EEE1024: Fundamentals of Electrical and Electronics Engineering

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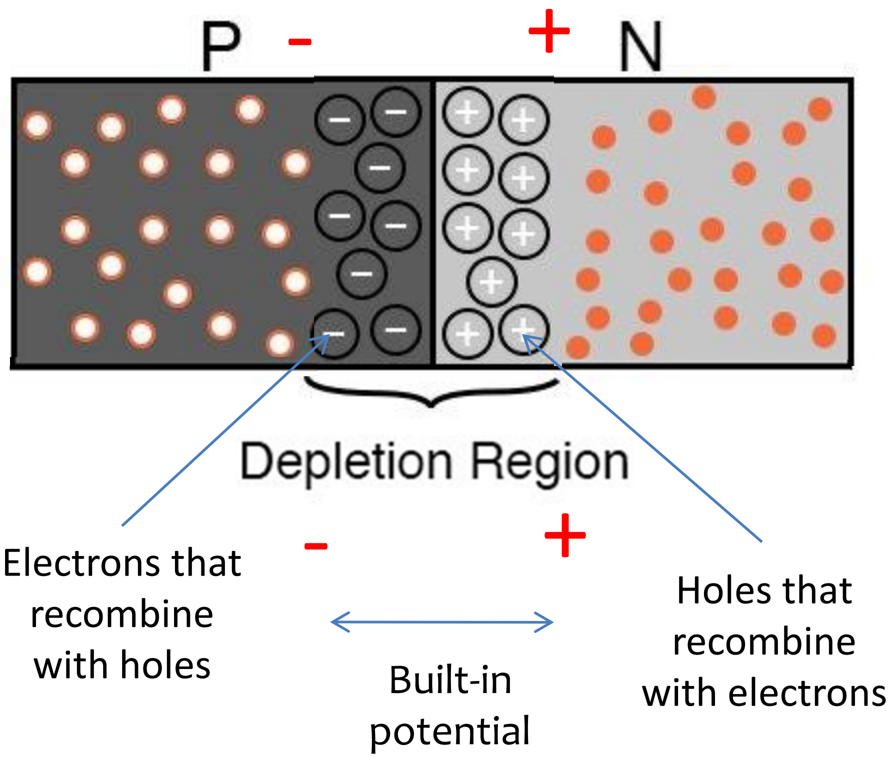
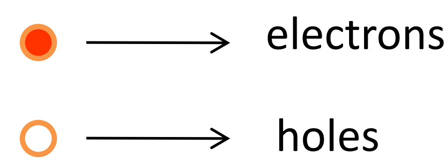
“p-n” Junction Diode

This device is formed by joining a p-type semiconductor with an n-type semiconductor





Because p and n type semiconductors are joined –

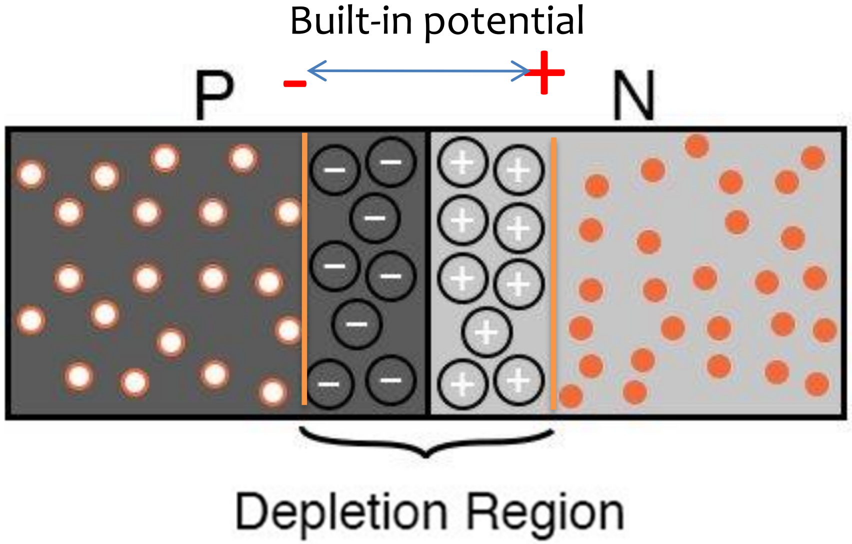
Holes from p-type can diffuse into n type

Electrons from n-type can diffuse into p-type

Built-In potential for Silicon – 0.6 to 0.7V

Will this happen till all holes come into n-type and electrons into p-type?

