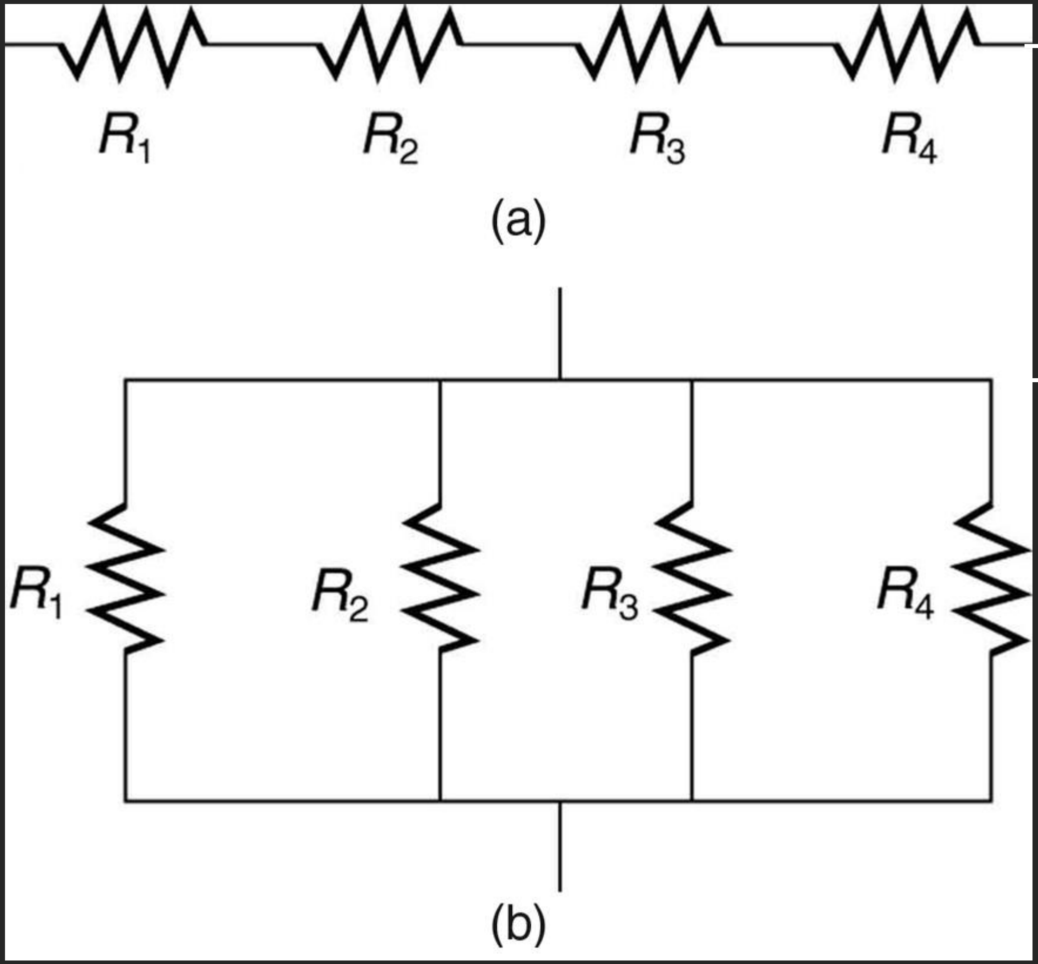


ELECTRICAL SIGNALS

What if we have several loads instead of one (several resistances)?



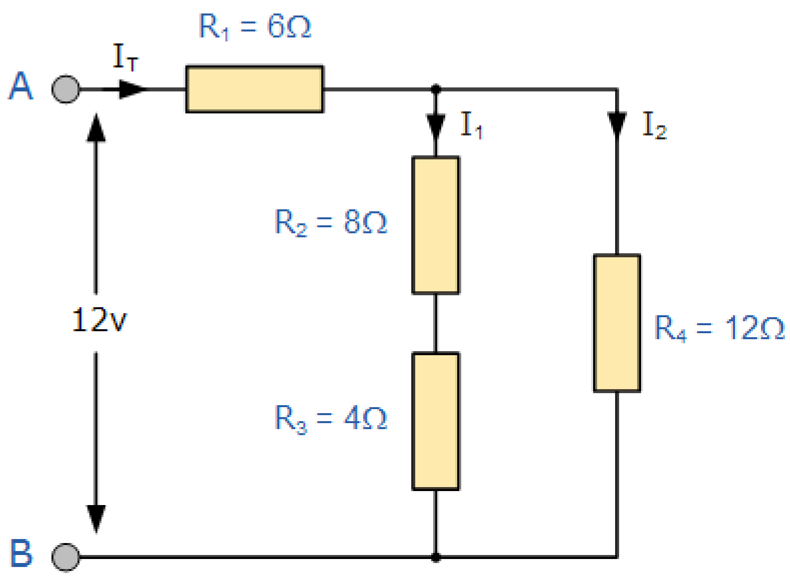
ELECTRICAL SIGNALS



R = R1 + R2 + R3 + R4 + …

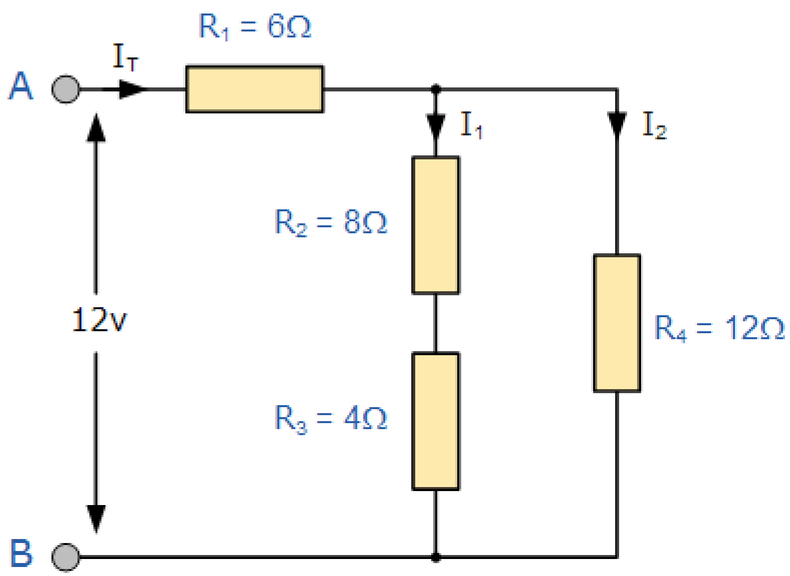
1÷R = 1÷R1 + 1÷R2 + 1÷R3 + 1÷R4 + …

ELECTRICAL SIGNALS



R_T = ?
I_T = ?

ELECTRICAL SIGNALS

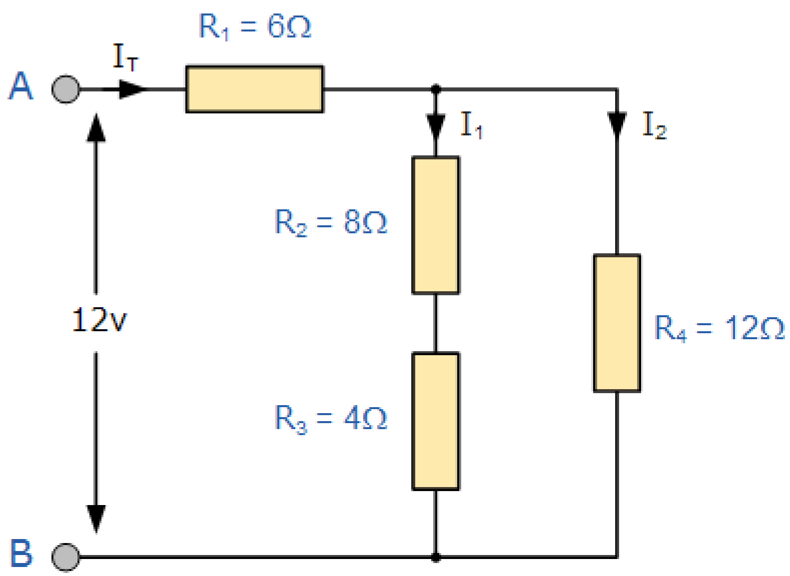


$R_2 + R_3 = 8\Omega + 4\Omega = 12\Omega$

$R_T = ?$

$I_T = ?$

ELECTRICAL SIGNALS



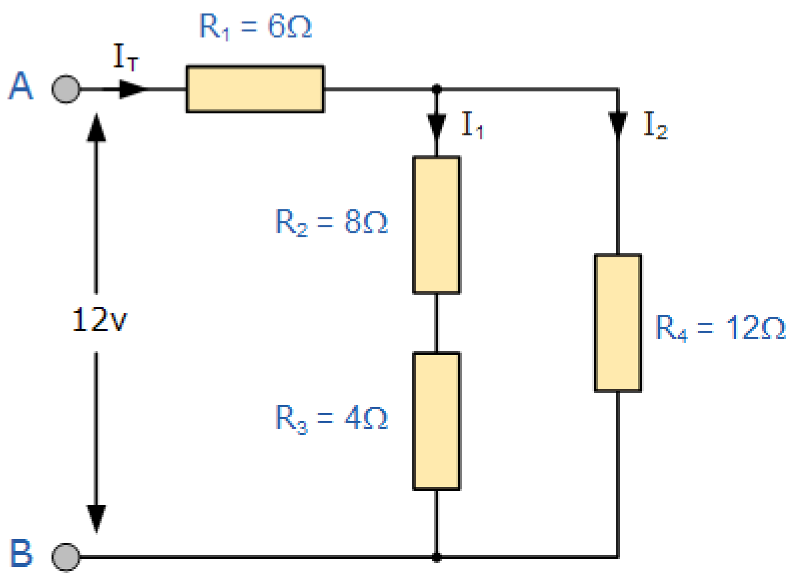
$$R_2 + R_3 = 8\Omega + 4\Omega = 12\Omega$$

$$\frac{1}{R_{(combination)}} = \frac{1}{R_A} + \frac{1}{R_4} = \frac{1}{12} + \frac{1}{12} = \frac{1}{6} \Rightarrow R_{(combination)} = 6\Omega$$

