MODULE 1

Electronic Components, Sources and Measuring Equipment’s

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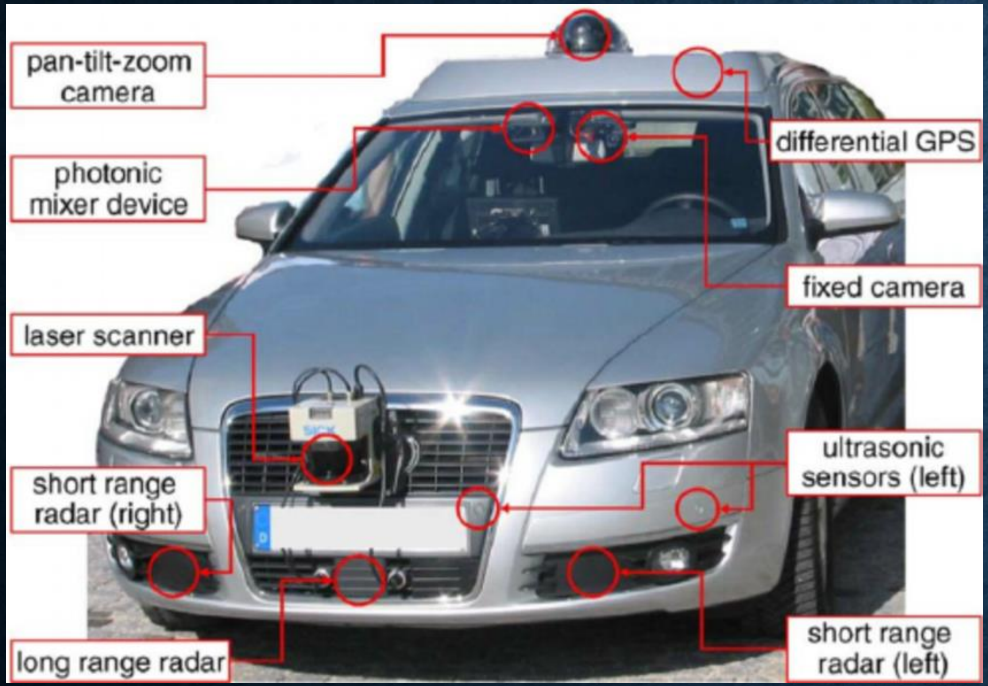
OUTLINE

- Evolution of Electronics
- Impact of Electronics in Industry and Society
- Familiarization of Resistors, Capacitors, Inductors | Color Coding – types and specifications
- Electro-mechanical components
- Relay and Contactors
- Regulated Power supply, Function Generator
- Multimeter
- CRO

TECHNOLOGY VS ELECTRONICS



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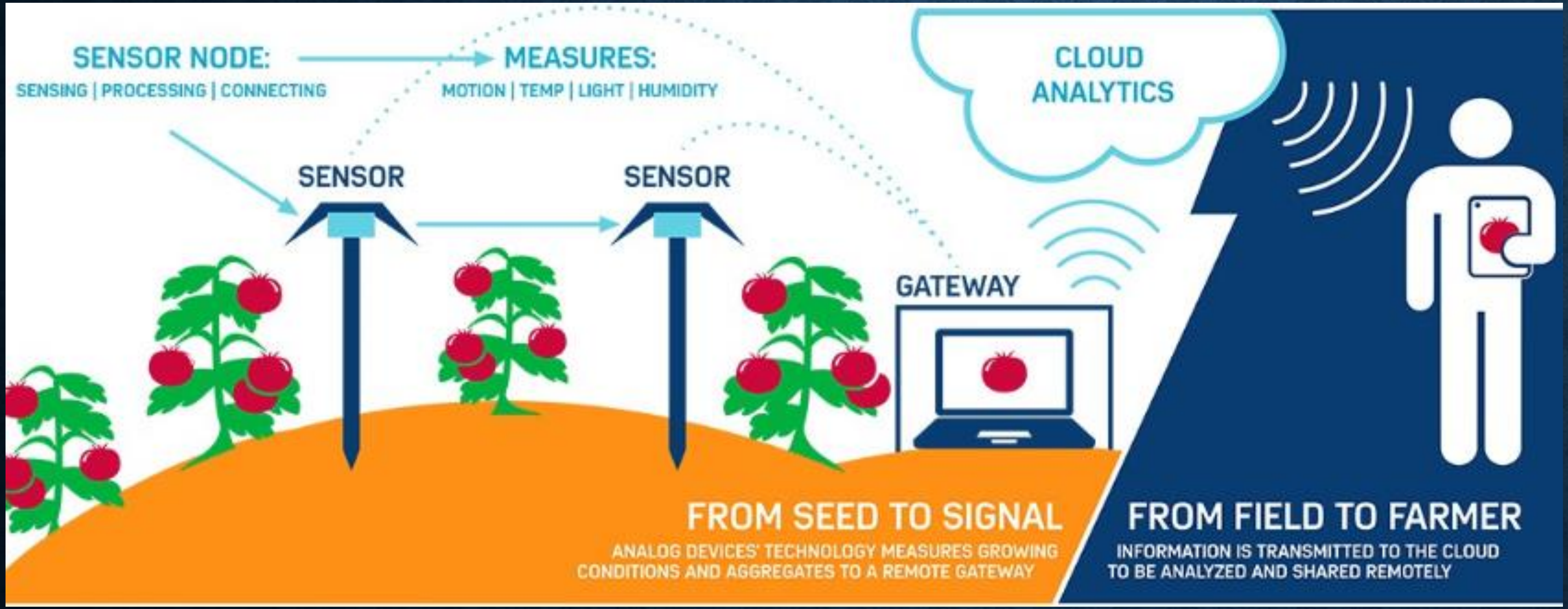
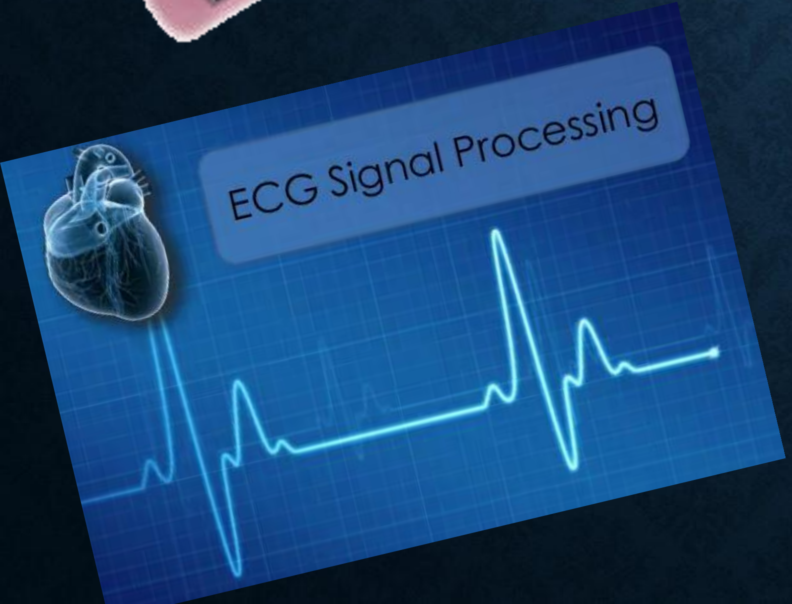
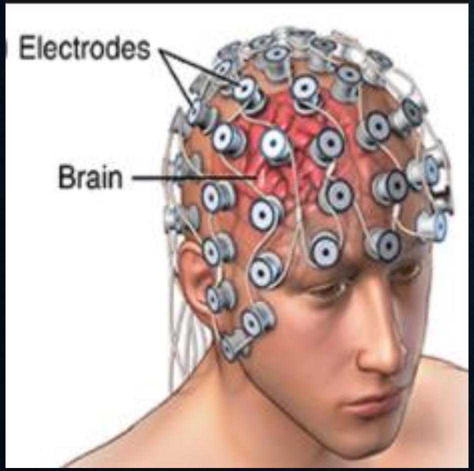


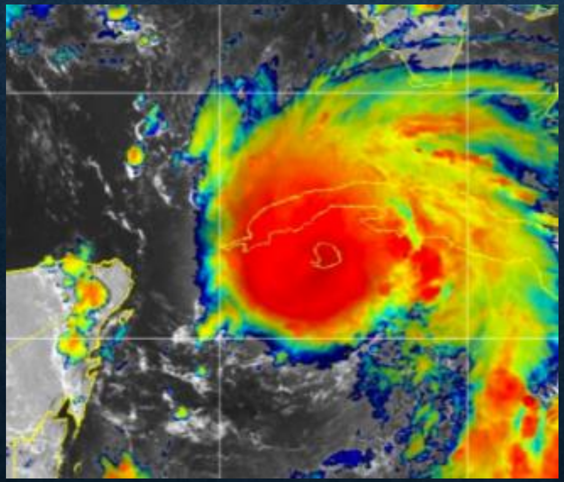
TECHNOLOGY VS ELECTRONICS



TECHNOLOGY VS ELECTRONICS



TECHNOLOGY VS ELECTRONICS



HISTORY OF ELECTRONICS

- There will be many inventions, but some breakthrough inventions for electronics are,

    Vacuum tubes (Gas)

    Transistors (Semiconductors)

    Integrated circuits (IC/chip)

    Microprocessor

    Artificial Intelligence

EVOLUTION OF ELECTRONICS

1900
- Vacuum tube (1st generation)

1947
- Transistor (2nd generation)

1958
- IC (3rd generation)

1960
- SSI (Small Scale Integration)

1966
- MSI (Medium Scale Integration)

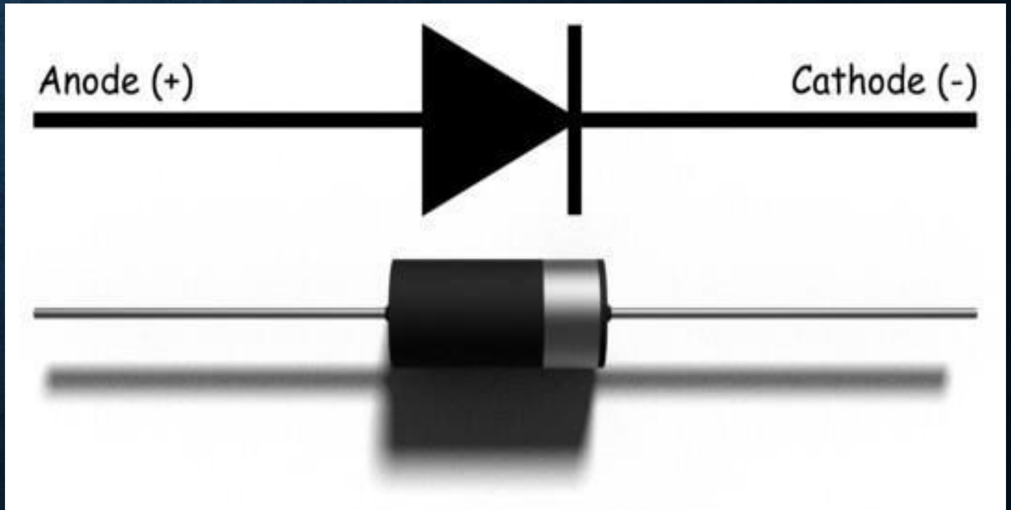
1969
- LSI (Large Scale Integration)

1975
- VLSI (Very Large Scale Integration) – 4th gen.

1995
- ULSI (Ultra Large Scale Integration) – 5th gen.

VACUUM TUBE

- The simplest vacuum tube, the diode
- Invented in 1904 by John Ambrose Fleming,
- Contains only a heated electron-emitting
- cathode and an anode.
- Electrons can only flow in one direction through the device (from the cathode to the anode)

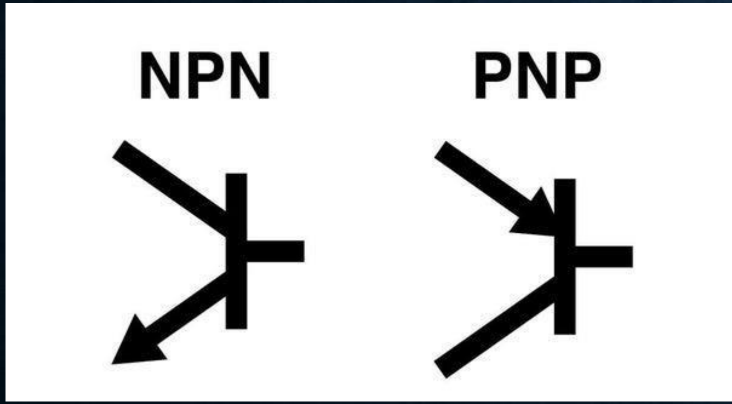


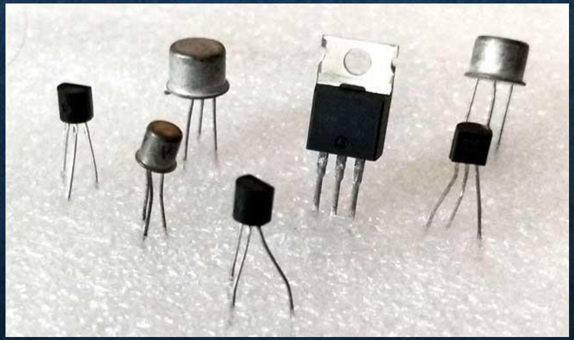
HOW VACUUM TUBE WORKS?

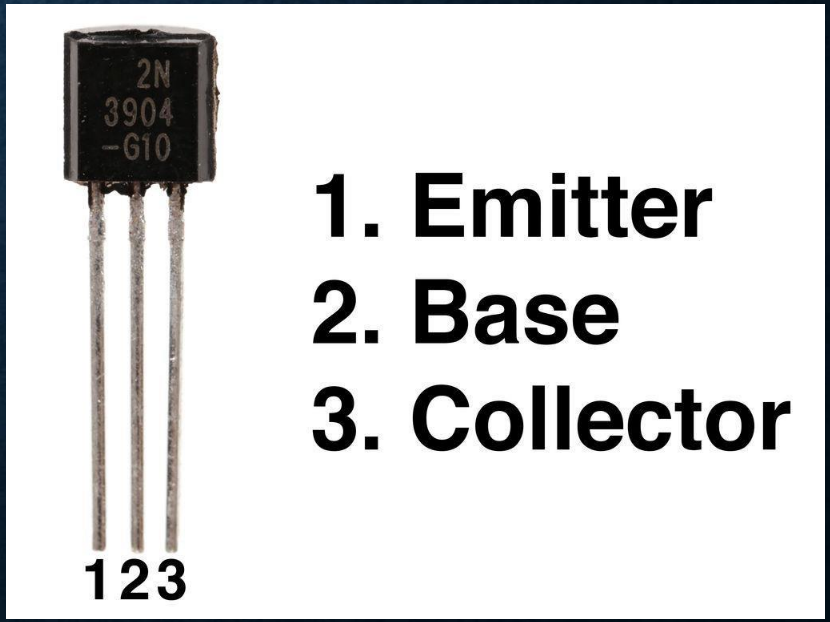
- https://www.youtube.com/watch?v=A7M1zcLfBKg&t=2s

TRANSISTOR

- A transistor can act as a switch or gate for electronic signals, opening and closing an electronic gate many times per second.
- It ensures the circuit is ON if the current is flowing and switched off if it isn't
- Semiconductor device | used to amplify or switch electronic signals and electrical power, Usually with at least three terminals for connection to an external circuit.

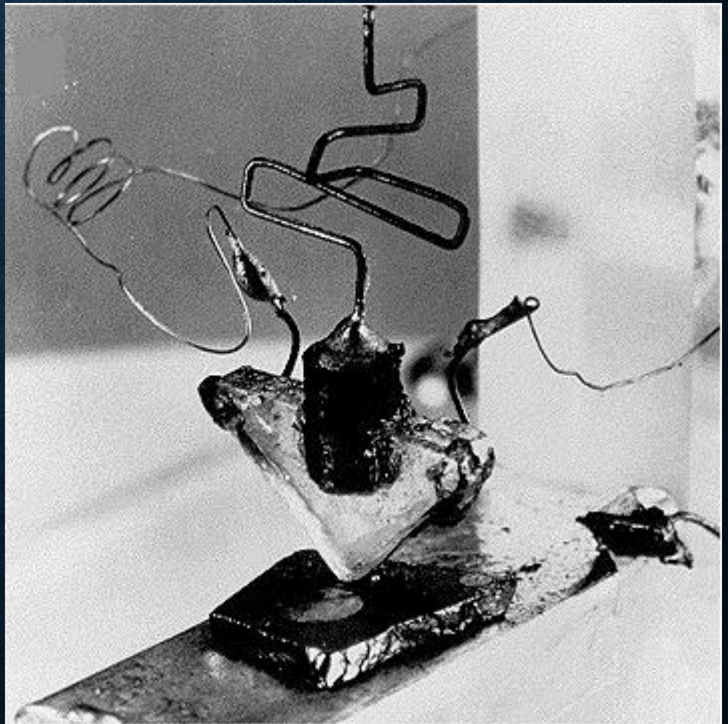






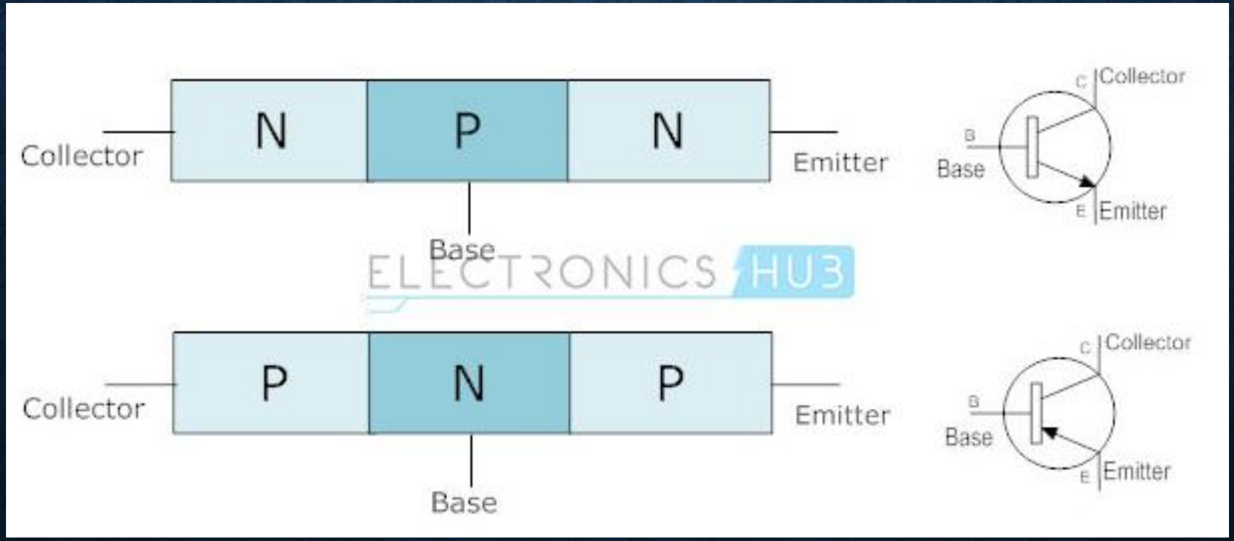
POINT TRANSISTORS

- 1947, John Bardeen, Walter Brattain and William Shockely, Bell Lab
- Revolutionized electronic industry
- Made it possible to develop an electronic computer
- Smaller and more efficient than its predecessors
- Field of electronics shifted from vacuum tubes (bulky and fragile device which consumed a significant power) to solid state devices
- Light weight, reliability, low cost and less power



