Elementary Theory of Alternating Currents

Presented by:

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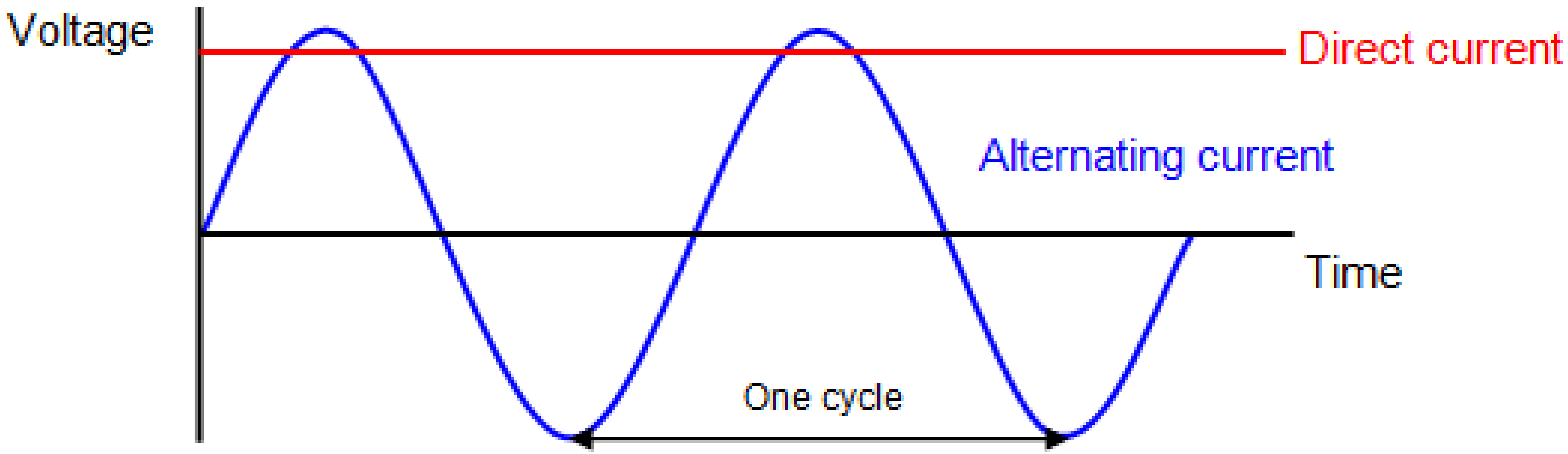
What is AC?

- AC, or Alternating Current, is the form of electric power that is found commonly all around us
- Alternating current is a changing current – its direction and size vary constantly, sometimes it flows in one direction in the circuit and a fraction of a second later it is flowing in the other.
- Audio and Radio waves carried via wires are forms of AC

What is DC?

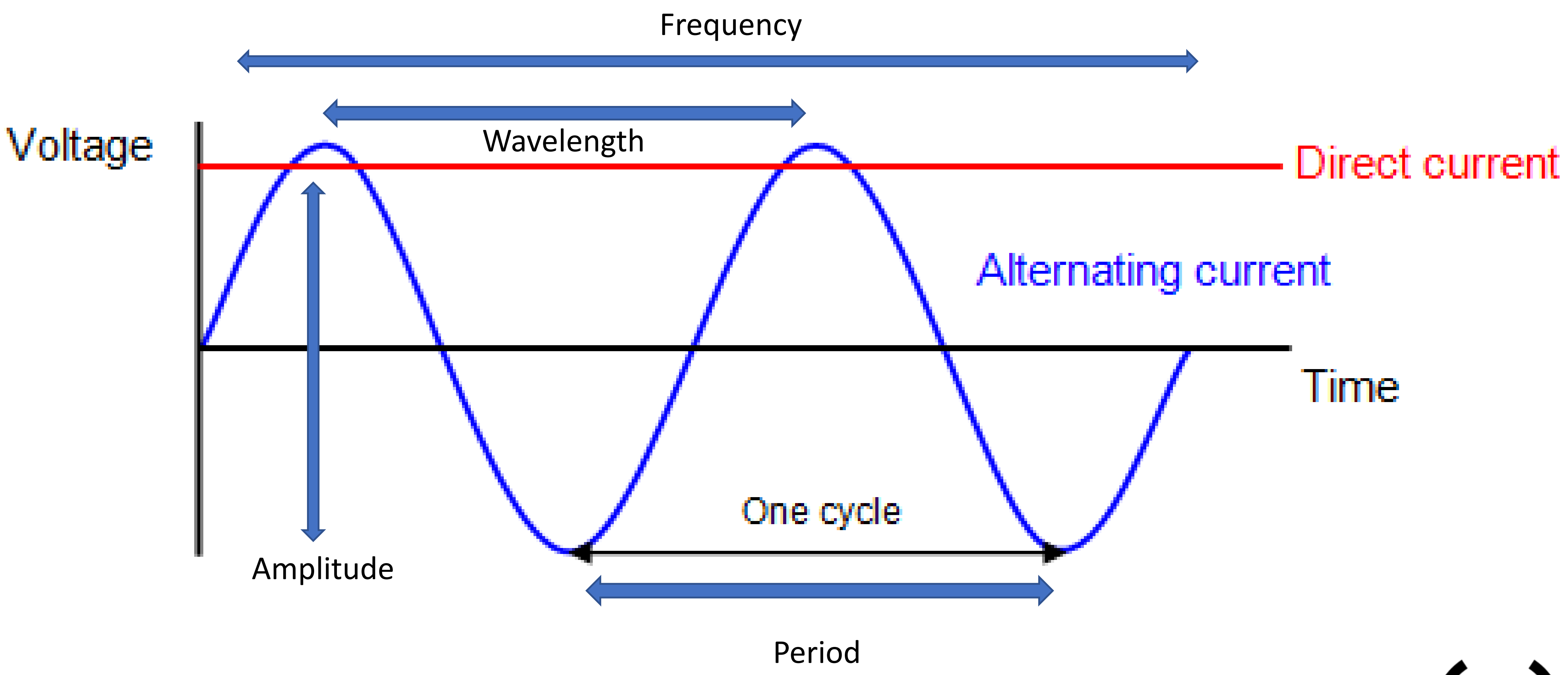
- Direct Current , or DC, is the form of current found in batteries
- Direct current, or DC, is a steady current – it does not change in size or direction with time
- DC powers most of our portable electronics such as phones, watches, laptop computers, etc.


Voltage
Direct current
Alternating current
Time
One cycle


AC
DC

Properties of AC

- Frequency : It is the number of occurrences of a repeating event per unit time, Denoted by "*f*"; measured in Hertz; denoted by Hz (Old: Cycles/Second)
- Period : Amount of time required to complete one cycle; measured in seconds/ cycle
- Wavelength : distance travelled by a wave in one cycle; denoted by Greek alphabet " *λ* " *Lambda*.
- Amplitude: Maximum extent of oscillation from equilibrium.

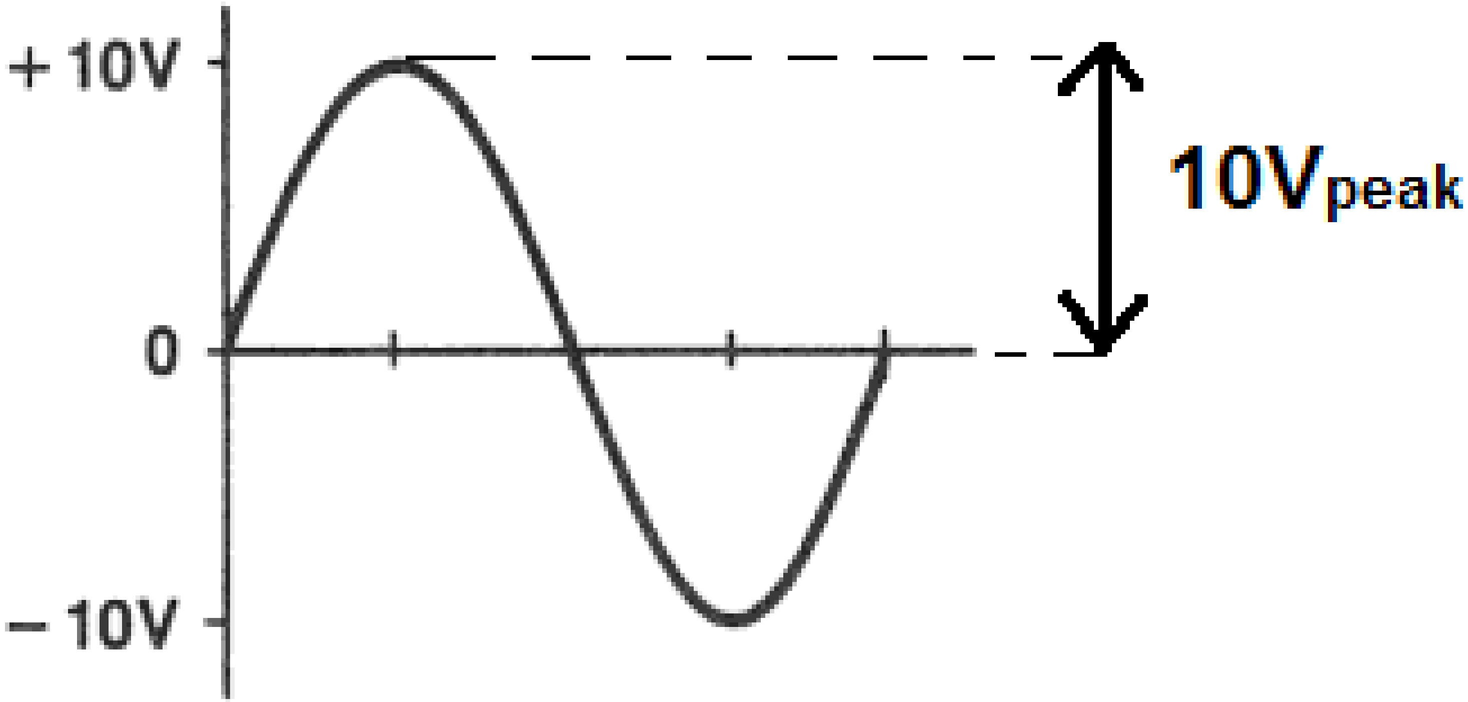

Frequency
Wavelength
Voltage
Direct current
Alternating current
Time
One cycle
Amplitude
Period

AC Versus DC

AC	DC
Efficient to send over distances	Inefficient to send over distances
Cannot be stored directly in batteries	Can be stored in batteries easily
Voltage can be stepped up or down efficiently	Voltage conversion is not as efficient as AC
Dangerous! Not suitable for portable gadgets	Not as dangerous as AC, not suitable for power hungry gadgets