$R_T = ?$

$I_T = ?$

ELECTRICAL SIGNALS



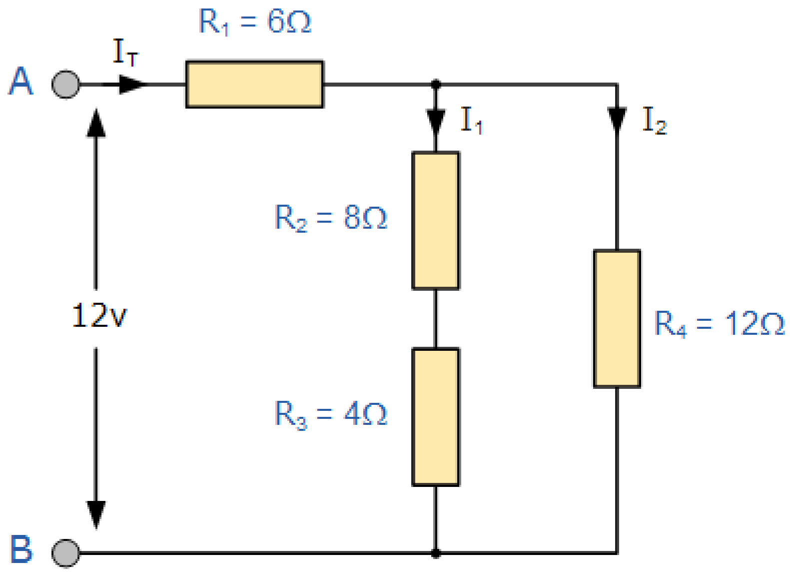
$R_T = ?$
$I_T = ?$

$$R_2 + R_3 = 8\Omega + 4\Omega = 12\Omega$$

$$\frac{1}{R_{(combination)}} = \frac{1}{R_A} + \frac{1}{R_4} = \frac{1}{12} + \frac{1}{12} = \frac{1}{6} \Rightarrow R_{(combination)} = 6\Omega$$

$$R_T = R_{com} + R_1 = 6\Omega + 6\Omega = 12\Omega$$

ELECTRICAL SIGNALS



$R_T = ?$
$I_T = ?$

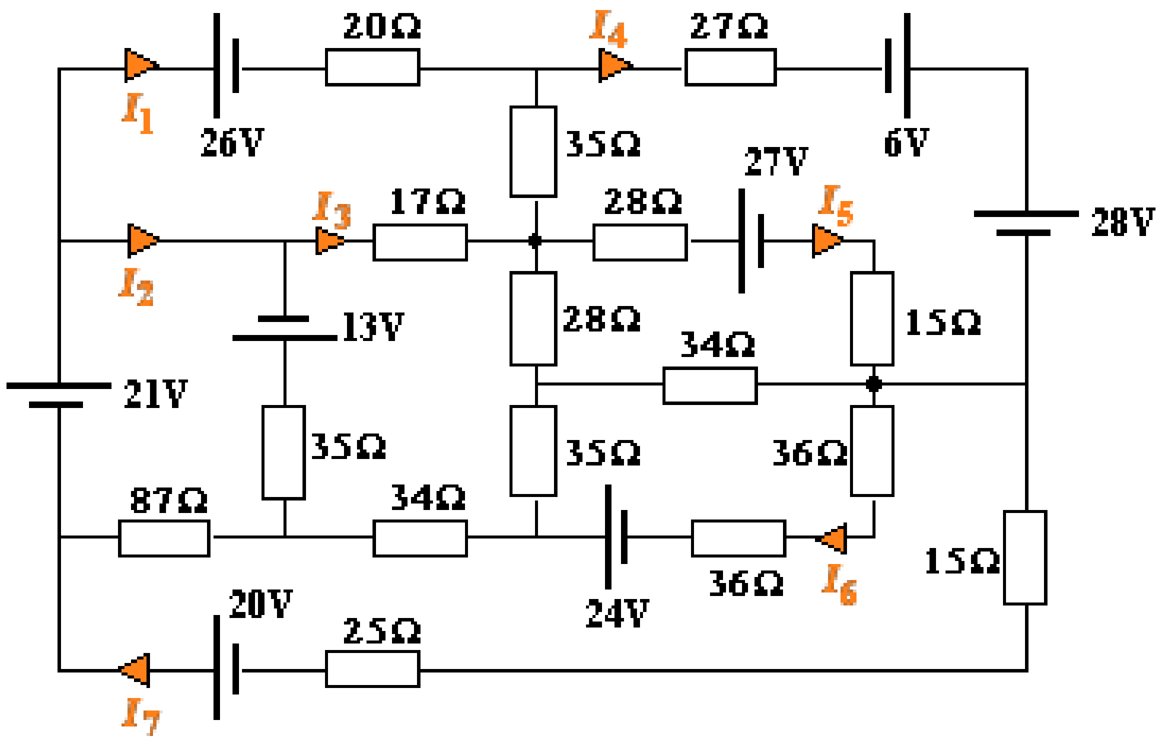
$R_2 + R_3 = 8\Omega + 4\Omega = 12\Omega$

$$\frac{1}{R_{(combination)}} = \frac{1}{R_A} + \frac{1}{R_4} = \frac{1}{12} + \frac{1}{12} = \frac{1}{6} \Rightarrow R_{(combination)} = 6\Omega$$

$R_T = R_{com} + R_1 = 6\Omega + 6\Omega = 12\Omega$

$I = 12v \div 12\Omega = 1A$

ELECTRICAL SIGNALS



ELECTRICAL SIGNALS

Two possibilities:

1. **Use measuring instruments**

+ Less electrical science and engineering expertise

- Handling susceptible instruments which sometimes cannot be used under live circuits (e.g., ohmmeter), or need to be used under live circuits (which may imply damaging the circuit or instruments in the first place), or can only be used in certain branches of the circuit (e.g., soldered branches where amperemeters cannot be deployed).

2. **Use Kirchhoff's Law**

+ Does not require additional equipment and can be done before turning power-on

- Can be mathematically complex and it is hard to account for all the components' characteristics (e.g., impedances)

MEASURING INSTRUMENTS

MEASURING INSTRUMENTS

Test meters are often used by electricians to measure voltage, current and resistance.

Meter that can measure voltage, current and resistance is called multimeter.

MEASURING INSTRUMENTS

Multimeter

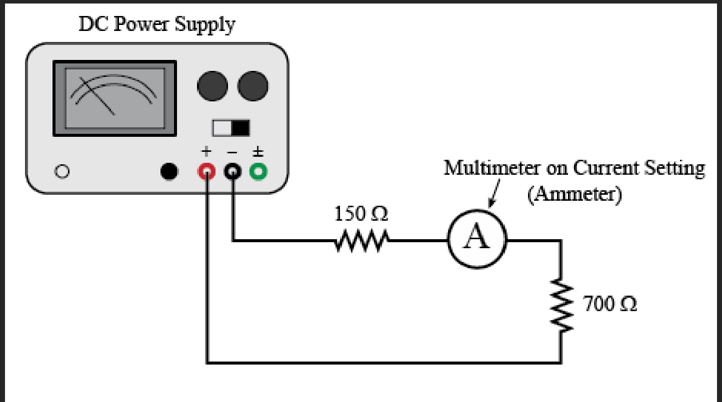
MEASURING INSTRUMENTS

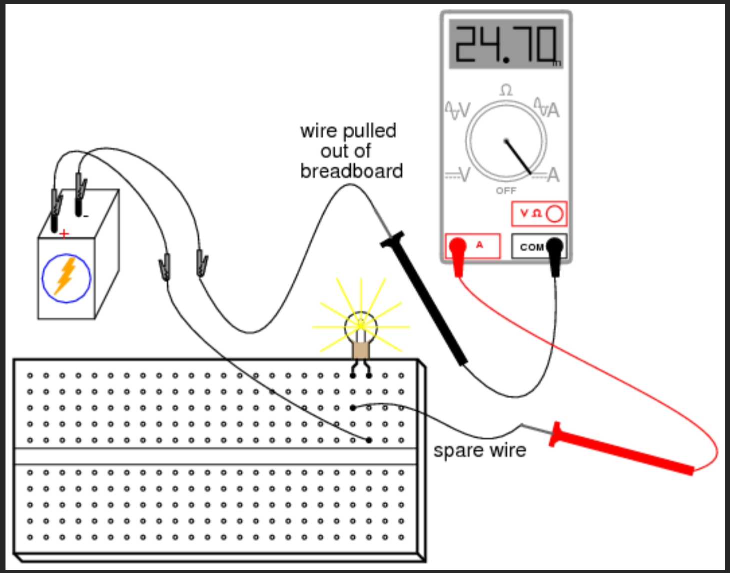
Multimeter

As theses meters are often used on live circuits, it is important to know the applicable **safety procedures**

The in-line **ammeter** can be used to measure current

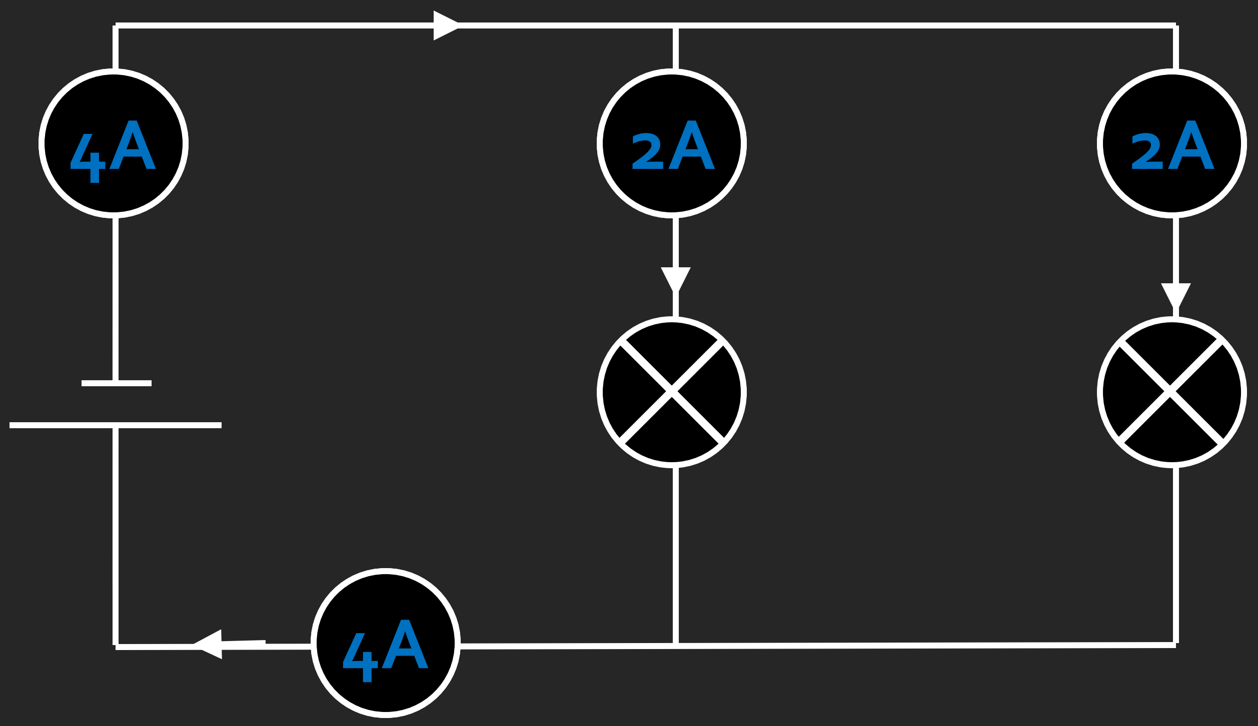
It is connected in series with the load,
never in parallel!





