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

AC/DC circuits and circuit elements

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Previous Lesson

- Ohm's Law
  - V = R * I
- Kirchoff's Voltage Law
  - The algebraic sum of voltage around a closed loop is zero.
- Kirchoff's Current Law
  - The algebraic sum of all currents entering and leaving a node is zero.

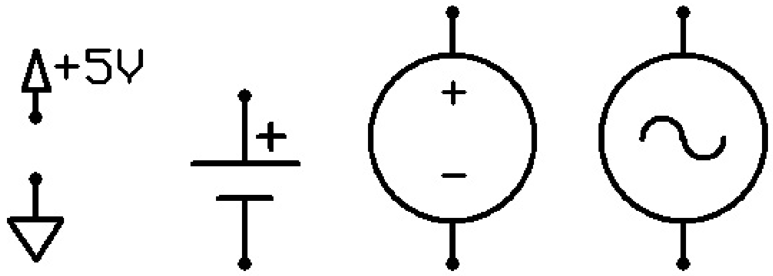
- Voltage/current division

Sources (Generators)

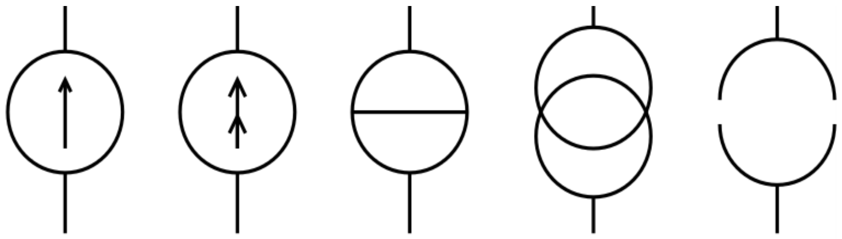
Voltage and current sources

- Active circuit elements –they 'create' something
- Representation varies

Voltage sources



Current sources

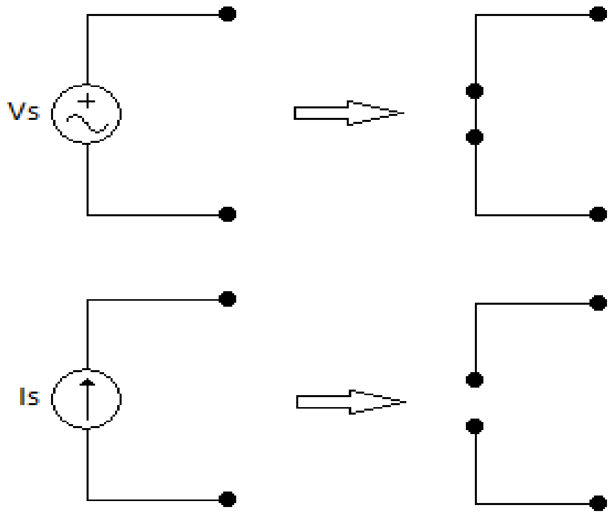


Sources (Generators)

How do you work with them

Superposition Theorem:

- Total current through or voltage across a resistor or branch is the algebraic sum of the responses caused by each independent source acting alone.
- Keep one source
- Replace all other sources
- Resultant responses are added together



AC/DC

DC

- The electric charge (current) only flows in one direction.

AC

- Electronic charge changes direction **periodically** (in time).
- Voltage also reverses because of current changes direction.