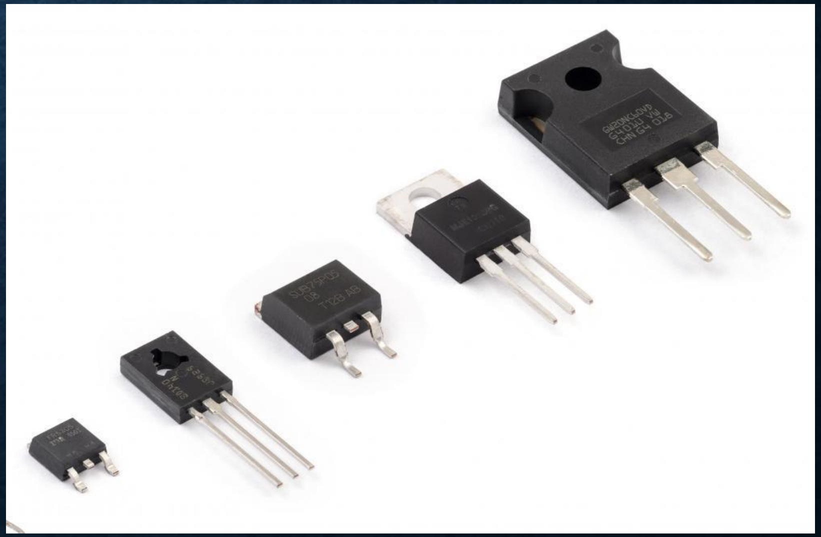
JUNCTION TRANSISTORS

- William Shockley, Bell Lab
- A transistor consists of three layers of semi conductor material
- Each layer is having the capability of transferring current to the other layers.
- Relatively bulky devices that were difficult to manufacture on a mass production basis



SILICON TRANSISTORS

- First commercial transistor was used in telephonic equipment
- Military computers in 1952
- In 1953 transistor is used in medical device (Hearing aid)
- First transistor is made of semiconductor material, polycrystals of Germanium (Ge) in 1950s

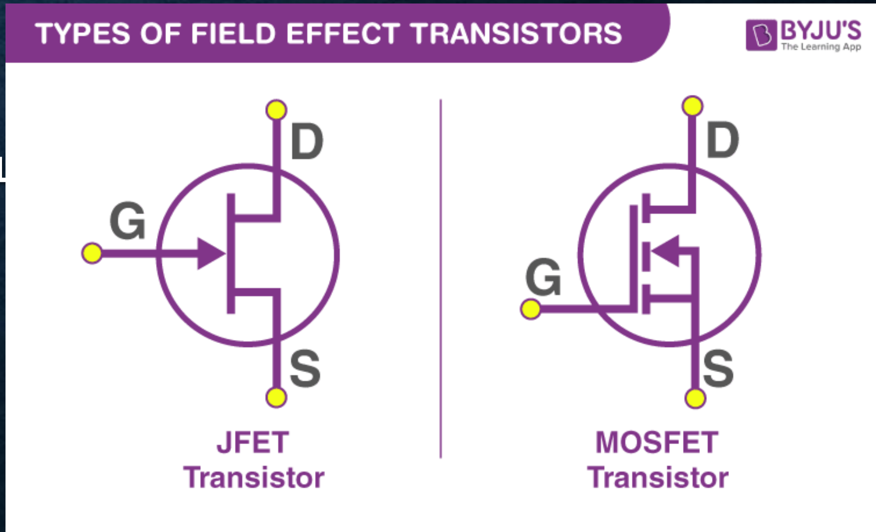


SILICON TRANSISTORS

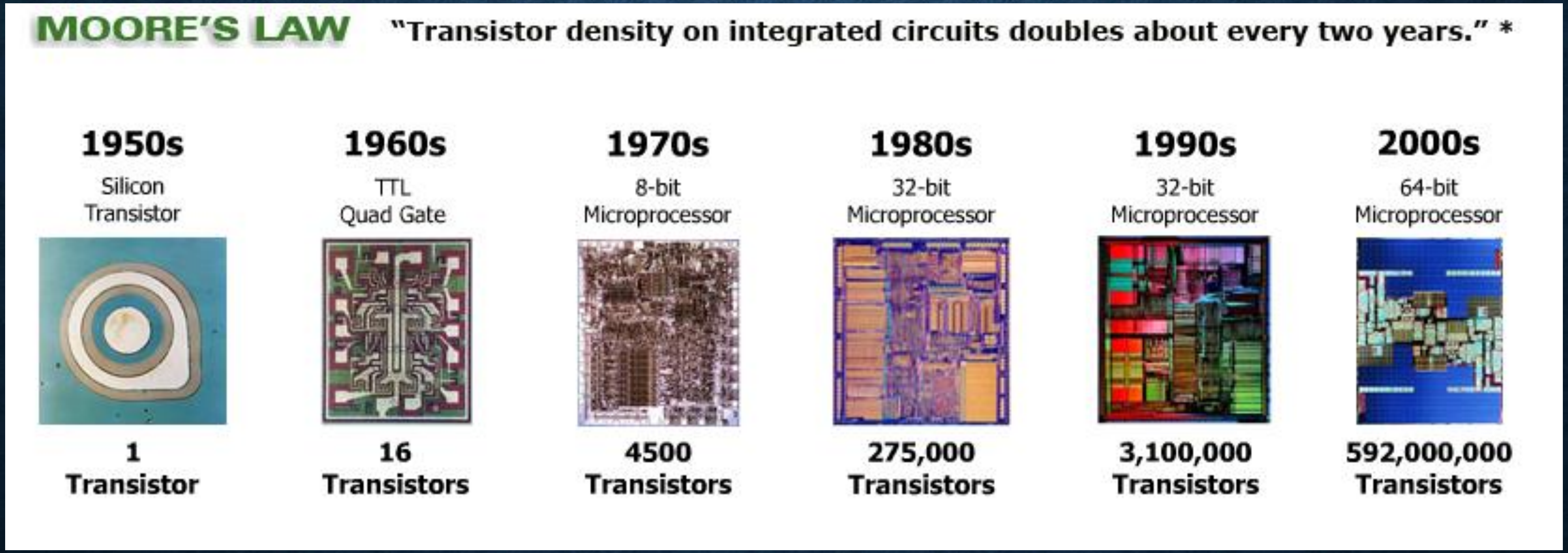
- Silicon (Si) replaced Ge with the development of techniques for purifications and crystal growth
- Si was considered as a better material due to less temperature sensitive resulting from relatively larger band gap
- Due to successful performance at high temperatures silicon transistor are used from the year 1954
- Beginning of sixties techniques were developed for integration of transistors, resistors and capacitors on a silicon chip

FIELD EFFECT TRANSISTOR

- 1959 Field effect transistor (MOSFET), Invented by Mohamed M. Atalla and Dawon Kahng at Bell Labs in 1959
- Consists of three layers metal (M-gate) ,Oxide(O-insulation), silicon (S-semiconductor)
- Basic element in most modern electronic equipment
- Most widely used electronic device in the world
- First truly compact transistor miniaturized and mass-produ

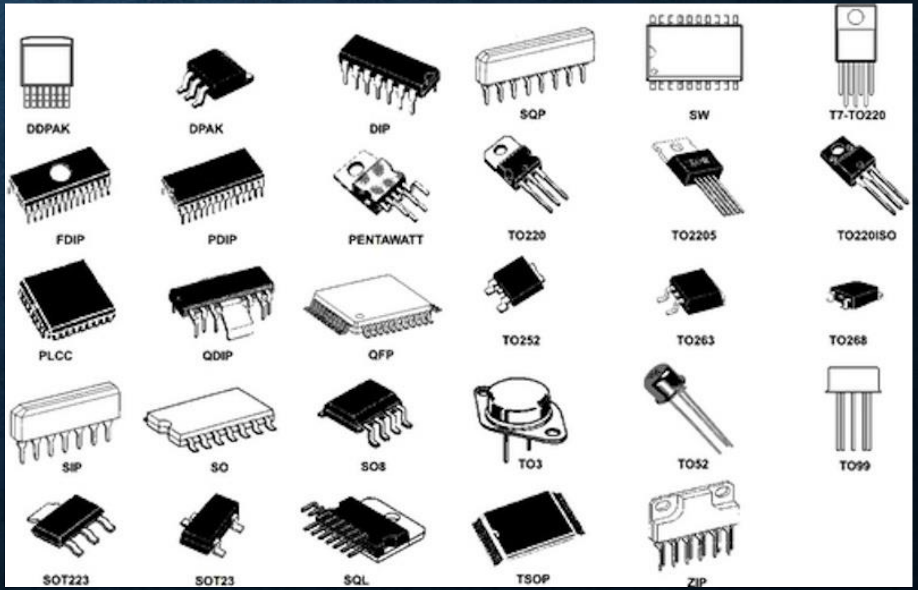


TRANSISTOR - ADVANCEMENT



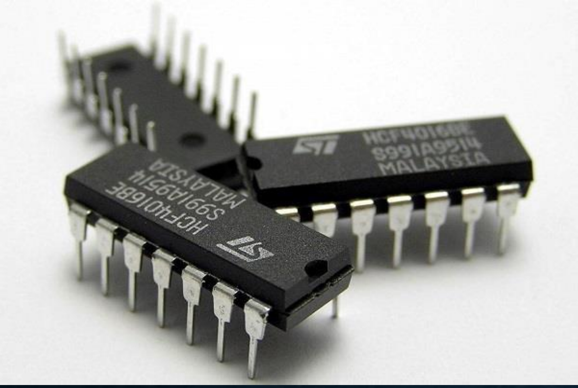
INTEGRATED CIRCUIT (IC)

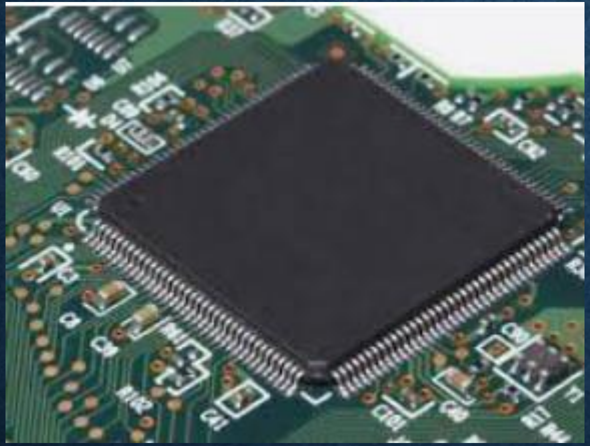
- Integration of larger number of electronic components on a single chip
- Beginning of microelectronics revolution
- 1958 Jack Kilby Texas instrument demonstrated first integrated circuit (IC/chip)

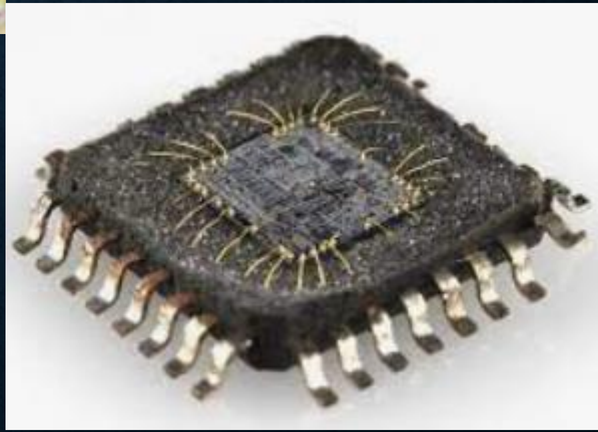


INTEGRATED CIRCUIT (IC)

- Chip or microchip, is a -semiconductor wafer on which a thousand or millions of tiny resistors, capacitors, and transistors are fabricated.







MICROPROCESSOR

- Thousands of integrated circuits were built onto a single silicon chip.
- Uses LOGIC (processes data)
- Can move data from one memory location to another.
- Can make decisions

SEMICONDUCTOR'S REACH

ARTIFICIAL INTELLIGENCE

- Biometric Detection and Recognition
- Human computer Interaction
- Email Spam and Malware Filtering
- Search Engine
- Social Media Services
- Surveillance and tracking
- Virtual Personal Assistants
- Online Customer Support
- Online shopping
- Cyber Security
- ………

IMPACT OF ELECTRONICS

- Communication
  - Telegram, Telephone, Fax, Radio, Mobile communication, Teleconference
- Military
  - RADAR, SONAR, Missile/Rocket launching, Wearable electronics
- Entertainment
  - TV, Social media, video game etc

IMPACT OF ELECTRONICS – CONT….

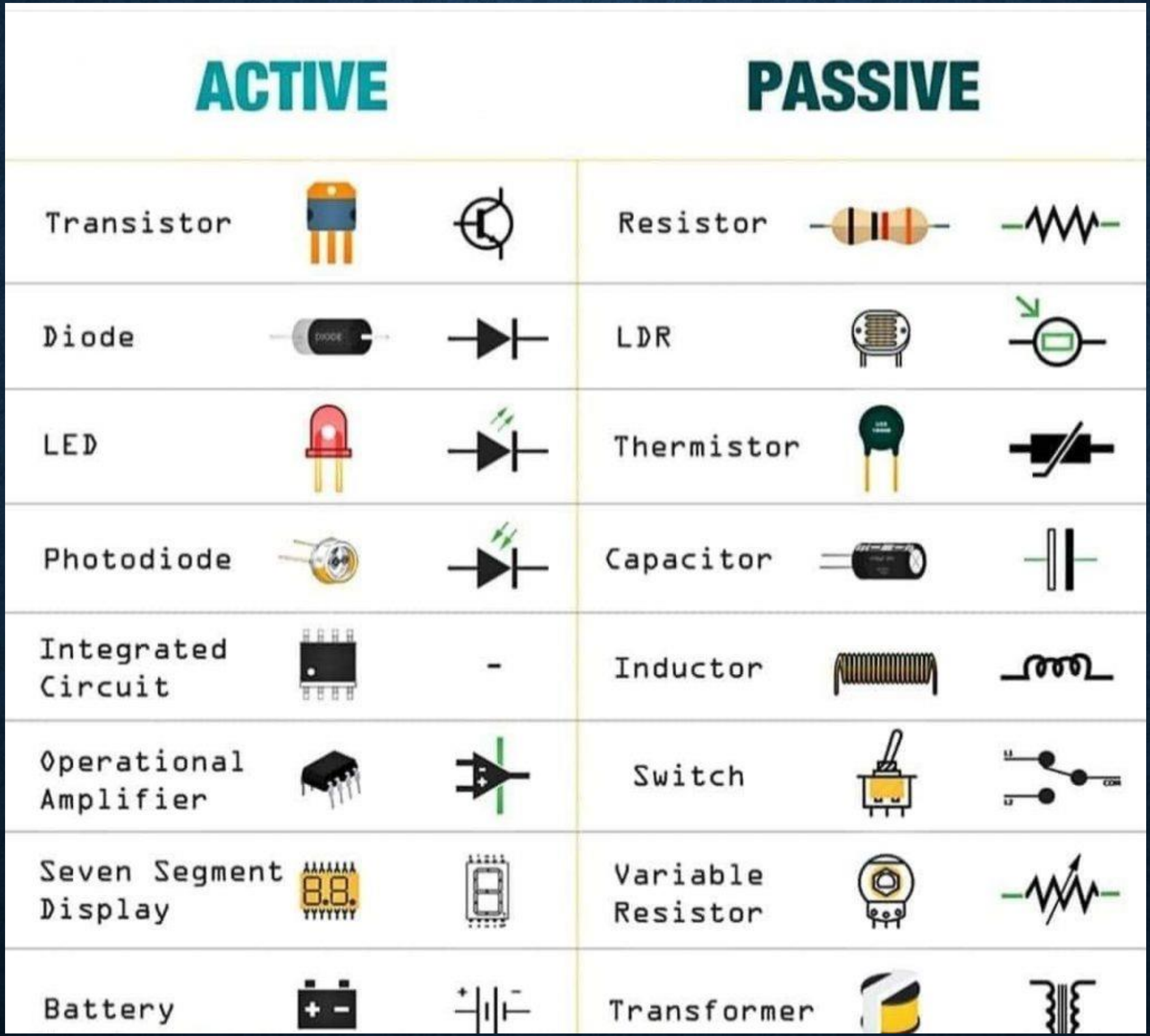
- Education
  - Online classes
- Automobile
  - ACB, GPS, driverless car
- Medical
  - ECG, EEG, X-Ray, MRI, CT scan, Telemedicine, Bio sensors etc

BASIC TERMINOLOGIES

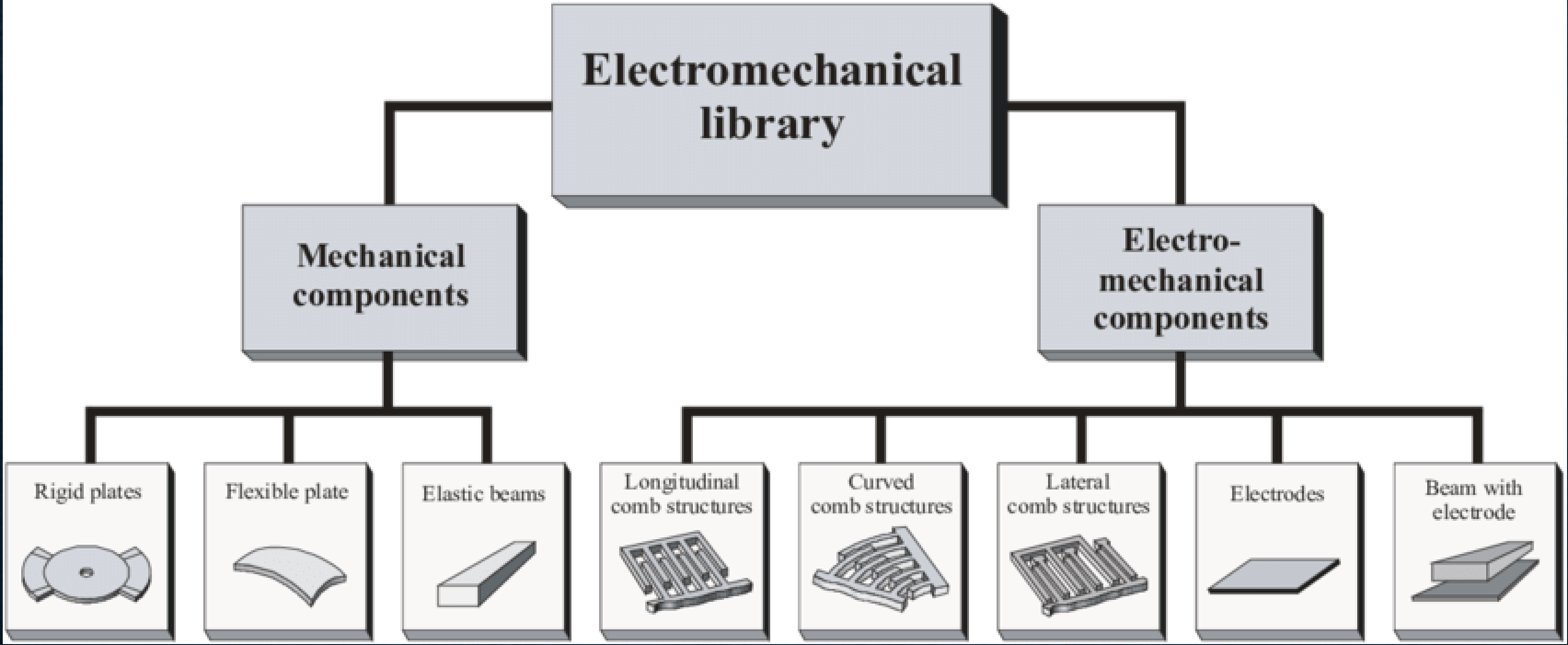
- **Charge (Q)** – most basic quantity in electric circuit.
- **Current (I)** – rate of change of charge passing through a conductor.
  - **direct current (DC)** – constant current
  - **alternating current (ac)** – time-varying current
- **Voltage (V)** – energy required to move a charge.
  - **DC voltage** – constant voltage
  - **ac voltage** – sinusoidal time-varying voltage
- **Power (P)** – rate of expending energy
  - **instantaneous power –** time-varying power ($p = vi$)
- **Energy (E)** – capacity to do work.

