BME 301

3-Electrical Elements

Electrical Basics

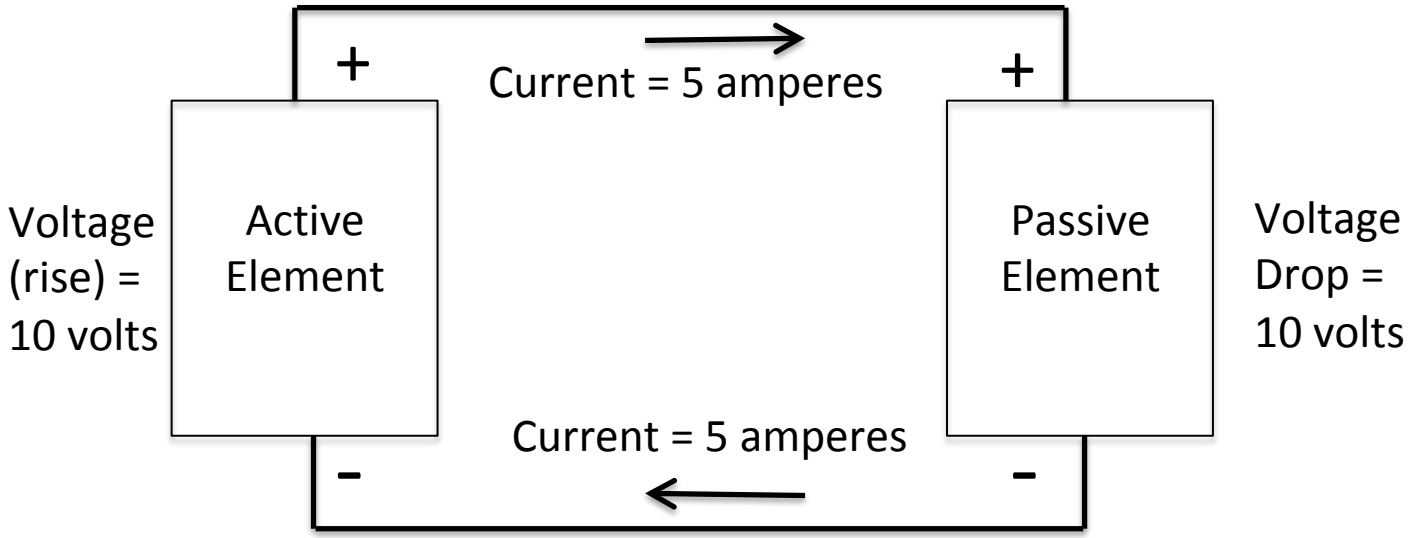
- Electric Circuits
  - Electric Circuits consist of circuit element with at least one active element and one passive element.
  - The circuit elements in a circuit must be connected together as a ***closed circuit*** such that current can flow from the active element(s) through the passive element(s) and return back to the active element.
  - If the circuit is not closed (there is no return path), current can not flow and the energy from the active element can not be used.

Electrical Basics

- Closed Circuits
  - When a circuit is closed, there is a current flowing through each element and a voltage appears across each element.
  - The voltage across the active element(s) is associated with the energy supplied by the active element and is the voltage provided by the source.
  - The voltage across the passive elements is associated with the energy used by the element and is called the voltage drop. (Therefore, sometimes the voltage across the active element is called a voltage rise.)

A Simple Closed Circuit

- Note the circuit is closed since there is a return path. Therefore there is the current flowing from the active element to the passive element is the same as current flowing from the passive element to the action element.
- Also note that the voltage provided by the active element equals the voltage used by the passive element. This is a consequence of conservation of energy.
- The electric power either delivered by a active element or used by an passive element is the product of the its voltage times the current flowing through it. In this example, the power is 10*5= 50 watts.
- Finally, note that the current flows out of the positive terminal of the active element and flows into the positive terminal of the passive element. So the polarity of the active elements voltage is in the opposite direction of the polarity of the passive element.