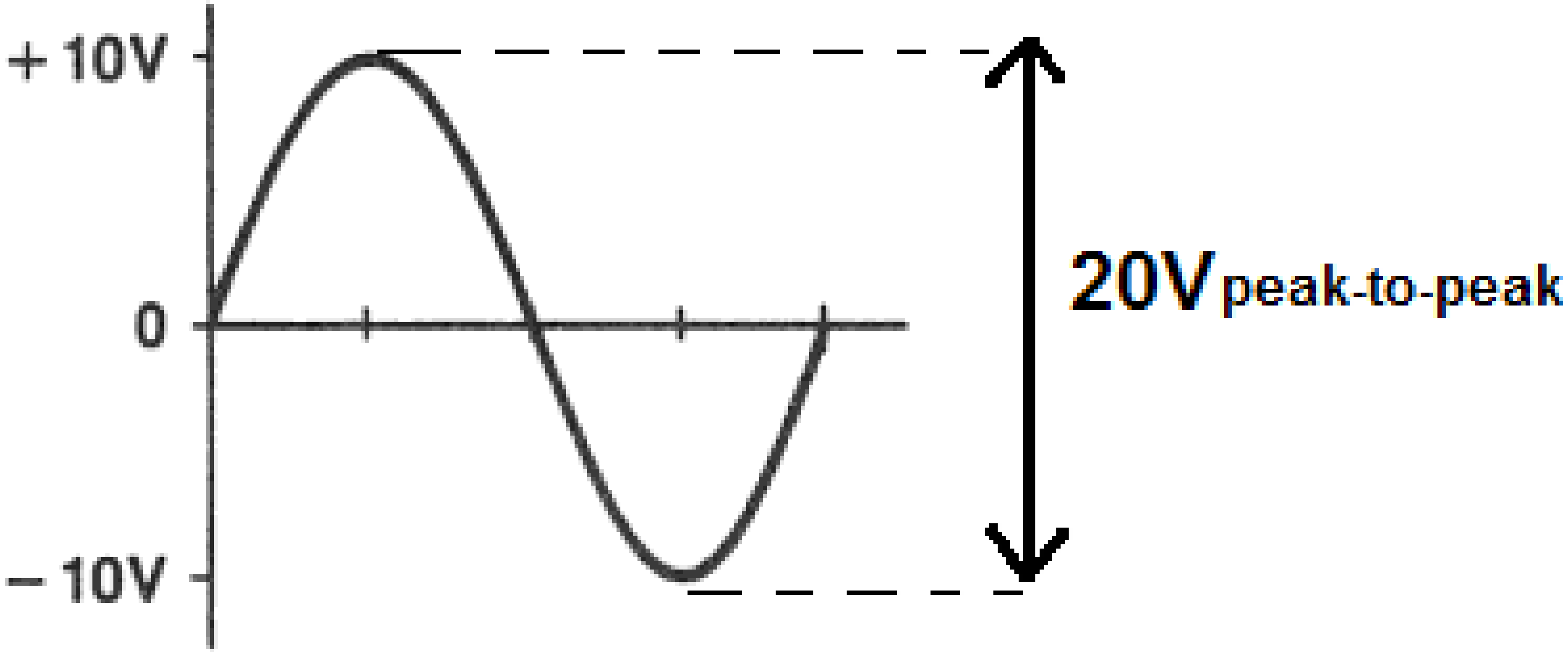
Measuring AC

- Peak Value



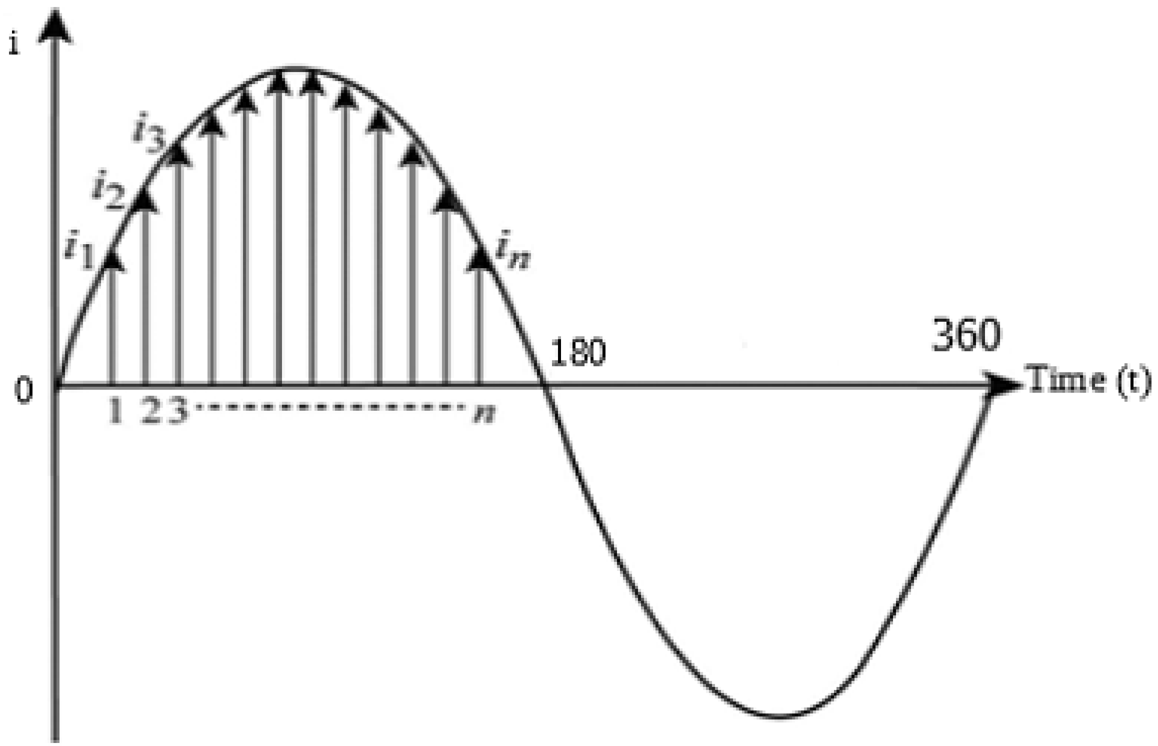
Measuring AC

- Peak to Peak value



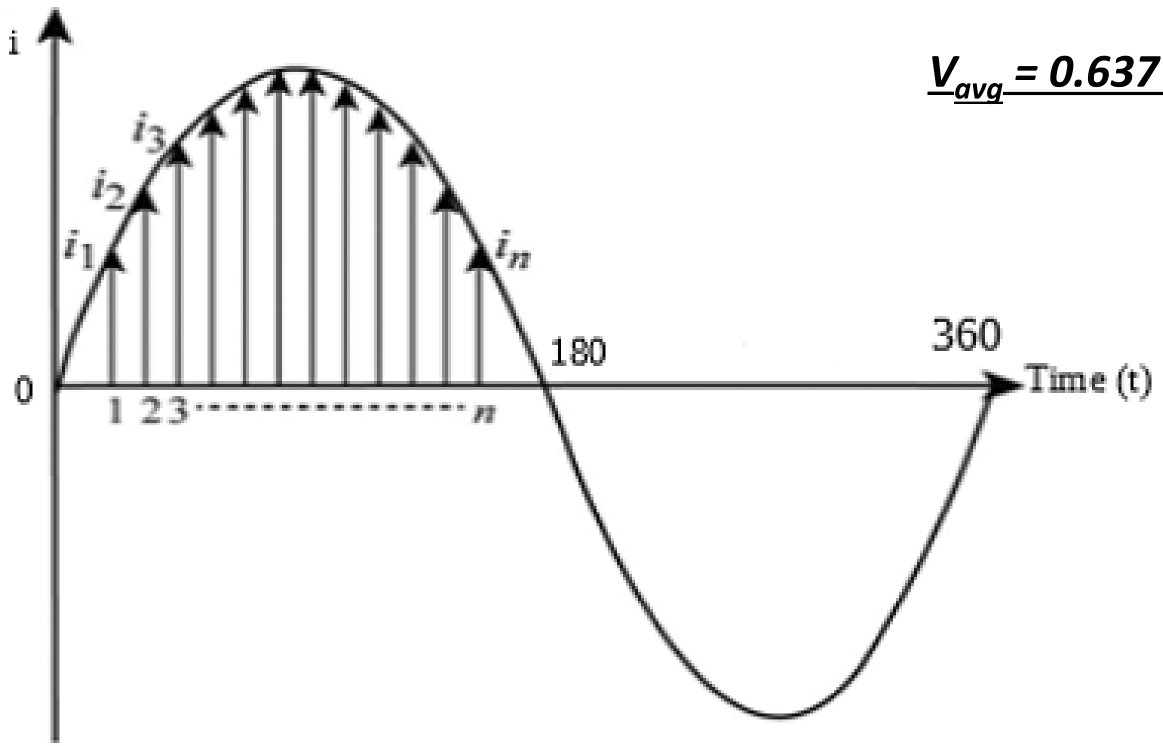
Measuring AC

- Instantaneous Value



Measuring AC

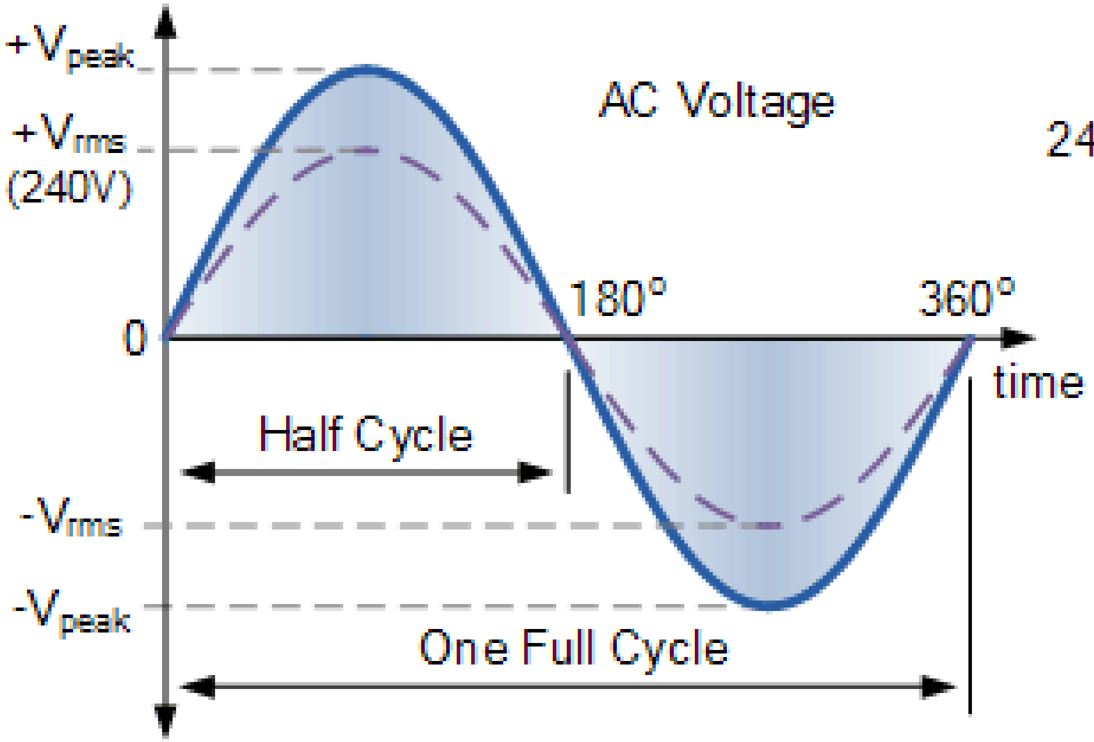
- Average Value

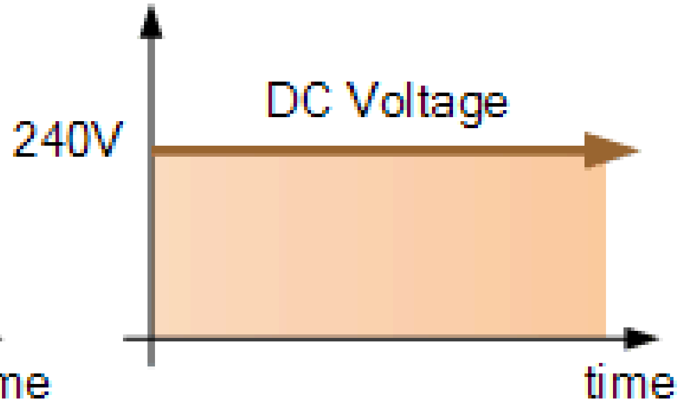


$$V_{avg} = 0.637 * V_{pk}$$

Measuring AC

- Effective or Root Mean Square Value



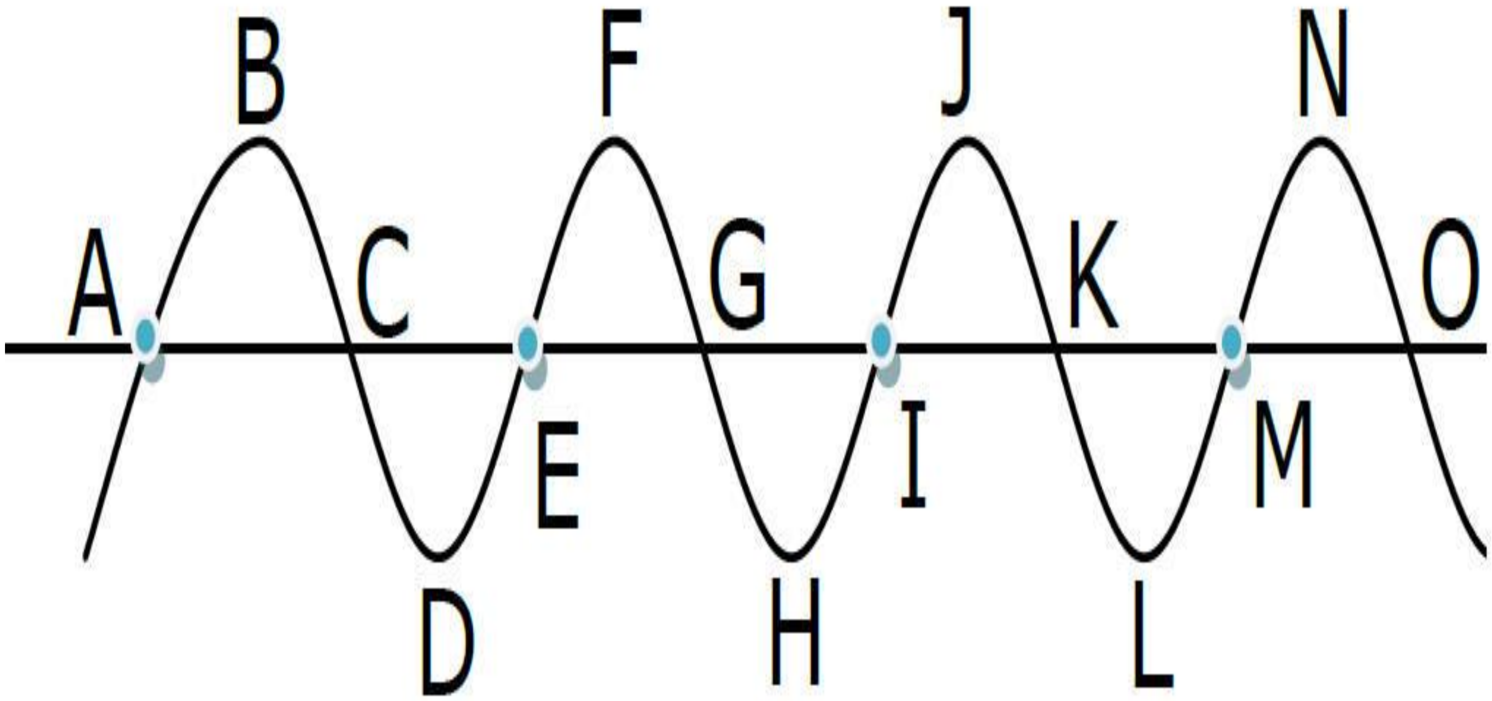


RMS = V_{pk} x 0.707

RMS is the standard!

