CENG2030 FUNDAMENTALS OF EMBEDDED SYSTEM DESIGN

LECTURE 4: CIRCUIT ANALYSIS

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- Common Electronic Components
- Ohm's Law
- KCL & KVL
- Voltage & Current Divider

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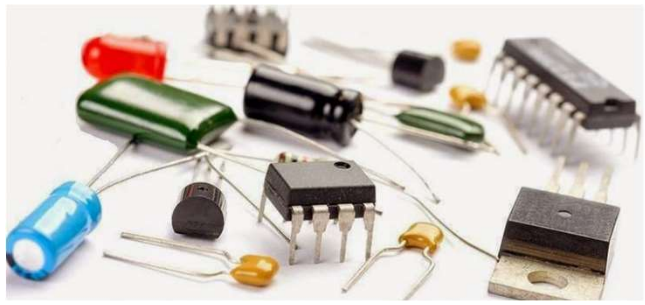
COMMON ELECTRONIC COMPONENETS

- Resistor
- Capacitor
- Inductor

- Diode
- Transistor
- Voltage Regulator



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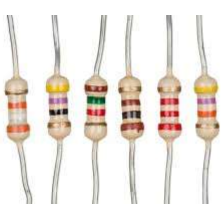
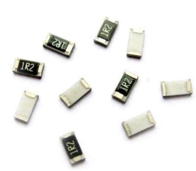
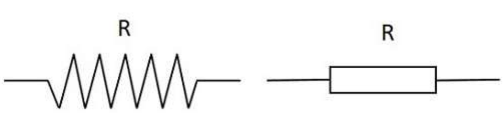
RESISTOR

- Resistor

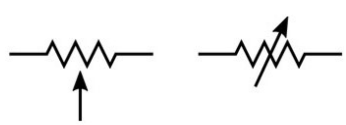






Symbol for a fixed resistor

- Variable Resistor



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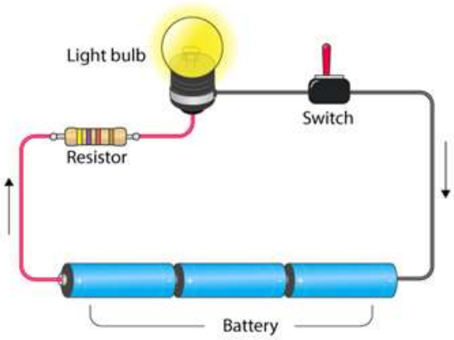
RESISTOR

- A resistor is a passive two-terminal electrical component that implements electrical resistance as a circuit element

- Uses of resistors:
  - To reduce current flow
  - To adjust signal levels
  - To divide voltages
  - To bias active elements
  - To terminate transmission lines



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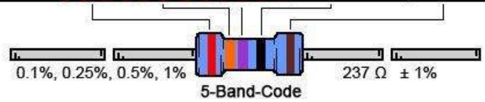
RESISTOR COLOR CODE

- 4-Band-Code Example

- 1st band = Green → 5
- 2nd band = Blue → 6
- 3rd band = Yellow → 10KΩ
- 4th band = Gold → ±5%

- 56x10KΩ ±5%
- = 560KΩ ±5%

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		± 0.05%
White	9	9	9		
Gold				0.1Ω	± 5% (J)
Silver				0.01Ω	± 10% (K)



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OHM'S LAW

- For purposes of circuit analysis, we refer the current in the resistor to the terminal voltage as:

$$v = iR$$

- v = the voltage in volts
- i = the current in amperes
- R = the resistance in ohms (Ω)

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CONDUCTANCE

- The reciprocal of the resistance is referred to as conductance.

$$G = \frac{1}{R}$$

- G = the conductance in siemens (S)
- R = the resistance in ohms

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POWER IN A RESISTOR

- Power: $$p = vi$$
- Power in terms of current: $$p = i^2 R$$
- Power in terms of voltage: $$p = \frac{v^2}{R}$$

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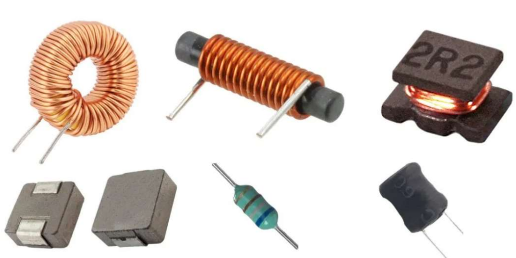
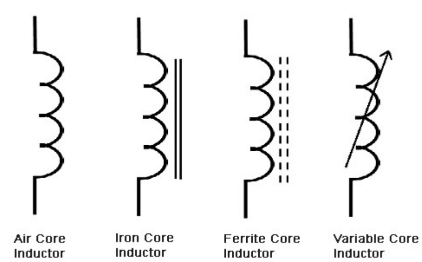
INDUCTOR





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INDUCTOR

- Inductance is the circuit parameter used to describe an inductor.