TYPES OF COMPONENTS

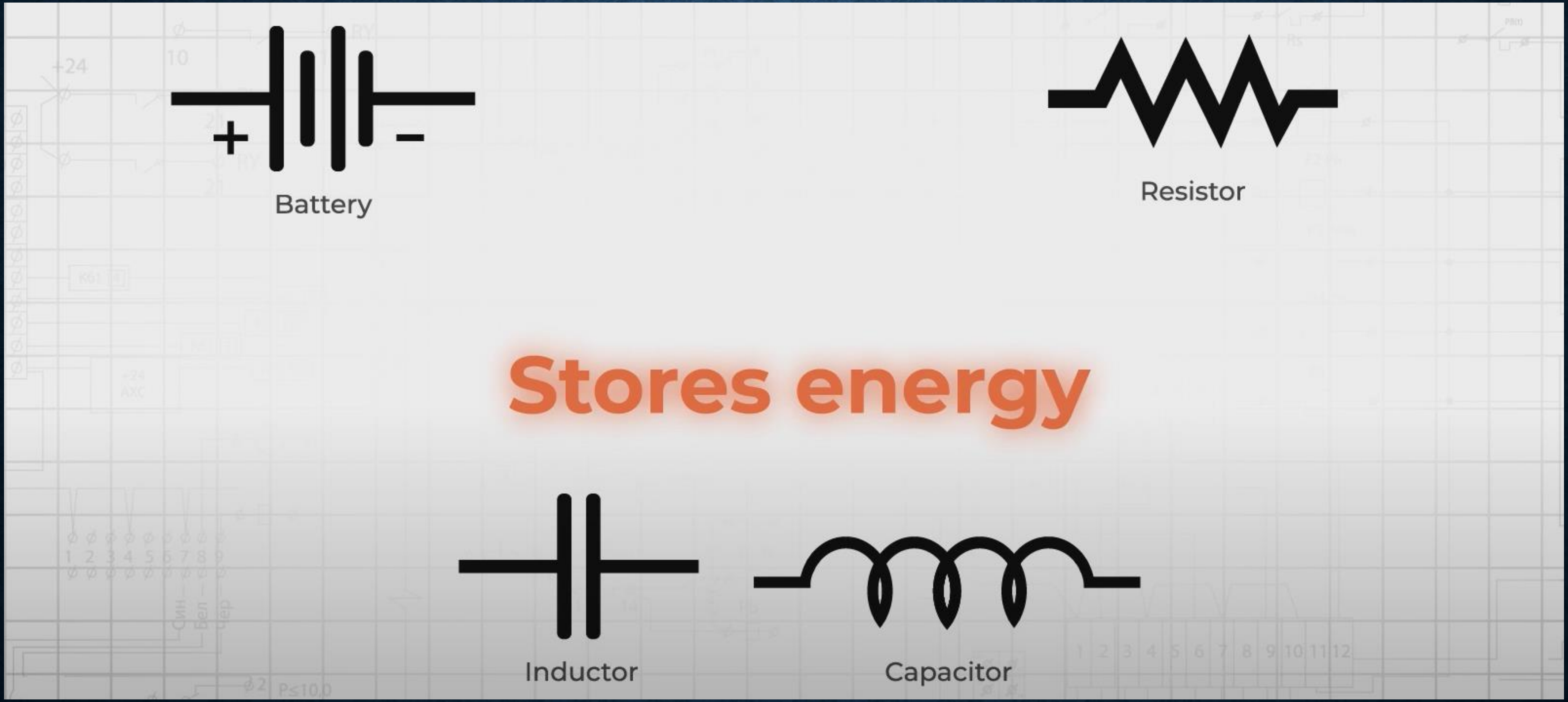
- Active Electronics
- Passive Electronics
- Electromechanical


ACTIVE
PASSIVE
Transistor
Resistor
Diode
LDR
LED
Thermistor
Photodiode
Capacitor
Integrated Circuit
-
Inductor
Operational Amplifier
Switch
Seven Segment Display
Variable Resistor
Battery
+ -
Transformer

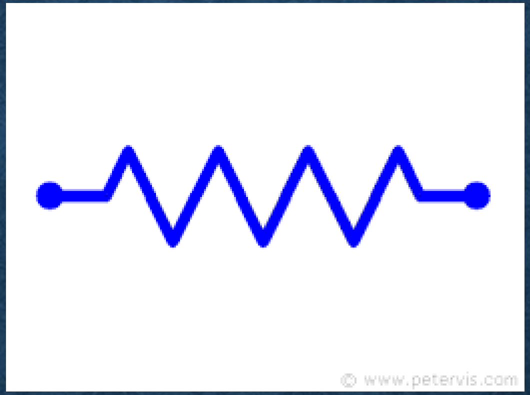
ELECTROMECHANICAL COMPONENTS

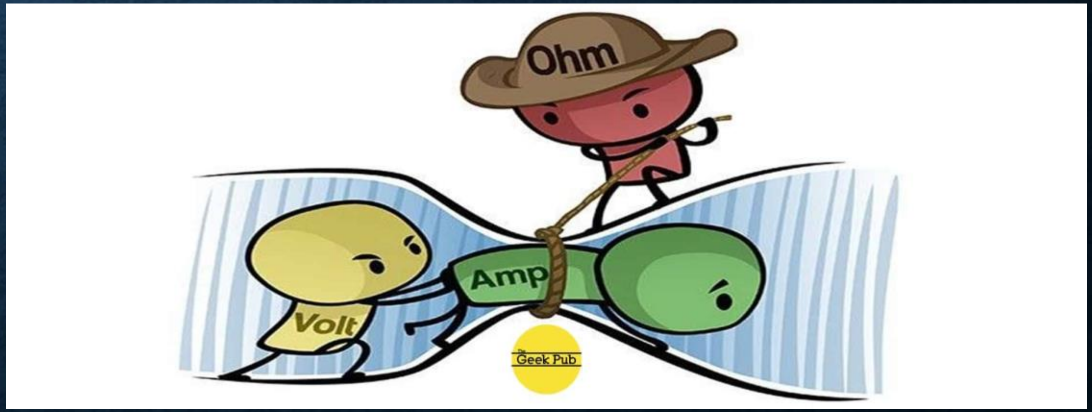


ELECTRONIC COMPONENTS


+
−
Battery
Resistor
Stores energy
Inductor
Capacitor

RESISTOR

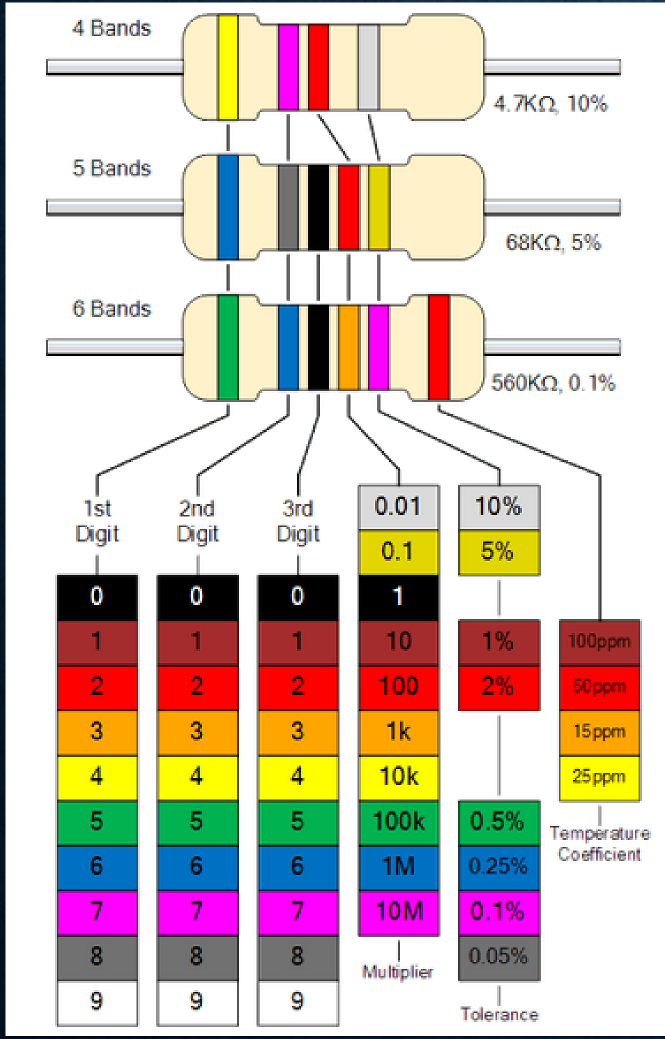




RESISTOR

- Electronic component that opposes the flow of current in an electrical circuit
- Resists – oppose the flow of current | control the current | Safety
- Resistance - ratio of voltage applied across a resistor terminal to the intensity of current through circuit | $V = IR$ or $R = V/I$
- Maintain stable resistance value, even when temperature of the environment changes
- Why important? Useful energy transfer as they are used to control the flow of current. Ex: Element in the kettle turns electric energy to heat energy – boil water
- Types : Fixed and variable resistor (Dimmer light & Volume control knobs on radios)

RESISTOR CODING



Digit, Digit, Multiplier = Colour, Colour x 10^{colour} in Ohm's (Ω)

Yellow Violet Red = 4 7 2 = 4 7 x 10^2 = 4700Ω
or 4k7 Ohm

Colour	Digit	Multiplier	Tolerance
Black	0	1	
Brown	1	10	± 1%
Red	2	100	± 2%
Orange	3	1,000	
Yellow	4	10,000	
Green	5	100,000	± 0.5%
Blue	6	1,000,000	± 0.25%
Violet	7	10,000,000	± 0.1%
Grey	8		± 0.05%
White	9		
Gold		0.1	± 5%
Silver		0.01	± 10%
None			± 20%

3, 4, 5 & 6 BAND RESISTOR

Number of Coloured Bands	3 Coloured Bands (E6 Series)	4 Coloured Bands (E12 Series)	5 Coloured Bands (E48 Series)	6 Coloured Bands (E96 Series)
1st Band	1st Digit	1st Digit	1st Digit	1st Digit
2nd Band	2nd Digit	2nd Digit	2nd Digit	2nd Digit
3rd Band	Multiplier	Multiplier	3rd Digit	3rd Digit
4th Band	–	Tolerance	Multiplier	Multiplier
5th Band	–	–	Tolerance	Tolerance
6th Band	–	–	–	Temperature Coefficient

RESISTOR COLOUR CODING

- https://www.calculator.net/resistor-calculator.html?bandnum=4&band1=brown&band2=green&band3=blue&multiplier=violet&tolerance=gold&temperatureCoefficient=brown&type=c&x=119&y=19
- In order to know the use the range https://www.allaboutcircuits.com/tools/resistor-color-code-calculator/

TYPES OF RESISTOR

- FIXED RESISTOR
  - Carbon Composite
  - Film
  - Wire Wound
  - Resistance Wire
- VARIABLE RESISTOR
  - Rheostat
  - Potentiometer
  - Thermistor
  - Humistor
  - Varistor
  - Photoresistor

CONNECTION - RESISTOR

- Series

Current remains CONSTANT

I = I1 = I2 = I3 … In

Voltage ADDs up

V = V1 + V2 + V3 … Vn

$$R_{eq} = R_1 + R_2 + \cdots + R_n$$

- Parallel

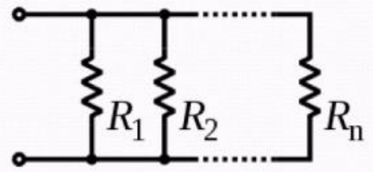
Current ADDs up

I = I1 + I2 + I3 … In

Voltage remains CONSTANT

V = V1 = V2 = V3 … Vn

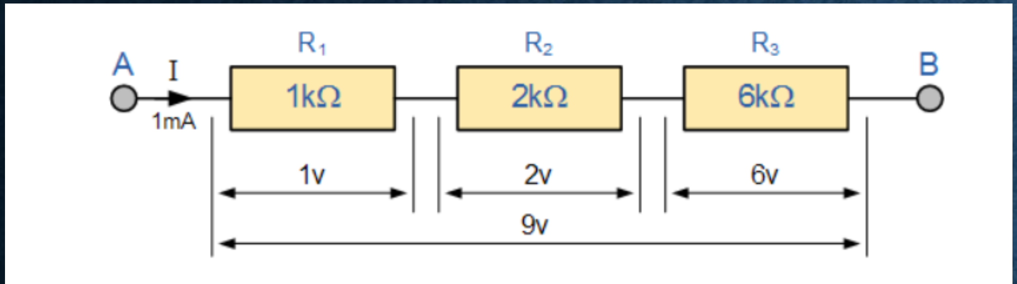
$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}$$



POWER RATING - RESISTOR

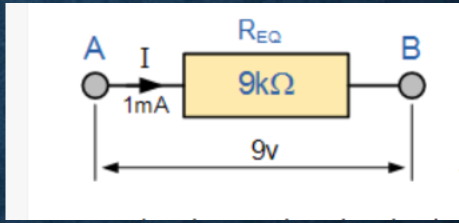
- Ohms Law : $V = I*R$
- Power rating: $P = V* I = I*R*I = I2R = V2 / R$
- Note: Larger the POWER, Greater the Physical size of the Resistor

RESISTOR - SERIES



$$I_{R1} = I_{R2} = I_{R3} = I_{AB} = 1mA$$

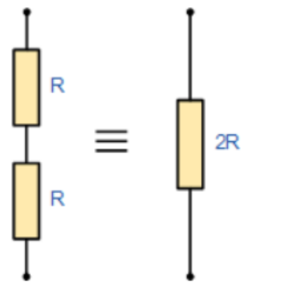
$$R_T = R_1 + R_2 + R_3$$



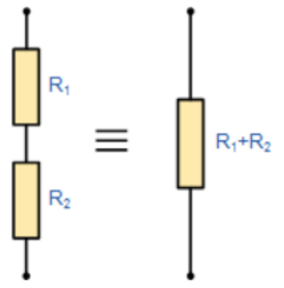
$$R_{EQ} = R_1 + R_2 + R_3 = 1k\Omega + 2k\Omega + 6k\Omega = 9k\Omega$$

a single value of resistance that can replace any number of resistors in series without altering the values of the current or the voltage in the circuit

RESISTOR - SERIES



If two resistances or impedances in series are equal and of the same value, then the total or equivalent resistance, R_T is equal to twice the value of one resistor. That is equal to 2R and for three equal resistors in series, 3R, etc.



If two resistors or impedances in series are unequal and of different values, then the total or equivalent resistance, R_T is equal to the mathematical sum of the two resistances. That is equal to $R_1 + R_2$. If three or more unequal (or equal) resistors are connected in series then the equivalent resistance is: $R_1 + R_2 + R_3 +...$, etc.