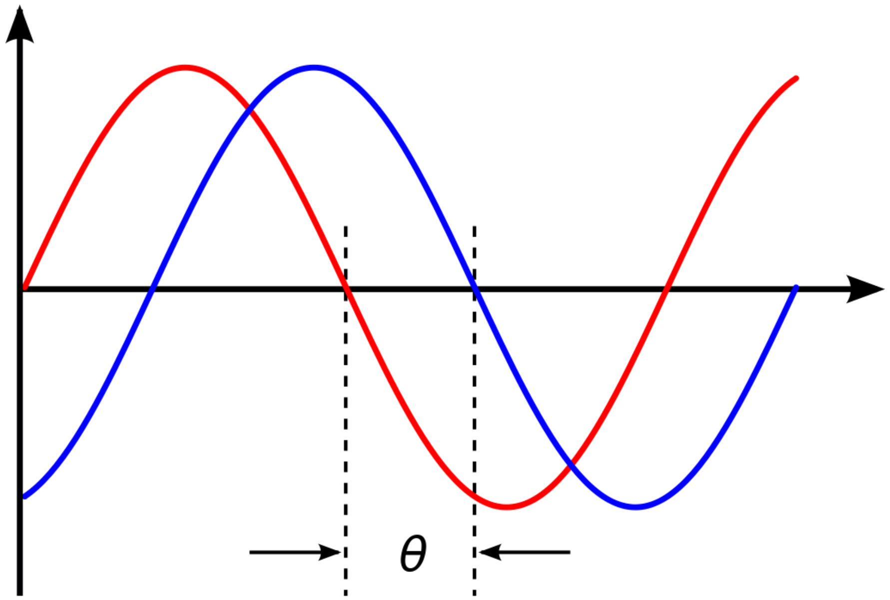
Phase

- Phase is the specific location of a point within a wave, with respect to time. It is measured in degrees or radian.



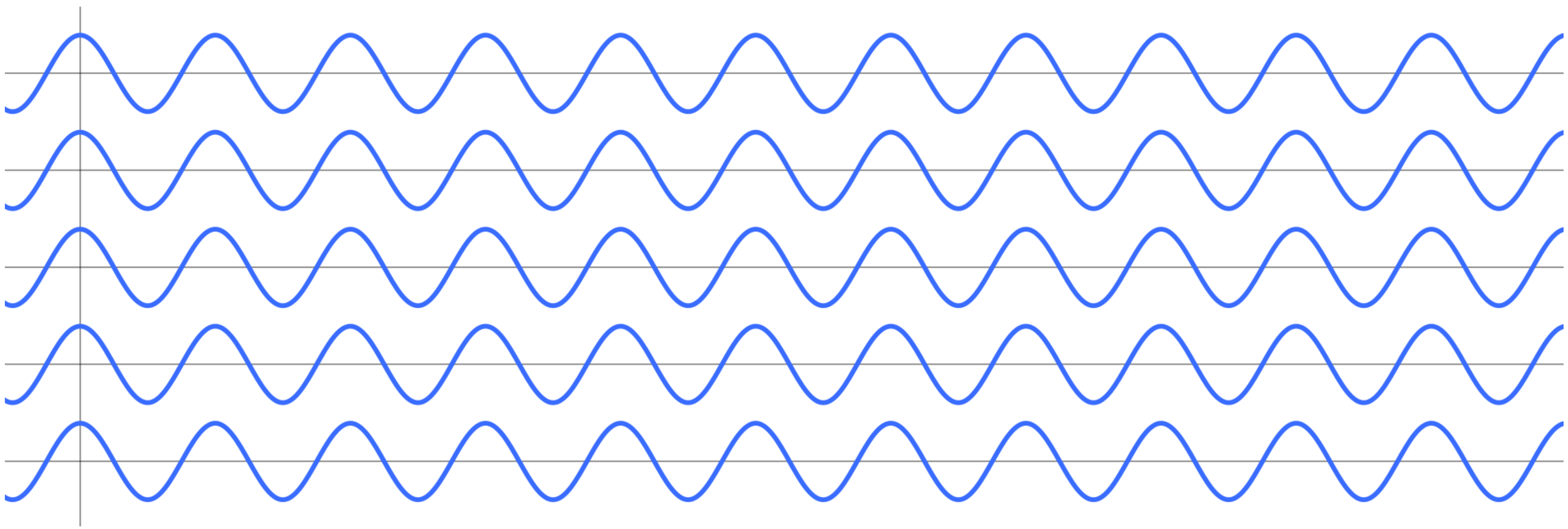
Phase Difference

- It is the difference, expressed in degrees or time, between two waves having the same frequency and referenced to the same point in time.



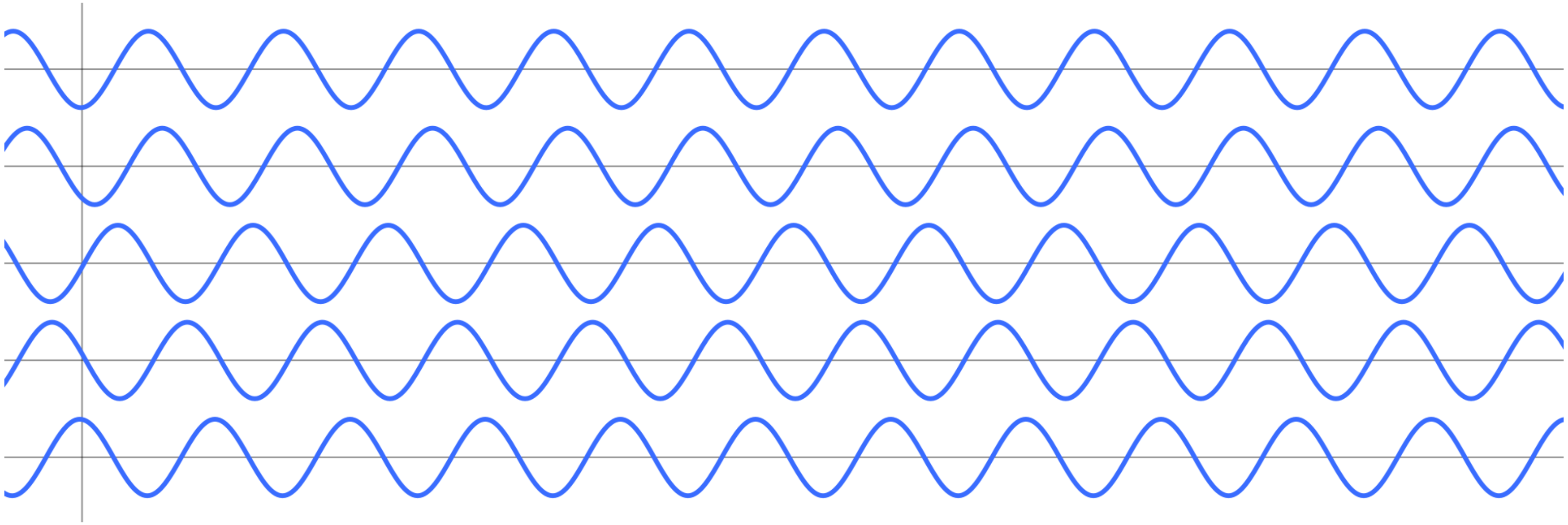
In Phase

- If the crests of two waves pass the same point or line at the same time, then they are in phase for that position