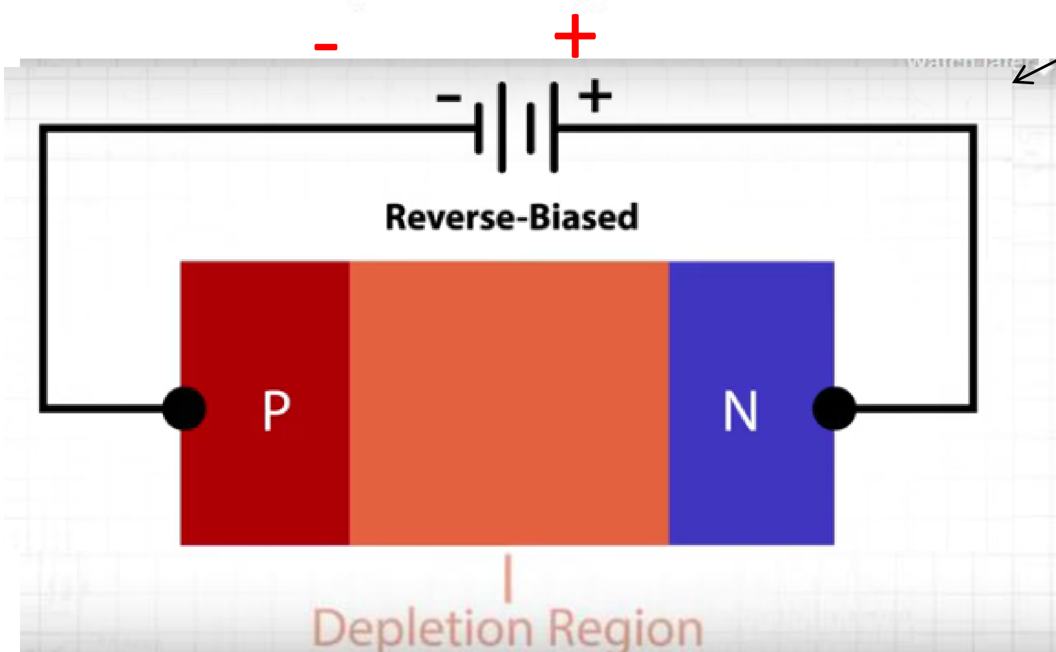
“p-n” Junction Diode – Working (RB)



The built-in potential will restrict the flow of diffusion current to either sides of the junction!

Built in potential = Barrier voltage

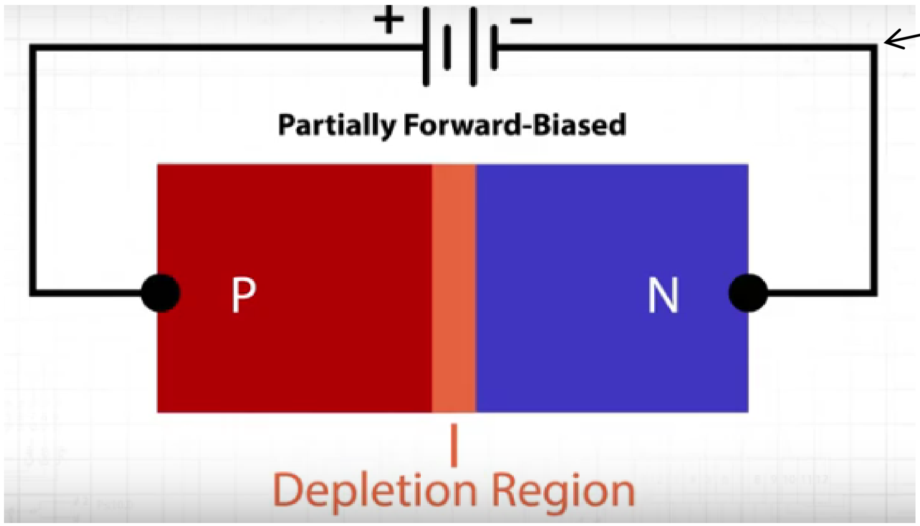
REVERSE - BIAS



- Holes in p-type: Attracted towards –ve terminal &
  Electrons in n-type: Attracted towards +ve terminal
- Depletion region increases
- Barrier voltage increases
- Diffusion current further reduced