RESISTOR - SERIES

$V_{AB} = V_{R1} + V_{R2} + V_{R3} = 9V.$

Using Ohm's Law, the voltage across the individual resistors can be calculated as:

Voltage across $R_1 = IR_1 = 1mA \times 1k\Omega = 1V$

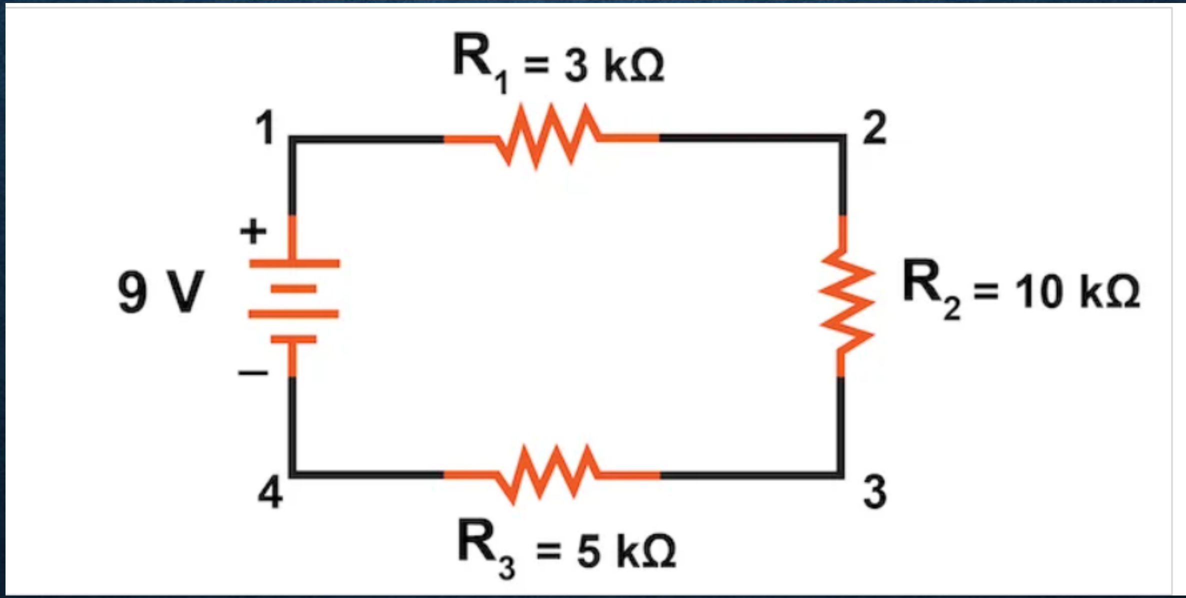
Voltage across $R_2 = IR_2 = 1mA \times 2k\Omega = 2V$

Voltage across $R_3 = IR_3 = 1mA \times 6k\Omega = 6V$

$$V_{Total} = V_{R1} + V_{R2} + V_{R3} + \ldots + V_N$$

RESISTOR – SERIES #01

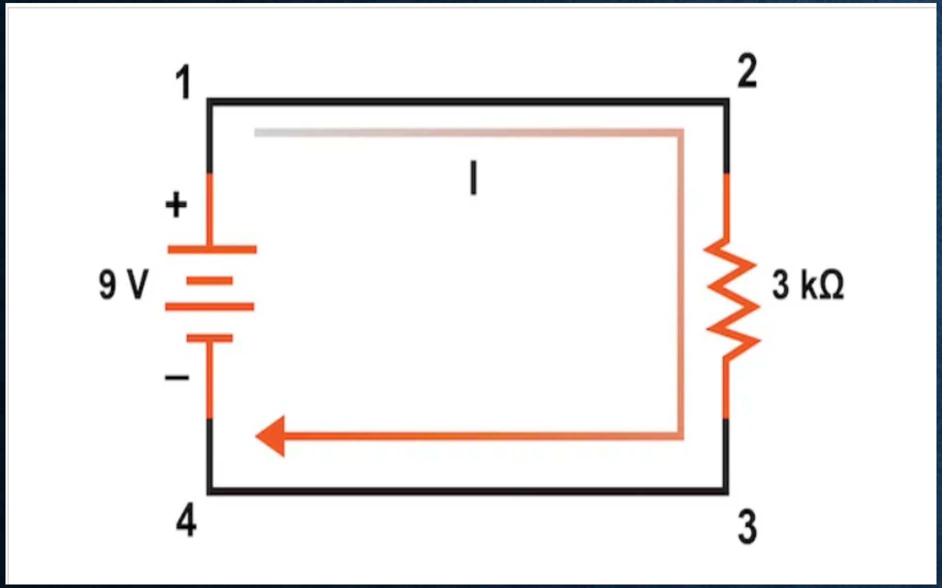
- **Current:** The current is the same through each component in a series circuit
- **Resistance:** The total resistance of a series circuit is equal to the sum of the individual resistances.
- **Voltage:** The total voltage drop in a series circuit equals the sum of the individual voltage drops.



CURRENT IN A SERIES CIRCUIT

- **Current:** The current is the same through each component in a series circuit

USING OHM'S LAW IN A SINGLE RESISTOR CIRCUIT

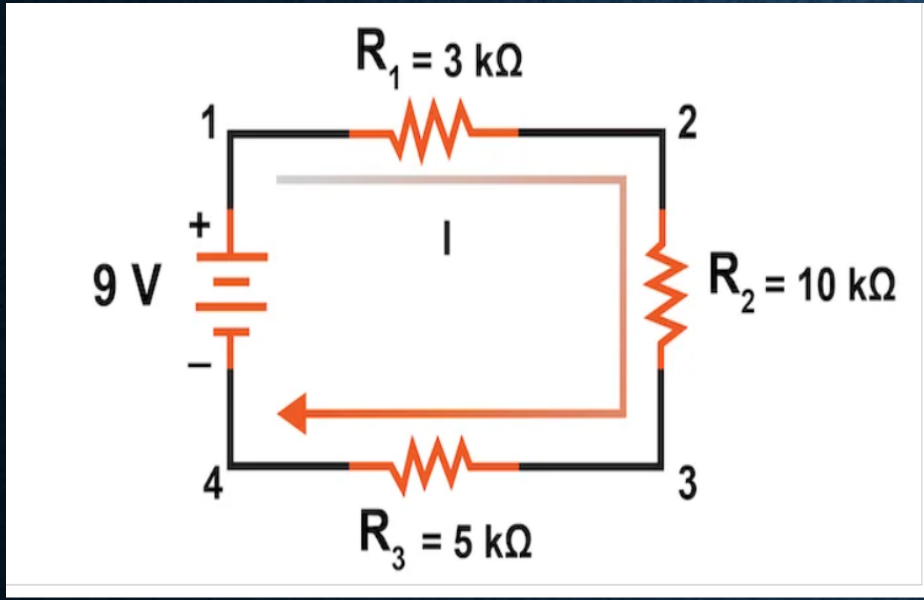


- Since the circuit has 9 V of electromotive force between points 1 and 4 (directly across the battery), it must also drop 9 V between points 2 and 3 (directly across the resistor)
- Because Kirchhoff's Voltage law states that the sum of all voltages in a loop must equal zero

$$I = \frac{V}{R}$$

$$I = \frac{9\ \mathrm{V}}{3\ \mathrm{k\Omega}} = 3\ \mathrm{mA}$$

USING OHM'S LAW FOR SERIES CIRCUITS WITH MULTIPLE RESISTORS



- 9 V between points 1 and 4, which is the amount of electromotive force driving the current through the series combination of R_1, R_2, and R_3.
- However, we cannot take the value of 9 V and divide it by 3 kΩ, 10 kΩ, or 5 kΩ to try to find a current value because we don't know how much voltage is across any one of those resistors individually.
- The voltage value of 9 V is the total quantity for the whole circuit, whereas the values of 3 kΩ, 10 kΩ, or 5 kΩ are individual quantities for individual resistors.

$$I_{R1} = \frac{V_{R1}}{3\ \mathrm{k\Omega}}$$

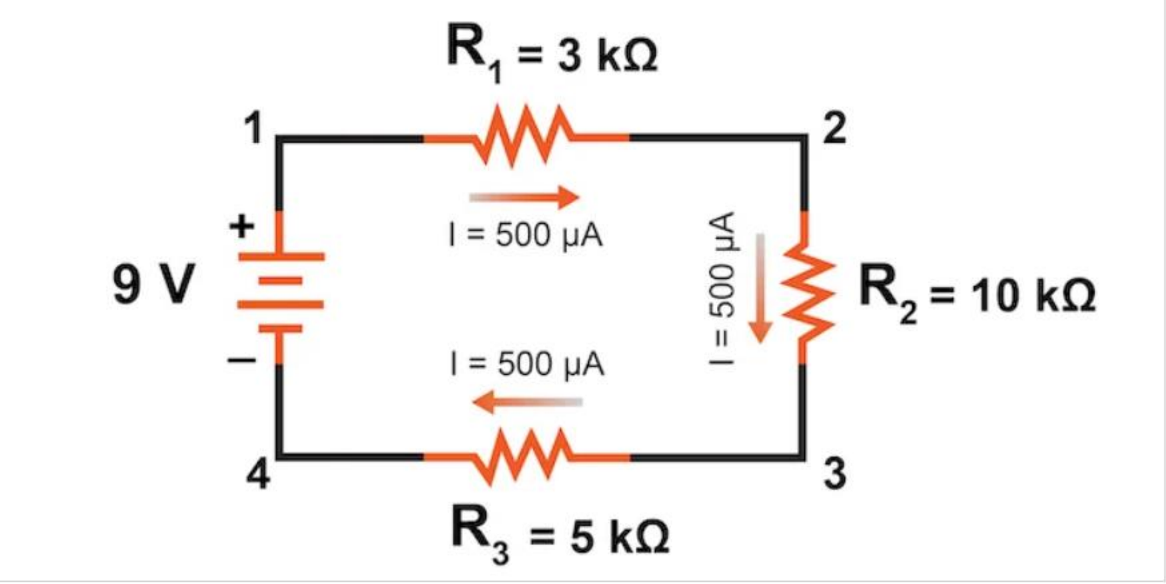
$$E_{R1} = I_{R1} \cdot 3\ \mathrm{k\Omega}$$

USING OHM'S LAW TO CALCULATE CIRCUIT CURRENT IN A SERIES CIRCUIT

$$I_{total} = \frac{V_{total}}{R_{total}}$$

$$I_{total} = \frac{9\ \text{V}}{18\ \text{k}\Omega} = 500\ \mu\text{A}$$

HOW TO CALCULATE VOLTAGE DROP IN A SERIES CIRCUIT



$$V_{R1} = I_{R1} \cdot R_1 = (500\ \mu\text{A}) \cdot (3\ \text{k}\Omega) = 1.5\ \text{V}$$

$$V_{R2} = I_{R2} \cdot R_2 = (500\ \mu\text{A}) \cdot (10\ \text{k}\Omega) = 5.0\ \text{V}$$

$$V_{R3} = I_{R3} \cdot R_3 = (500\ \mu\text{A}) \cdot (5\ \text{k}\Omega) = 2.5\ \text{V}$$

Notice that sum of the voltage drops (1.5 + 5.0 + 2.5 = 9.0 V) is equal to the battery (supply) voltage of 9 V

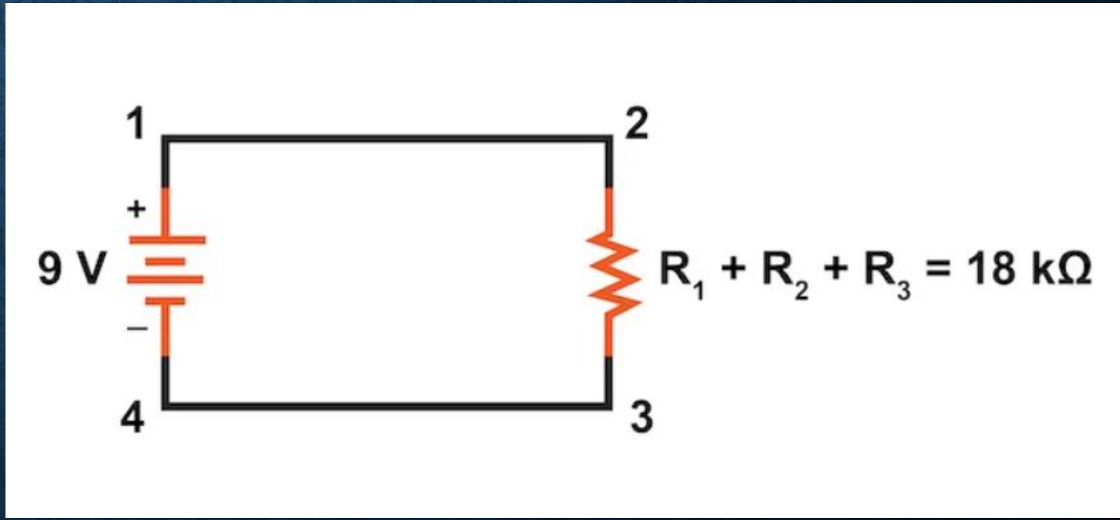
HOW TO CALCULATE TOTAL RESISTANCE IN A SERIES CIRCUIT

- The total resistance of a series circuit is equal to the sum of the individual resistances.

$$R_{total} = R_1 + R_2 + R_3$$

$$R_{total} = 3\ \text{k}\Omega + 10\ \text{k}\Omega + 5\ \text{k}\Omega$$

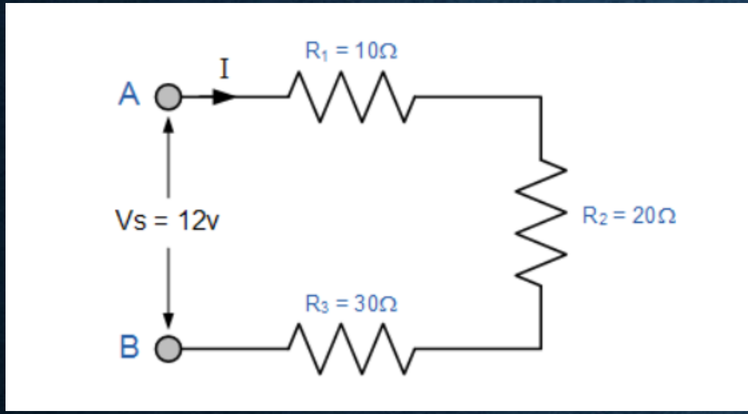
$$R_{total} = 18\ \text{k}\Omega$$



SERIES CIRCUIT FUNDAMENTALS

- All components in a series circuit conduct the same current: $I_{total} = I_1 = I_2 = \ldots I_n$
- The total equivalent resistance of a series circuit is equal to the sum of the individual resistances: $R_{total} = R_1 + R_2 + \ldots R_n$
- The total voltage drop in a series circuit is equal to the sum of the individual voltage drops $V_{total} = V_1 + V_2 + \ldots V_n$

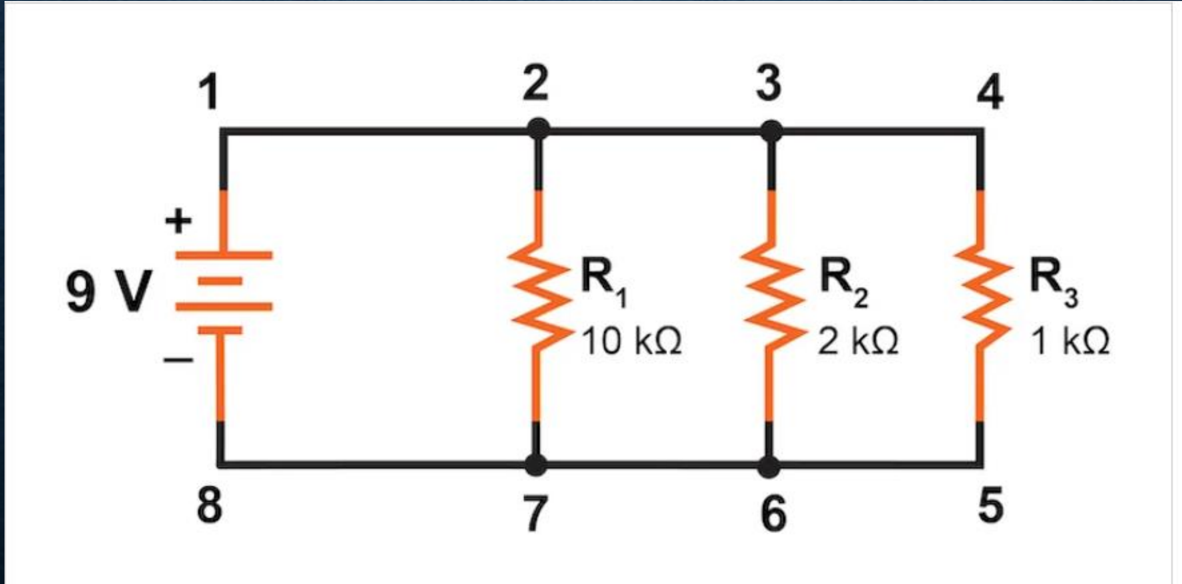
RESISTOR – SERIES #02



Resistance	Current	Voltage	Power
$R_1 = 10\Omega$	$I_1 = 200mA$	$V_1 = 2V$	$P_1 = 0.4W$
$R_2 = 20\Omega$	$I_2 = 200mA$	$V_2 = 4V$	$P_2 = 0.8W$
$R_3 = 30\Omega$	$I_3 = 200mA$	$V_3 = 6V$	$P_3 = 1.2W$
$R_T = 60\Omega$	$I_T = 200mA$	$V_S = 12V$	$P_T = 2.4W$

RESISTOR - PARALLEL

- **Voltage**: The voltage is equal across all components in a parallel circuit.
- **Current**: The total circuit current equals the sum of the individual branch currents.
- **Resistance**: The total resistance of a parallel circuit is *less* than any of the individual brand resistances.



RESISTOR - PARALLEL

- First principle - Parallel circuits is that the voltage is equal across each parallel component
- There are only two sets of electrically common points in a parallel circuit, and the voltage measured between sets of common points must always be the same at any given time.
- Nodes 1, 2, 3, and 4 are the same electrical node.
- Likewise, nodes 5, 6, 7, and 8 are the same electrical node
- Voltage across R_1 is equal to the voltage across R_2, which is equal to the voltage across R_3, and is then equal to the voltage across the battery (9 V).

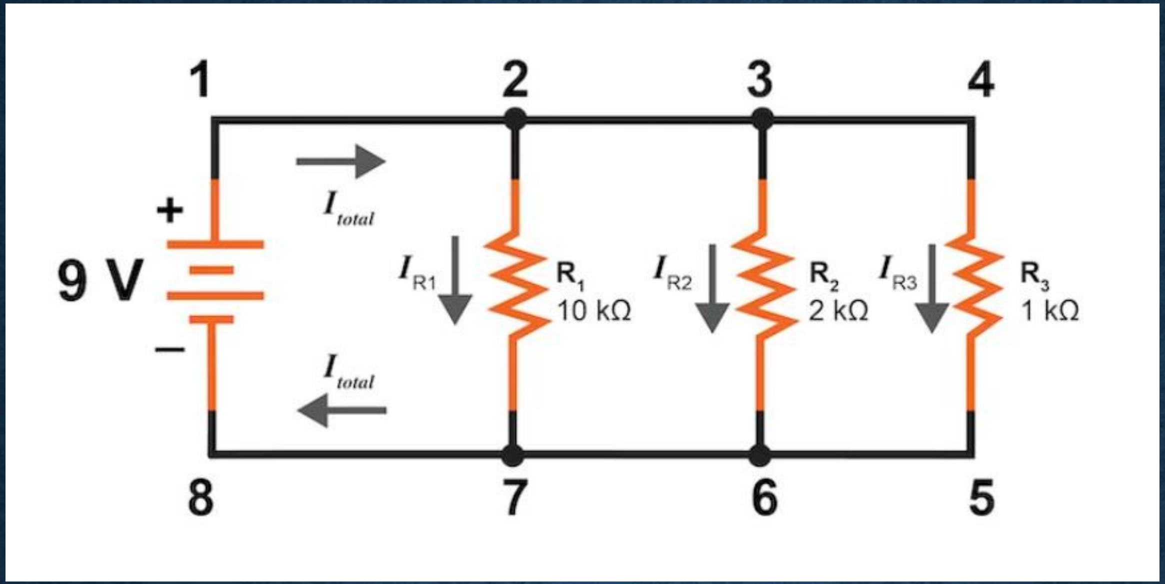
USING OHM'S LAW FOR PARALLEL CIRCUITS TO DETERMINE CURRENT

$$I_{R1} = \frac{V_{R1}}{R_1} = \frac{9\text{ V}}{10\text{ k}\Omega} = 0.9\text{ mA}$$

$$I_{R2} = \frac{V_{R2}}{R_2} = \frac{9\text{ V}}{2\text{ k}\Omega} = 4.5\text{ mA}$$

$$I_{R3} = \frac{V_{R3}}{R_3} = \frac{9\text{ V}}{1\text{ k}\Omega} = 9.0\text{ mA}$$

we still don't know the total current or total resistance for this parallel circuit. Despite that, if we think carefully about what is happening, it should become apparent that the total current must equal the sum of all individual resistor ("branch") currents



river branching into several smaller streams, the combined flow rates of all streams must equal the flow rate of the whole river

$$I_{total} = I_{R1} + I_{R2} + I_{R3} = 0.9 + 4.5 + 9.0 = 14.4\ \mathrm{mA}$$

This is the second principle of parallel circuits: the total parallel circuit current equals the sum of the individual branch currents.