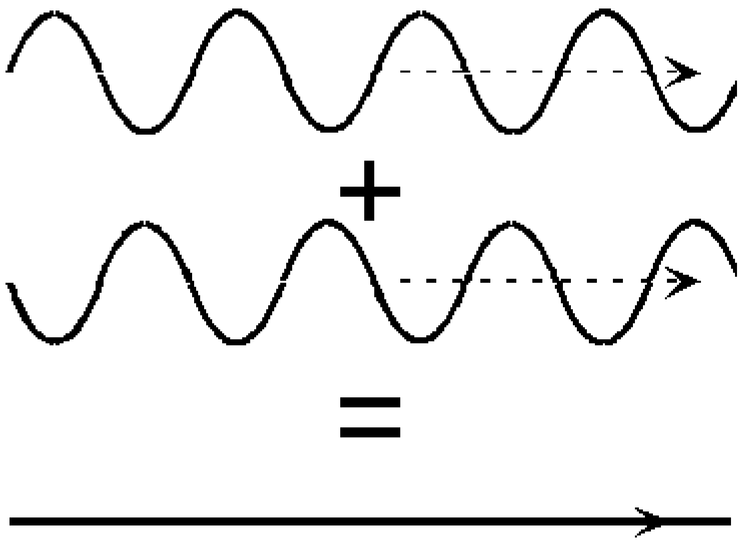
Out of Phase

- If the crests of one wave and the trough of another pass through the same point or line at the same time, they are said to be Out of Phase



Antiphase

- If the phase difference between two waves is 180 degrees, then the two waves are said to be in antiphase; this can lead to destructive interference, a phenomena in which both waves cancel each other



Reactance

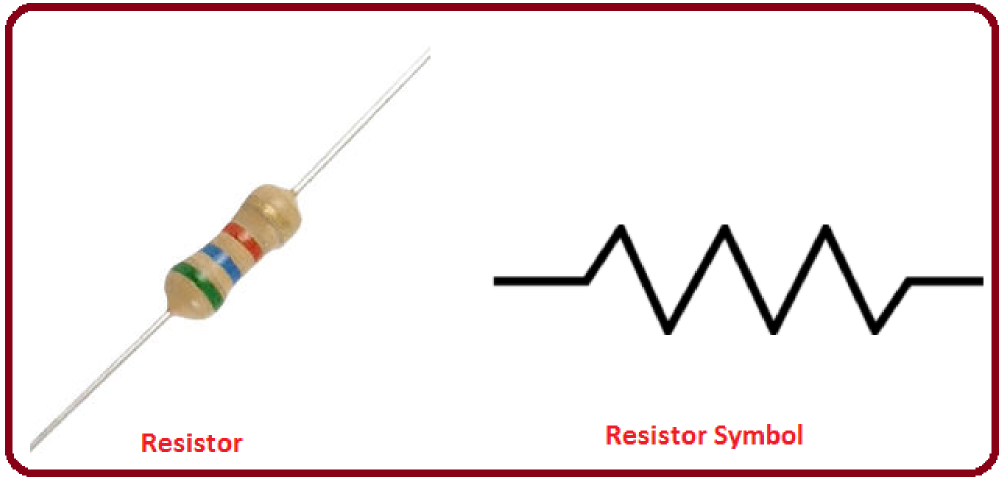
- Reactance is the measure of opposition in a AC circuit
- Two kinds of reactance : Inductive and Capacitive
- Inductive Reactance, X_L, is calculated using $2\pi f\mathrm{L}$
- Capacitive Reactance, X_C, is calculated using $1/(2\pi f\mathrm{C})$
- with DC: No Reactance; with AC and DC : Reactance; DC, Switched: Reactance but temporary

Impedance

- Impedance is the term used to describe the combined effect of both resistance and reactance in a circuit; it is given in Ohms.
- Electrical impedance is just a form of resistance that depends on frequency
- Impedance of circuits, and matching them between connecting circuits is very important to prevent any losses

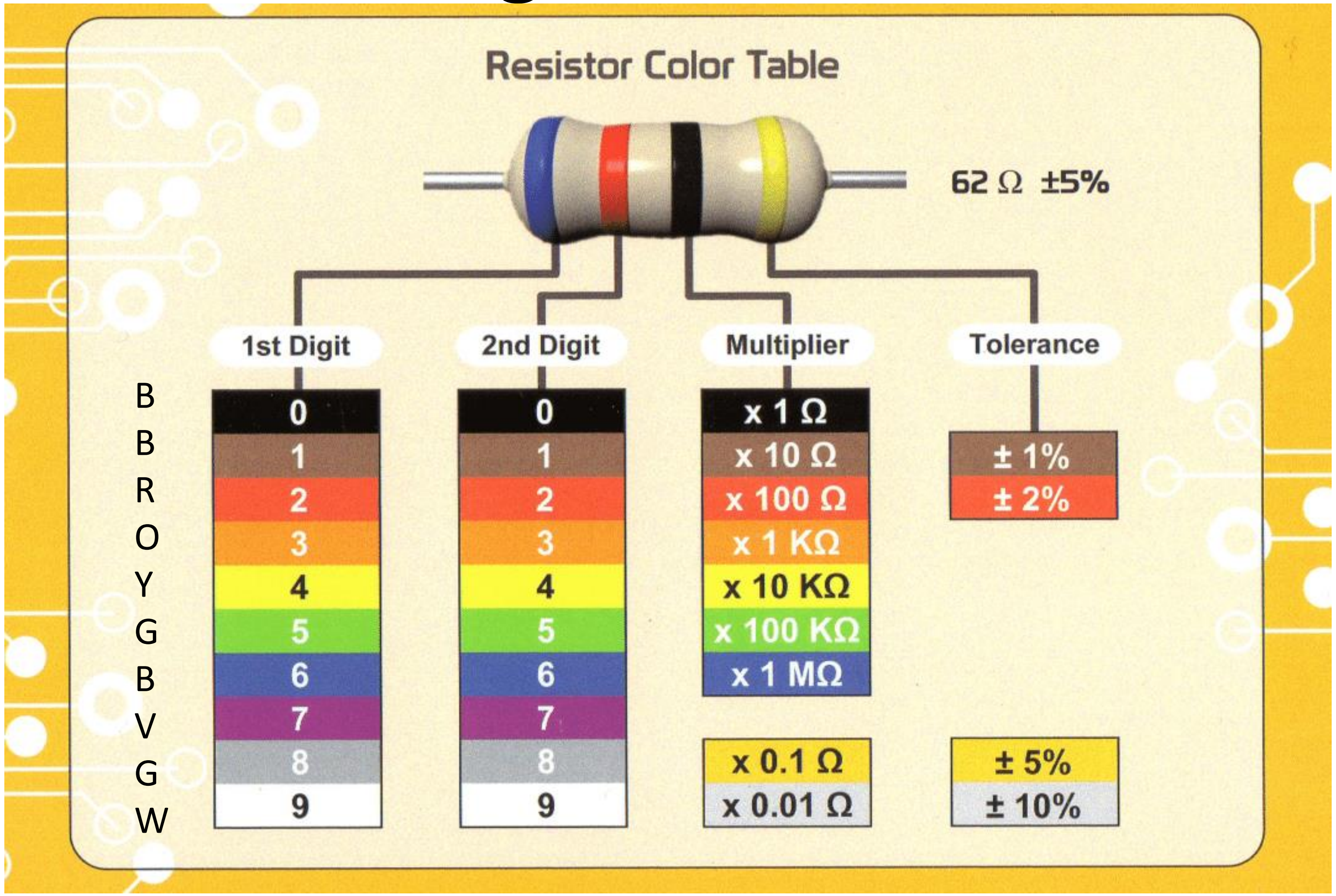
Resistance

- Resistance is the opposition to the flow of current in a circuit. It is measured in Ohms (symbol Ω)
- They are used to control the flow of current or voltage in a circuit
- Resistors are colour coded to indicate their value

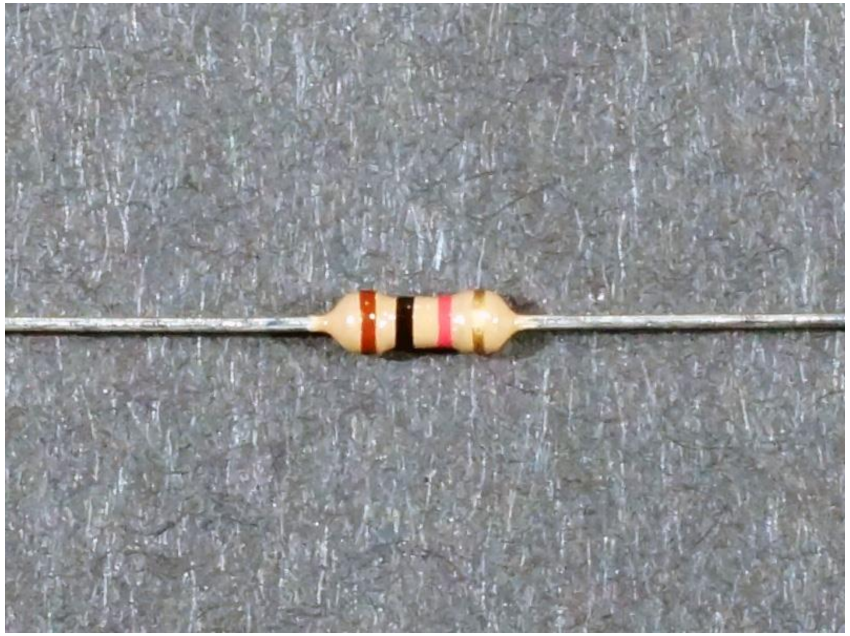


Decoding Resistor Values

B
B
R
O
Y
G
B
V
G
W

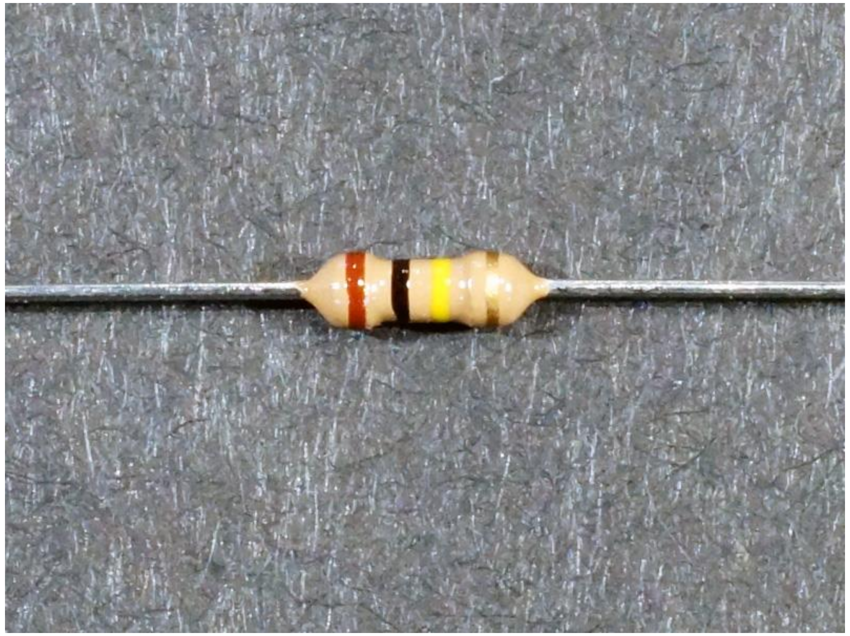


Decoding resistor values ..