"p-n" Junction Diode – Working (FB)

0.4V



FORWARD – BIAS(partial)

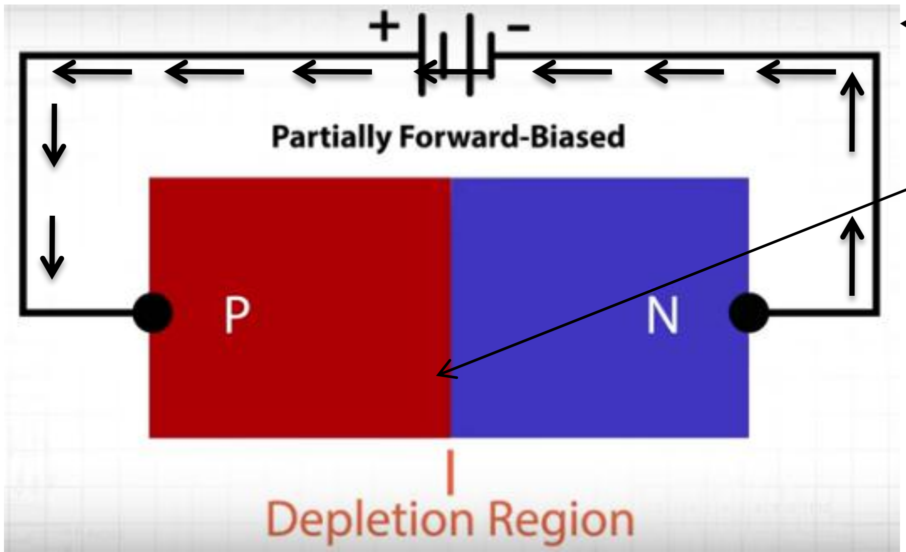
- Holes in p-type: Repelled by +ve terminal &

Electrons in n-type: Repelled by -ve terminal

- Depletion region decreases
- Barrier voltage reduces

- Diffusion current starts to flow across the junction
- **Amount of current - low**

0.6-0.7V



FORWARD – BIAS (full)

Fully collapsed depletion region

- Applied voltage = Barrier voltage

- Barrier voltage fully overcome

- Enormous diffusion current starts to flow across the junction
- **Amount of this current – very high!**