MEASURING INSTRUMENTS

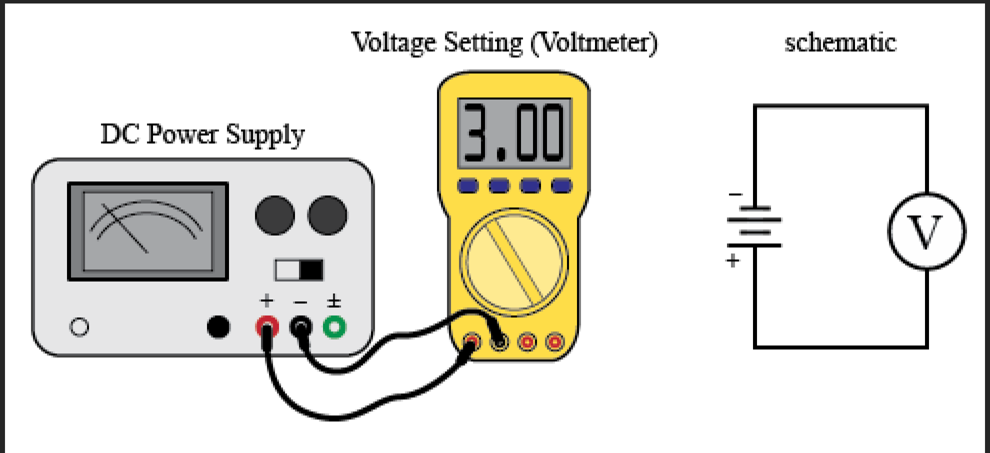
Multimeter

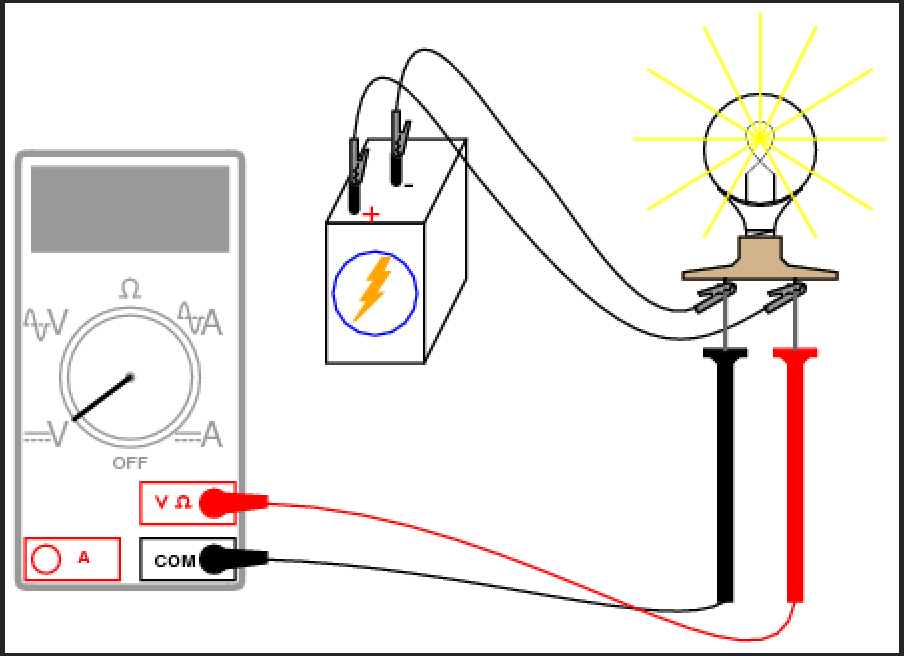


MEASURING INSTRUMENTS

Multimeter

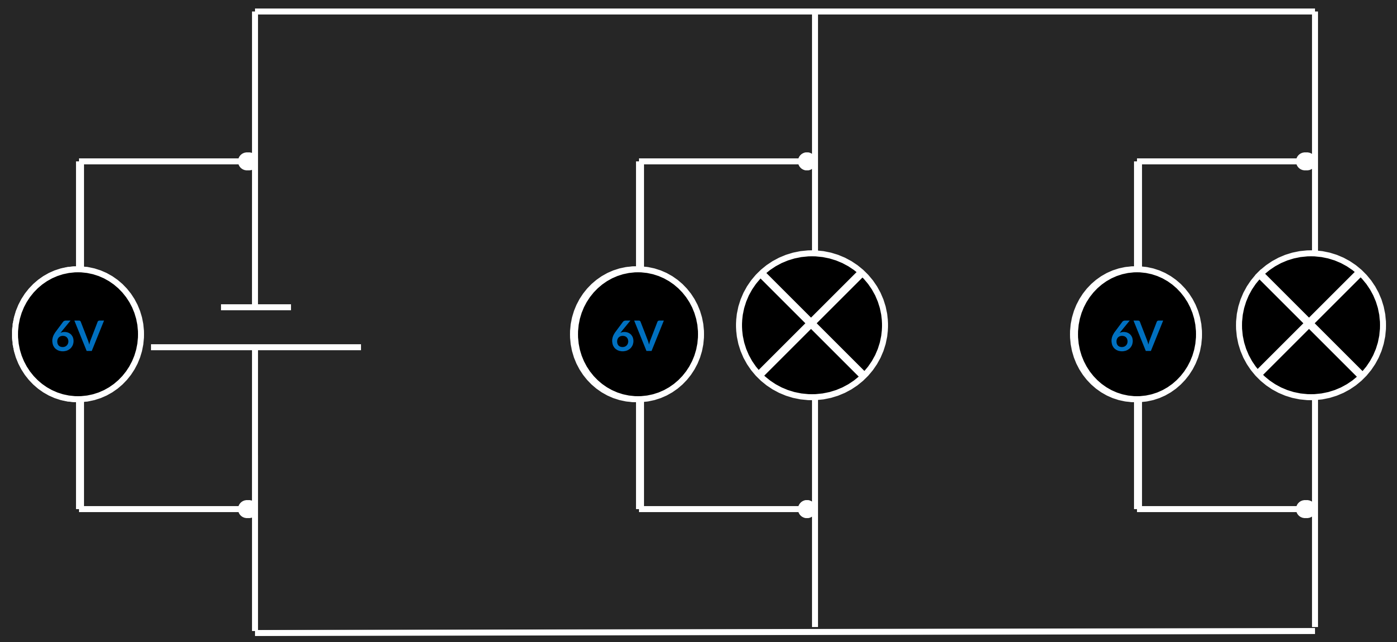
As opposed, the **voltmeter** is connected in parallel with the load





MEASURING INSTRUMENTS

Multimeter

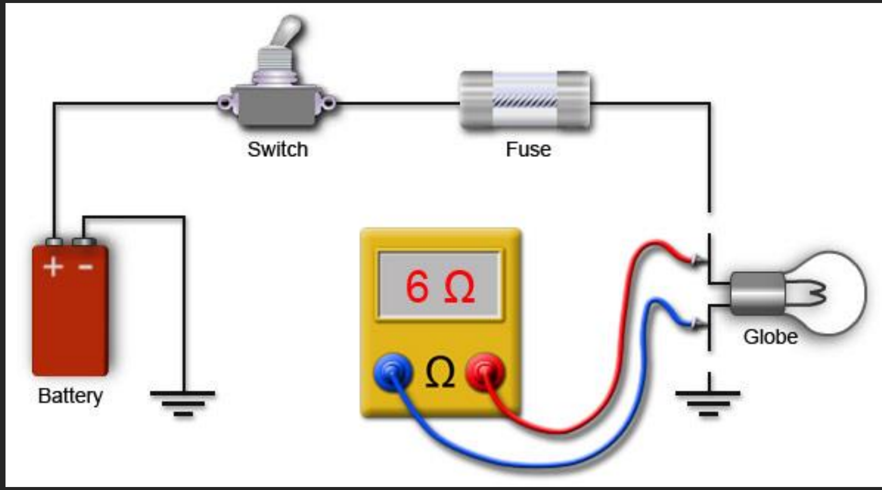


MEASURING INSTRUMENTS

Multimeter

The **ohmmeter** has a built-in battery power source, and must **always be used with the circuit de-energized**

An ohmmeter is used to **measure resistance** and to **check continuity** in circuits

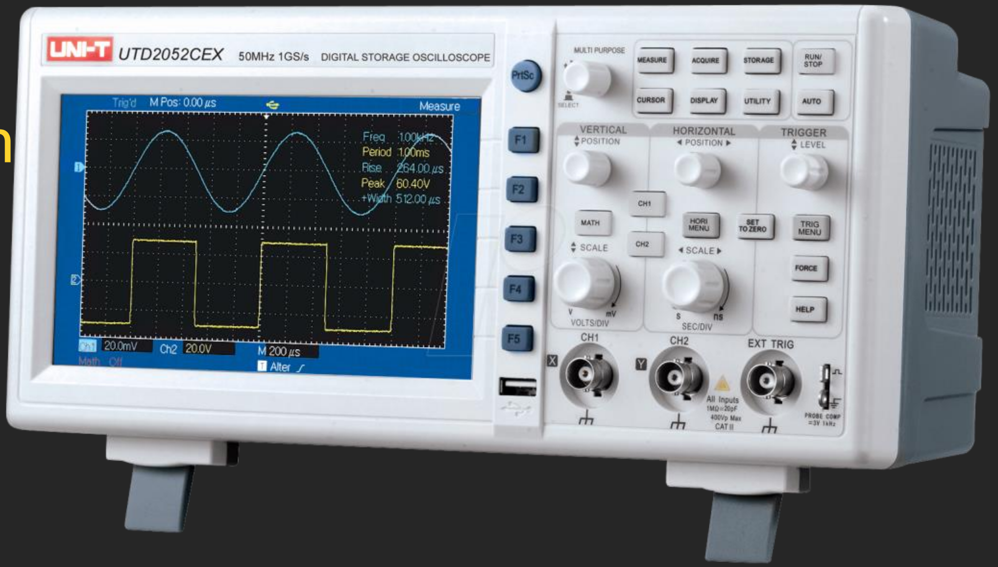


MEASURING INSTRUMENTS

Oscilloscope

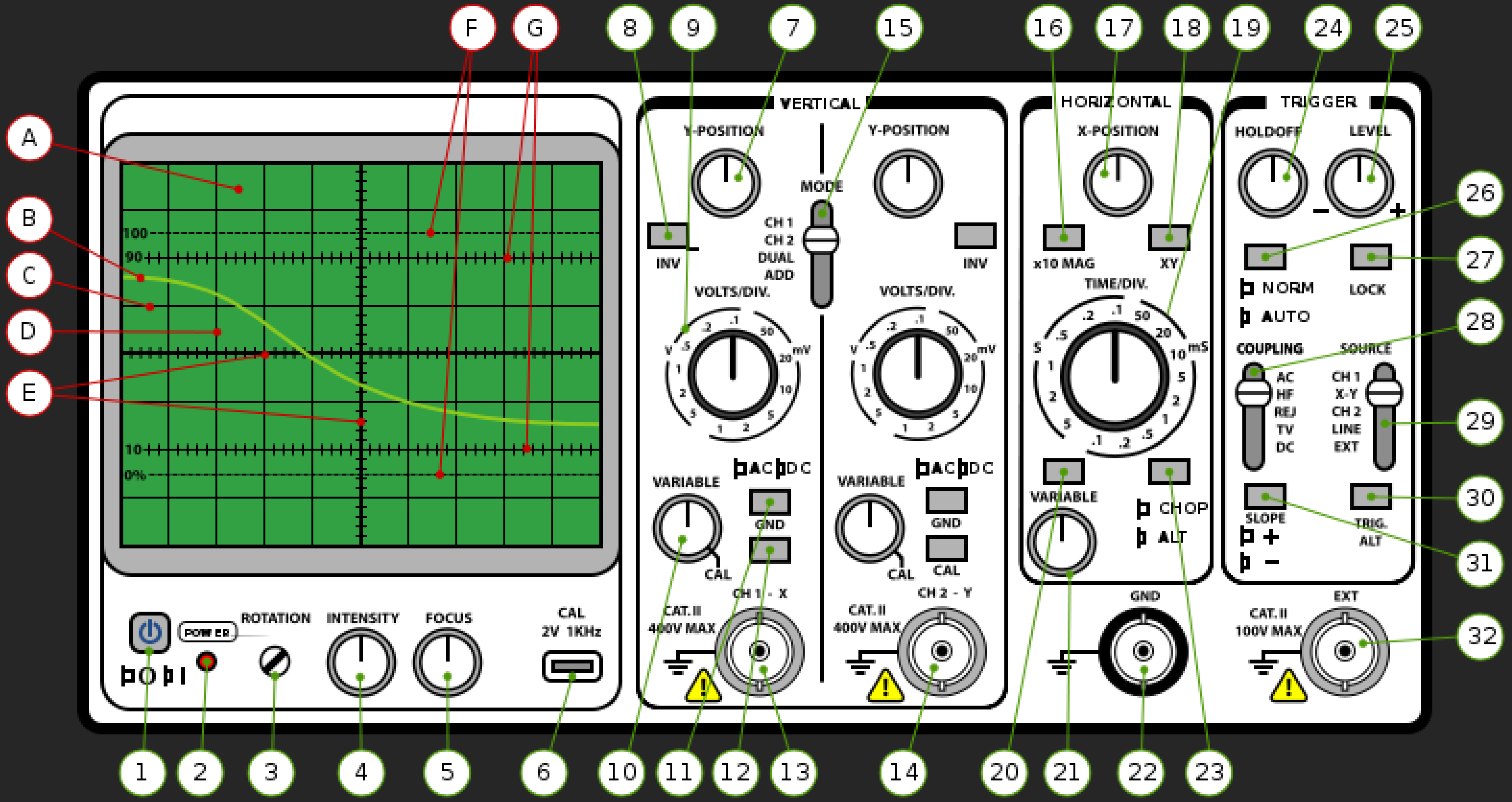
- The oscilloscope is an important piece of test equipment used in the world of electronics