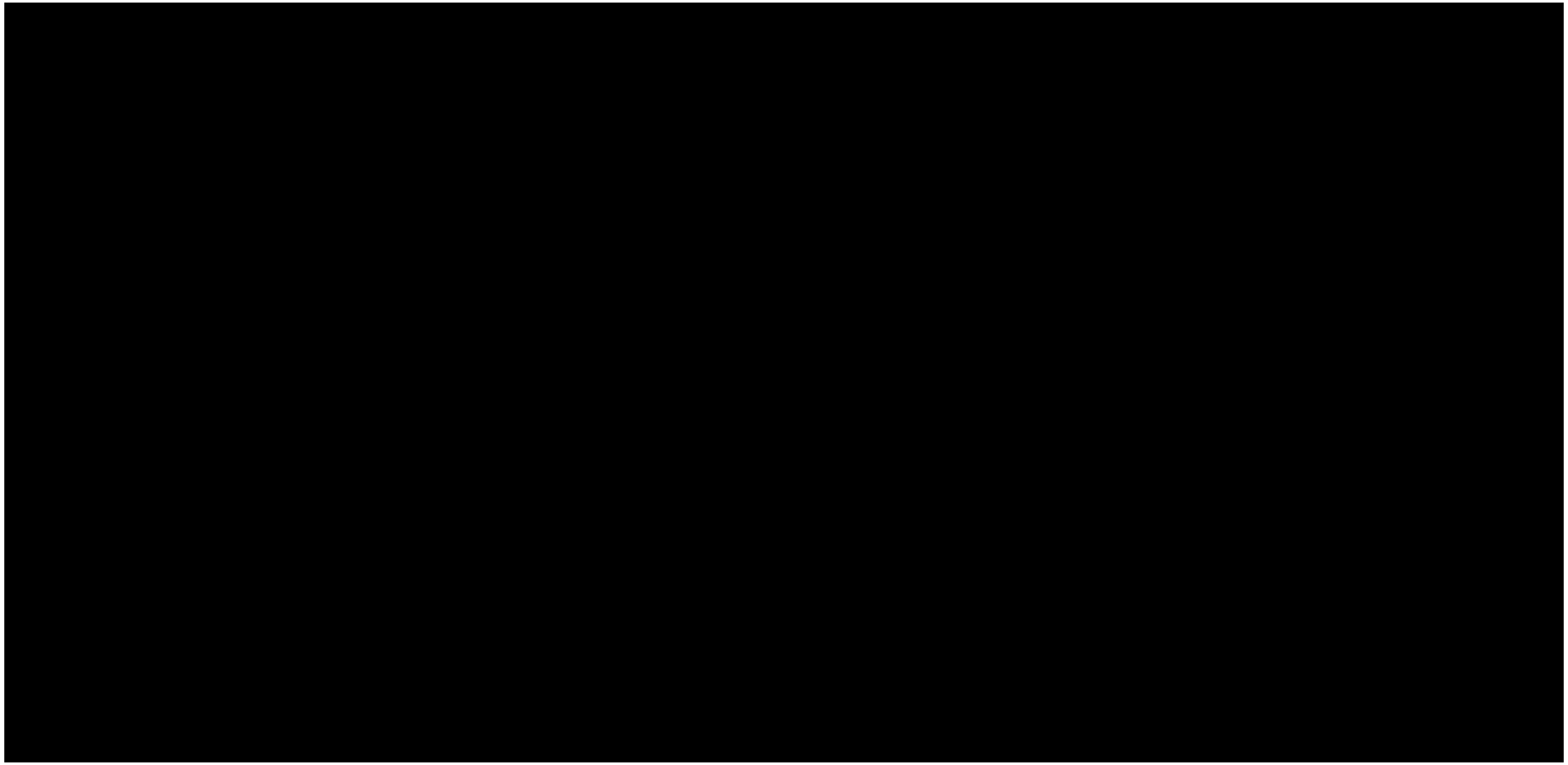
AC/DC(2)

Generating AC

- Is produced using an alternator.
  - Special type of generator designed to produce AC
- A loop of wire is spun inside of a magnetic field,
- This induces a current along the wire.
- As the wire spins and enters a different magnetic polarity periodically, the voltage and current alternates on the wire.