"p-n" Junction Diode – *Unique feature!*

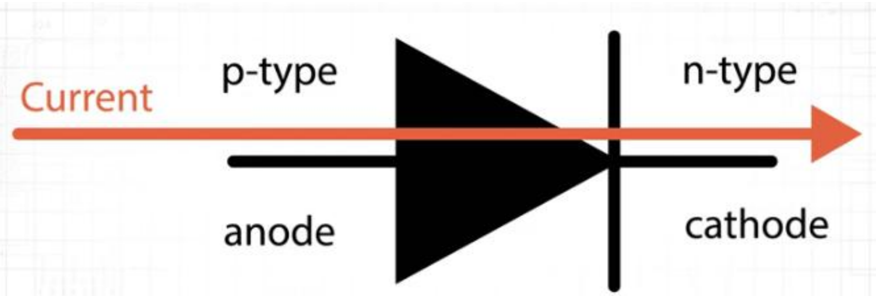
REVERSE- BIASED p-n junction diode,

Resists Current flow

FORWARD- BIASED p-n junction diode,

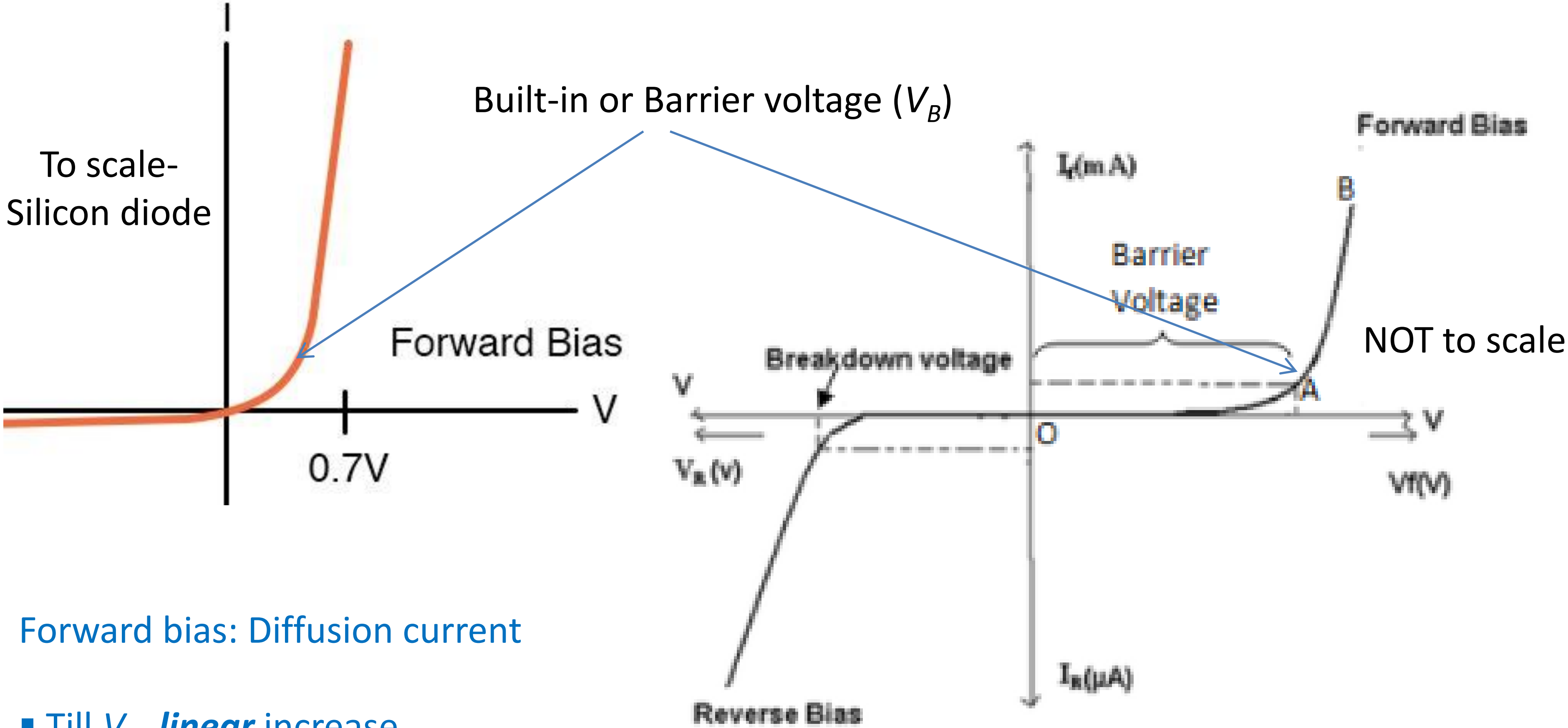
Allows Current flow

Diode ⟶ acts like a switch!!!



Circuit symbol

“p-n” Junction Diode: *I-V characteristics*



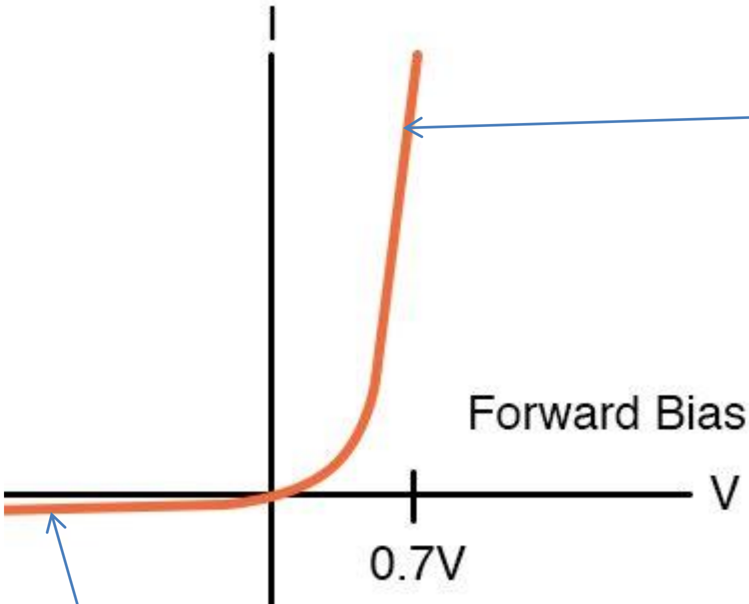
Forward bias: Diffusion current

- Till V_B, ***linear*** increase
- After V_B, ***exponential*** increase

Reverse bias: Leakage current

- Very small current flows and is constant till a voltage called ***breakdown voltage***