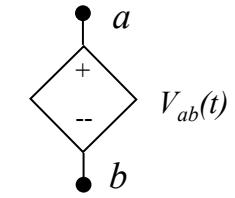


Characterize Circuit Elements

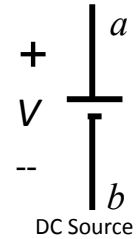
- Active Devices: Provider of energy
- Passive Devices: dissipates or stores energy
  - Linear
  - Non-linear

Circuit Elements

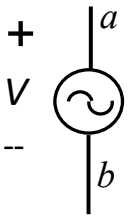
- Active Elements
  - Voltage Source
    - The voltage across the voltage source is always the same and never changes. That is, if it's a 1.5 volt battery, the voltage will always be 1.5volts.
    - However, the current flowing through will depend on the passive elements connected to it.
    - Examples:
      - Batteries provide a constant (over time) voltage or DC voltage.
      - Wall socket voltages are provided by the electric company. In the US, the voltage is a sinusoidal shaped voltage or an 120volt AC 60 Hz voltage
      - Function generators can provide Square Wave, triangular Wave, and Sawtooth Wave voltages.



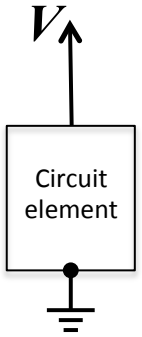
General Voltage Source



DC Source



AC Source



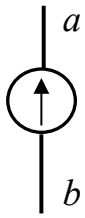
DC Source special case : V volts to ground

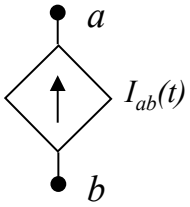

Icon for ground reference

Circuit Elements
Active Elements

– Current Sources

- Analogous to Voltage sources, there are current sources which provides a current which is always the same and never changes.
- However, the voltage across it will depend on the passive elements connected to it.
- Current sources are typically built with voltage sources and other devices.





Circuit Elements – Linear Passive Devices

- **Linear**: supports a linear relationship between the voltage across the device and the current through it.
  - **Resistor**: which dissipates energy provided by the active device in the form of heat
  - **Capacitor**: which stores energy provided by the active device in the form of an electrical field
  - **Inductor**: which stores energy provided by the active device in the form of a magnetic field

Circuit Elements – Linear Passive Devices

– **Resistor**: supports a voltage and current which are proportional, device dissipates heat, and is governed by Ohm's Law, units: resistance or ohms Ω

$$V_R(t) = I_R(t)R$$

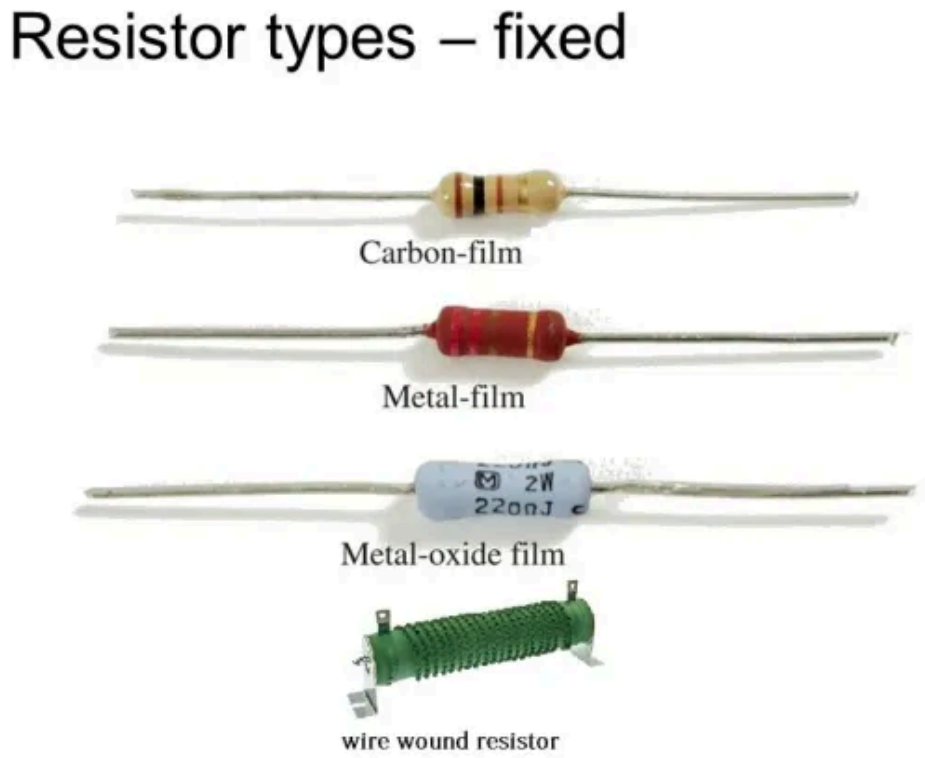
where $V_R(t)$ is the voltage across the resistor;

where $I_R(t)$ is the current flowing through the resistor;

and where R is the value of the resistance associated with the resistor

– Used in most circuits to support the performance of the circuit.