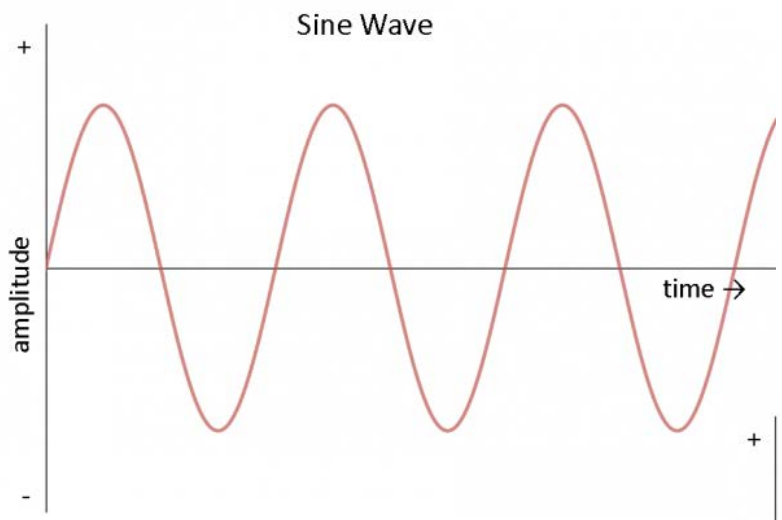
Video link

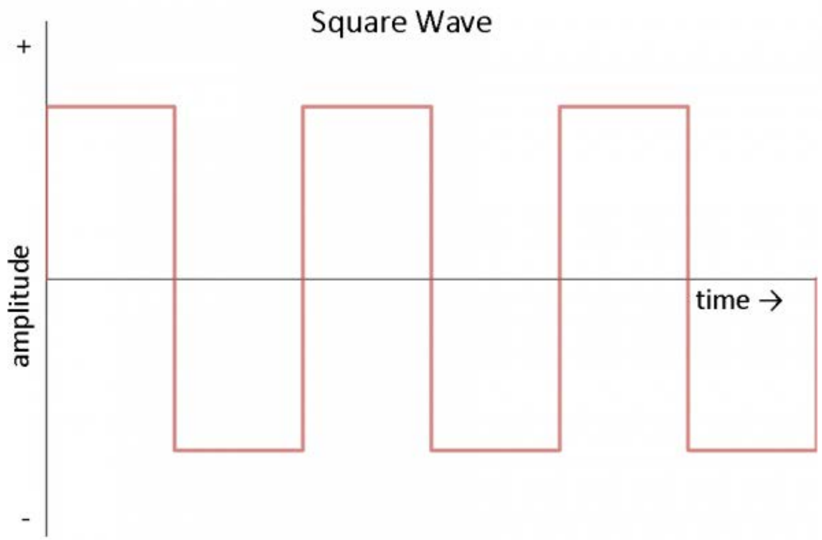
AC/DC(3)

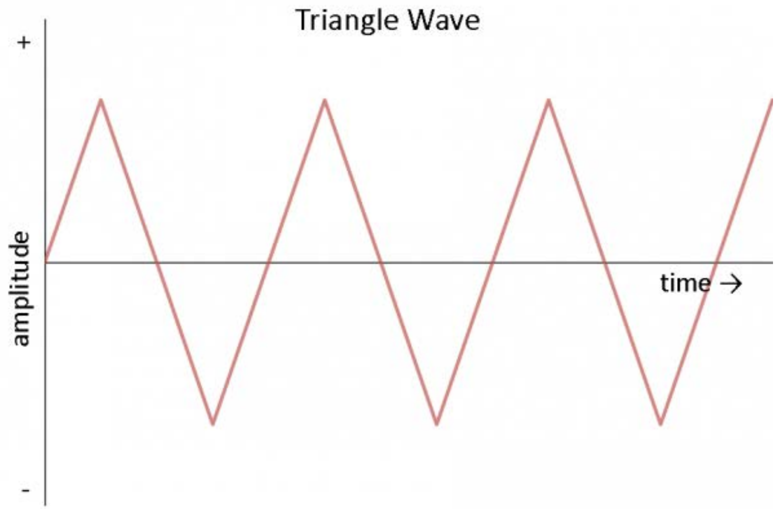


AC/DC (4)

Waveforms







AC/DC (5)

How do we use AC circuit elements

- Ohm’s and Kirchoff’s laws still apply
- Vectorial representation on the complex plane
  - Rotating vector
  - Vector length (peak value)
  - Vector angle (phase)

Capacitors

- A capacitor is an energy storage element.
- It can store electrical pressure (voltage) for periods of time.
  - -When a capacitor has a difference in voltage (electrical pressure) across its plate, it is said to be charged.
  - -A capacitor is charged by having a one-way current flow through it for a period of time.
  - -It can be discharged by letting a current flow in the opposite direction out of the capacitor.

Capacitors(2)

On an ideal capacitor:

$$Q = C * V$$

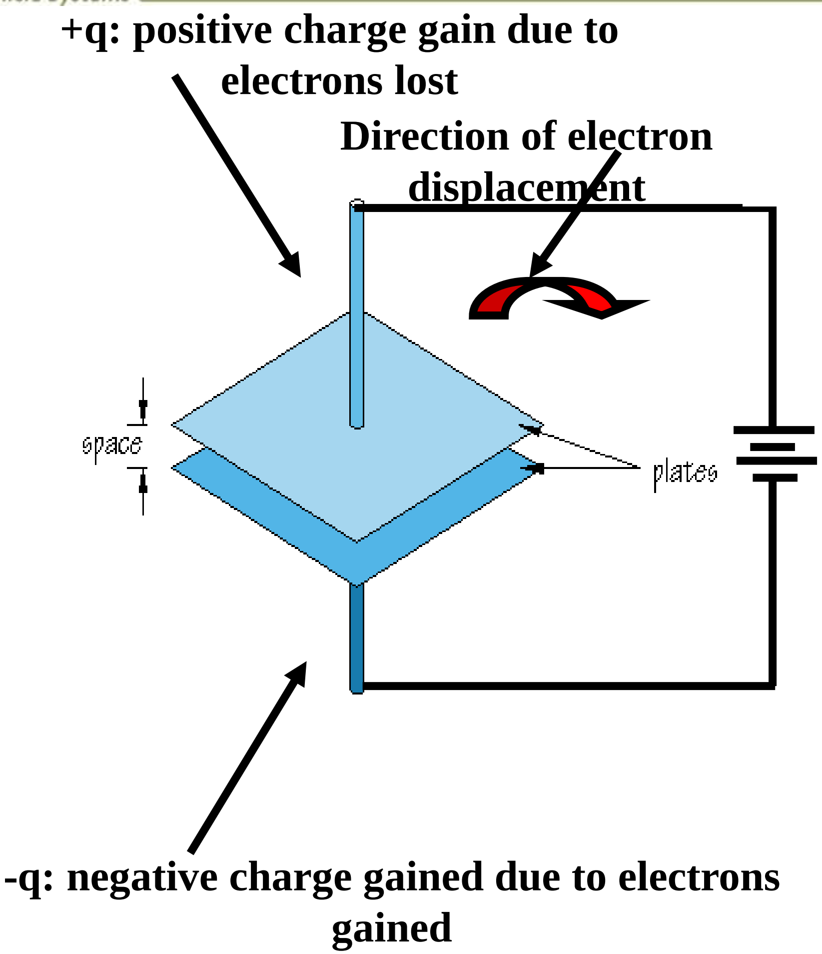
C is the ability of a body to store an electric charge (unit: F - Farad)

The the V-I characteristic of a capacitor is:

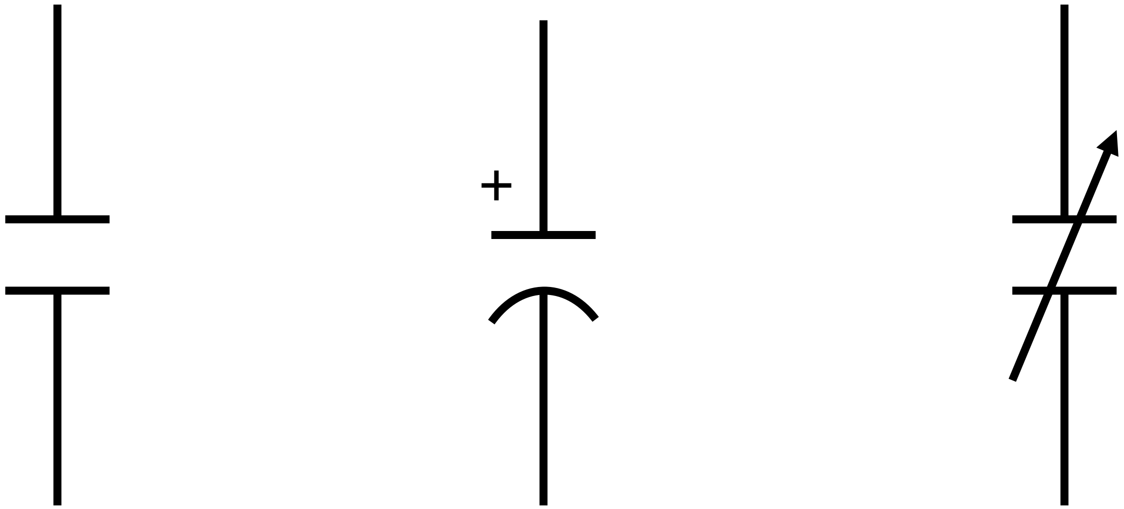
$$I(t) = \frac{dQ}{dt} = C * \frac{dV}{dt}$$

Capacitors (3)

- A capacitor is constructed using a pair of parallel conducting plates separated by an insulating material (dielectric).
- When the two plates of a capacitor are connected to a voltage source as shown, charges are displaced from one side of the capacitor to the other side, thereby establishing an electric field.
- The charges continue to be displaced in this manner until the potential difference across the two plates is equal to the potential of voltage source.