"p-n" Junction Diode: *Ideal diode equation*



$$I = I_o\left(e^{\frac{qV_A}{kT}} - 1\right)$$

Ideal diode equation for Forward bias

$$\frac{kT}{q} = 0.026V$$

$$I = -I_o$$

Ideal diode equation for Reverse bias

Example - $I_o \approx 10^{-15} A$

$I \approx 39.47 \mu A$

Find applied voltage V_A

$$\ln\left(\frac{I}{I_o} + 1\right) = \frac{qV_A}{kT}$$

$$\ln\left(\frac{39.47 \times 10^{-6}}{10^{-15}} + 1\right) = \frac{V_A}{0.026}$$

$$17.49 \times 0.026 = V_A$$

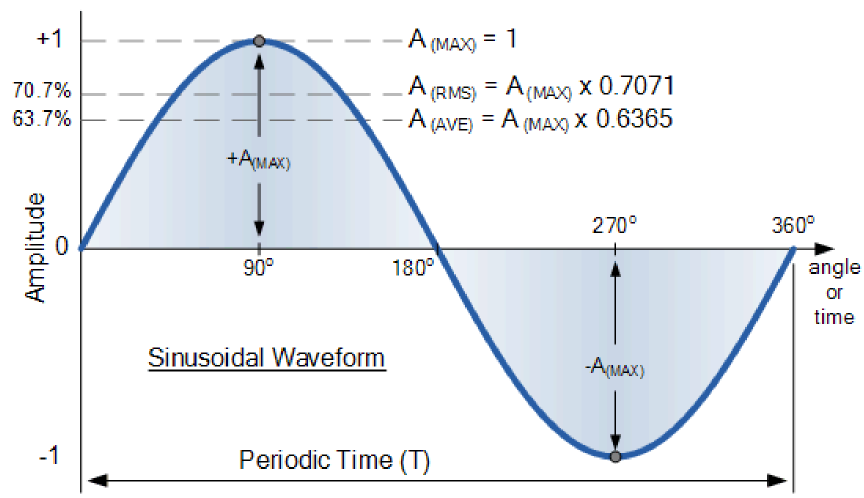
$$V_A = 0.454V$$

Rectification – *Half wave & Full wave*

Rectification - process of converting an oscillating sinusoidal AC voltage source into a constant current DC voltage supply by means of diodes, thyristors, transistors, or converters.