- Hold resistor such that gold or silver band is to the right
- Note down the colours; in this case Brown, Black, Red, Gold
- On comparing against the colur code chart, we get the values of Brown = 1, Black =0, Red = x100 Ohms, Gold = 5% tolerance
- 1000 Ohms or 1 Kilo Ohms

Decoding resistor values ..



- Brown, Black, Yellow, Gold
- Brown = 1, Black = 0 , Yellow = x10000 Ohms, Gold = 5%
- 1,00,000 Ohms or 100 Kilo Ohms
- Tolerance indicates the accuracy of the part; in this case, the resistor can be anywhere from 95K Ohms to 105K Ohms

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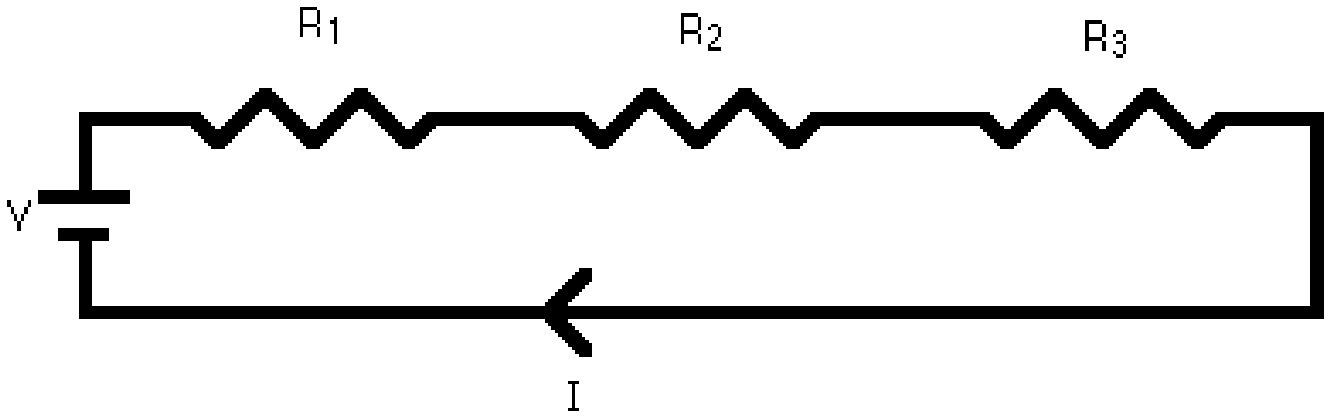
Decoding resistor values ..

- Orange, Orange, Red, Gold
- Orange = 3, Red = 1000 Ohms, Gold = 5%
- 3300 Ohms or 3.3 Kilo Ohms or 3K3 Ohms

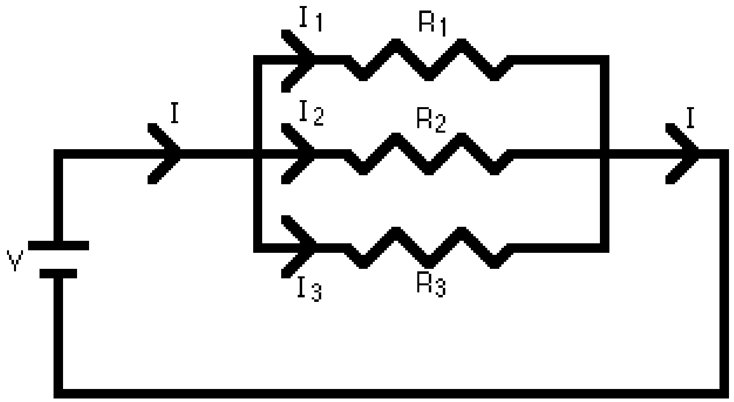
Resistors – Series circuits

- Resistors are components that add "friction" to the flow of current in a circuit; when they are arranged in a chain, where current has only one path to take, the resistors are said to be in "Series"; The current is the same through each resistor. Equivalent resistance is R1+R2+R3

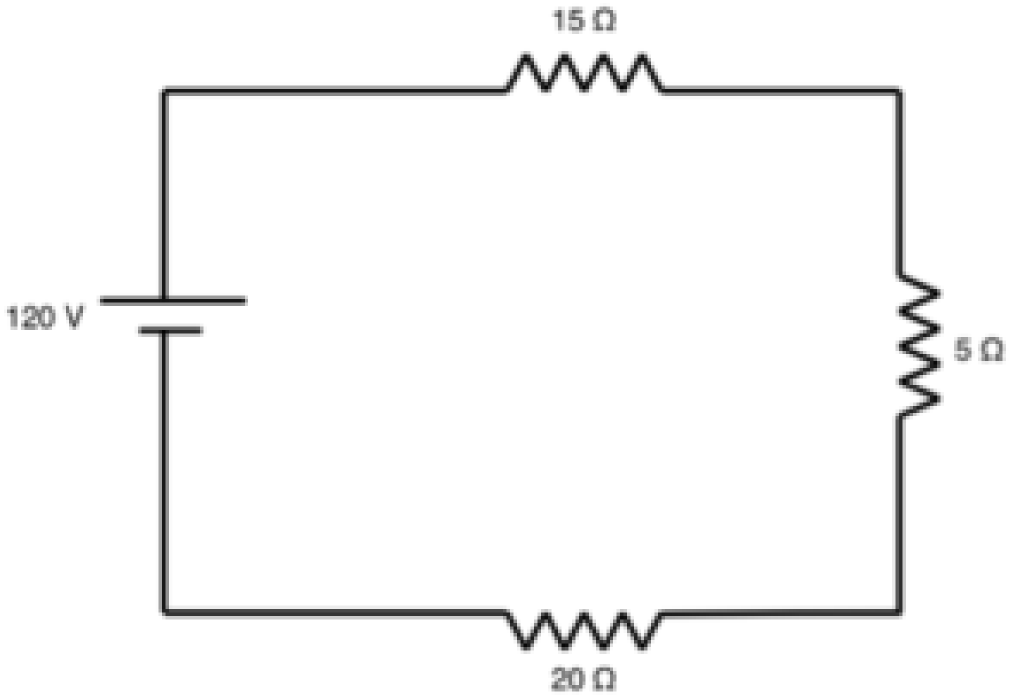


Resistors – Parallel circuits

- A circuit in which the resistors are arranged with their heads connected together, and their tails connected together, is said to be parallel circuit. The current in a parallel circuit breaks up, with some flowing along each parallel branch and re-combining when the branches meet again. The voltage across each resistor in parallel is the same. Equivalent resistance is 1/R = 1/R1+ 1/R2+ 1/R3

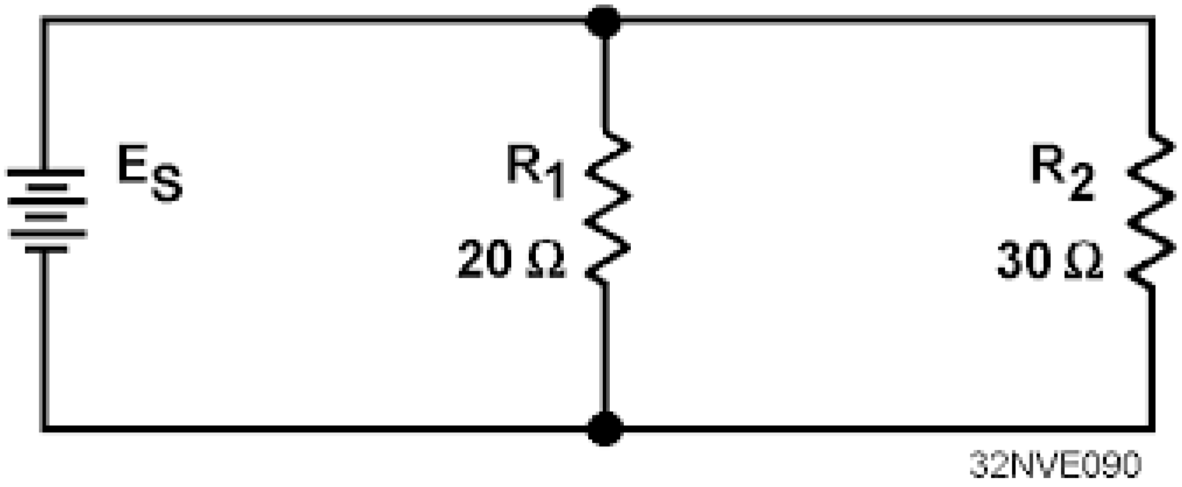


Series Circuits - Example



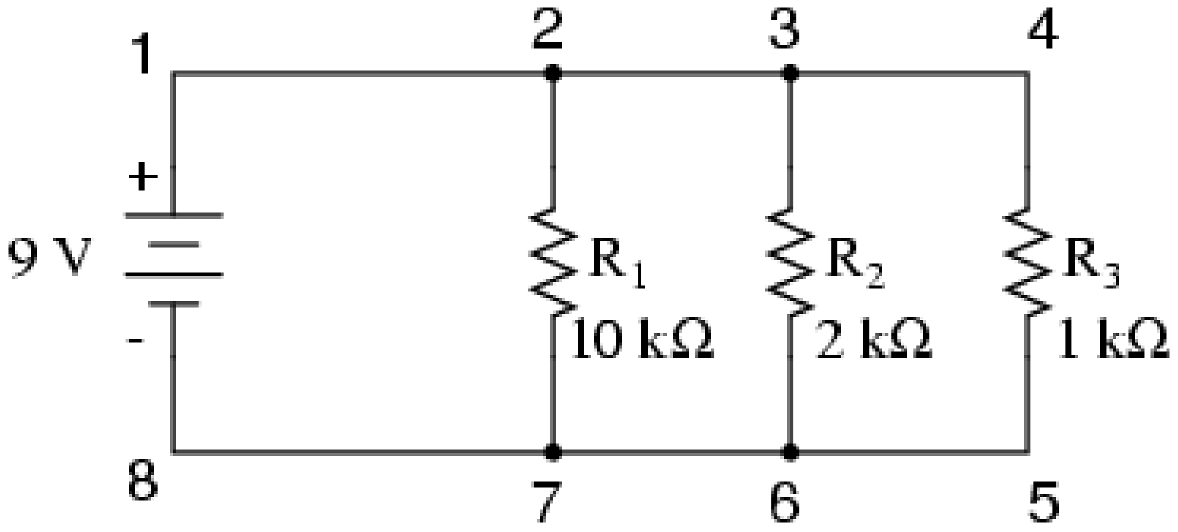
- Series Resistance = R1+R2+R3
- 15+5+20 Ohms = 40 Ohms