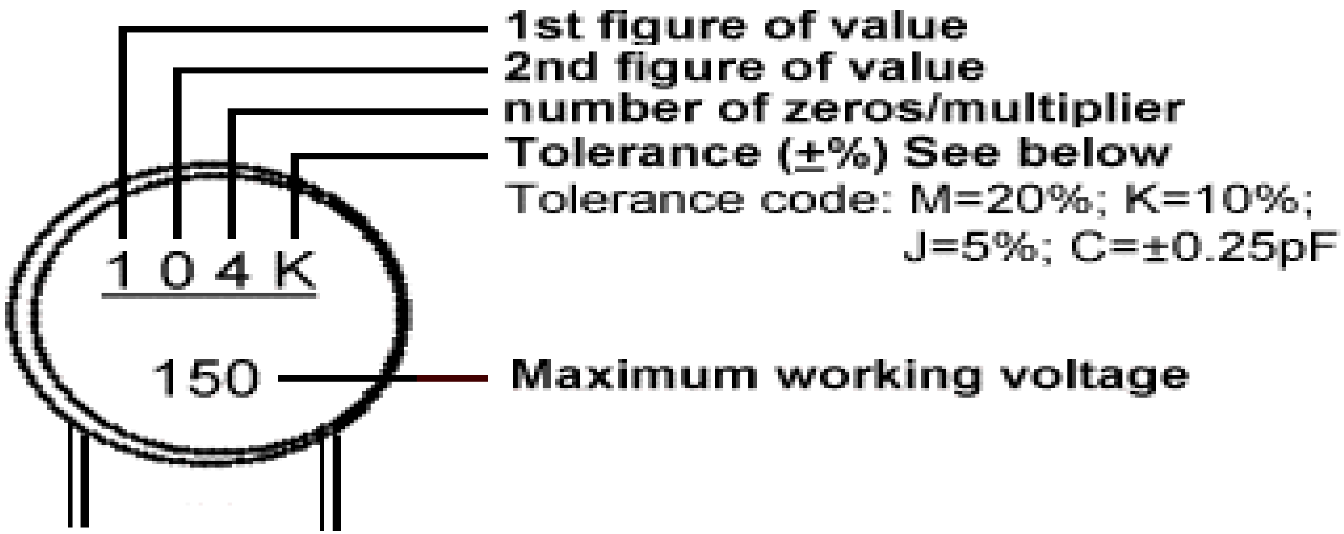


Capacitor symbols



Fixed capacitor | **Polarized capacitor** | **Variable capacitor**

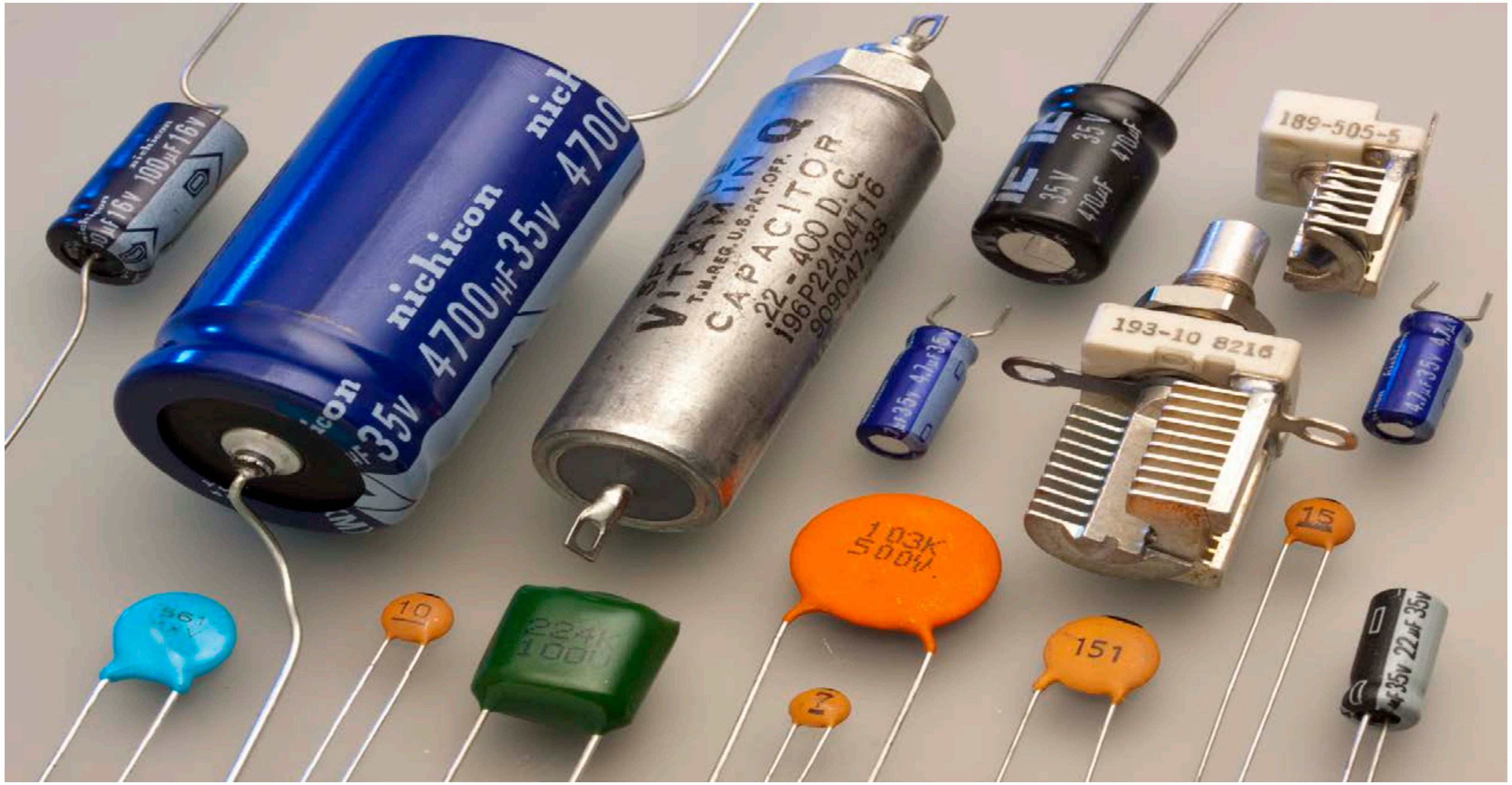
Capacitor Reading Example



$$10\times10^{4}\,\mathrm{pF}=10^{5}\times10^{-12}\,\mathrm{F}=10^{-7}\,\mathrm{F}=0.1\times10^{-6}\,\mathrm{F}=0.1\mu\mathrm{F}$$

- Thus, we have a 0.1µF capacitor with ±10% tolerance.

Capacitor Variatons



Inductors

- Inductor is a passive energy storage element that stores energy in the form of magnetic field.