- Inductance
  - is symbolized by the letter L,
  - is measured in henrys (H),
  - is represented graphically as a coiled wire, and
  - is a consequence of a conductor linking a magnetic field.

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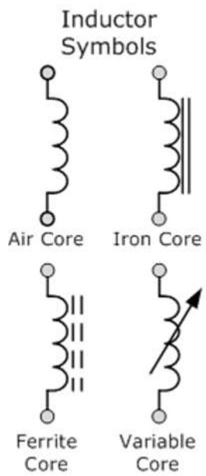
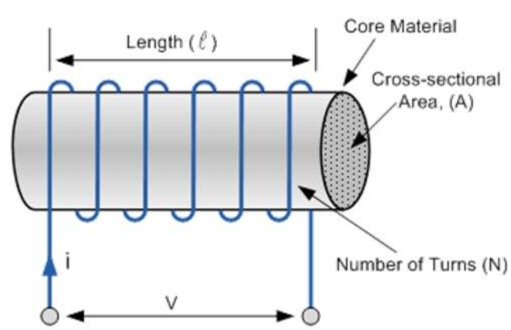
SYMBOLS OF INDUCTORS





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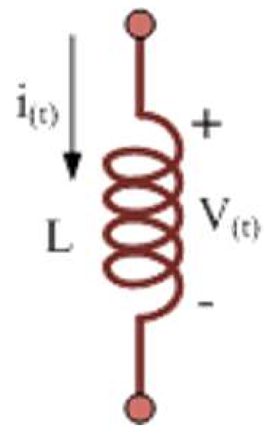
INDUCTOR V-I EQUATION

$$v = L\frac{di}{dt}$$

- The current reference is in the direction of the voltage drop across the inductor.
  - v is measured in volts
  - L in henrys
  - i in amperes
  - t in seconds



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INDUCTOR I-V EQUATION

$$i(t) = \frac{1}{L}\int_{t_0}^{t} v(\tau)d\tau + i(t_0)$$

- i(t) is the current corresponding to t,
- $i(t_0)$ is the value of the inductor current when we initiate the integration

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INDUCTOR POWER EQUATION

- Power in an inductor:

$$p = vi$$
$$= iL\frac{di}{dt}$$

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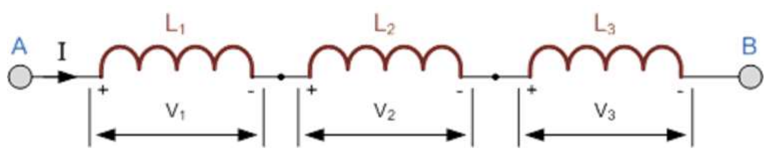
INDUCTORS IN SERIES

- Inductors in series are added together because the number of coil turns is effectively increased, with the total circuit inductance L_T being equal to the sum of all the individual inductances added together.



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INDUCTORS IN SERIES

- Inductors in series have a common current, I, flowing through them:
- $I_{L1} = I_{L2} = I_{L3} = I_{AB}$
- So the total inductance is given as:

$$L_T \frac{di}{dt} = L_1 \frac{di}{dt} + L_2 \frac{di}{dt} + L_3 \frac{di}{dt}$$

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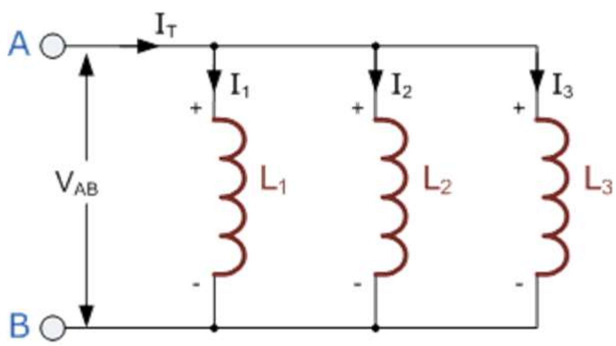
INDUCTORS IN PARALLEL

- $V_{L1} = V_{L2} = V_{L3} = V_{AB}$



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PARALLEL INDUCTANCE

- The total inductance L_T for N inductors in parallel.

$$\frac{1}{L_T} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} \cdots\cdots + \frac{1}{L_N}$$