- It provides a visual display of waveform for measurement and comparison

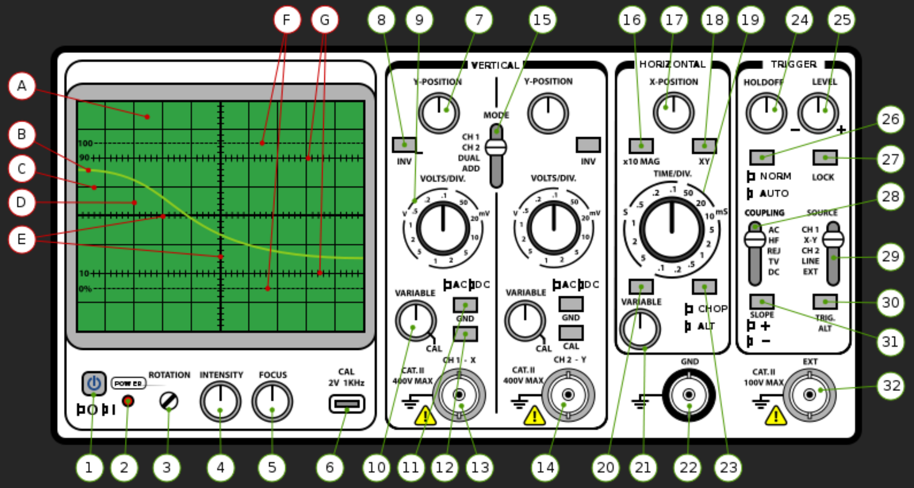


MEASURING INSTRUMENTS

Oscilloscope



Oscilloscope



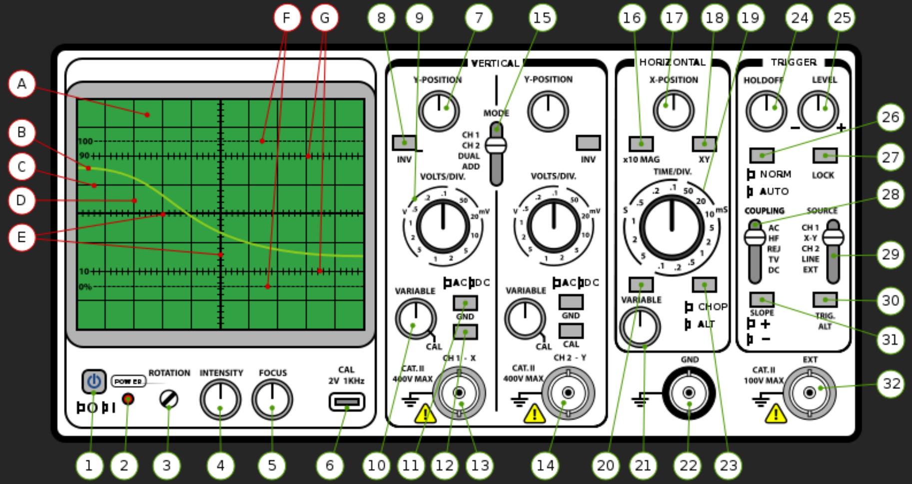
Display

A. Display. This can be a phosphor screen or an LCD, and is usually about 100 mm corner to corner.

B. ‘Trace'. This is the line drawn by the scope to represent the signal. On a CRO, this line is created by a bright dot moving across the screen at high speed. On a digital scope, the line is drawn on the LCD like a graphical calculator.

MEASURING INSTRUMENTS

Oscilloscope



Power, Calibration and Display Controls

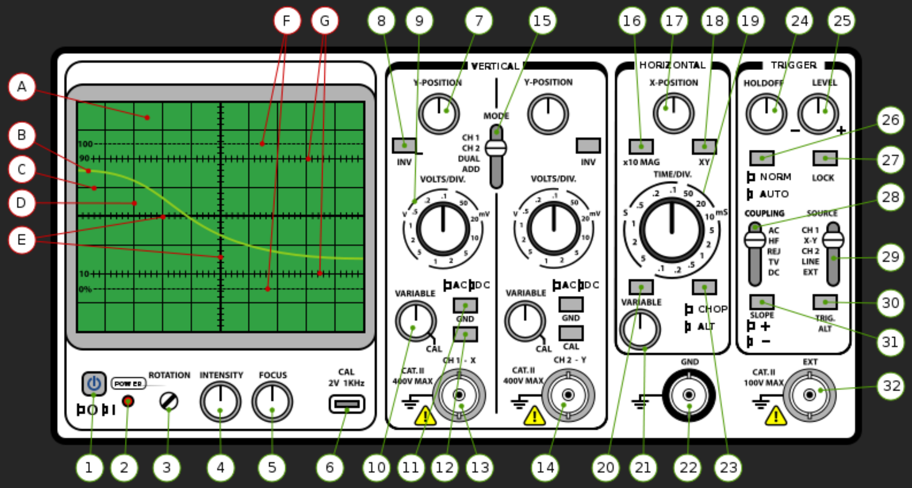
1. Power On/Off Button.

2. Power Indicator which lights when the oscilloscope is on. This may be an LED in newer scopes or a neon tube in older scopes.

3. Trace rotation (TR) control. This sets the inclination of a flat signal relative to the graticule. This is usually a Trimpot and needs to be set using a flat-bladed screwdriver. Once set, this control should retain its position and will rarely need adjusting.

MEASURING INSTRUMENTS

Oscilloscope



Power, Calibration and Display Controls

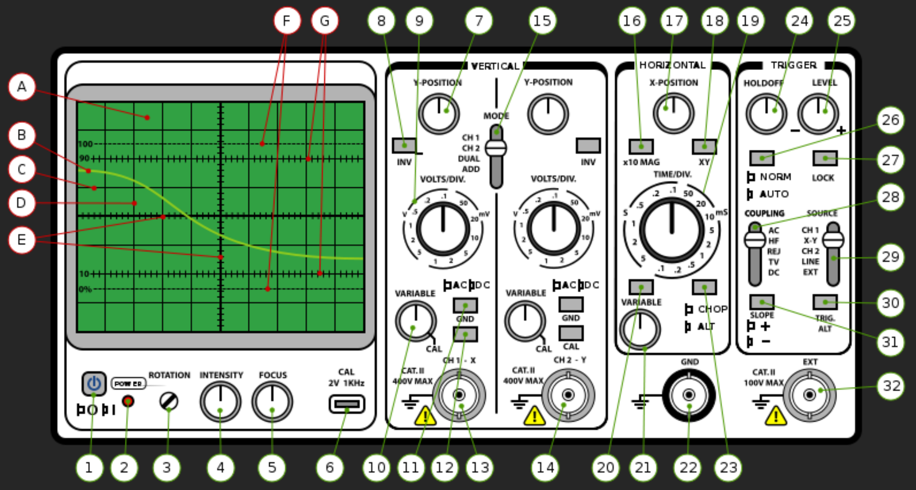
4. Intensity of the trace. Turning this up increases the brightness of the trace, and turning it down makes it dimmer.

5. Focus control. Focuses the beam to form a trace about 1mm wide.

6. Calibration point. This gives a steady square wave at a set frequency and voltage, allowing the scaling of the trace to be set accurately.

MEASURING INSTRUMENTS

Oscilloscope



Vertical Axis Controls

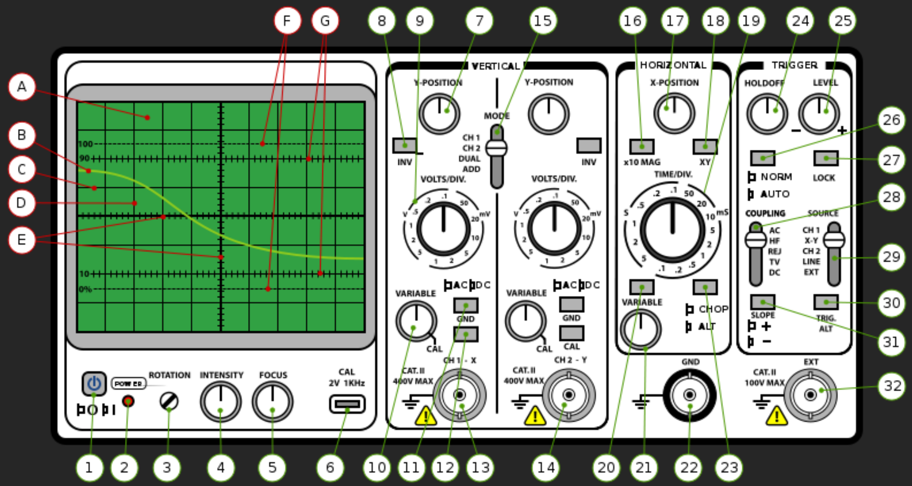
7. Controls the position of the trace. It can be adjusted to set the voltage relative to a ground, or it can be adjusted to separate the two signals.

8. Inverts the relevant channel. That is, the negative voltage is displayed, and the trace is upside-down.

9. Vertical scale control, often called the volts/div. control. This sets the height of the trace. It operates in discrete steps.