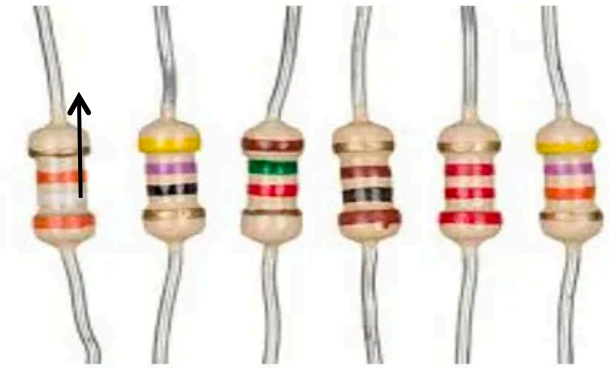
Resistors


Resistor types – fixed
Carbon-film
Metal-film
2W
Metal-oxide film
wire wound resistor

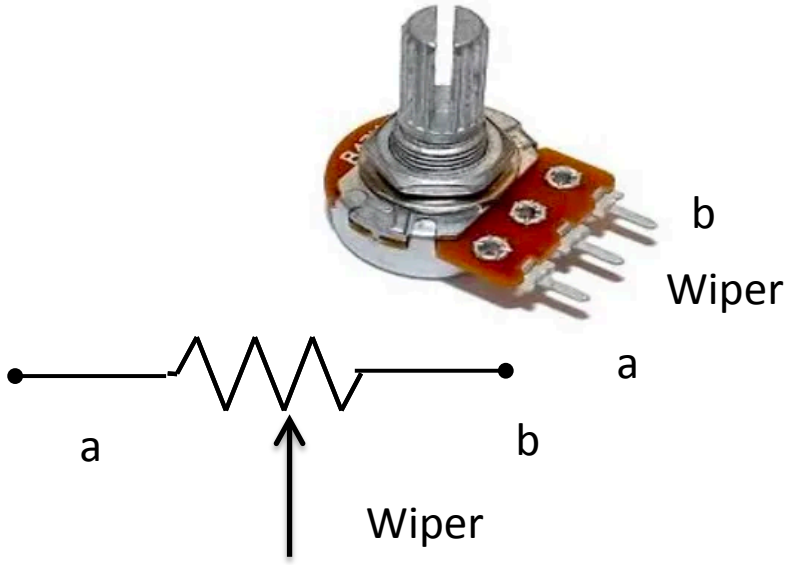
Resistors

Types of Linear Resistor

Fixed Resistor

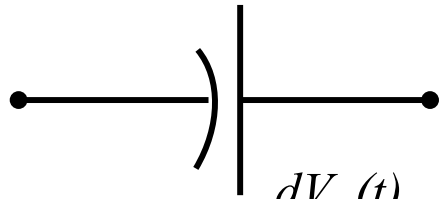


Variable Resister



Circuit Elements – Linear Passive Devices

– **Capacitor**: supports a current which is proportional to its changing voltage, device stores an electric field between its plates, and is governed by Gauss' Law, units: capacitance or farads, f



$$I_C(t) = C\frac{dV_C(t)}{dt}$$

where $V_C(t)$ is the voltage across the capacitor;

where $I_C(t)$ is the current flowing through the capacitor;

where C is the value of the capacitance associated with the capacitor

– Used to support filtering of signals and maintain voltage levels

Capacitors

- A capacitor is made up a two conducting electrodes (called plates) with each having opposite charges stored.
- These plates are separated by a dielectric (or insulator) which prevents charges to flow between the plates.
- This storing of opposite charges creates an electric field (and therefore a voltage) across the capacitor's plates.

Capacitors

- Capacitance is equal to the amount of charge stored on each plate divided by the voltage across each plate.

$$C = \frac{Q}{V}$$

where C is the capacitance in Farads;

where Q is the charge in Coulumbs;

and where V is the voltage across the Capacitor.