HOW TO CALCULATE TOTAL RESISTANCE IN A PARALLEL CIRCUIT

$$R_{total} = \frac{V_{total}}{I_{total}} = \frac{9\text{ V}}{14.4\text{ mA}} = 625\Omega$$

The total circuit resistance is only 625 Ω. This is *less* than any one of the individual resistors.
In a series circuit, the total resistance is the sum of the individual resistances and is, therefore, always *greater* than any of the resistors individually.
However, here in the parallel circuit, the opposite is true. Each parallel resistor added to a circuit reduces the total equivalent resistance. Mathematically, the relationship between total resistance and individual resistance in a parallel circuit looks like this

$$R_{total} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$

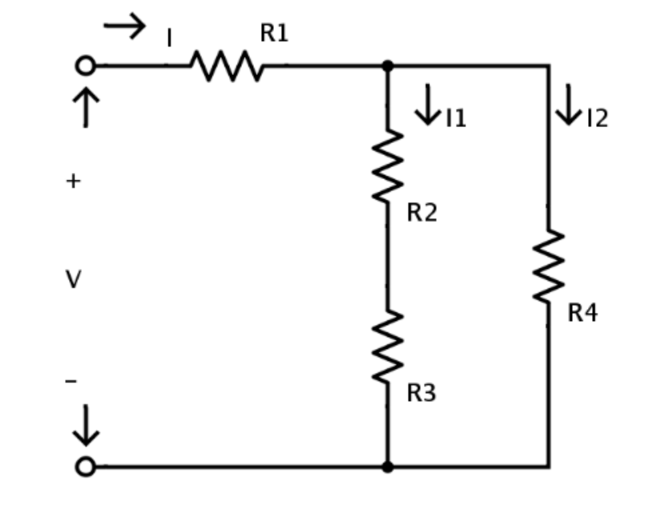
- If we think of our parallel circuit in terms of conductance rather than resistance, this often makes more sense. The conductance of a parallel circuit is the sum of the individual branch conductance's as the circuit gets more conductive as we add more paths for currents to flow

$$G_{total} = G_1 + G_2 + G_3$$

RESISTOR - PARALLEL

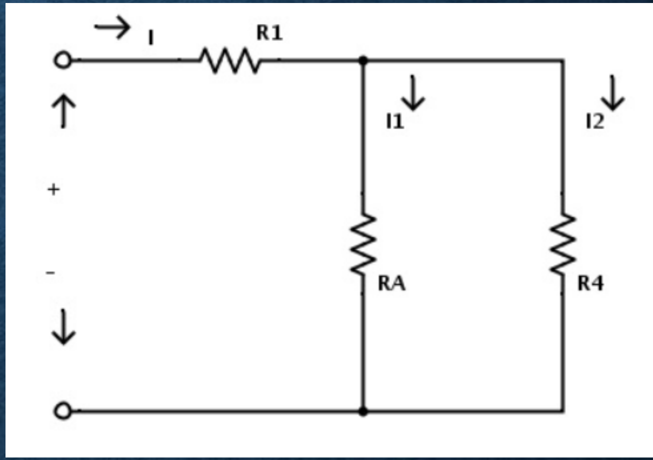
- The voltage is the same for all components in a parallel circuit: $V_1 = V_2 = \ldots V_n$
- The total parallel circuit current is the sum of the individual branch currents: $I_{total} = I_1 + I_2 + \ldots I_n$
- The total resistance of a parallel circuit is ***less*** than any of the individual brand resistances: Rtotal=1/(1/R1+1/R2+1/R3)

PARALLEL & SERIES - RESISTOR



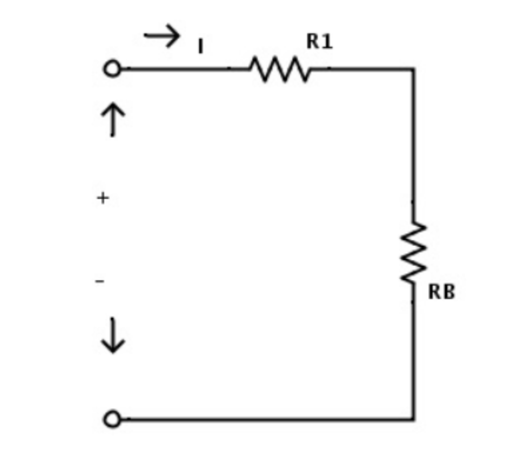
STEP 1 – SERIES CONDITION

$R_A = R2 + R3$



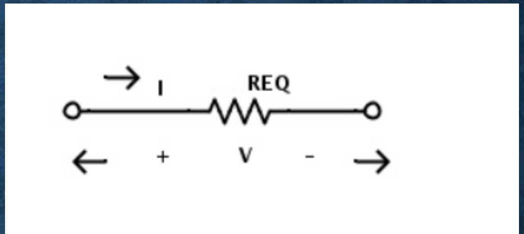
STEP 2 – PARALLEL CONDITION

$R_B = R_A \times R4 / (R_A + R4)$

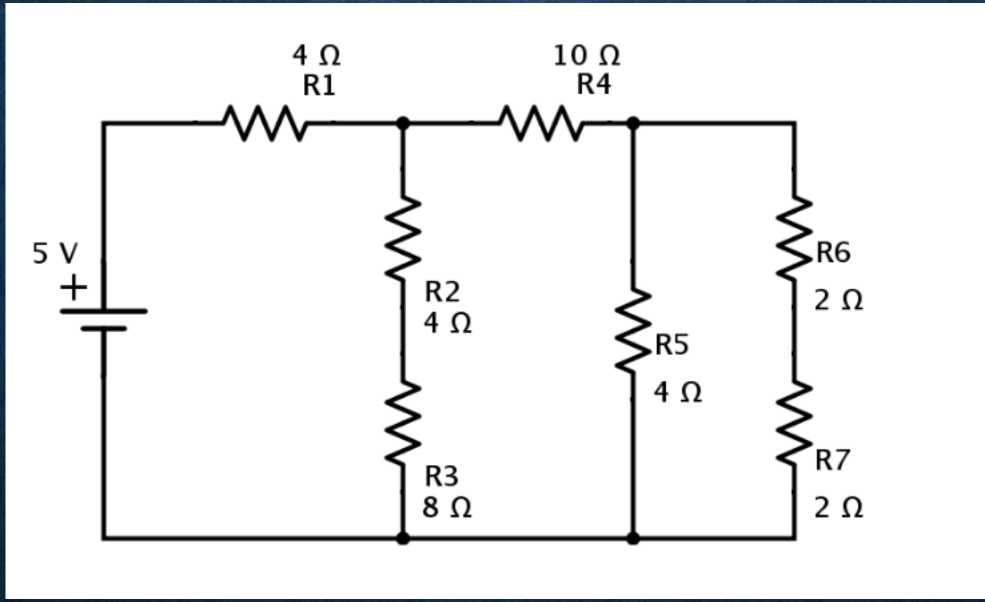


STEP 3 – SERIES CONDITION

$R_{EQ} = R1 + R_B$

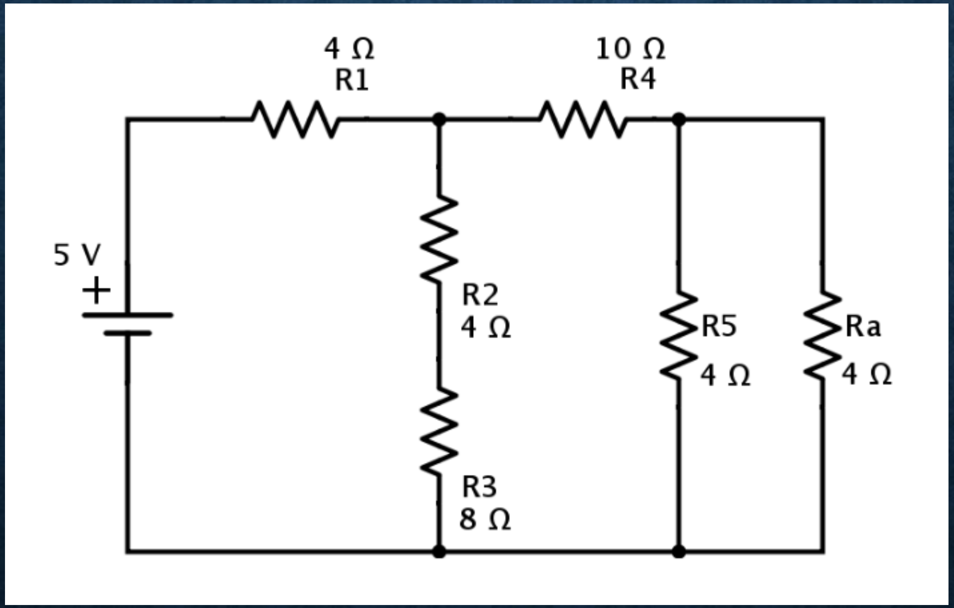


PARALLEL & SERIAL – RESISTOR #01



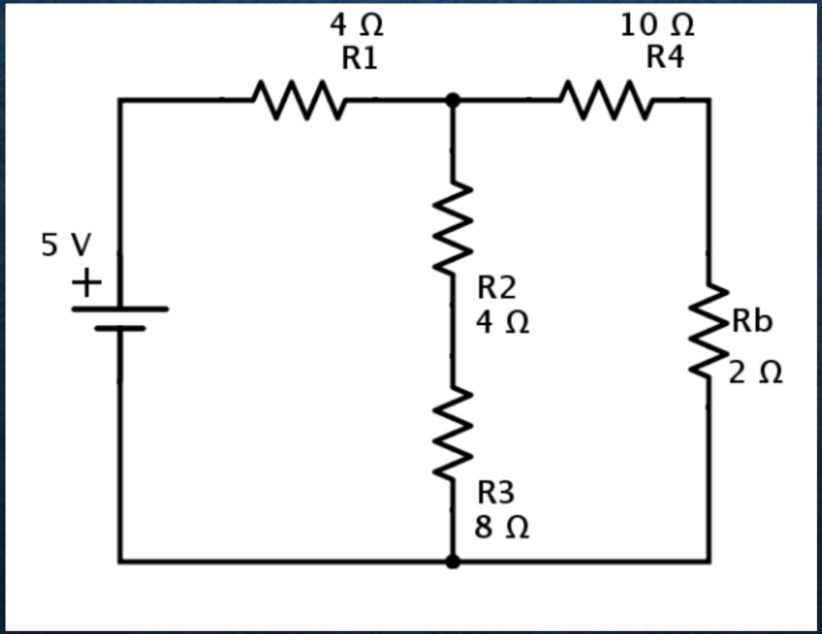
STEP 1

- Resistors R6 and R7 are in series combination. If the equivalent resistance of R6 and R7in series is Ra, then, Ra = R6 + R7 = 2+2 = 4Ω



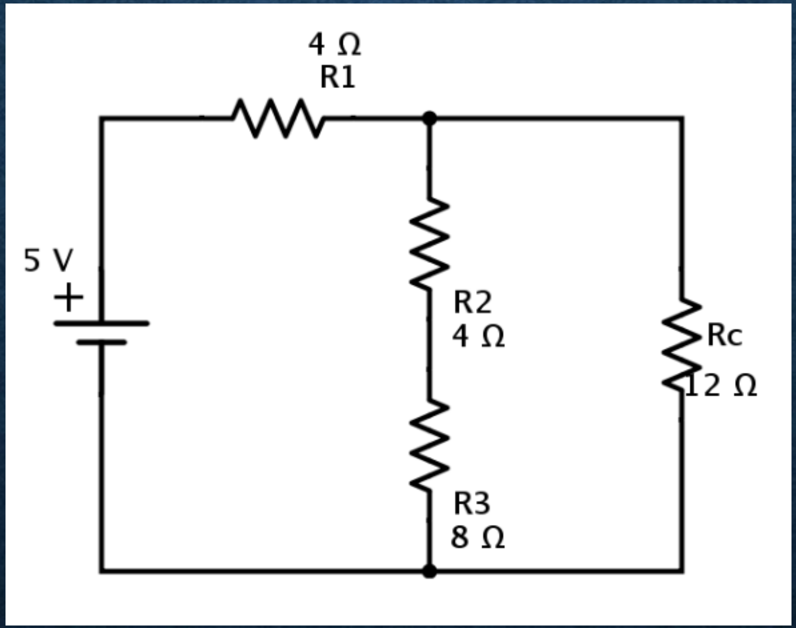
STEP 2

- Resistors Ra and R5 are in parallel combination. Hence the equivalent resistance of Ra and R5 is, $R_b = (R_a \times R_5) / (R_a + R_5) = (4 \times 4) / (4 + 4) = 2\Omega$.



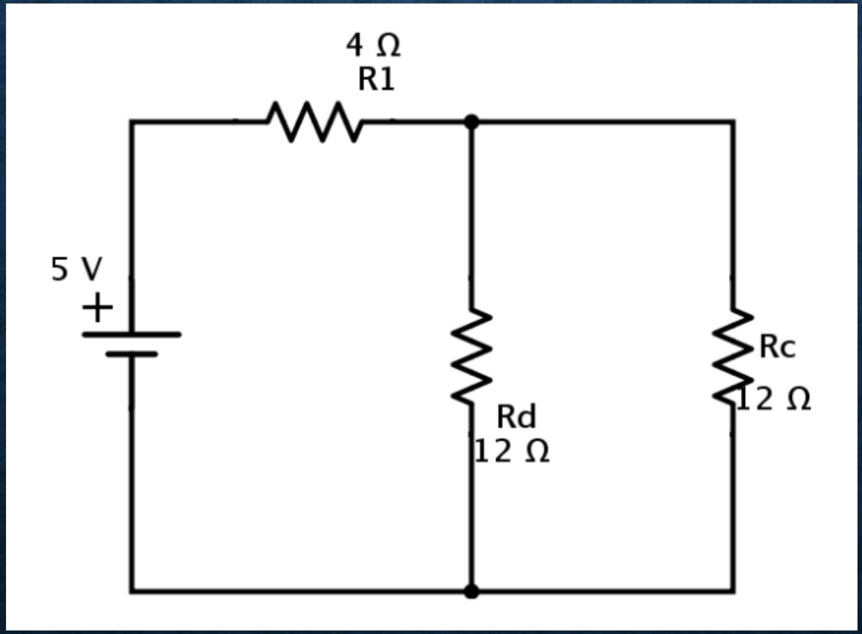
STEP 3

- Resistors R4 and R_b are in series combination, Rc = R4 + R_b = 10 + 2 = 12 Ω.



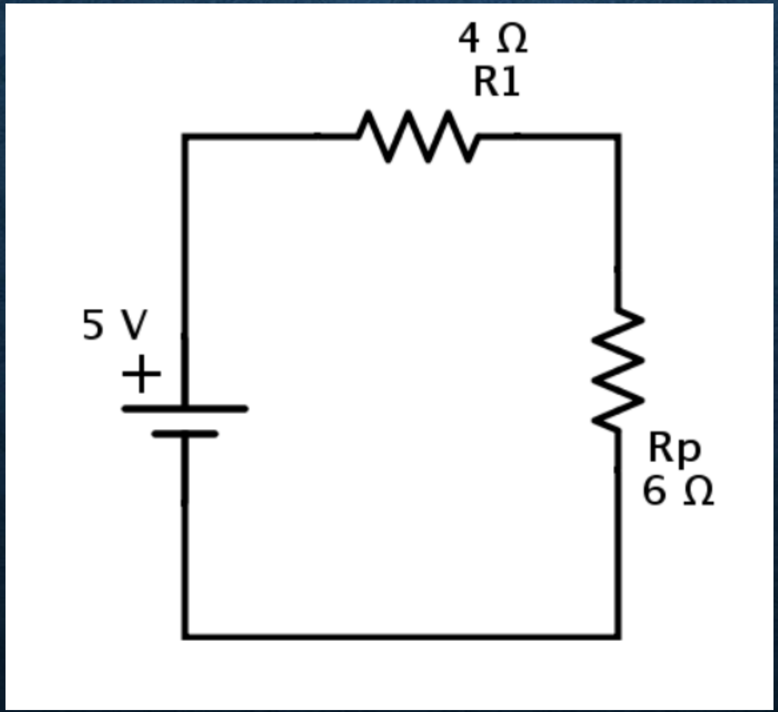
STEP 4

- Resistors R2 and R3 are in series combination. If Rd is the equivalent resistance of R2 and R3 then, Rd = R2 + R3 = 4 + 8 = 12 Ω.