MEASURING INSTRUMENTS

Oscilloscope

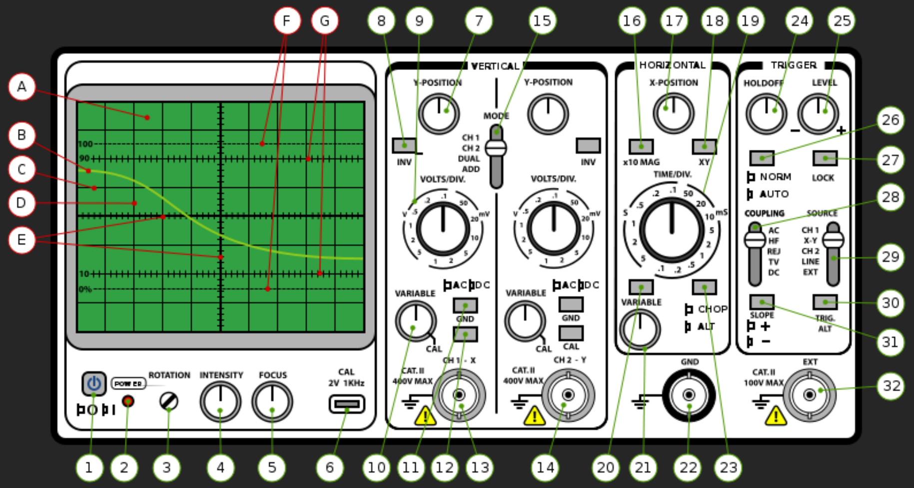


Vertical Axis Controls

10. Variable height control. It can adjust the height of the trace up to the next set increment on the volts/div. control.
11. AC/DC toggle. When set to AC, any DC component of the voltage is filtered out. When set to DC, the signal is displayed as is.
12. GND toggle. By selecting this, the input signal is ignored, and the trace shows 0V.
13. Channel 1 signal input.
14. Channel 2 input.

MEASURING INSTRUMENTS

Oscilloscope



Horizontal Axis Controls

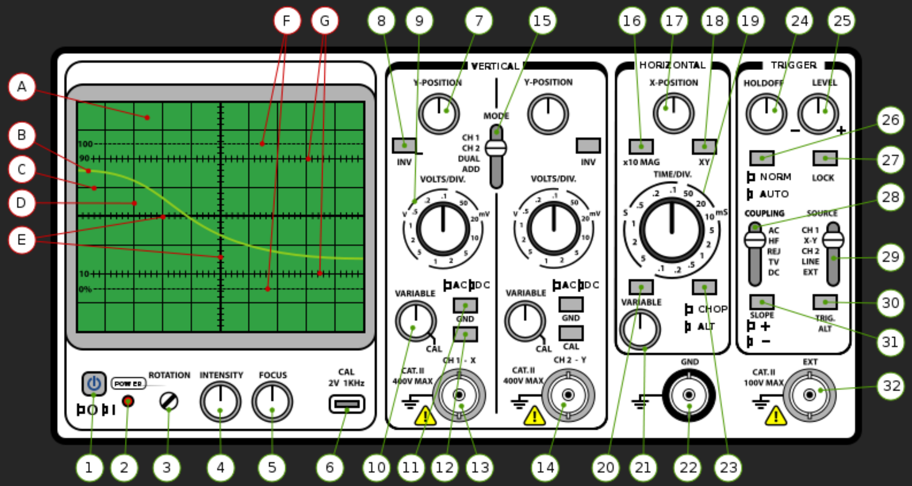
17. Control position of the trace.

18. Toogles the mode between the usual voltage vs. time format and the XY mode. This continuously plots the voltage on Channel 1 along the horizontal axis against the voltage on Channel 2 (the vertical axis).

19. Time base selector. The time base is the length of time displayed per major horizontal division on the screen. This ranges from about 0.1 milliseconds to about 1 second (or more on digital scopes).

MEASURING INSTRUMENTS

Oscilloscope



Horizontal Axis Controls

20 and 21. Act in much the same way as 10 does on the vertical axis. This diagram shows it to be slighly different from the vertical control.

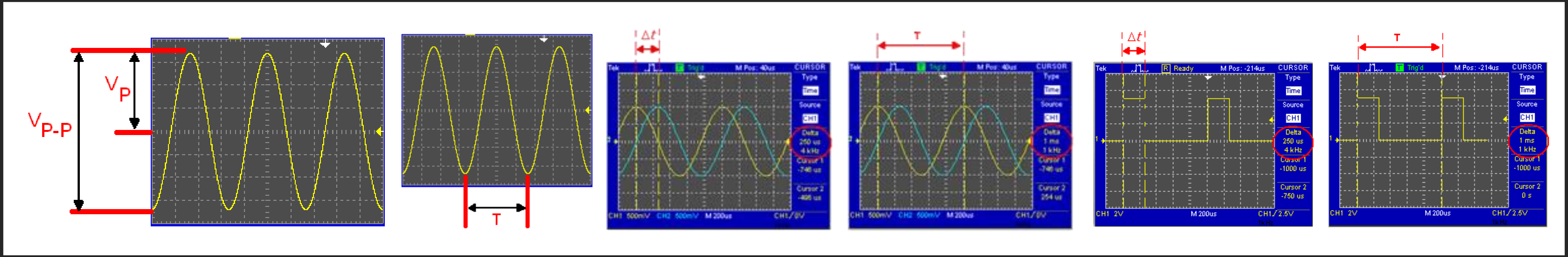
22. GND terminal of the scope. This is used to set a "datum" voltage against which to measure the voltages on the input channels

23. Toggles between chop-mode and alt-mode. Chop-mode means that when the scope is drawing two signals side by side it alternates rapidly between the two over the course of passing across the screen. This action is called chopping. Alt-mode alternates at the end of each pass, and can appear to flicker at slow speeds.

MEASURING INSTRUMENTS

Oscilloscope

- Why use such complex instrument?
  - **To view waveforms**, showing the changes in amplitude over a certain amount of time. The amplitude of the signal is measured on the y-axis (vertically), while time is measured on the x-axis (horizontally).
  - **To measure waveforms**, including the amplitude (maximum voltage of the waveform), peak-to-peak Voltage, frequency, pulse width, phase shift, duty cycle,



MEASURING INSTRUMENTS

Resistor Color Code

- The most traditional “measuring instrument” of all – the **resistor color code**

- The resistance value for a resistor is generally indicated through the use of a 4 (or 3, or 5) band color code

MEASURING INSTRUMENTS

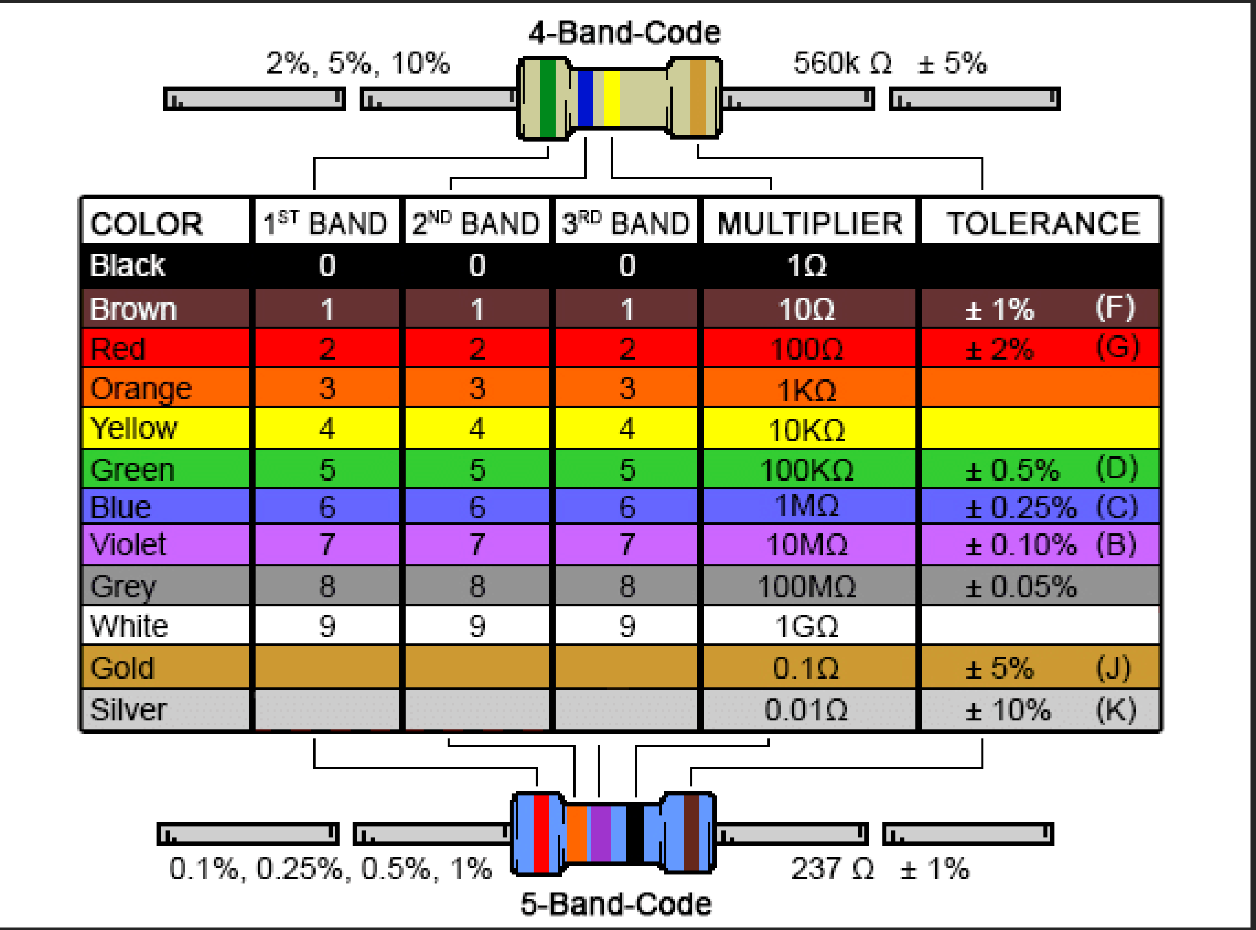
Resistor Color Code

- Four-band color code: the first two bands tell you the first two digits of the resistance, the third band tells you how many zeros to add, and the fourth band tells you the tolerance.

- Five-band color code: the first three bands tell you the first three digits of the resistance, the fourth band tells you how many zeros to add, and the fifth band tells you the tolerance.