Types of Rectifiers

AC Sinusoidal Waveform



a) Half-wave rectifiers

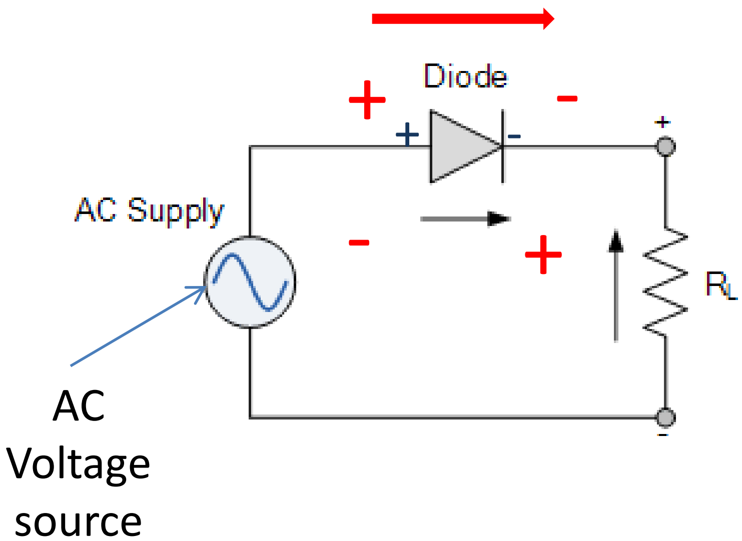
b) Full-wave rectifiers

Semiconductor Diodes

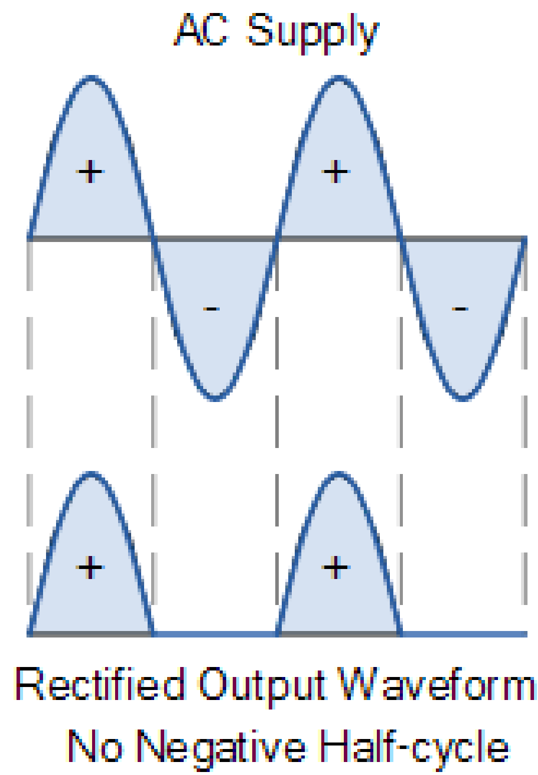
c) Uncontrolled rectifiers

d) Fully-controlled rectifiers

Half wave Rectifier

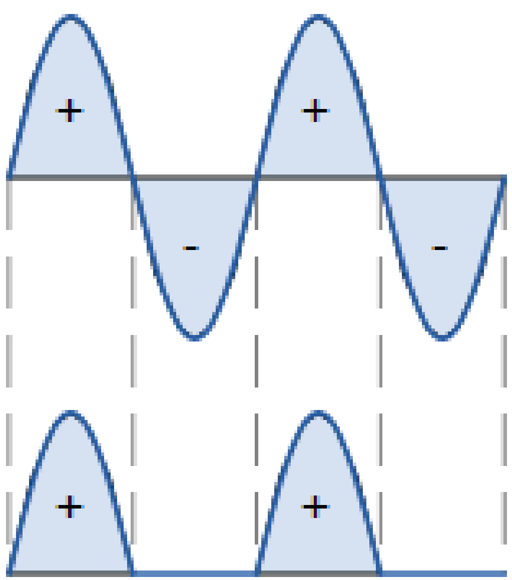


Unique feature of a pn-junction diode utilized to convert the ***bi-directional*** alternating supply into a ***one-way unidirectional*** current by eliminating one-half of the supply.



Half wave Rectifier

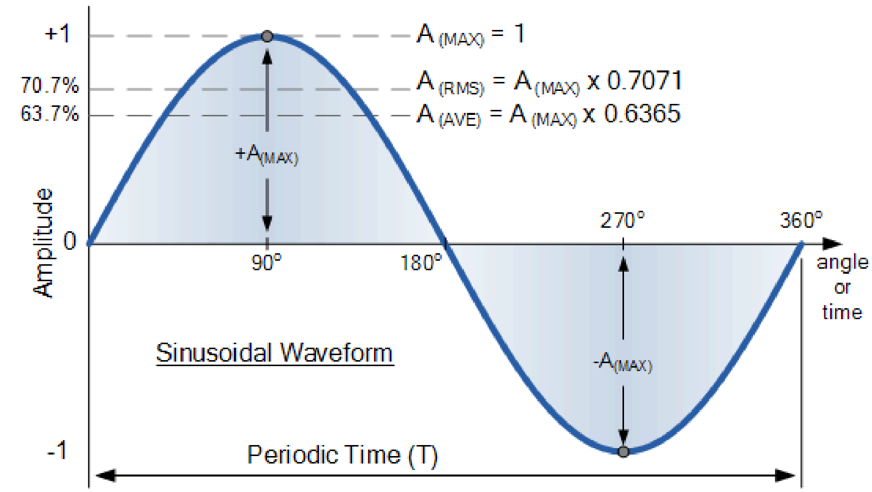
AC Supply



Rectified Output Waveform

No Negative Half-cycle

AC Sinusoidal Waveform



$$A_{AVG} = \frac{0.637}{2} \times A_{MAX} = \frac{A_{MAX}}{\pi} = 0.318 A_{MAX}$$