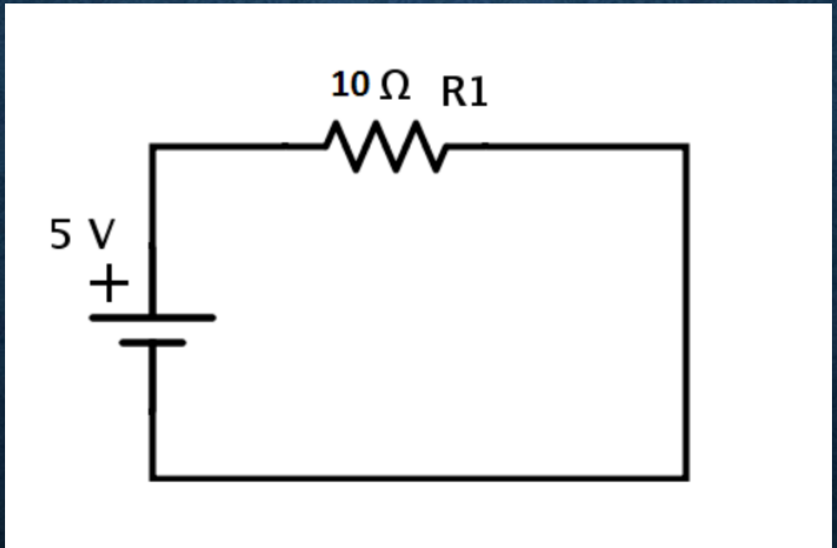
STEP 5

- Resistors Rc and Rd are in parallel combination. Let Rp be the equivalent resistance of Rc and Rd in parallel. Then, $R_p = (R_c \times R_d) / (R_c + R_d) = (12 \times 12) / (12 + 12) = 6\ \Omega$.



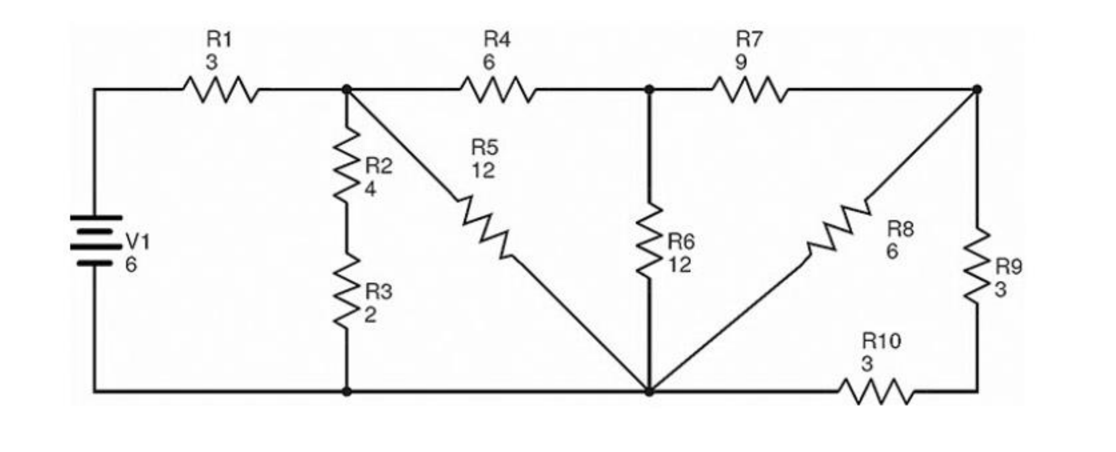
STEP 6

- Resistors R1 and Rp are in series combination. Let R_{EQ} be the equivalent resistance of this combination. Then, $R_{EQ} = R1 + Rp = 4 + 6 = 10\ \Omega$.



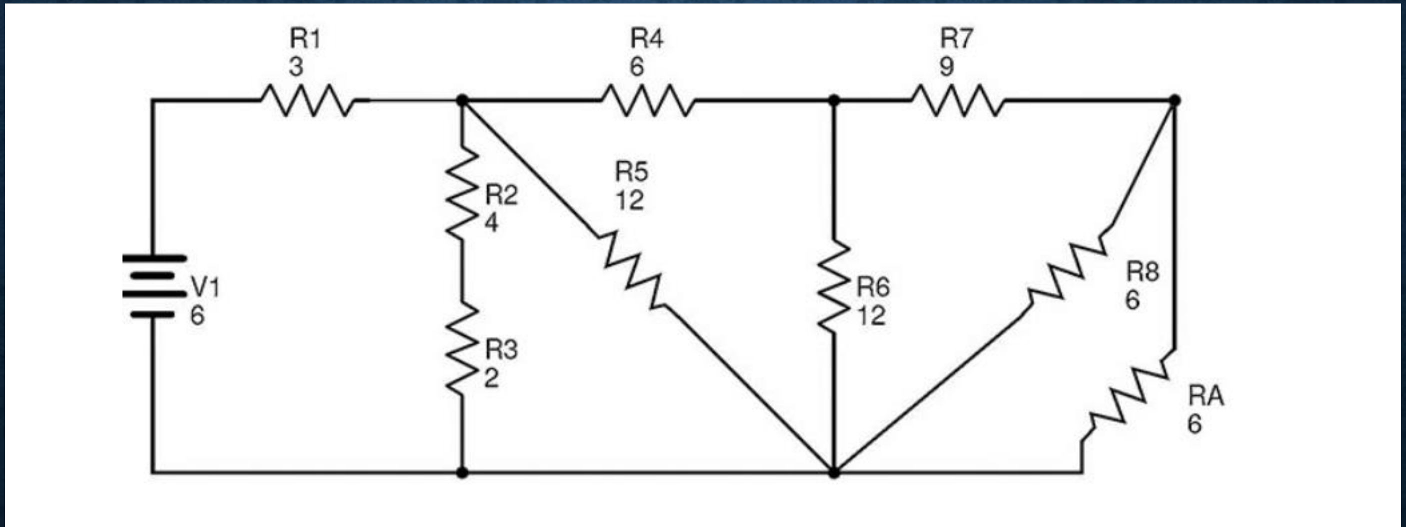
- Current in the circuit can be calculated from Ohm's law, $I = V / R_{EQ} = 5 / 10 = 0.5$ A

PARALLEL & SERIAL – RESISTOR #02



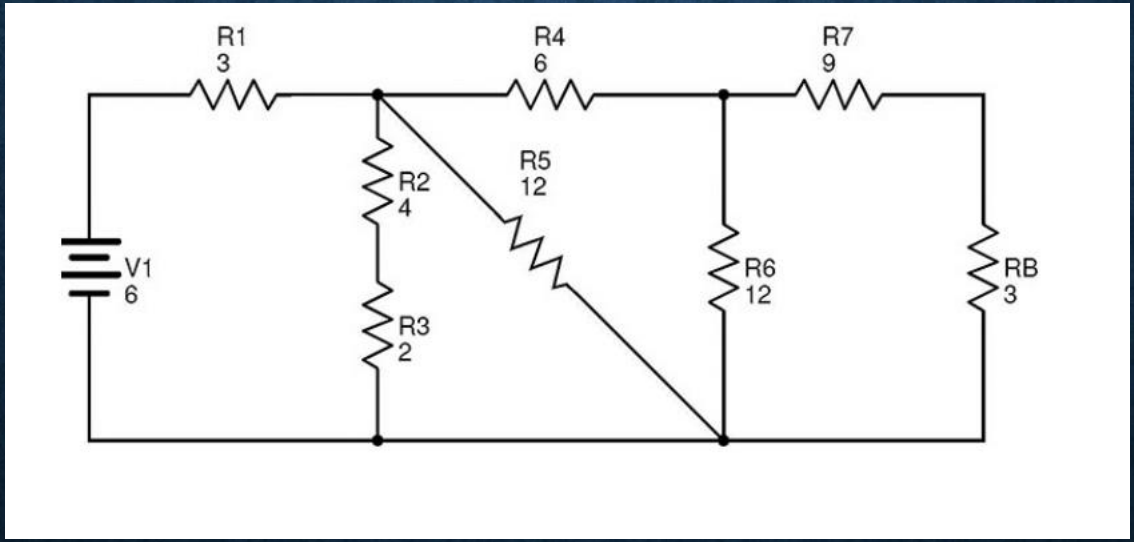
STEP 1

- Rresistors R9 and R10 are in series combination. Let R_A is the equivalent resistance of this combination, Therefore R_A = R9 + R10 = 3 + 3 = 6 Ω.



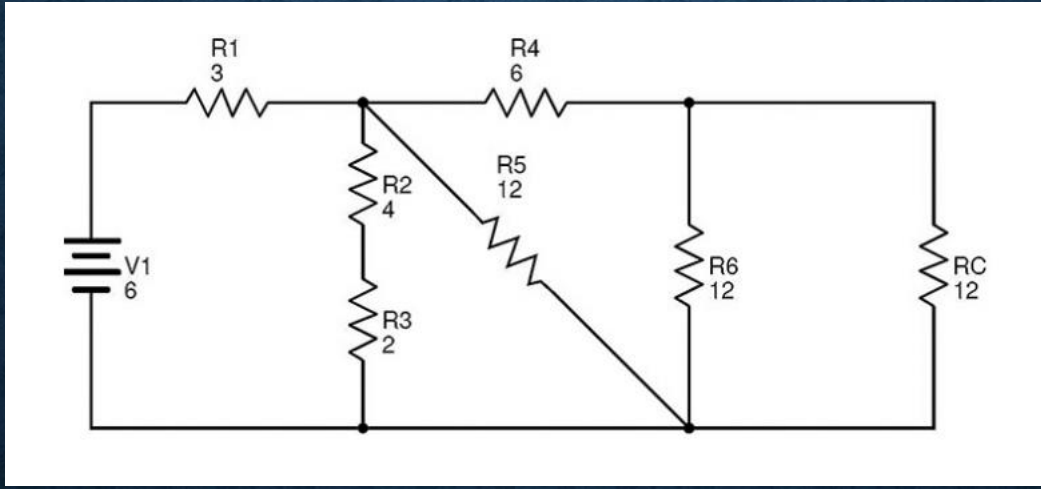
STEP 2

- Resistors R8 and R_A are in parallel combination. Then the equivalent resistance of R8 and R_A is $R_B = (R8 \times R_A) / (R8 + R_A) = (6 \times 6) / (6 + 6) = 3\ \Omega$



STEP 3

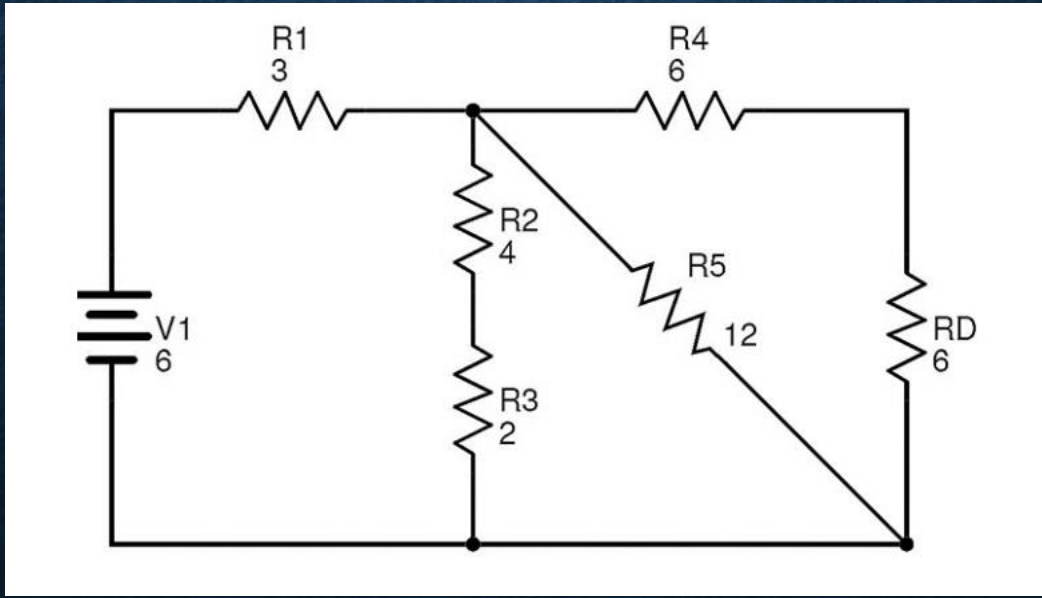
- Resistors R7 and R_B are in series combination, $R_C = R7 + R_B = 9 + 3 = 12\ \Omega$.



STEP 4

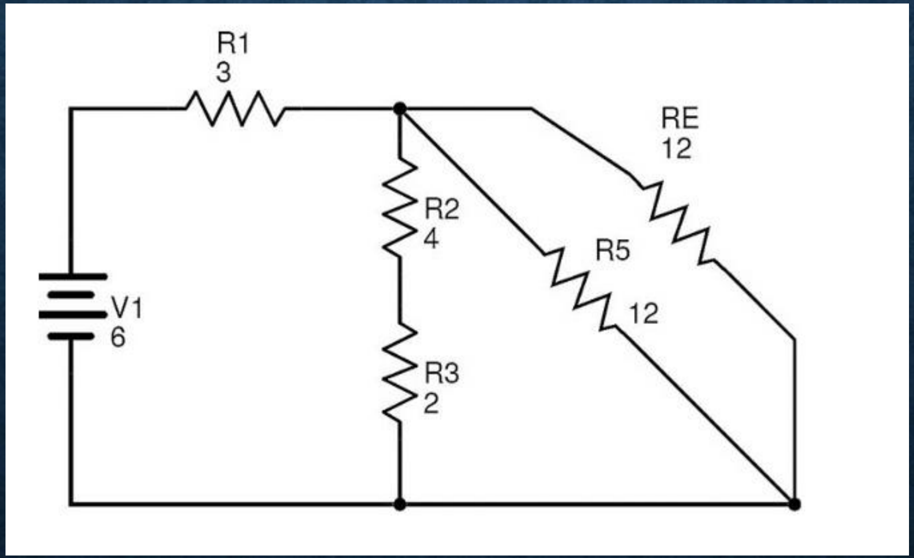
- It is clear that the resistors R6 and Rc are in parallel combination. If R_D is the equivalent resistance of this combination, then

$$R_D = (R6 \times Rc) / (R6 + Rc) = (12 \times 12) / (12 + 12) = 6\ \Omega$$



STEP 5

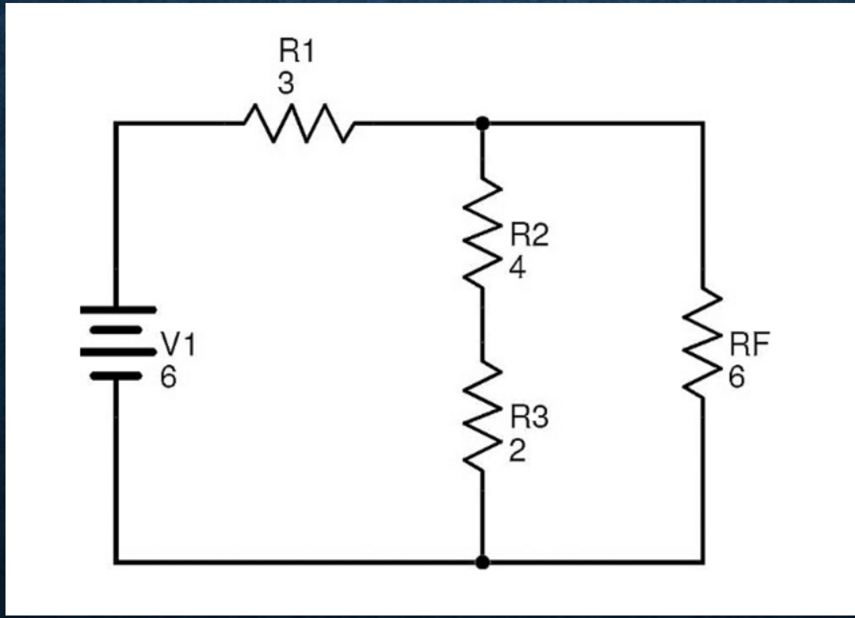
- Resistors R4 and RD are in series combination. If RE is the equivalent resistance of R4 and RD then, $R_E = R4 + R_D = 6 + 6 = 12\ \Omega$.



STEP 6

- Resistors R5 and R_E are in parallel combination. Let R_F be the equivalent resistance of R5 and R_E in parallel. Then

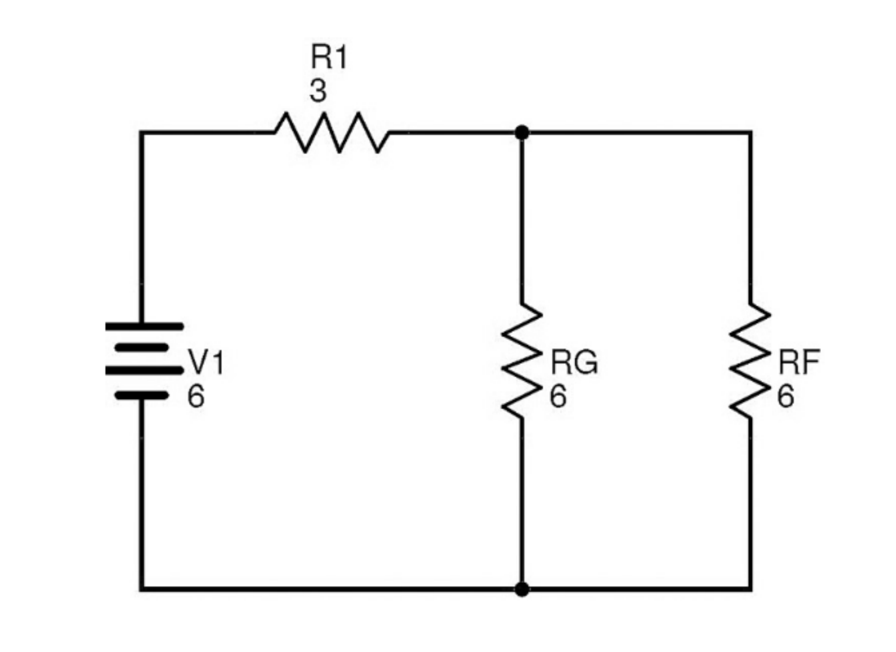
$$R_F = (R5 \times R_E) / (R5 + R_E) = (12 \times 12) / (12 + 12) = 6\ \Omega$$



STEP 7

- Resistors R2 and R3 are in series. If RG is the equivalent of this combination, then

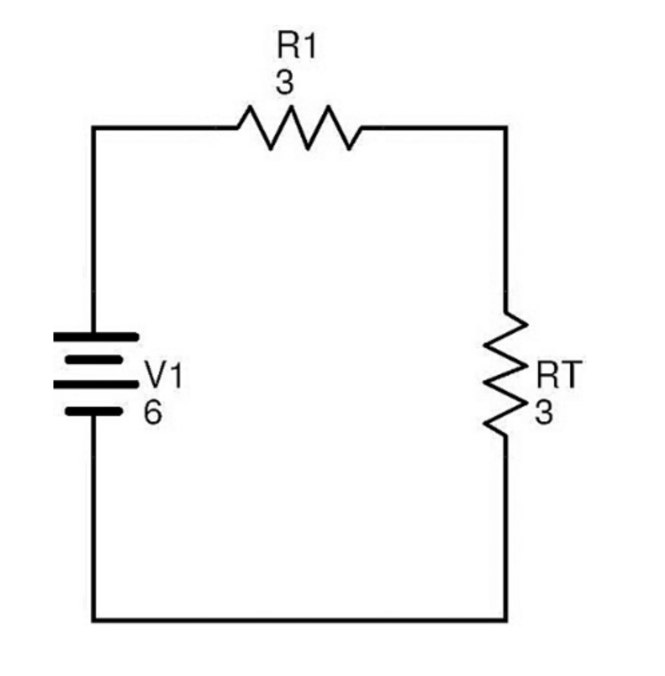
$$R_G = R2 + R3 = 4 + 2 = 6\ \Omega$$



STEP 8

- Resistors RF and RG are in parallel. Let R_T be the equivalent of this combination.

