Introduction to Electrical Engineering Practice

Course Code: EE 113

Department: Electrical Engineering

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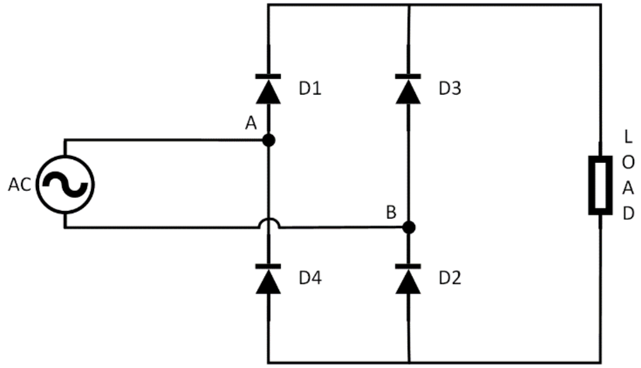
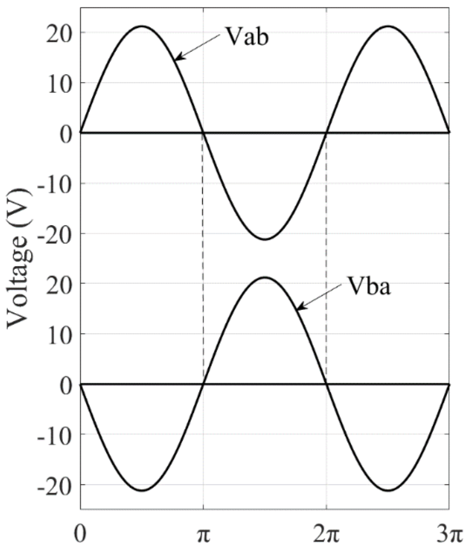
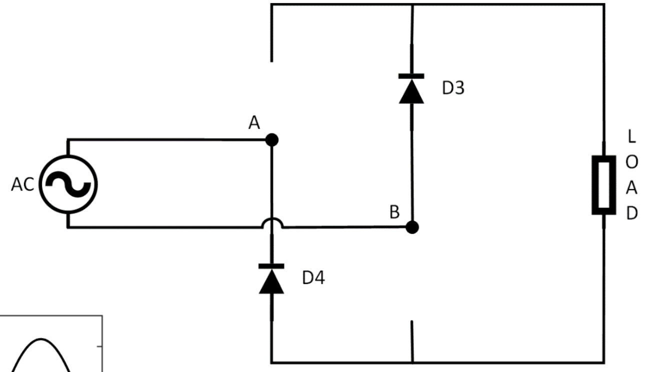
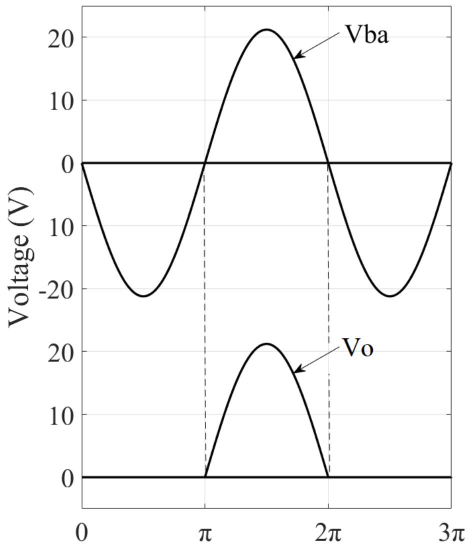
Diode Rectifier



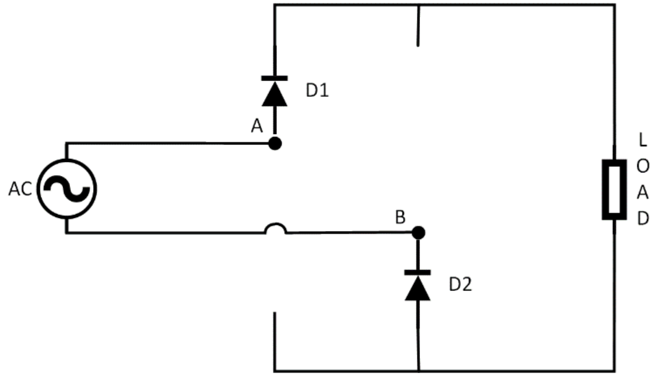


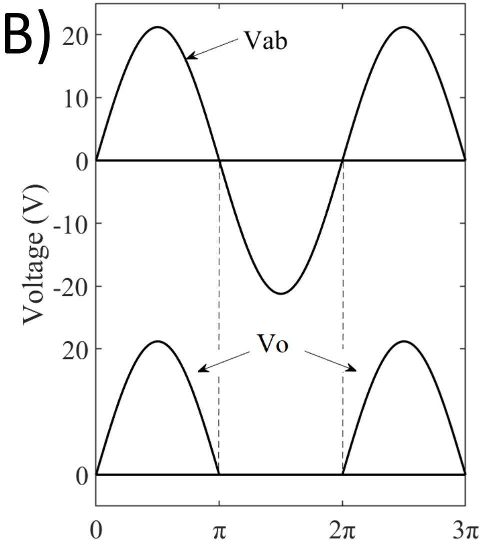
π - 2π V_{BA} is +ve (Pot of B > Pot of A)