- Inductor characteristic is governed by Faraday's law:

$$V(t) = \frac{d\lambda}{dt}$$

V = voltage induced across an inductor

λ = magnetic flux (unit: Webers, Wb) through the coil windings (a coil made using resistance-less wires) due to current flowing through inductor.

Inductors (2)

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- For an ideal coil, magnetic flux is proportional to current, so

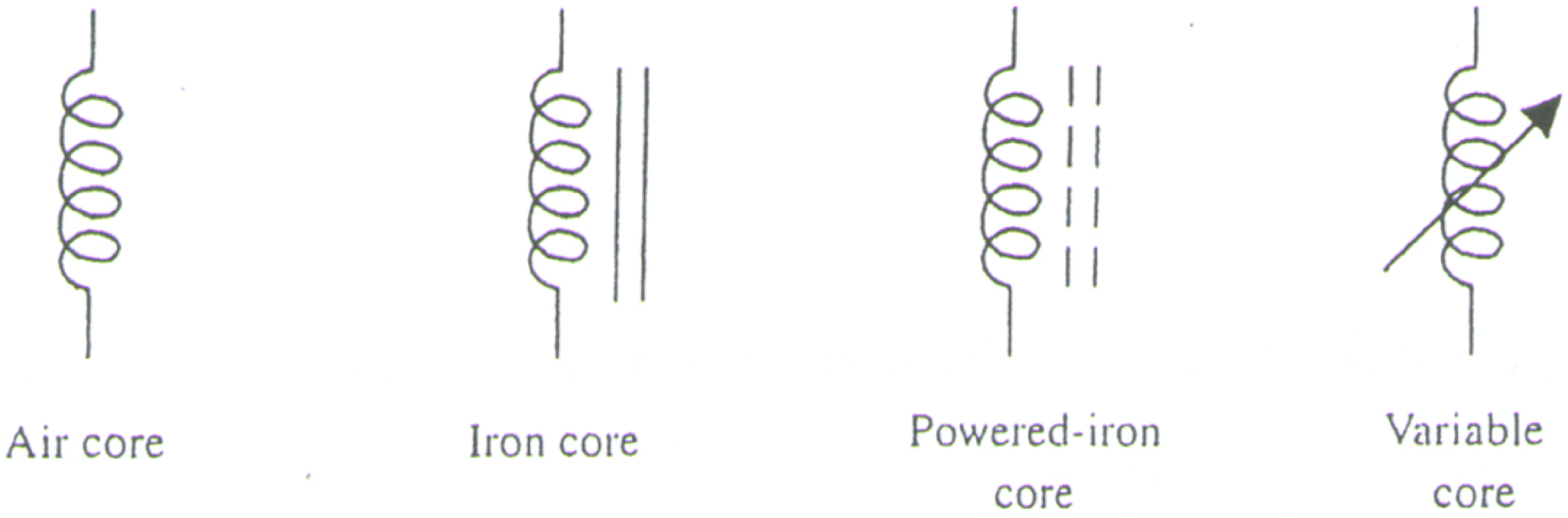
$$\lambda \sim I \;\; or \;\; \lambda = LI$$