MEASURING INSTRUMENTS

Resistor Color Code

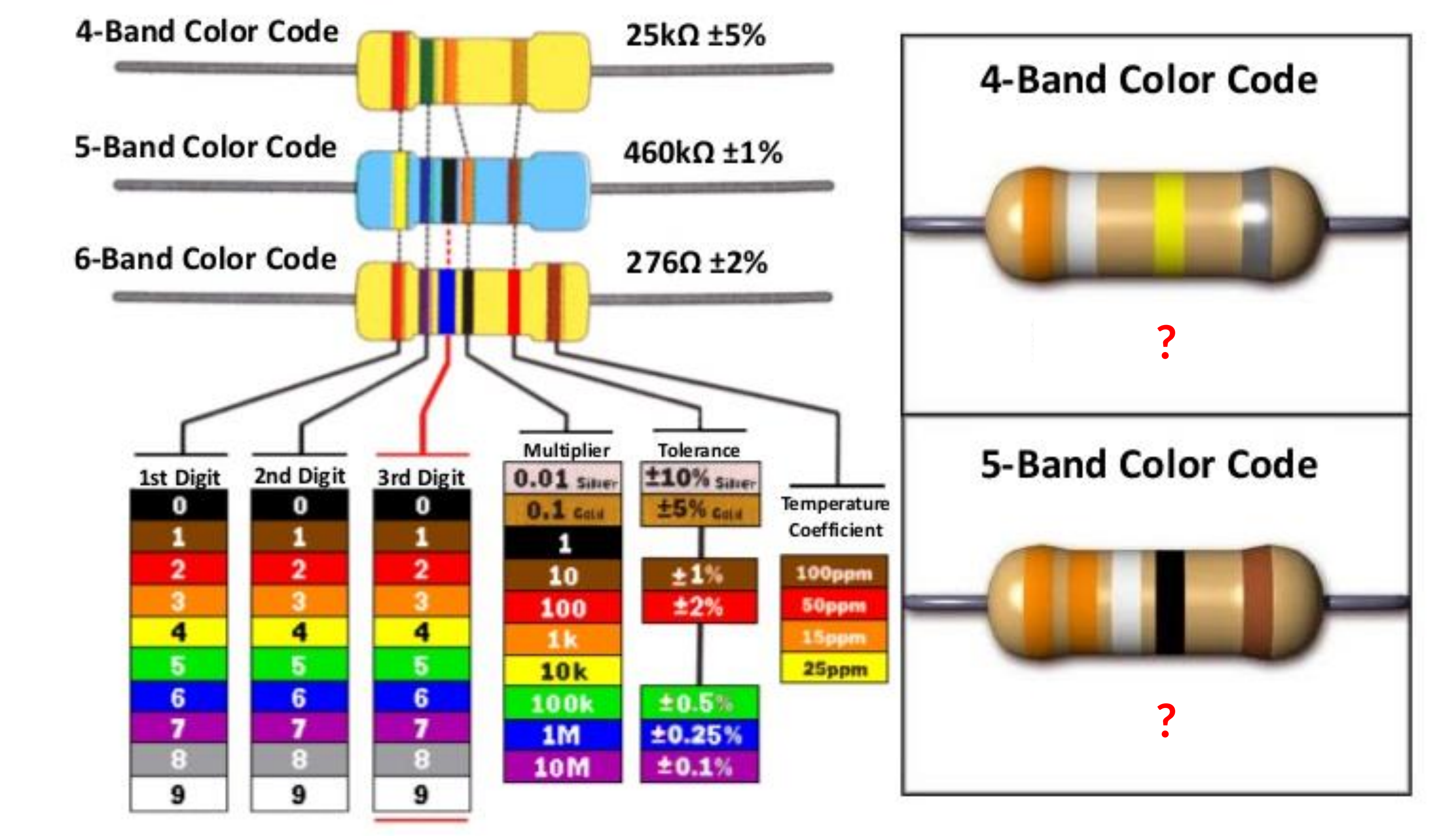


COLOR	1ST BAND	2ND BAND	3RD BAND	MULTIPLIER	TOLERANCE
Black	0	0	0	1Ω	
Brown	1	1	1	10Ω	± 1% (F)
Red	2	2	2	100Ω	± 2% (G)
Orange	3	3	3	1KΩ	
Yellow	4	4	4	10KΩ	
Green	5	5	5	100KΩ	± 0.5% (D)
Blue	6	6	6	1MΩ	± 0.25% (C)
Violet	7	7	7	10MΩ	± 0.10% (B)
Grey	8	8	8	100MΩ	± 0.05%
White	9	9	9	1GΩ	
Gold				0.1Ω	± 5% (J)
Silver				0.01Ω	± 10% (K)

https://www.digikey.com/en/resources/conversion-calculators/conversion-calculator-resistor-color-code-4-band

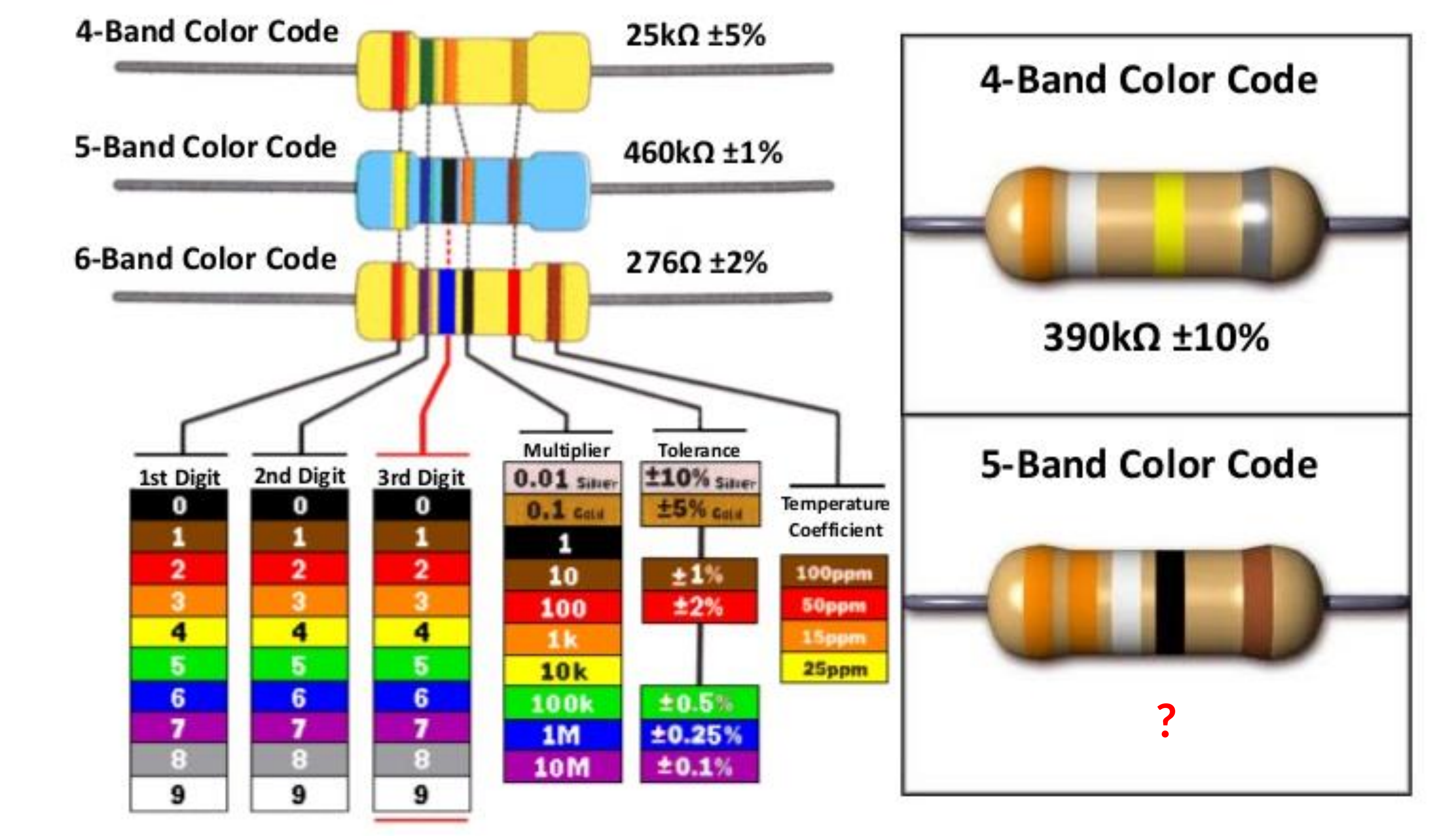
MEASURING INSTRUMENTS

Resistor Color Code



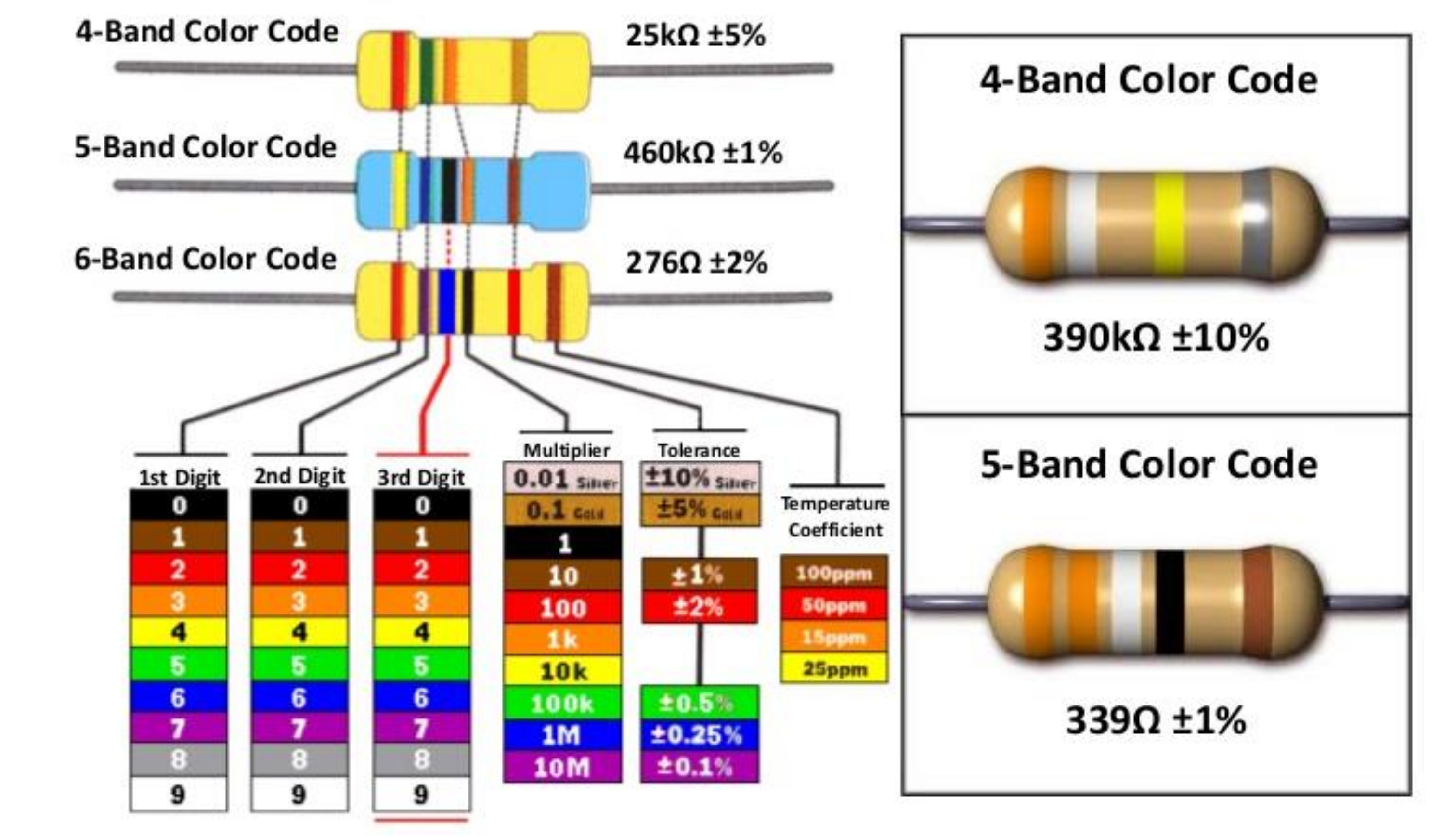
MEASURING INSTRUMENTS

Resistor Color Code



MEASURING INSTRUMENTS

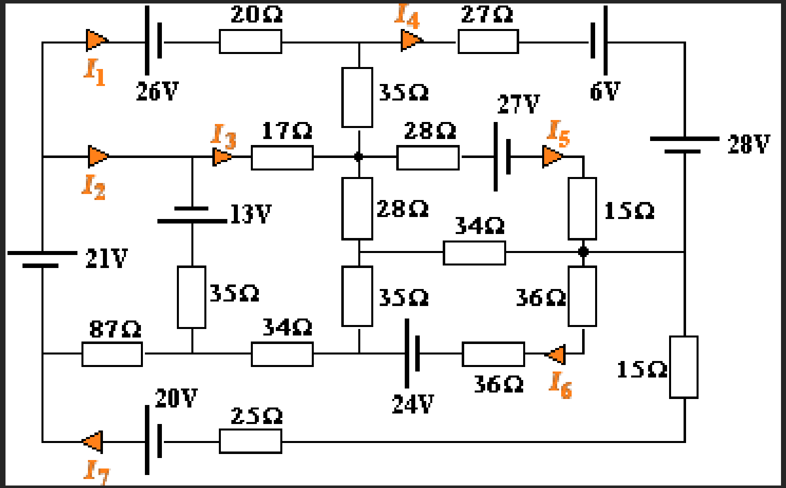
Resistor Color Code



KIRCHHOFF’S LAW

KIRCHHOFF'S LAW

- As previously addressed, we can analyse simple circuits using the law of the triangles (e.g., Ohm's law) and the rules for series and parallel combinations of resistors