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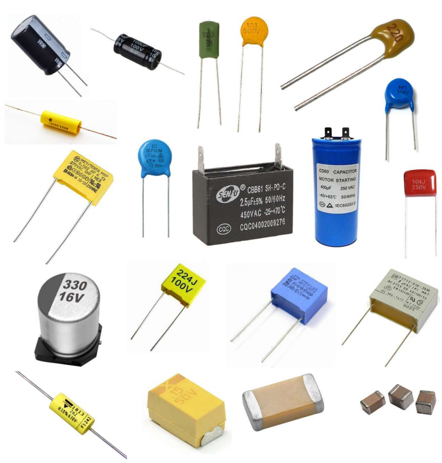
CAPACITOR



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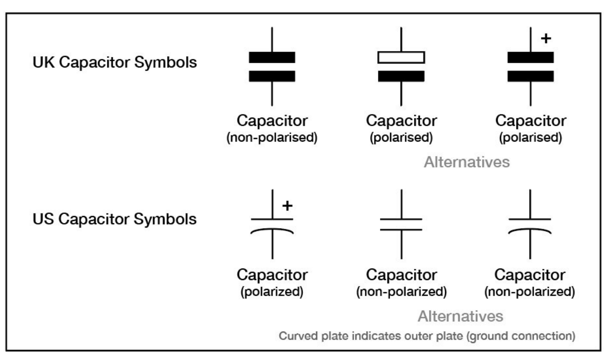

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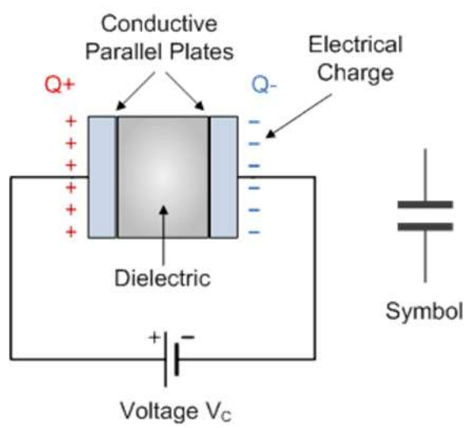
CAPACITOR CONSTRUCTION AND SYMBOL

- Capacitor, sometimes referred to as a Condenser, is a passive device, and one which stores its energy in the form of an electrostatic field producing a potential difference (Static Voltage) across its plates.
- In its basic form a capacitor consists of two or more parallel conductive (metal) plates that do not touch or are connected but are electrically separated either by air or by some form of insulating material such as paper, mica or ceramic called the Dielectric.



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CHARGE ON A CAPACITOR

- Capacitors can store the electrical charge (Q) between its plates is proportional to the applied voltage, V for a capacitor of known capacitance in Farads.

$$Q = C \times V \quad \text{Coulombs}$$

- The actual charge Q on the plates of the capacitor and can be calculated as:

$$C = \frac{Q}{V} \quad \text{or} \quad V = \frac{Q}{C}$$

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DISPLACEMENT CURRENT

- As the voltage varies with time, the displacement of charge also varies with time, causing what is known as the displacement current.

- The current is proportional to the rate at which the voltage across the capacitor varies with time.

$$i = C\frac{dv}{dt}$$

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CAPACITOR V-I EQUATION

- Carrying out the integration of both sides, we have:

$$v(t) = \frac{1}{C}\int_{t_0}^{t} i(\tau)d\tau + v(t_0)$$

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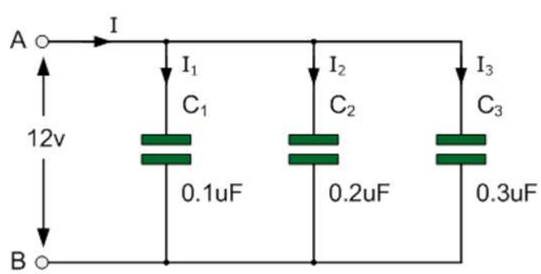
CAPACITOR POWER EQUATION

- We can derive the power relationship for the capacitor.

$$p = vi$$
$$= vC\frac{dv}{dt}$$

CAPACITORS IN PARALLEL

- Capacitors in Parallel have a common voltage supply across them giving
- $V_{C1} = V_{C2} = V_{C3} = V_{AB}$