- L is constant of proportionality, called inductance (unit: Henry, Wb/Amp).
- So, now, the V-I characteristic of an inductor is:

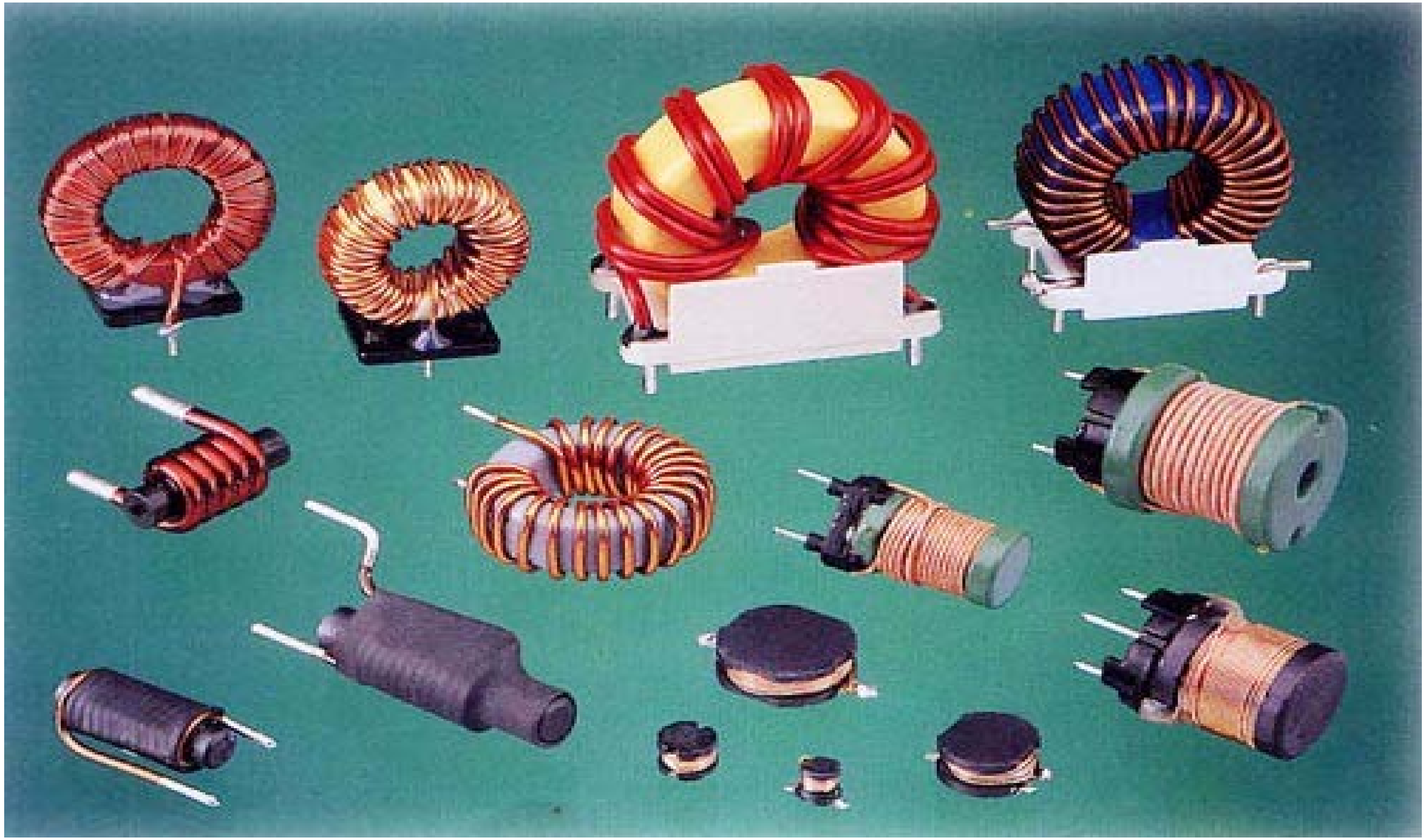
$$V(t) = \frac{d}{dt}(\lambda) = \frac{d}{dt}(LI) = L\frac{dI}{dt} \qquad I(t) = \frac{1}{L}\int_0^t V(\tau)d\tau$$

- The above V-I characteristics demonstrate that the current through an inductor can not be altered instantaneously.