$$V_{AVG} = 0.318 * V_{MAX}$$

$$I_{AVG} = 0.318 * I_{MAX}$$

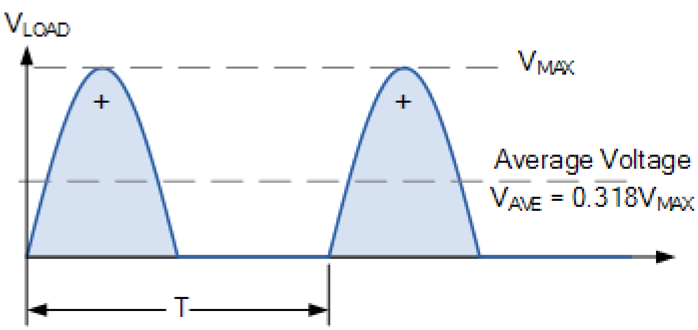
$$\frac{V_{AVG}}{V_{RMS}} = 0.9$$

$$V_{AVG} = 0.45 * V_{RMS}$$

$$I_{AVG} = 0.45 * I_{RMS}$$

Half wave Rectifier

Example A single phase half-wave rectifier is connected to a 50V RMS 50Hz AC supply. If the rectifier is used to supply a resistive load of 150 Ohms. Calculate the equivalent DC voltage developed across the load, the load current and power dissipated by the load. Assume ideal diode characteristics.



$$V_m = V_p = V_{PK} = V_{MAX}$$

$$V_{RMS} = 50volts$$ Given

$$V_{\max} = V_P = 1.414 * V_{RMS} = 1.414 * 50 = 70.7 \text{ volts}$$

$V_{RMS} = V_{PK} \times 0.707$ $\frac{V_{RMS}}{V_P} = 0.707$ $\frac{V_P}{V_{RMS}} = \frac{1}{0.707} = 1.414$

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

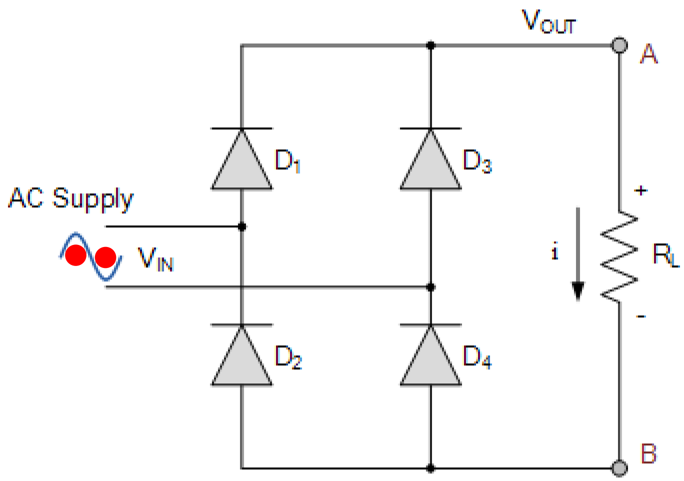
Equivalent DC voltage $= 0.318 * V_P = 0.318 * 70.7 = 22.5$ volts

Load current $I_L = \frac{V_{DC}}{R_L} = 22.5/150 = 0.15A$ or 150mA

Power dissipated by load $P_L = V_{DC} \times I$ or $I^2 * R_L = 22.5 * 0.15 = 3.375W \cong 3.4W$

Full wave Rectifier

Full wave BRIDGE Rectifier



During +ve half cycle of V_{IN},

D_1 and D_4 are forward biased, whereas,

D_2 and D_3 are reverse biased

This bridge configuration of diodes provides full-wave rectification because at any time two of the four diodes are forward biased while the other two are reverse biased.