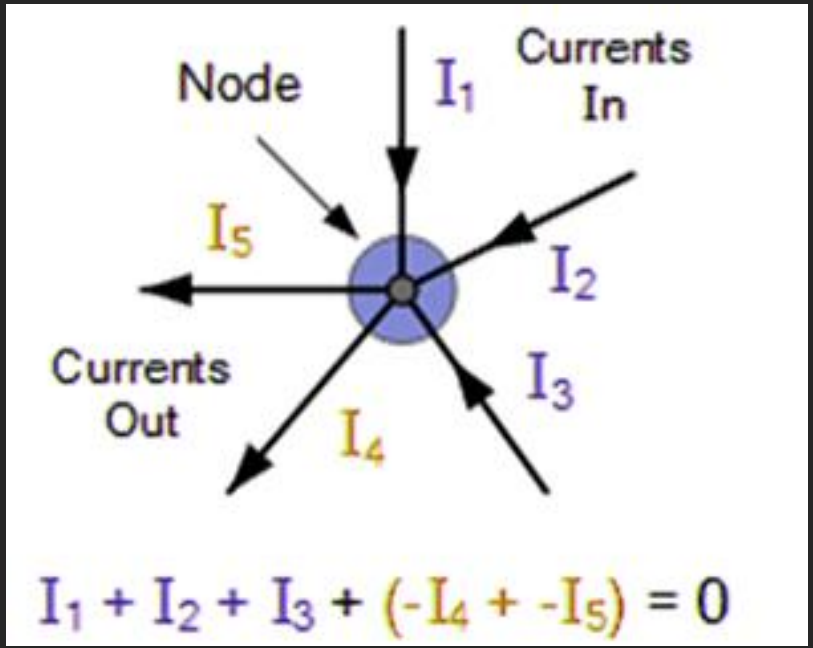
- Very often, however, it is not possible to reduce a circuit to a single loop - the procedure for analysing more complex circuits is greatly simplified if we use two principles from **Kirchhoff's Law**

KIRCHHOFF’S LAW

Kirchhoff's current law (KCL)

- The algebraic sum of currents in a network of conductors meeting at a point is zero

$$\sum I = 0$$

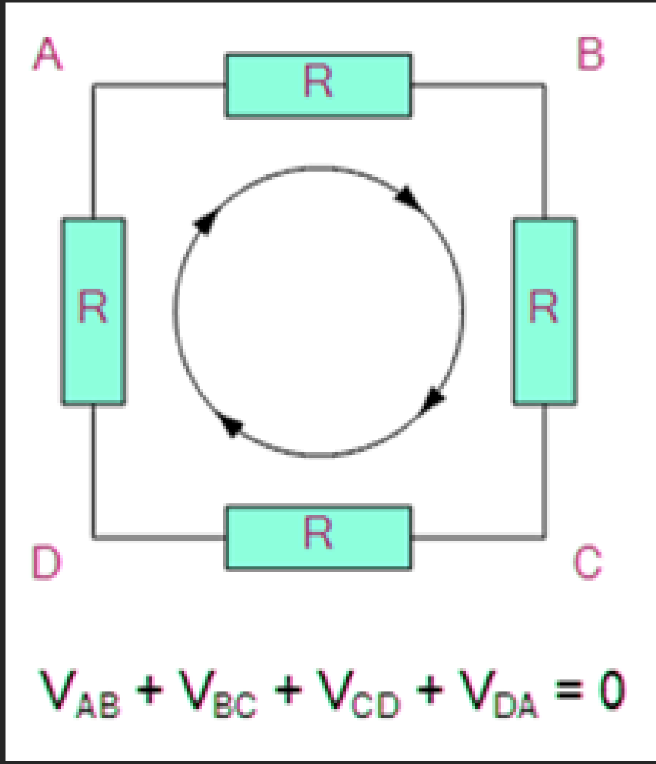


KIRCHHOFF’S LAW

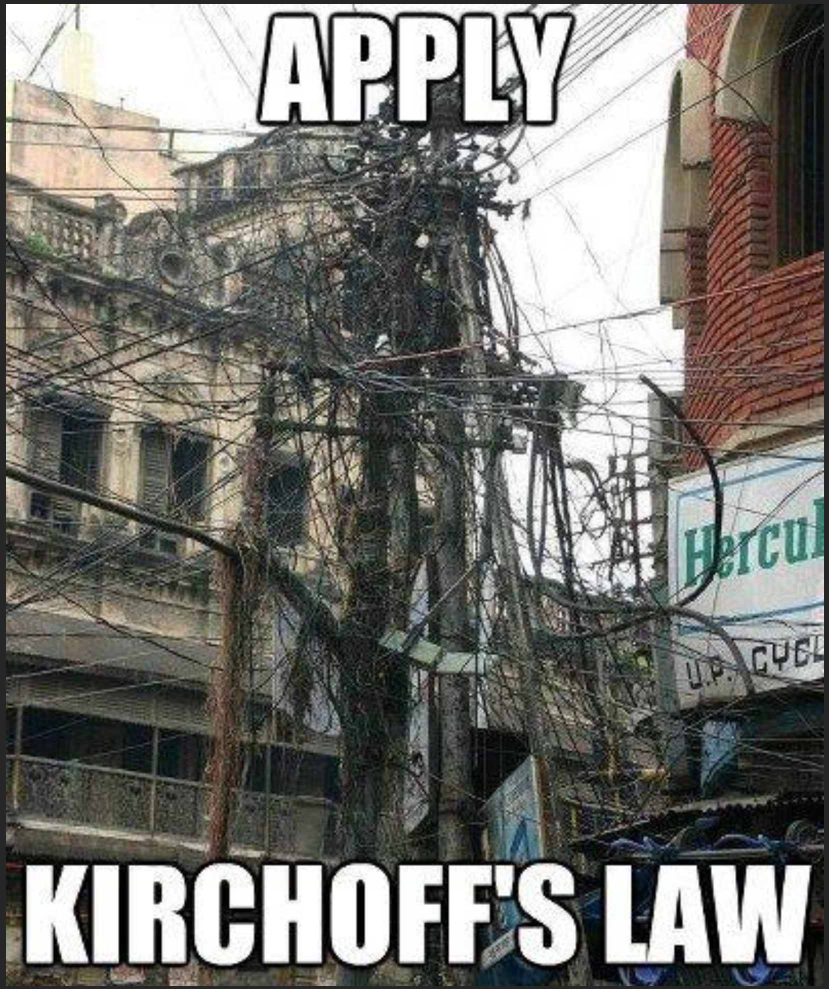
Kirchhoff’s voltage law (KVL)

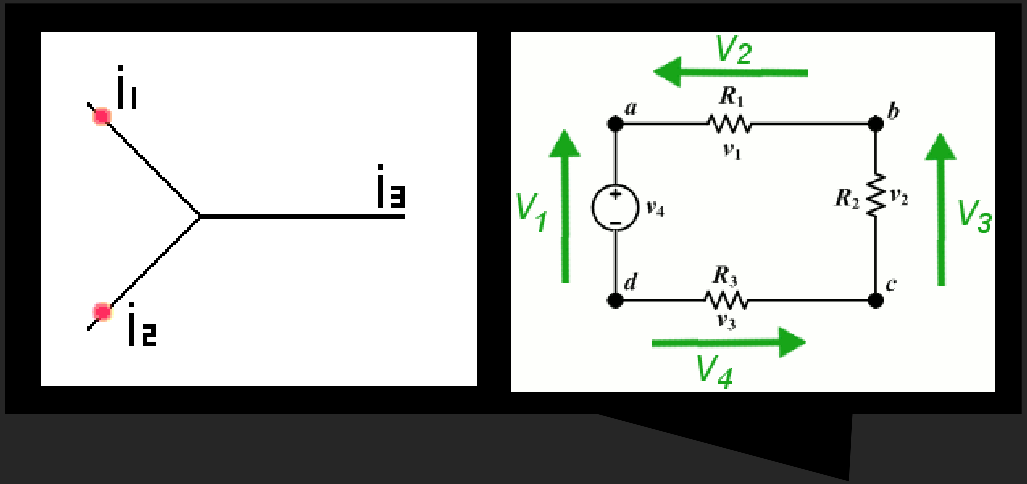
- The directed sum of the potential differences (voltages) around any closed loop is zero