Inductor symbols

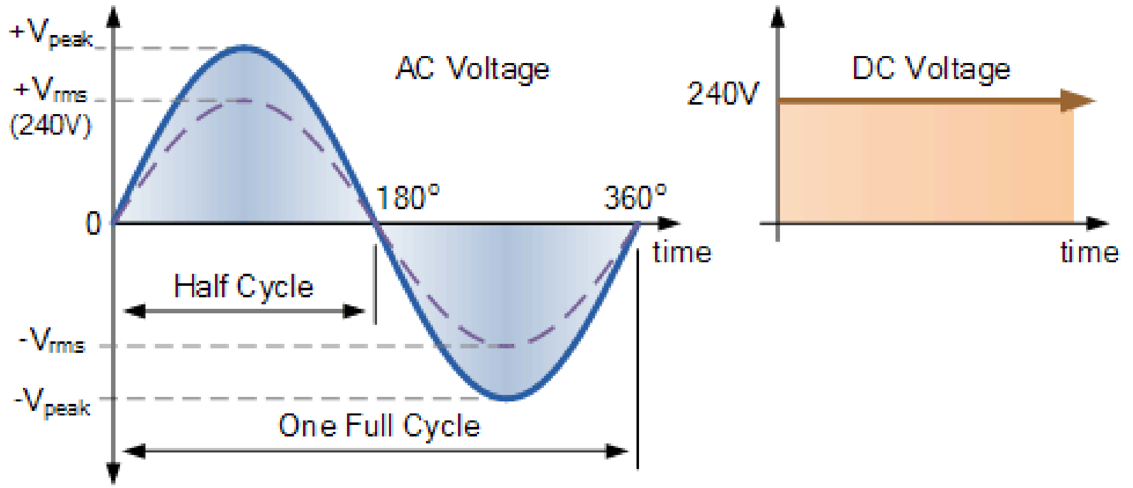


Inductor variatons



Measuring AC Voltage

- Vpeak – peak to 0 voltage
- Vpp – peak to peak voltage
- Vaverage
- VRMS – Root Mean Square voltage



- VRMS - amount of AC power that produces the same heating effect as an equivalent DC power
- This is what gets measured on voltmeters (and ampmeters)

Measuring AC Voltage(2)

- V_{RMS} calculation

$$Vrms = \sqrt{\frac{1}{T}\int_0^T v(t)^2 dt}$$

- For sine waves only: $Vrms = Vpeak * \frac{1}{\sqrt{2}} = Vpeak * 0.7071$

Impedance

- Is defined as the frequency domain ratio of the voltage to the current.
  - In other words, it is the voltage–current ratio for a single complex exponential at a particular frequency ω.

- Polar form:

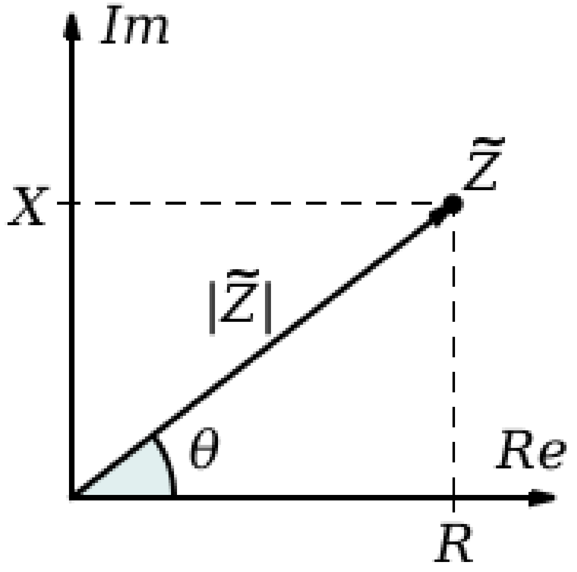
$$Z = |Z|\, e^{j * arg\,(Z)}$$

  - the magnitude |Z| represents the ratio of the voltage difference amplitude to the current amplitude
  - the argument arg(Z) (commonly given the symbol theta) gives the phase difference between voltage and current.

Impedance(2)

- Cartesian form:

$$Z = R + jX$$



  - the real part of impedance is the resistance R
  - the imaginary part is the reactance X.

- Ohm' Law

$$V = I * Z = I * |Z|e^{j*arg\,(Z)}$$

Impedance and Phasors

Resistor

Z = R

Voltage – current are in phase

Pure resistive – no complex part

Capacitor

$$Z = \frac{1}{jwC}$$

Capacitive reactance

$$Xc = \frac{1}{wC}$$

Current leads voltage by 90°

Inductance

Z = jwL

Inductive reactance

$X_L = wL$

Voltage leads current by 90°