$$R_T = (R_F \times R_G) / (R_F + R_G) = (6 \times 6) / (6 + 6) = 3\ \Omega$$

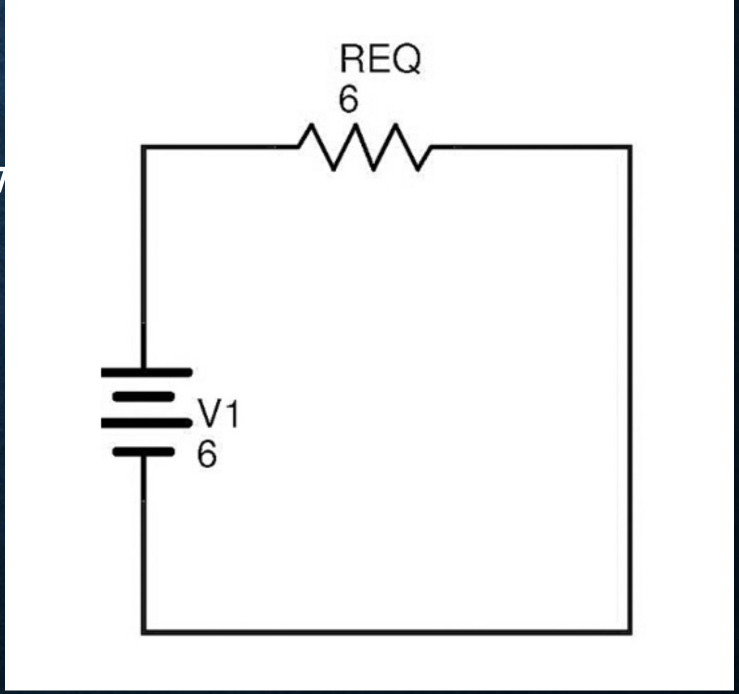


STEP 9

- Resistors R1 and RT are in series. If REQ is the total circuit equivalent resistance, then

$$REQ = R1 + RT = 3 + 3 = 6\ \Omega$$

Finally the above complex circuit can be redrawn as follows



Total current in the circuit can be calculated using Ohm's law

$$I = V1 / R_{EQ} = 6 / 6 = 1\ A$$

SERIES – PARALLEL RESISTOR PROBLEM

https://www.youtube.com/watch?v=eFlJy0cPbsY

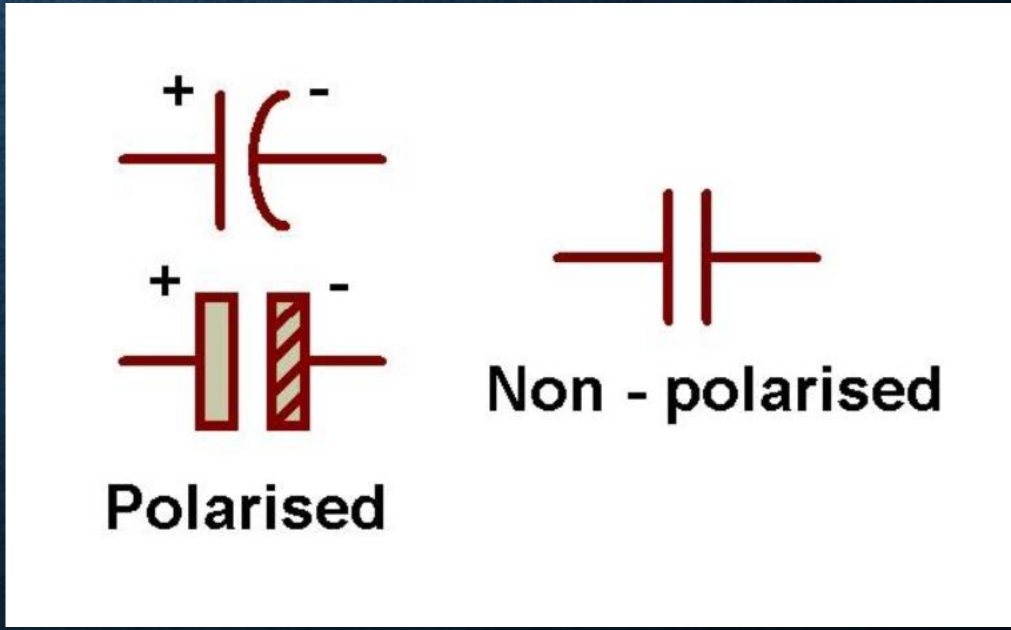
CAPACITOR

- Also known as Condenser
- Used for storage – charge – in the form of electric field

CAPACITOR

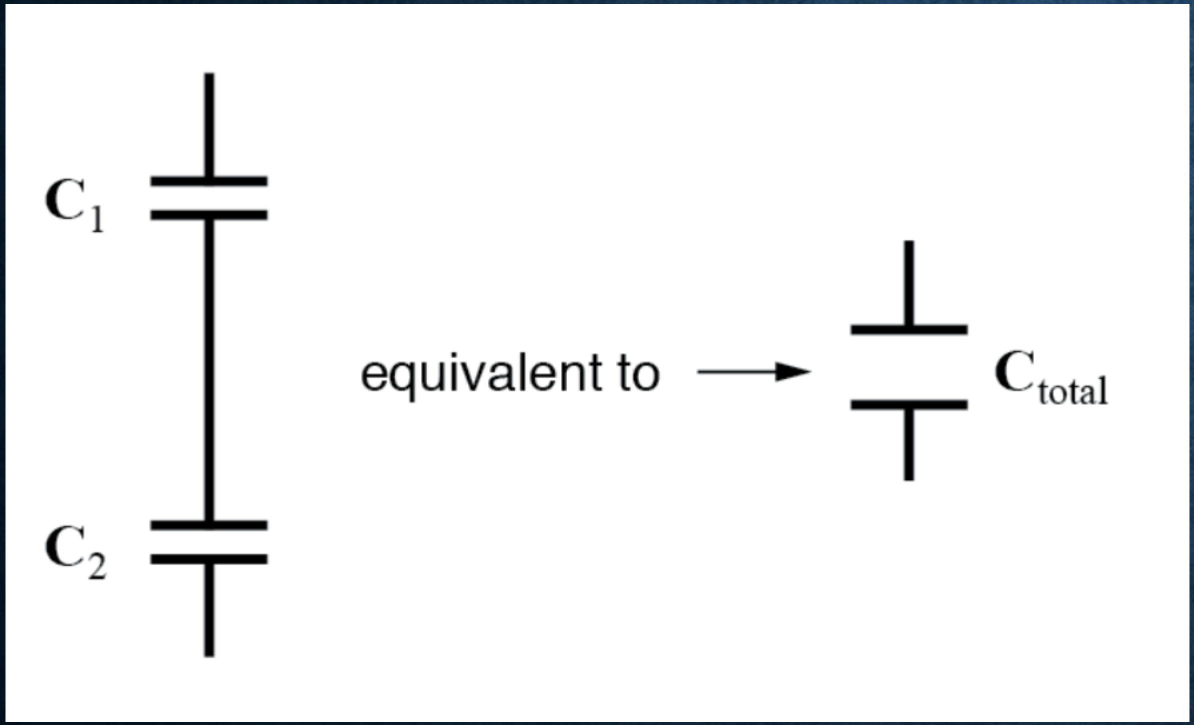
- Capacitor has two parallel metal plates which are not connected to each other.
- The two plates in the capacitor are separated by non conducting medium (insulating medium) this medium is commonly known as **Dielectric**
- Unlike a resistor, an ideal capacitor does not

  dissipate energy



TYPES OF CAPACITORS

PARALLEL CAPACITANCE

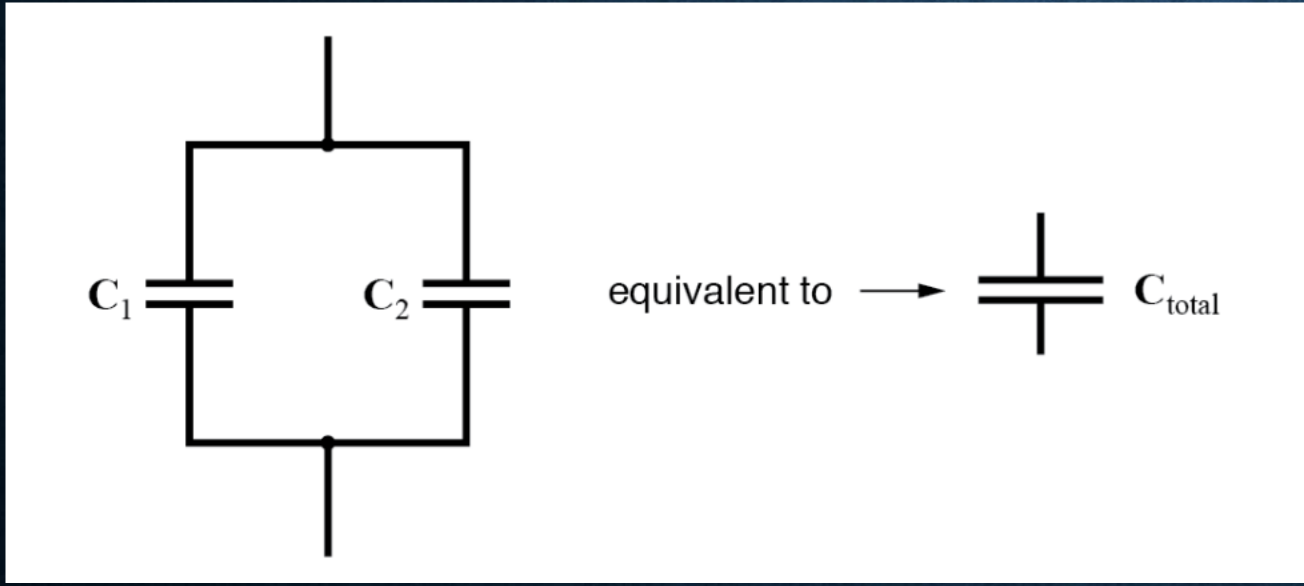


Series Capacitances

$$C_{total} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \ldots \frac{1}{C_n}}$$

Exactly the opposite of the phenomenon exhibited by resistors. With resistors, series connections result in additive values while parallel connections result in diminished values. With capacitors, its the reverse: parallel connections result in additive values while series connections result in diminished values.

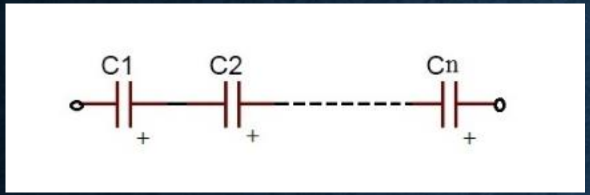
SERIES CAPACITANCE



Parallel Capacitances

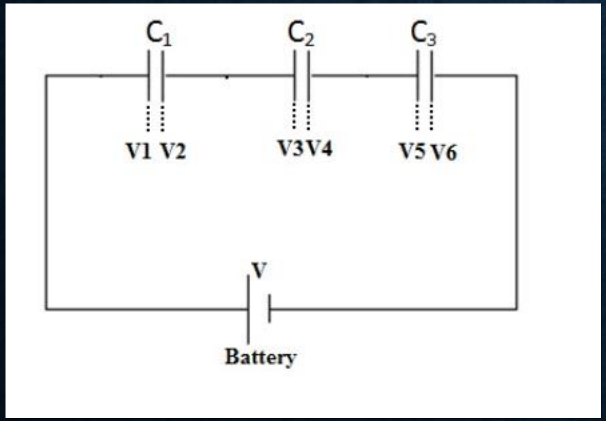
$$C_{total} = C_1 + C_2 + \dots C_n$$

CAPACITOR IN SERIES



$QT = Q1 = Q2 = Q3 = \text{————-} = Q$

$IC = I1 = I2 = I3 = \text{———} = IN$



Each plate will have different potential. But the magnitude of charge on the plates is same.

overall potential difference between the plates, $VT = V1+V2+V3$

$Q=CV$ $C=Q/V$

$Ceq = Q/V1 + Q/V2 + Q/V3$ (As charge is same)

$1/Ceq = (V1+ V2+ V3)/Q$

$VT = Q/Ceq = Q/C1 + Q/C2 + Q/C3$

Hence, $1/Ceq = 1/C1 + 1/C2 + 1/C3$

SERIES CAPACITANCE #01

Calculate the equivalent capacitance and the individual voltage drops across the set of two capacitors in series have 0.1uF and 0.2uF respectively when connected to a 12V a.c. supply.

1/Ceq = 1/C1 + 1/C2

Ceq = (C1C2) / (C1 + C2)

Ceq = (0.1uF*0.2uF) / (0.1uF+0.2uF)

Ceq = 0.066uF = 66nF

Voltage drops across the two given capacitors in series are,

V1 = (C2*VT)/ (C1+C2) = (0.2uF*12V)/ (0.1uF+0.2uF) = 8Volts

V2 = (C1*VT)/ (C1+C2) = (0.1uF*12V)/ (0.1uF+0.2uF) = 4Volts

From these results we observed that the equivalent capacitance 66nF is less than the smallest capacitance 0.1uF of the given two capacitors. The individual voltage drops across the given two capacitors are different

But the sum of individual voltage drops of both the capacitors is equal to the total voltage. i.e 8V+4V=12V.

Now we calculate the charge stored in individual capacitor,

Q1 = V1* C1 = 8V * 0.1uF = 0.8uC

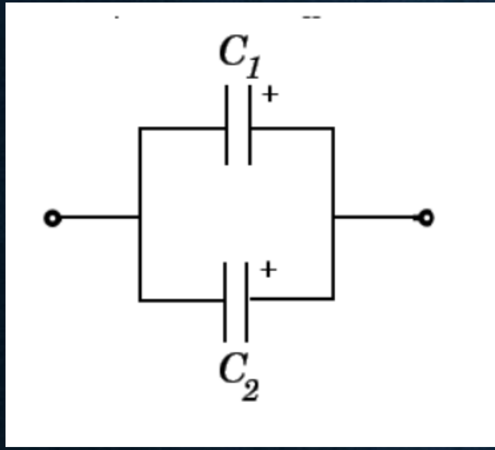
Q2 = V2* C2 = 4V * 0.2uF = 0.8uC

Here we observed that equal charge 0.8uC is stored in both the capacitors C1 and C2 which are connected in series.

PARALLEL CAPACITANCE

- All the capacitors which are connected in parallel have the same voltage and is equal to the VT applied between the input and output terminals of the circuit.
- Then, parallel capacitors have a 'common voltage' supply across them .i.e. VT = V1 = V2 etc.
- The equivalent capacitance, Ceq of the circuit where the capacitors are connected in parallel is equal to the sum of all the individual capacitance of the capacitors added together.
- This is because the top plate of each capacitor in the circuit is connected to the top plate of adjacent capacitors.In the same way the bottom plate of each capacitor in the circuit is connected to the bottom plate of adjacent capacitors

PARALLEL CAPACITANCE



The total charge (Q) across the circuit is divided between the two capacitors, means the charge Q distributes itself between the capacitors connected in parallel. charge Q is equal to the sum of all the individual capacitor charges.

Thus Q=Q1+Q2

Q=Ceq VT

Here, Q = Q1+Q2

Ceq VT = C1xV1+C2xV2

Since VT = V1 = V2 = V

Ceq VT = C1xV+C2xV

Ceq VT = (C1+C2)V

Hence Ceq=C1+c2

Consider the capacitance values of the two capacitors C1 =0.2uF and C2 =0.3uF which are shown in above figure 4. Now calculate the equivalent capacitance of the circuit

$$C_{eq} = C_1 + C_2$$

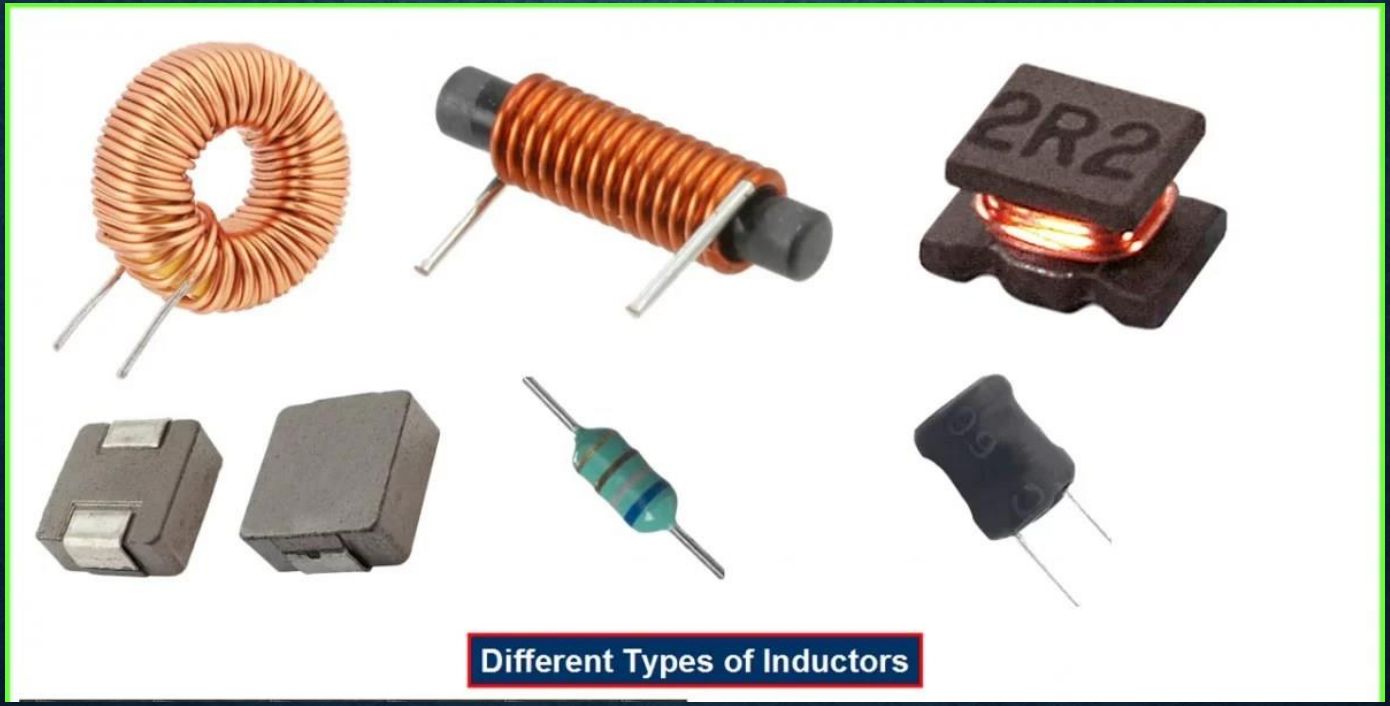
$$C_{eq} = 0.2uF + 0.3uF$$

$$C_{eq} = 0.5uF$$

VIDEOS –RELATED - CAPACITOR

- Capacitor – in detail https://www.youtube.com/watch?v=BimpNou0orc
- Capacitor in Series & Parallel - https://www.youtube.com/watch?v=zaT4JorVUz0
- Capacitor in Series & Parallel - https://www.youtube.com/watch?v=a-gPuw6JsxQ