Parallel Circuits - Example



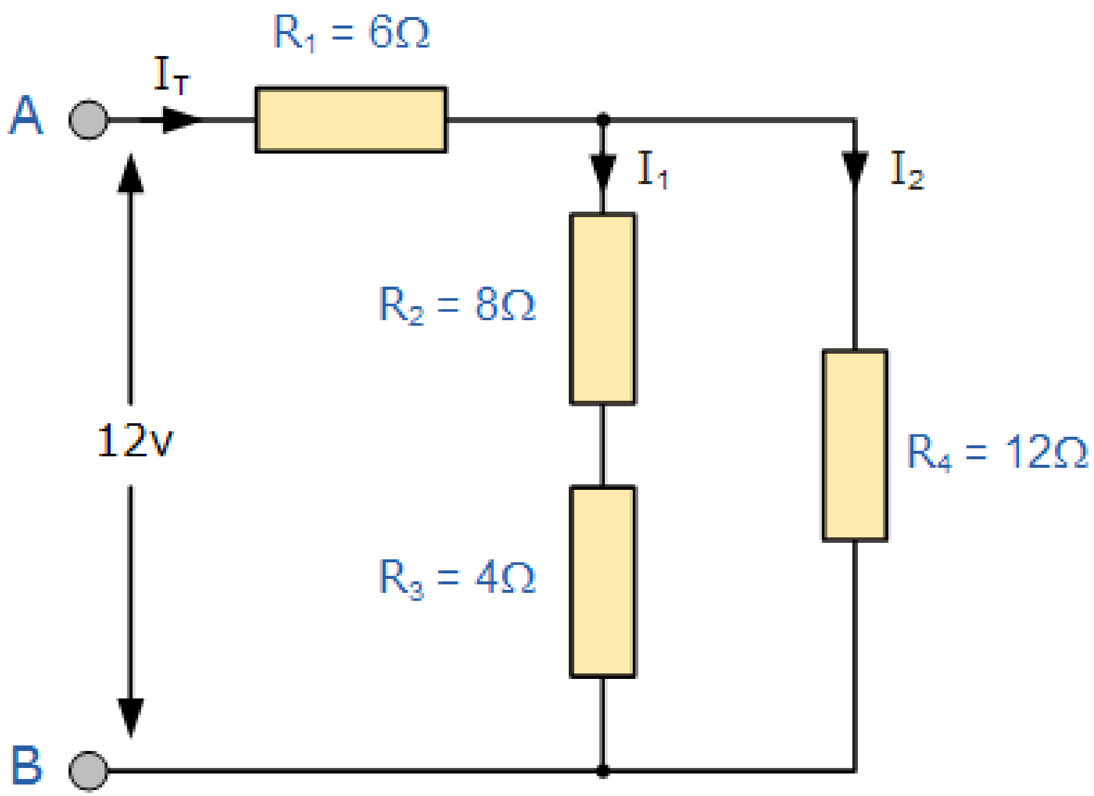
- Parallel resistance = 1/R = 1/R1+1/R2
- 1/R = 1/20+1/30= 1/.05+.033= 1/.833 = 12 Ohms
- An easier method for two resistors : R1 x R2 / R1+ R2
- R = 20*30/20+50 = 600/50 = 12 Ohms

Parallel Circuits - Example



- Parallel resistance = 1/R = 1/R1+1/R2+1/R3
- 1/R = 1/10000+1/2000+1/1000 =1/.0001+.0005+.001 = 1/.0016 = 625Ohms
- Always remember, Equivalent Parallel resistance will be lower than smallest resistance!

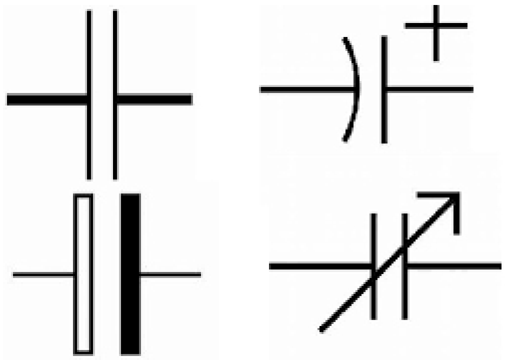
Series and Parallel Combination



- Current passes from A through series R1 and then can travel through Series network R2+R3 and R4
- Solve Series R2 + R4 = 12 Ohms
- Solve Parallel (R2+R3) x R4 / (R2+R3) + R4 = (12) x 12 / (12) + 12 = 144/24= 12 Ohms

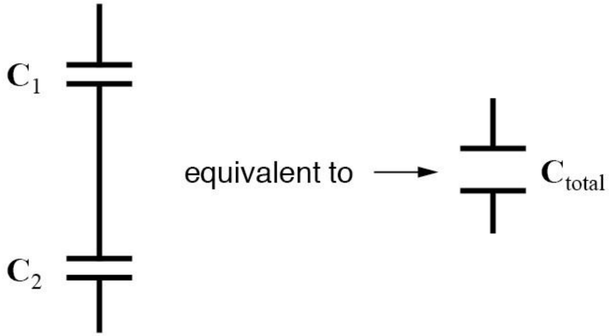
Capacitors

- A capacitor is a passive electrical component that can store energy in the electric field between a pair of conductors (called "plates")
- A capacitor's ability to store charge is measured by its capacitance, in units of farads (F)
- Capacitors block DC and allow AC



Capacitors - Series

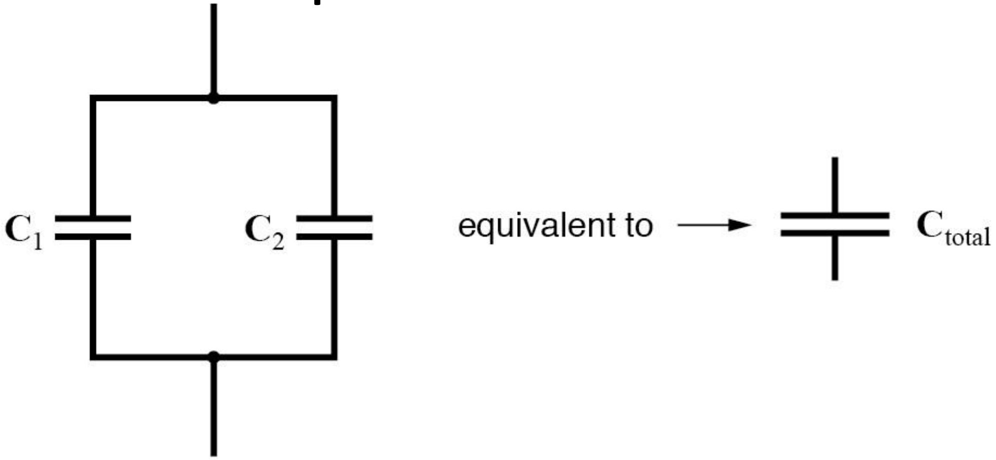
- When capacitors are connected in series, the total capacitance is less than any one of the series capacitors' individual capacitance
- If two capacitors are connected in series, the overall effect is that of a single capacitor having the sum total of the plate spacings of the individual capacitors



$$1/\,C_{Total} = 1/C1 + 1/C2 + 1/C3$$

Capacitors - Parallel

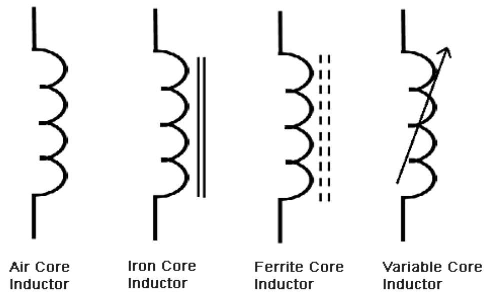
- When capacitors are connected in parallel, the total capacitance is the sum of the individual capacitors capacitance
- If two capacitors are connected in parallel, the overall effect is that of a single capacitor having the sum total of the plate areas of the individual capacitors

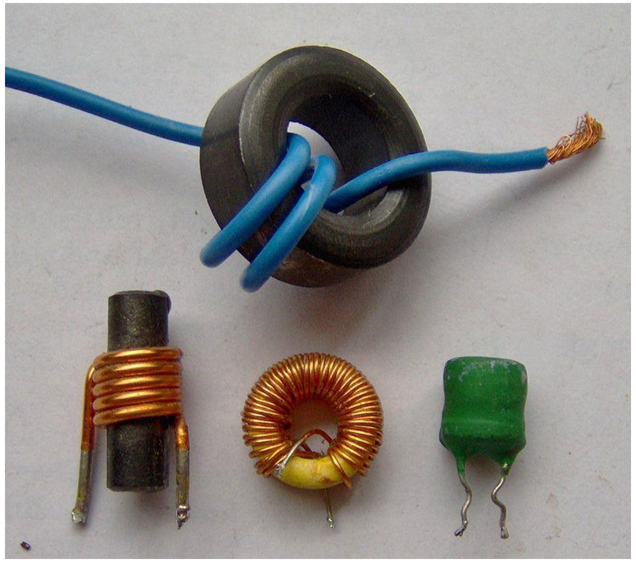


C_{Total} = C1+C2+C3

Inductors

- An inductor, also called a coil, is a passive two-terminal electrical component that stores energy in a magnetic field when electric current flows through it
- The unit used to measure inductance is Henrys (H)
- Inductors block AC and allow DC

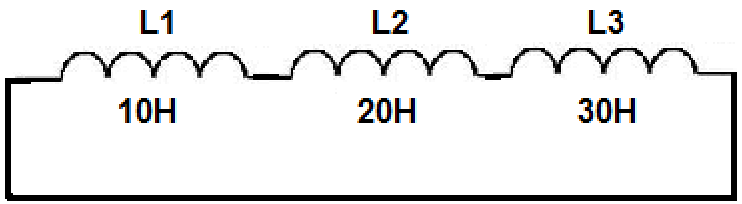




SIARS

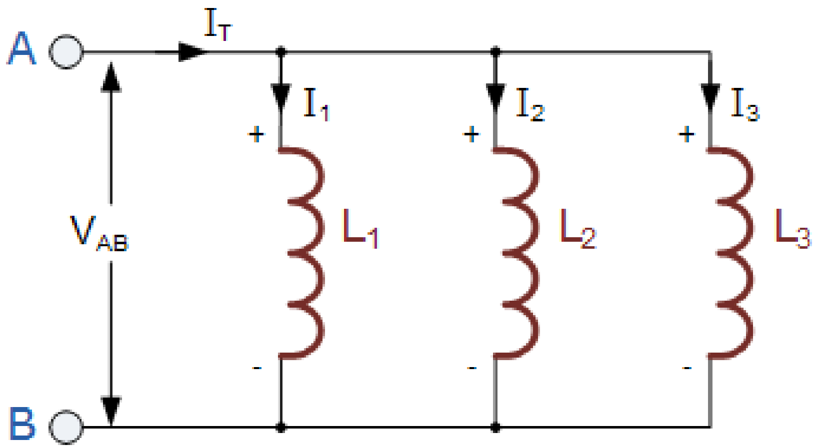
Inductors – Series

- When Inductors are connected in series, the total inductance is the sum of the individual inductors’ inductance ; L = L1+L2+L3 …
- The total inductance for series inductors is more than any one of the individual inductors’ inductance



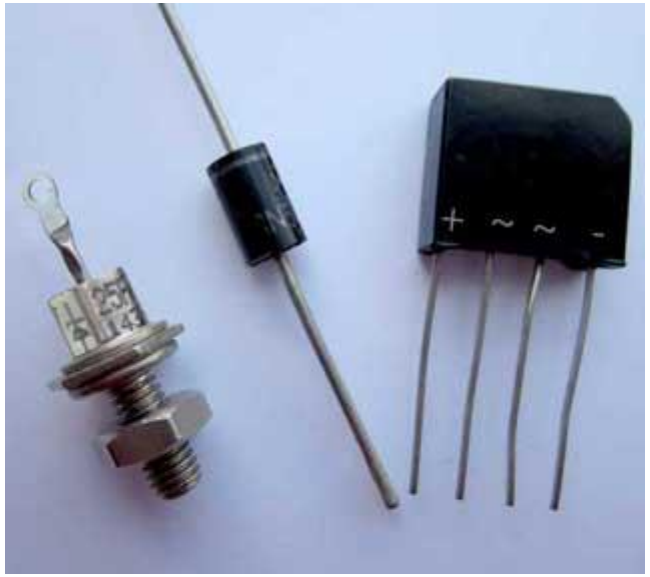
Inductors- Parallel

- When Inductors are connected in parallel, the total inductance is less than any one of the series inductors' individual inductance
- The Equivalent parallel inductance of inductors in parallel is 1/L= 1/L1+ 1/L2 +1/L3