CAPACITORS IN PARALLEL

- Based on the above circuit, we have

$$i_1 = C_1 \frac{dv}{dt}, \quad i_2 = C_2 \frac{dv}{dt}, \quad i_3 = C_3 \frac{dv}{dt}$$

$$i_T = i_1 + i_2 + i_3$$

$$\therefore i_T = C_1 \frac{dv}{dt} + C_2 \frac{dv}{dt} + C_3 \frac{dv}{dt}$$

$$i_T = \left(C_1 + C_2 + C_3\right)\frac{dv}{dt}$$

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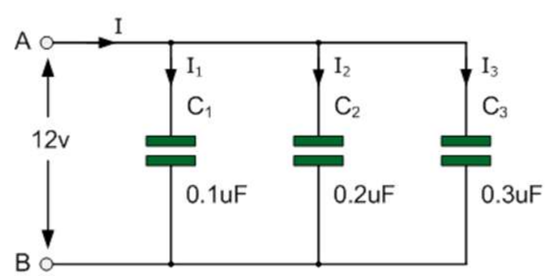
CAPACITORS IN PARALLEL



$$C_T = C_1 + C_2 + C_3 + \ldots.etc$$

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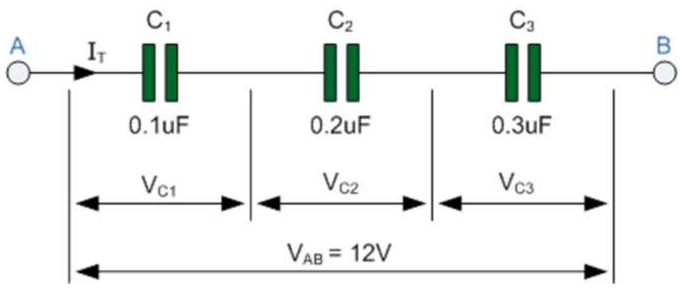
CAPACITORS IN SERIES

- When capacitors are in series, the charging current flowing through the capacitors is the same for all capacitors as it only has one path to follow and $i_T = i_1 = i_2 = i_3$ etc



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CAPACITORS IN SERIES

- Capacitors in series all have the same current so each capacitor stores the same amount of charge regardless of its capacitance.

- QT = Q1 = Q2 = Q3

$$V_{AB} = V_{C1} + V_{C2} + V_{C3} = 12V$$

$$V_{C1} = \frac{Q_T}{C_1},\ V_{C2} = \frac{Q_T}{C_2},\ V_{C3} = \frac{Q_T}{C_3}$$

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CAPACITORS IN SERIES

- The total value for capacitors in series equals the reciprocal of the sum of the reciprocals of the individual capacitances.

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + \ldots.\text{etc}$$

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KIRCHHOFF'S LAWS

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KIRCHHOFF'S LAWS

- A circuit is said to be solved when the voltage across and the current in every element have been determined.
- Ohm's law is an important equation for deriving such solutions.
- However, Ohm's law may not be enough to provide a complete solution.

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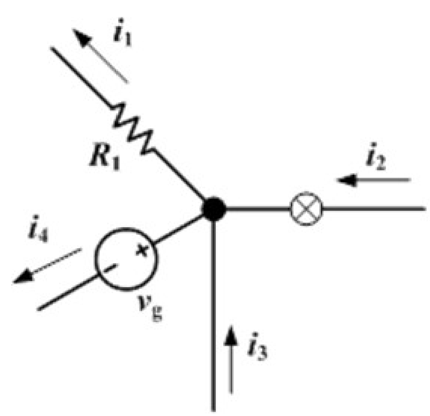
KIRCHHOFF'S CURRENT LAW (KCL)

- Kirchhoff's Current Law (KCL) states that the algebraic sum of all the currents at any node in a circuit equals zero.
- For example in the figure, $i_1 - i_2 - i_3 + i_4 = 0$



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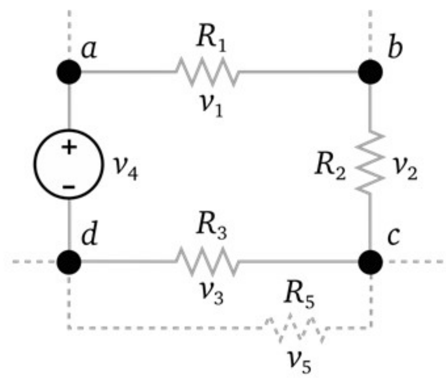
KIRCHHOFF'S VOLTAGE LAW (KVL)

- Kirchhoff's Voltage Law (KVL) states that the algebraic sum of all the voltages around any closed path in a circuit equals zero.
- For example in the figure, $v_1 + v_2 + v_3 + v_4 = 0$



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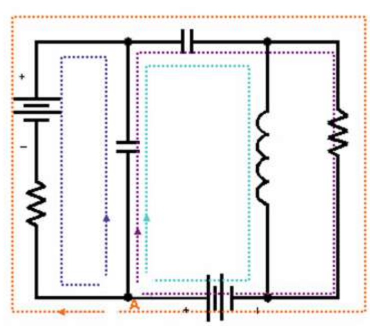
CLOSED PATH

- A closed path is also called a loop.
- Starting at an arbitrarily selected node, we trace a closed path in a circuit through selected basic circuit elements and return to the original node with out passing through any intermediate node more than once.



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ANY QUESTIONS ?

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