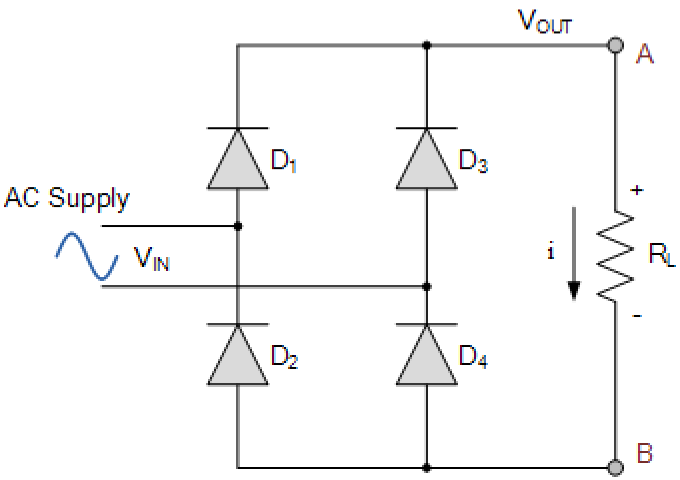
During -ve half cycle of V_{IN},

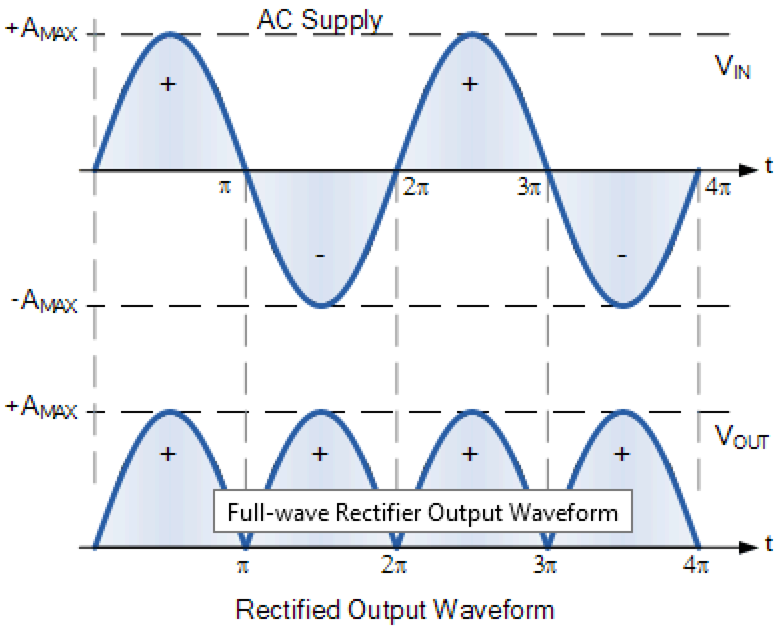
D_2 and D_3 are forward biased, whereas,

D_1 and D_4 are reverse biased

Full wave Rectifier

Full wave BRIDGE Rectifier





$V_{AVG} = 0.637 * V_{MAX}$

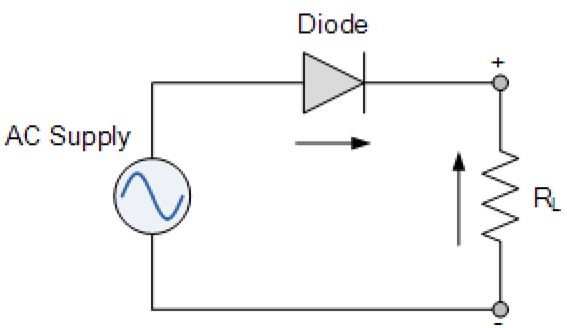
$I_{AVG} = 0.637 * I_{MAX}$

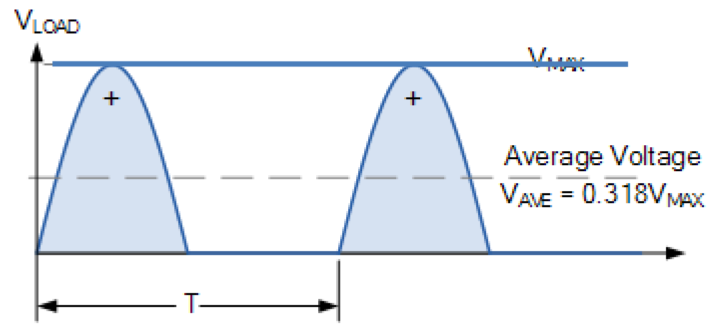
$V_{AVG} = 0.9 * V_{RMS}$

$I_{AVG} = 0.9 * I_{RMS}$

Ripple Factor

Half wave Rectifier





DC Output
(Filtered)

Ripple Factor γ –

Unwanted AC component remaining while converting AC waveform into DC

$$\gamma = \sqrt{\left(\frac{V_{rms}}{V_{DC}}\right)^2 - 1}$$

Acknowledgements

1. https://www.electronics-tutorials.ws/power/single-phase-rectification.html
2. https://www.electrical4u.com/half-wave-rectifiers/