Rectifiers

- Rectifiers, or Diodes, are components that convert AC to DC
- Rectifiers typically act like a one way street for the flow of electrons
- Rectifiers are primarily found in circuits that require AC-DC conversion



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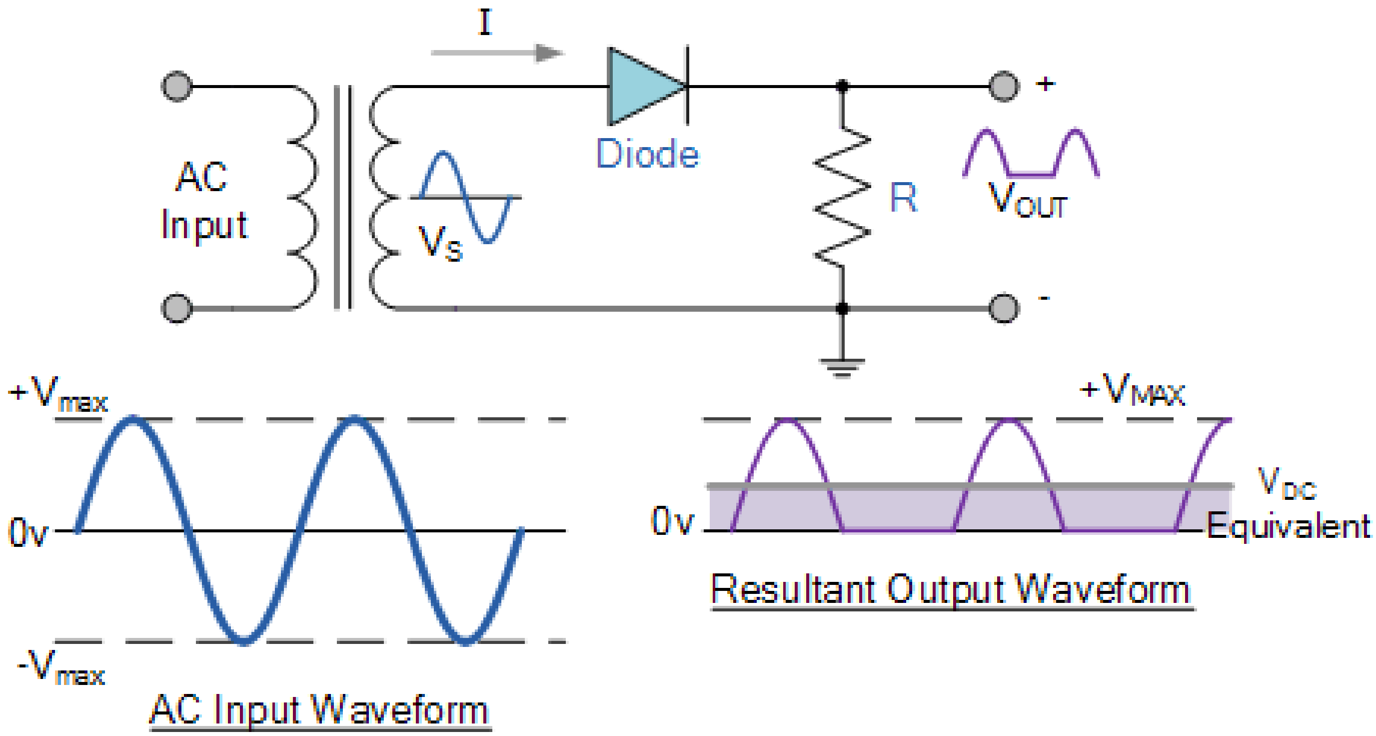
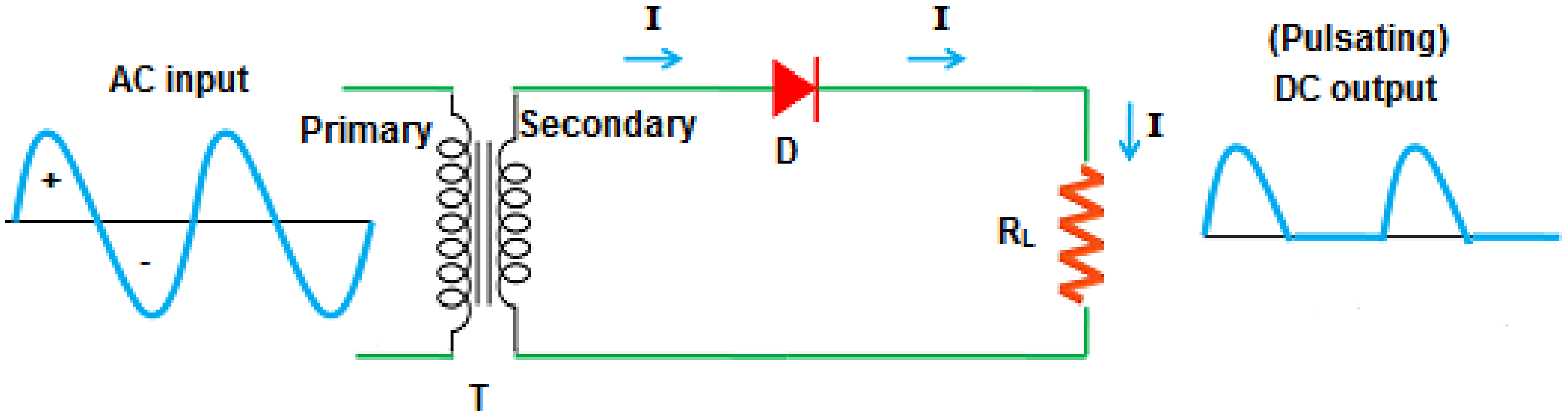
Half Wave Rectifier

- A half wave rectifier is a single diode circuit, that converts AC to Pulsating DC; they require heavy filtering



Half Wave Rectifier …

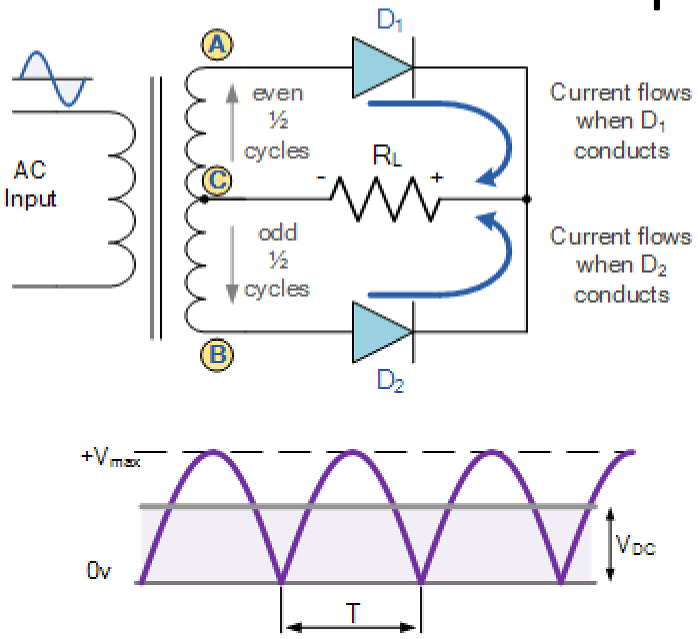


I = Current
D = Diode
R_L = Load resistor
T = Transformer
+ = Positive half cycle
- = Negative half cycle

Positive half wave rectifier

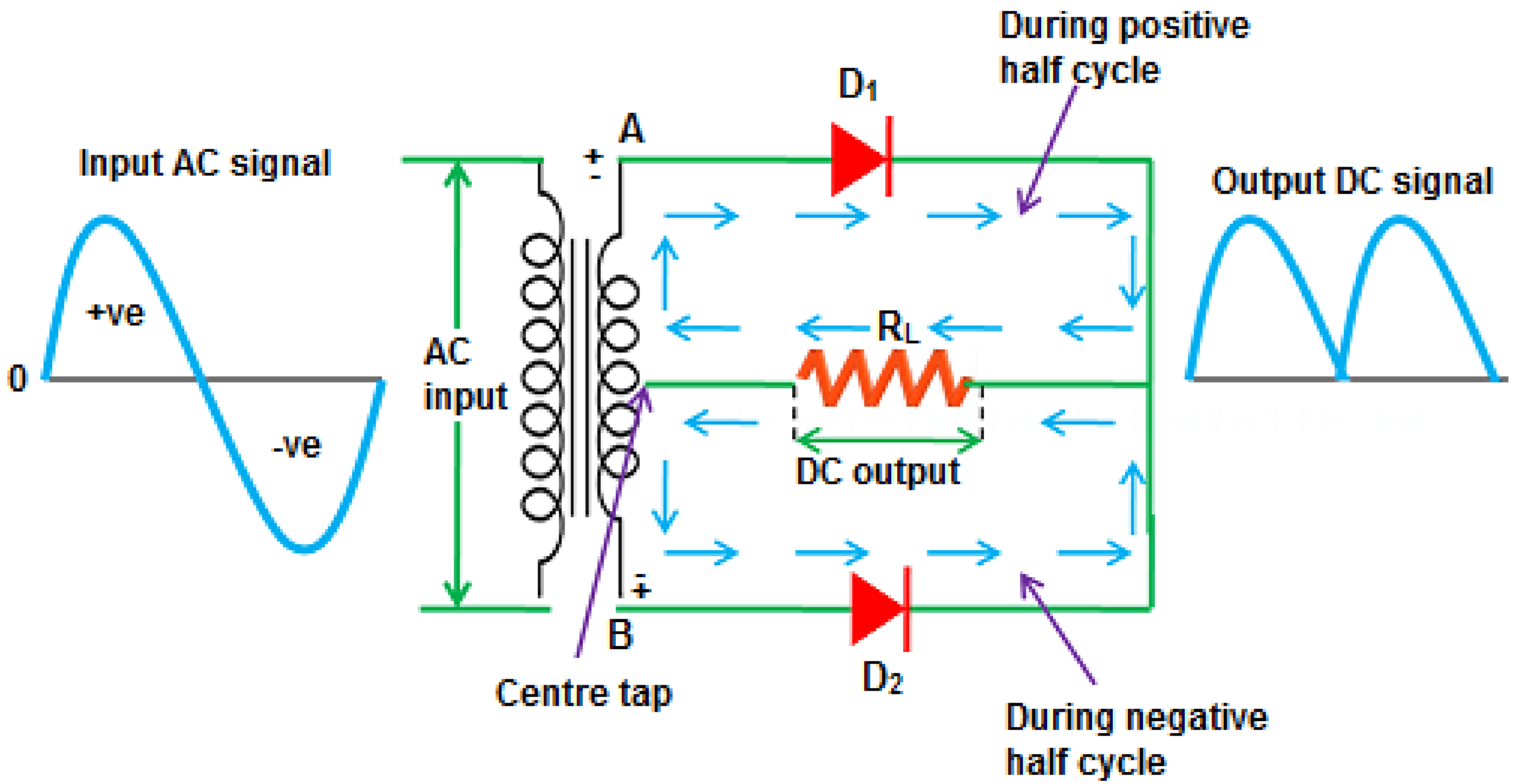
Full Wave Rectifier

- A full wave rectifier is a two diode circuit that converts AC to pulsating DC; they are slightly more efficient than half wave rectifiers, they avg. DC is higher than half wave rectifiers and require less filtering