Capacitors

According to Gauss' Law a current only flows if there is a changing voltage across the capacitor.

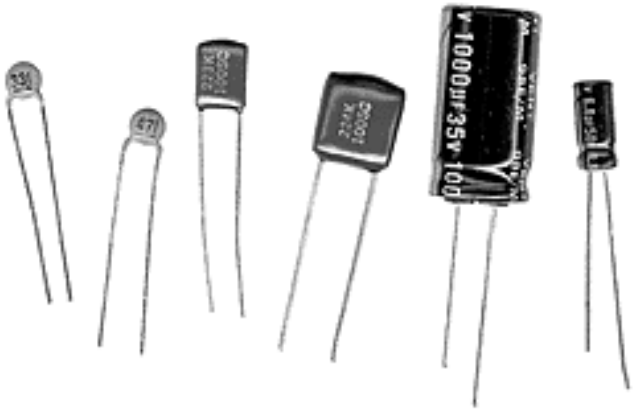
$$I_C(t) = C\frac{dV_C(t)}{dt}$$

Since charges can not flow through the dielectric (insulator),
the current is due to the charges flowing into/out of the plates to support the changing current. (This is called a displacement current as opposed to the conduction current flowing through a resistor.)

Capacitor Types

aluminum electolytic capacitors

Electrolytic capacitors which are polarized



Ceramic capacitors which are non-polarized

Circuit Elements – Linear Passive Devices

- **Inductor**: supports a voltage which is proportional to its changing current, device stores a magnetic field through its coils and is governed by Faraday's Law, units: inductance or henries, h

$$V_L(t) = L\frac{dI_L(t)}{dt}$$

where $V_L(t)$ is the voltage across the inductor;

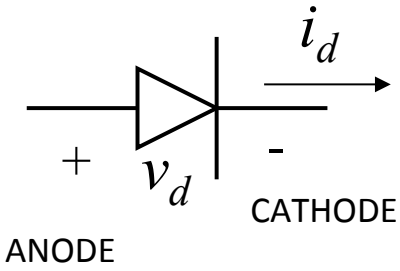
where $I_L(t)$ is the current flowing through the inductor;

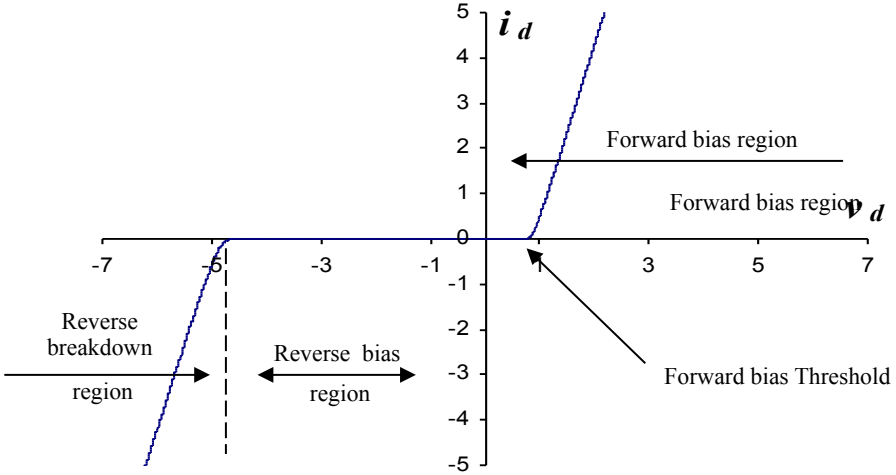
where L is the value of the inductance associated with the inductor

- Used in motors, generators and transformers and to create sudden high voltages (automotive).

Circuit Elements - Passive Devices Continued

- **Non-linear**: supports a non-linear relationship among the currents and voltages associated with it
  - **Diodes**: supports current flowing through it in only one direction





Circuits

- A circuit is a grouping of passive and active elements
- Elements may be connecting is series, parallel or combinations of both

Homework

1. Describe each of the circuit elements.
2. For the passive elements that store energy, describe how the energy is stored; that is, what are features of these elements that lend themselves to this type of energy storage.
3. HONORS STUDENTS ADD THE FOLLOWING

   What type of passive circuit elements would be required to filter out the noise from a bio-signal?