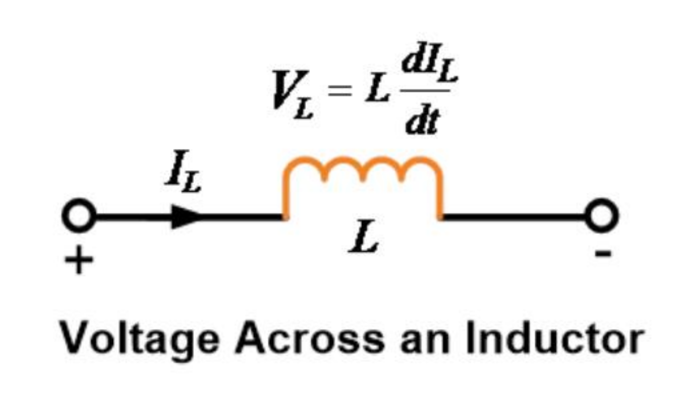
INDUCTOR & ITS TYPES

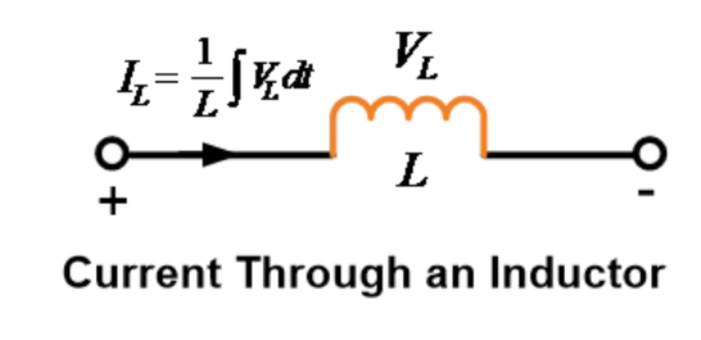


INDUCTOR

- An inductor, also called a coil, choke, or reactor, is a passive two-terminal electrical component that stores energy in a magnetic field when electric current flows through it.
- An inductor typically consists of an insulated wire wound into a coil.
- An inductor is characterized by its inductance: ratio of the voltage to the rate of change of current.
- Unit of inductance is the henry (H)
- In the measurement of magnetic circuits, it is equivalent to weber/ampere.
- Inductors have values that typically range from 1 μH (10^{-6} H) to 20 H.
- Many inductors have a magnetic core made of iron or ferrite inside the coil, which serves to increase the magnetic field and thus the inductance.
- **Inductance** – property that exhibits opposition to the change of current, measured in ***henrys (H)***.

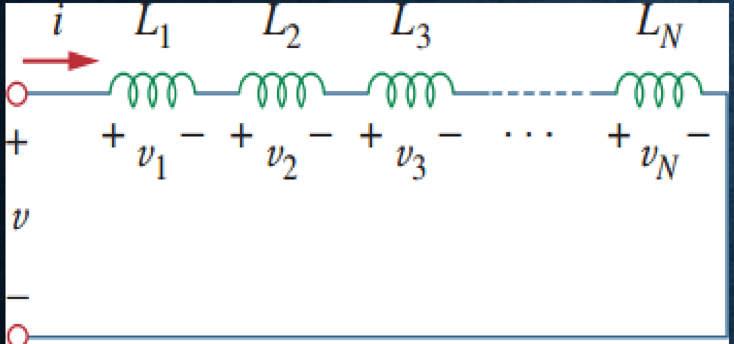
INDUCTOR EQUATION





SERIES & PARALLEL - INDUCTOR

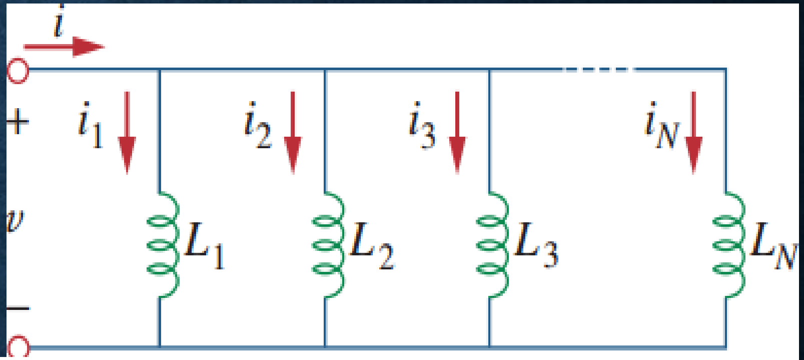
Inductors in **series**, **add**. In **parallel**, they act like resistors in **parallel**.



$$L_{eq} = L_1 + L_2 + L_3 + \cdots + L_N$$

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

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



$$\mathbf{L}_{\text{total}} = \frac{1}{\frac{1}{\mathbf{L}_1} + \frac{1}{\mathbf{L}_2} + \ldots \frac{1}{\mathbf{L}_n}}$$

INDUCTOR SERIES

- Three inductors of 10mH, 40mH and 50mH are connected together in a series combination with no mutual inductance between them. Calculate the total inductance of the series combination.

$$L_T = L_1 + L_2 + L_3 = 10mH + 40mH + 50mH = 100mH$$

- Two inductors of 10mH respectively are connected together in a series combination so that their magnetic fields aid each other giving cumulative coupling. Their mutual inductance is given as 5mH. Calculate the total inductance of the series combination.

$$L_T = L_1 + L_2 + 2M$$
$$L_T = 10mH + 10mH + 2(5mH)$$
$$L_T = 30mH$$

INDUCTOR SERIES

- Two coils connected in series have a self-inductance of 20mH and 60mH respectively. The total inductance of the combination was found to be 100mH. Determine the amount of mutual inductance that exists between the two coils assuming that they are aiding each other.

$$L_T = L_1 + L_2 \pm 2M$$

$$100 = 20 + 60 + 2M$$

$$2M = 100 - 20 - 60$$

$$\therefore M = \frac{20}{2} = 10\text{mH}$$

INDUCTOR PARALLEL #01

- Three inductors of 60mH, 120mH and 75mH respectively, are connected together in a parallel combination with no mutual inductance between them. Calculate the total inductance of the parallel combination in millihenries.

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

$$\therefore L_T = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3}} = \frac{1}{\frac{1}{60\text{mH}} + \frac{1}{120\text{mH}} + \frac{1}{75\text{mH}}}$$

$$L_T = \frac{1}{38.333} = 26\text{mH}$$

INDUCTOR PARALLEL #02

- Two inductors whose self-inductances are of 75mH and 55mH respectively are connected together in parallel aiding. Their mutual inductance is given as 22.5mH. Calculate the total inductance.

$$L_T = \frac{L_1 \times L_2 - M^2}{L_1 + L_2 - 2M}$$

$$L_T = \frac{75mH \times 55mH - 22.5mH^2}{75mH + 55mH - 2 \times 22.5mH}$$

$$L_T = 42.6mH$$

INDUCTOR – SERIES & PARALLEL #01

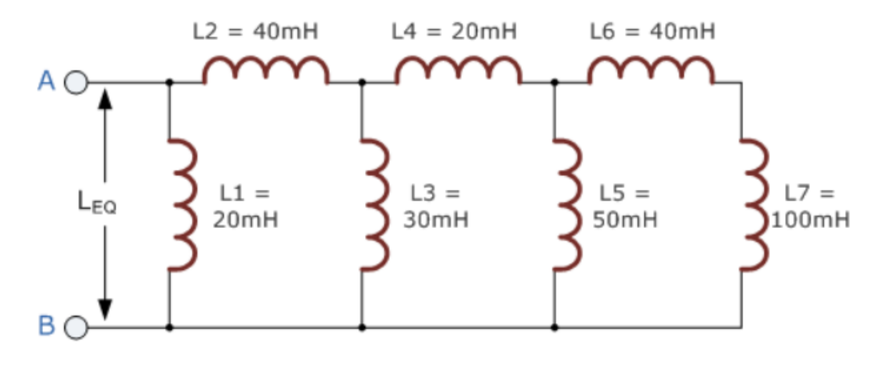
- Two inductors whose self-inductances are of 75mH and 55mH respectively are connected together in parallel aiding. Their mutual inductance is given as 22.5mH. Calculate the total inductance.

$$L_T = \frac{L_1 \times L_2 - M^2}{L_1 + L_2 - 2M}$$

$$L_T = \frac{75mH \times 55mH - 22.5mH^2}{75mH + 55mH - 2 \times 22.5mH}$$

$$L_T = 42.6mH$$

INDUCTOR – SERIES & PARALLEL #02



Calculate the first inductor branch L_A, (Inductor L_5 parallel with inductors L_6 and L_7)

$$L_A = \frac{L5\times(L6+L7)}{L5+L6+L7} = \frac{50mH\times(40mH+100mH)}{50mH+40mH+100mH} = 36.8mH$$

Calculate the second inductor branch L_B, (Inductor L_3 in parallel with inductors L_4 and L_A)

$$L_B = \frac{L3\times(L4+L_A)}{L3+L4+L_A} = \frac{30mH\times(20mH+36.8mH)}{30mH+20mH+36.8mH} = 19.6mH$$

$$L_{EQ} = \frac{L1\times(L2+L_B)}{L1+L2+L_B} = \frac{20mH\times(40mH+19.6mH)}{20mH+40mH+19.6mH} = 15mH$$

VIDEOS - INDUCTOR

- Inductor & its working - https://www.youtube.com/watch?v=KSylo01n5FY
- Series & Parallel inductor - https://www.youtube.com/watch?v=jgKoRUBX0Y4

RESISTOR VS CAPACITOR VS INDUCTOR

Relation	Resistor (R)	Capacitor (C)	Inductor (L)
v-i:	$v = iR$	$v = \frac{1}{C}\int_{t_0}^{t} i(\tau)d\tau + v(t_0)$	$v = L\frac{di}{dt}$
i-v:	$i = v/R$	$i = C\frac{dv}{dt}$	$i = \frac{1}{L}\int_{t_0}^{t} v(\tau)d\tau + i(t_0)$
p or w:	$p = i^2R = \frac{v^2}{R}$	$w = \frac{1}{2}Cv^2$	$w = \frac{1}{2}Li^2$
Series:	$R_{eq} = R_1 + R_2$	$C_{eq} = \frac{C_1C_2}{C_1 + C_2}$	$L_{eq} = L_1 + L_2$
Parallel:	$R_{eq} = \frac{R_1R_2}{R_1 + R_2}$	$C_{eq} = C_1 + C_2$	$L_{eq} = \frac{L_1L_2}{L_1 + L_2}$
At dc:	Same	Open circuit	Short circuit

	Capacitors	Inductors
Energy stored in:	Electric field	Magnetic field
When connected to voltage:	V increases I decreases	I increases V decreases
Time constant for charging/discharging:	RC	RL
When disconnected from power:	Maintains voltage	Maintains current

OTHER ELECTRONIC COMPONENTS

- Decade Resistance Box
- Decade Capacitance Box
- Decade Inductance Box
- Regulated Power Supply
- Function Generator
- Multimeter
- Cathode Ray Oscilloscope

DECADE BOX


eisco
Decade Resistance Box
X 1 KΩ
X 10 KΩ
X 100 KΩ
(1 watt, 1% mfr)
X 100 Ω
X 10 Ω
X 1 Ω


BOITE A DECADES
DE CAPACITES
DC05


Micro Logics
DECADE INDUCTANCE BOX
ML - 3005
X 1H
X 100mH
X 10mH
X 1mH
X 100µH

REGULATED POWER SUPPLY

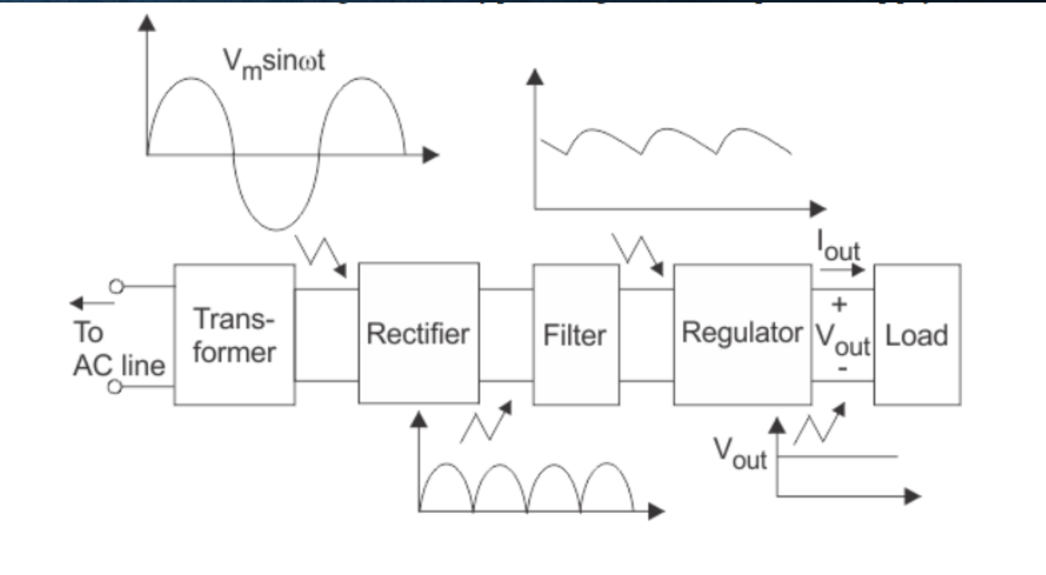
- A **regulated power supply** converts unregulated AC (Alternating Current) to a constant DC (Direct Current).
- A regulated power supply is used to ensure that the output remains constant even if the input changes
- Basic building blocks of a regulated DC power supply

  A step-down transformer

  A rectifier

  A DC filter

  A regulator



Components of typical linear power supply

FUNCTION GENERATOR

- Generates a variety of signals for testing and troubleshooting electronic circuits
- The most common types of signals are Triangular Wave, Sine Wave, Square Wave and Sawtooth Wave.

FUNCTION GENERATORS

MULTI-METER

A multimeter is a combination of Voltmeter, Ammeter and Ohmmeter

Multimeters can measure values in both AC and DC

OSCILLOSCOPE

- Observing continuously varying signals is an Oscilloscope
- We can observe the changes in an electrical signal like voltage, over time.
- Oscilloscopes are used in a wide range of field like Medical, Electronic, Automobile, Industrial and Telecommunication Applications.
- Oscilloscopes are made up of Cathode Ray Tube (CRT) displays but nowadays, almost all Oscilloscopes are Digital Oscilloscopes with advanced features like storage and memory

CATHODE RAY OSCILLOSCOPE

- CRO stands for a cathode ray oscilloscope
- It is typically divided into four sections which are display, vertical controllers, horizontal controllers, and Triggers
- Most of the oscilloscopes are used the probes and they are used for the input of any instrument.
- We can analyze the waveform by plotting amplitude along with the x-axis and y-axis.
- The applications of CRO are mainly involved in the radio, TV receivers, also in laboratory work involving research and design

CATHODE RAY OSCILLOSCOPE

- The oscilloscope observes the changes in the electrical signals over time, thus the voltage and time describe a shape and it is continuously graphed beside a scale.
- By seeing the waveform, we can analyze some properties like amplitude, frequency, rise time, distortion, time interval, and etc.

- How to use Function Generator & CRO? https://www.youtube.com/watch?v=yQiYDGVUHgA

ELECTRO-MECHANICAL COMPONENTS

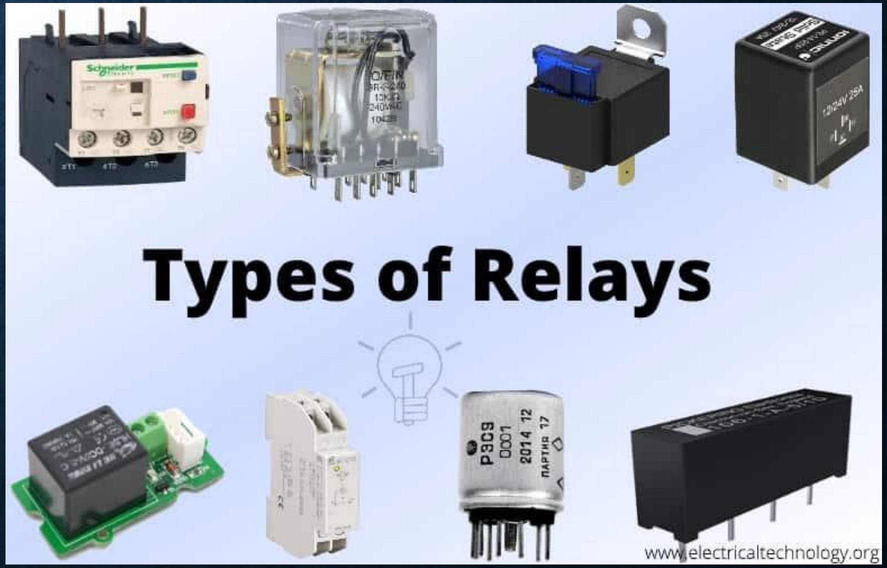
- An electromechanical component is one that uses an electrical signal to cause some kind of mechanical change, such as motor turning.
- These normally use an electrical current to create a magnetic field which causes a physical movement.
- All types of relays and switches are available in this category

SWITCHES - EM

- An electromechanical switch is a manually operated switch used to make or break the connection in an electric circuit by means of magnetic field and moving contacts.

RELAYS - EM

- Relays are designed to emulate higher-level switch functions.
- Relays are normally multipole, double throw devices and are usually designed for low-current switching.
- Relays are used extensively for control applications and are found in nearly every electromechanical appliance manufactured.



- How relay works?

  https://www.youtube.com/watch?v=Ca20ktPygY8