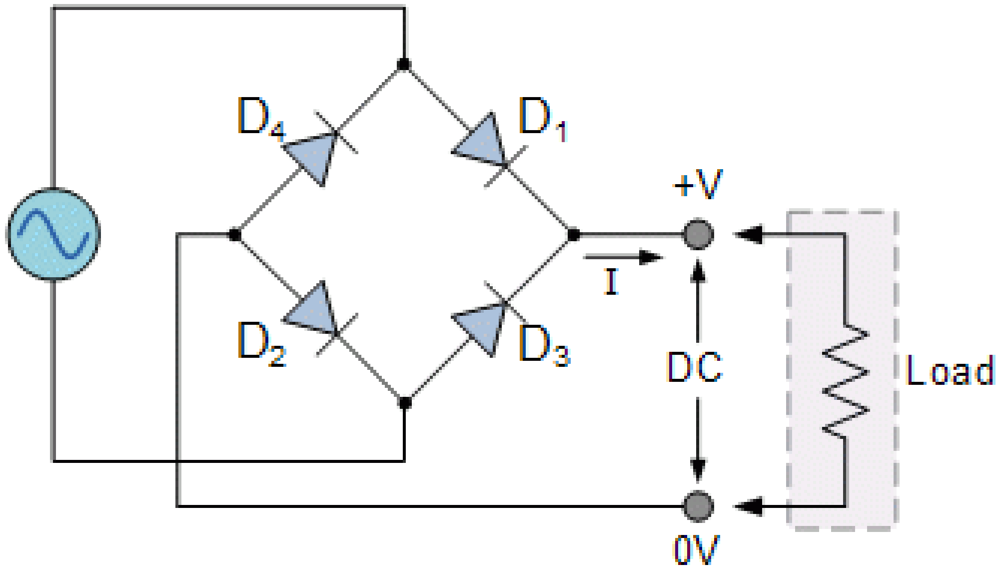
Resultant Output Waveform

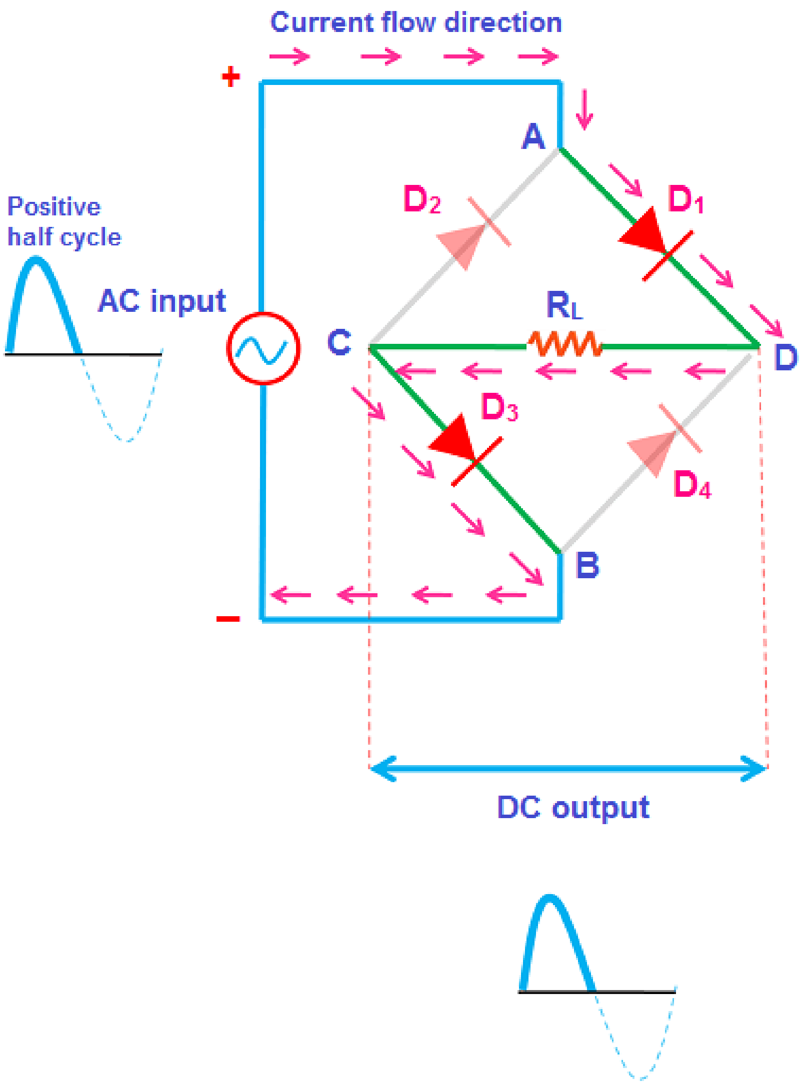
Full Wave Rectifier



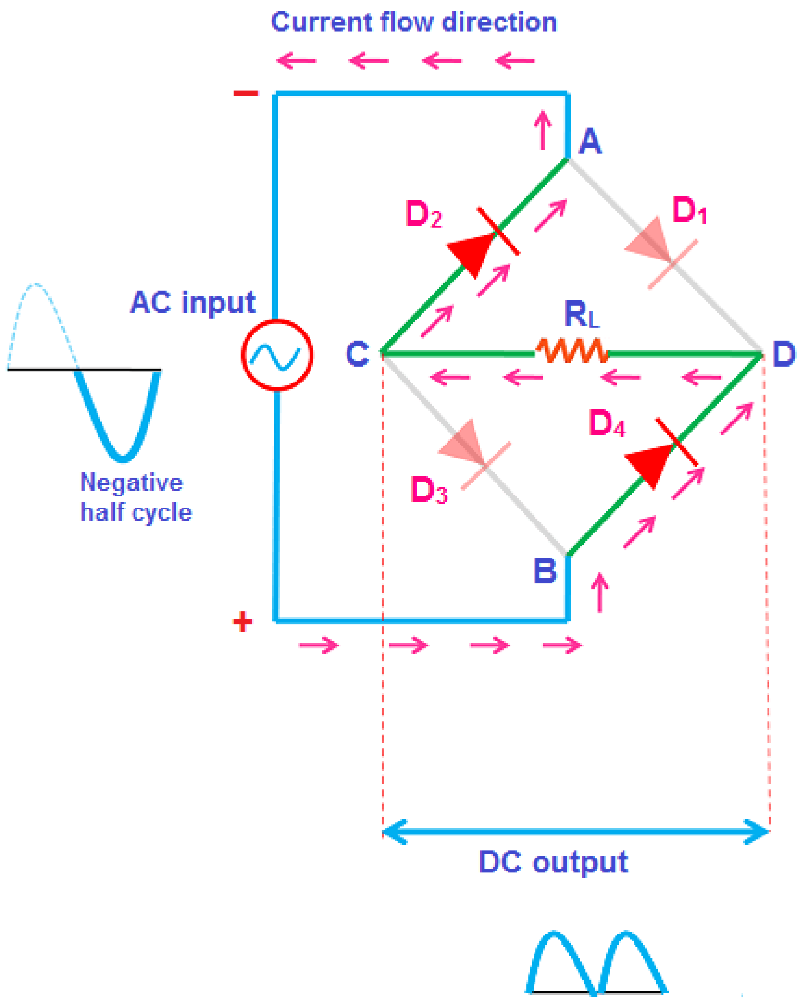
Bridge Rectifier

- Bridge rectifiers are 4 diode circuits, arranged to form a loop(Bridge), to convert AC to Pulsating DC; they are far more efficient than half and full wave rectifiers



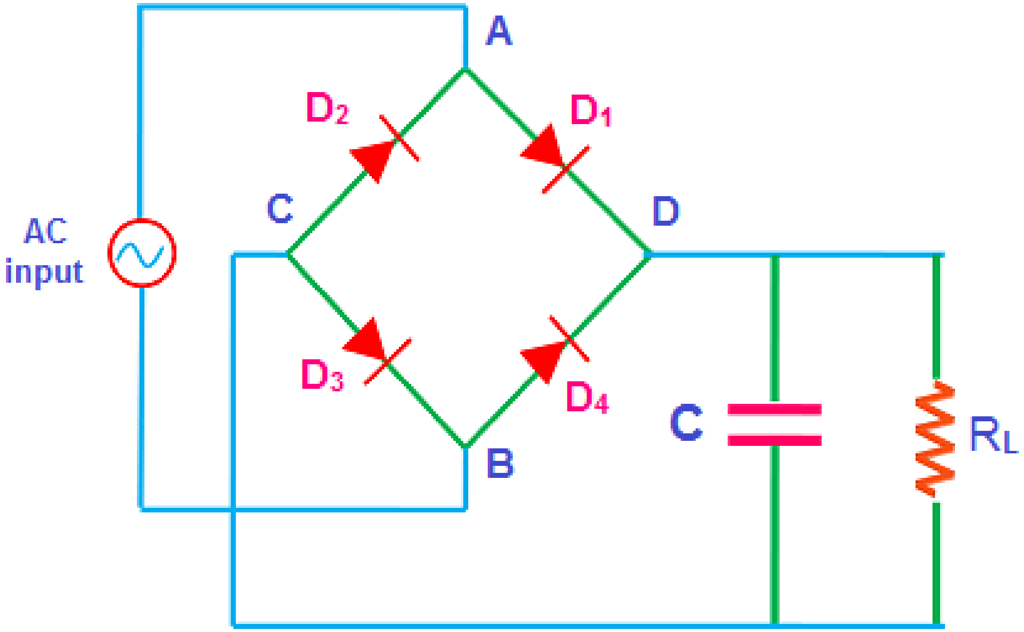


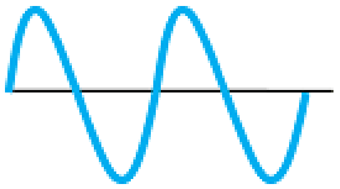
Current flow direction
+
A
D2
D1
Positive
half cycle
AC input
RL
C
D
D3
D4
B
–
DC output


Current flow direction
−
+
A
B
C
D
D_1
D_2
D_3
D_4
R_L
AC input
Negative
half cycle
DC output

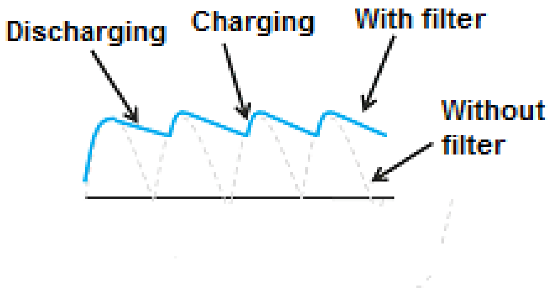
Smoothening Capacitor

- A large value capacitor is often connected in parallel with the Pulsating DC output of rectifiers to smoothen out the pulsating DC, which contains a small AC component, into pure, or near-pure, DC
- The value of the capacitor must be sufficiently large enough to remove the AC component in the output





AC input



DC output

Thank you!

Please type your questions in the chat box, or by unmuting your microphone