$$\sum V = 0$$

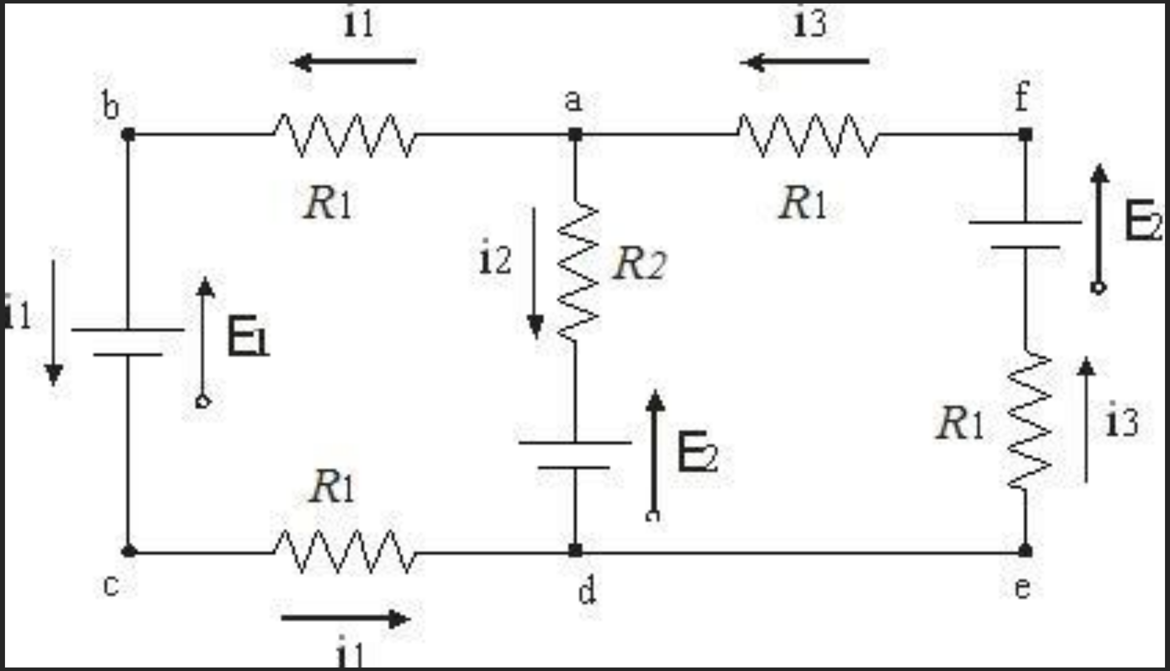


KIRCHHOFF'S LAW

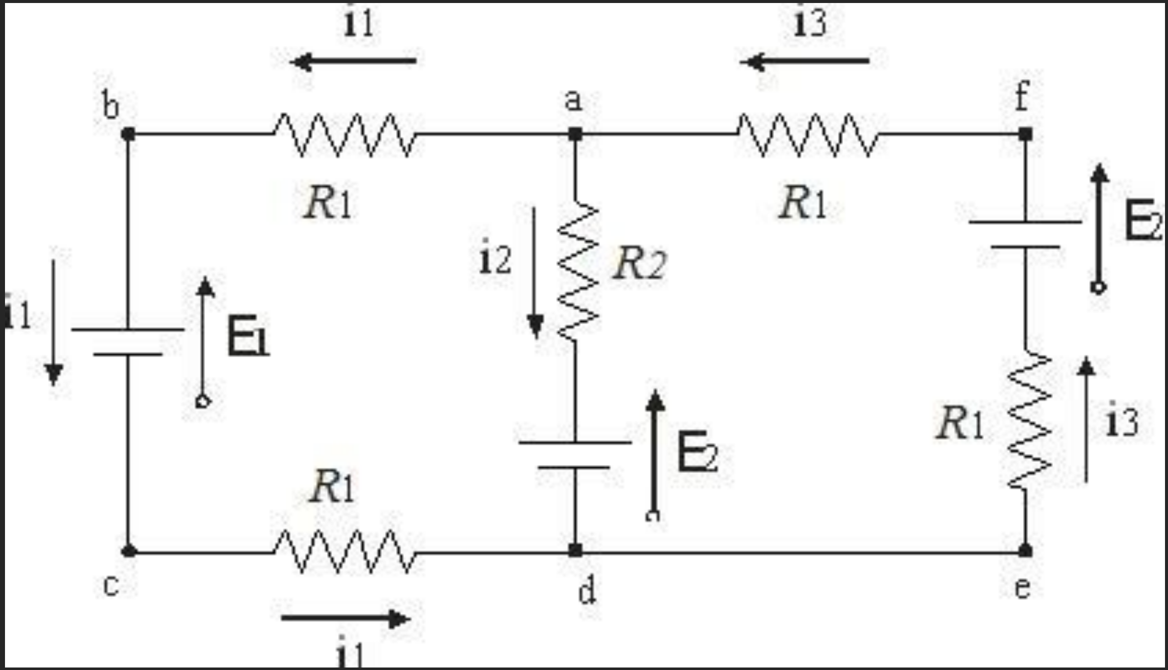




KIRCHHOFF'S LAW



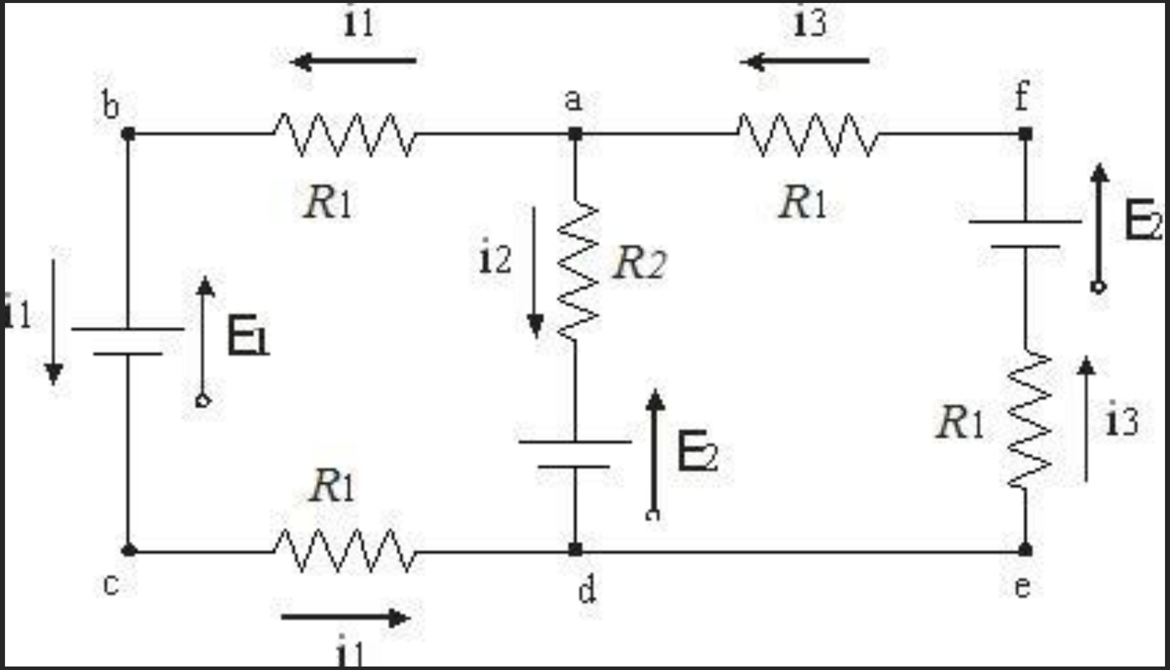
KIRCHHOFF’S LAW



According to the first law:

$i1 + i2 = i3$

KIRCHHOFF'S LAW



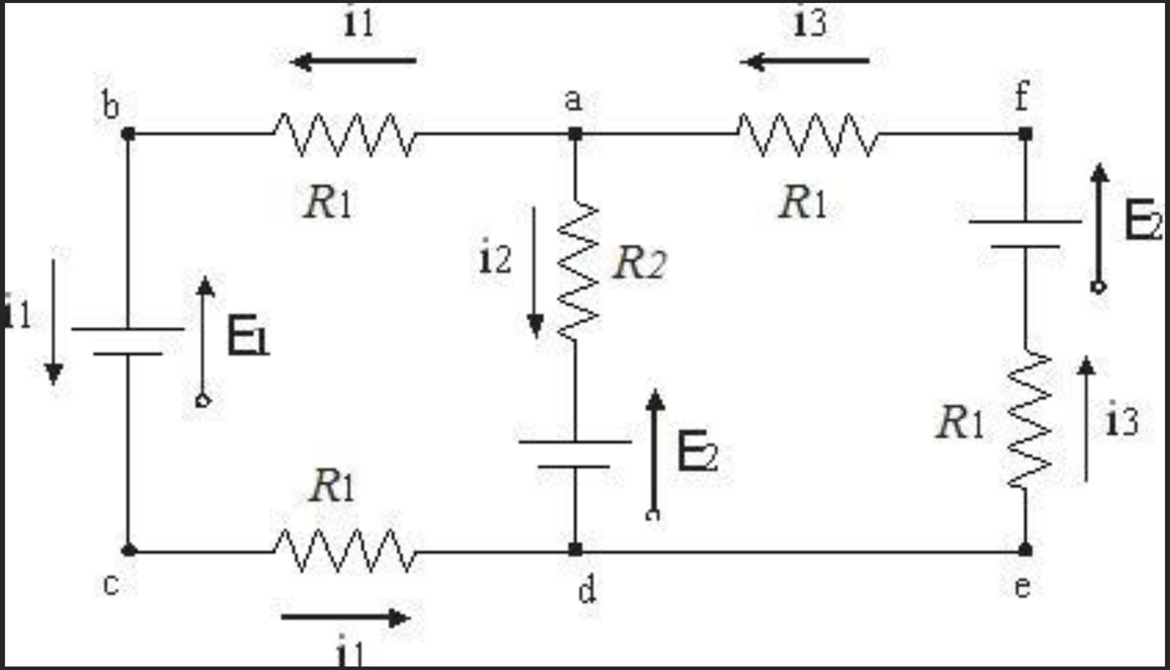
According to the first law:

$i1 + i2 = i3$

According to the second law (starting in ***a*** in counter-clockwise):

$-i1R1 - E1 - i1R1 + E2 + i2R2 = 0$

KIRCHHOFF’S LAW



According to the first law:

i1 + i2 = i3

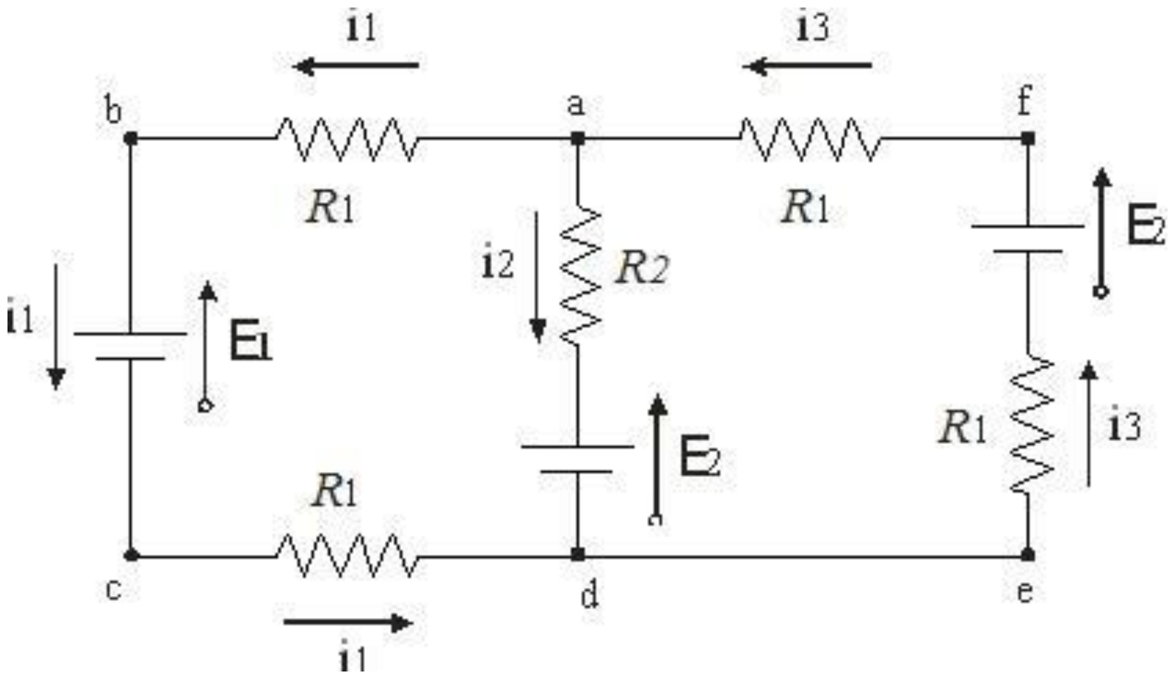
According to the second law
(starting in ***a*** in counter-clockwise):

– i1R1 – E1 – i1R1 + E2 + i2R2 = 0

(starting in ***a*** in clockwise):

i3R1 – E2 + i3R1 + E2 + i2R2 = 0

KIRCHHOFF'S LAW



$$\begin{cases} i_1 + i_2 = i_3 \\ 2i_1R_1 - i_2R_2 = \varepsilon_2 - \varepsilon_1 \\ 2i_3R_1 + i_2R_2 = 0 \end{cases}$$

CRAFT #3

Thank you

André Araújo, andre@ingeniarius.pt
Miguel Araújo, miguel@ingeniarius.pt

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