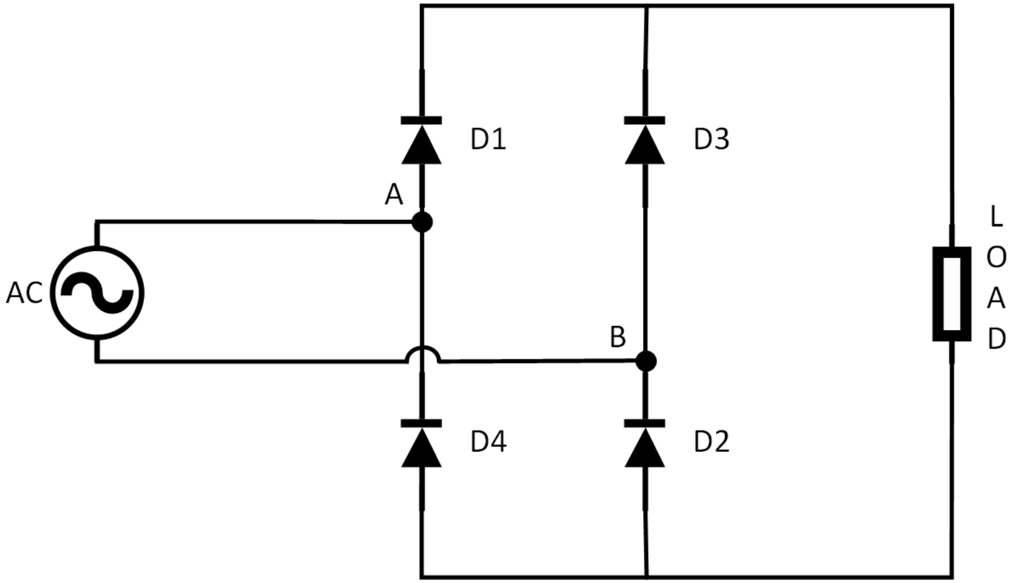


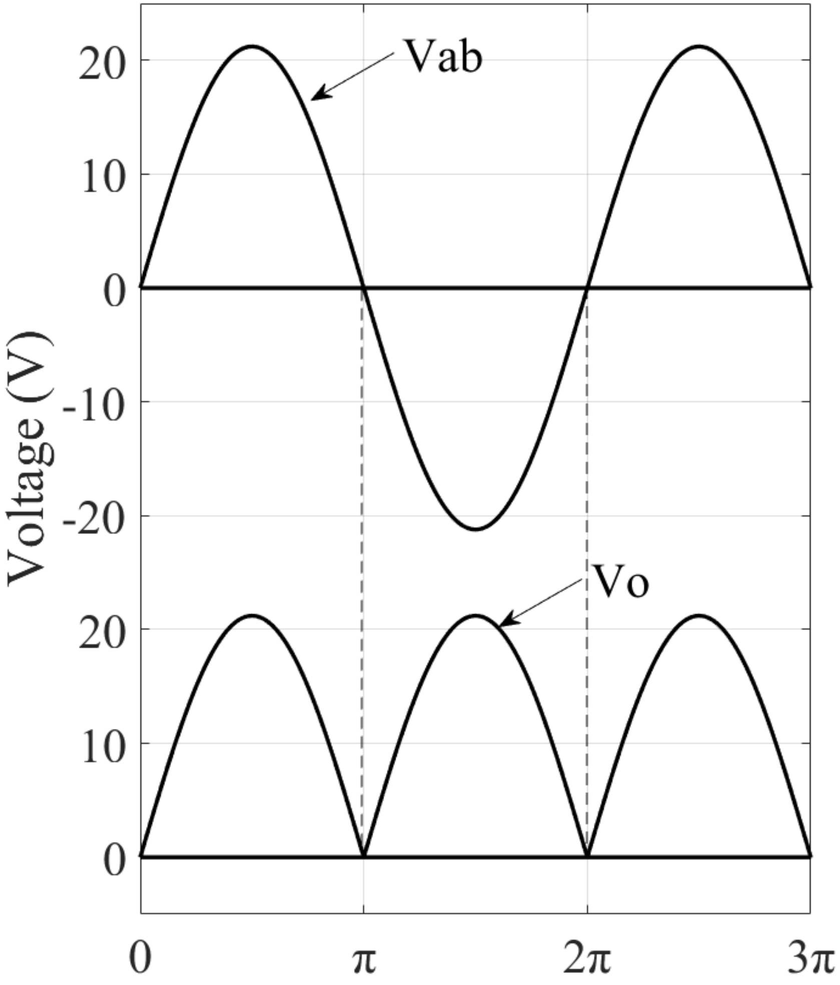
0 - π V_{AB} is +ve (Pot of A > Pot of B)





Diode Bridge Rectifier





Output Voltage across the load is pulsating and therefore the current.

In case the load requires a constant voltage

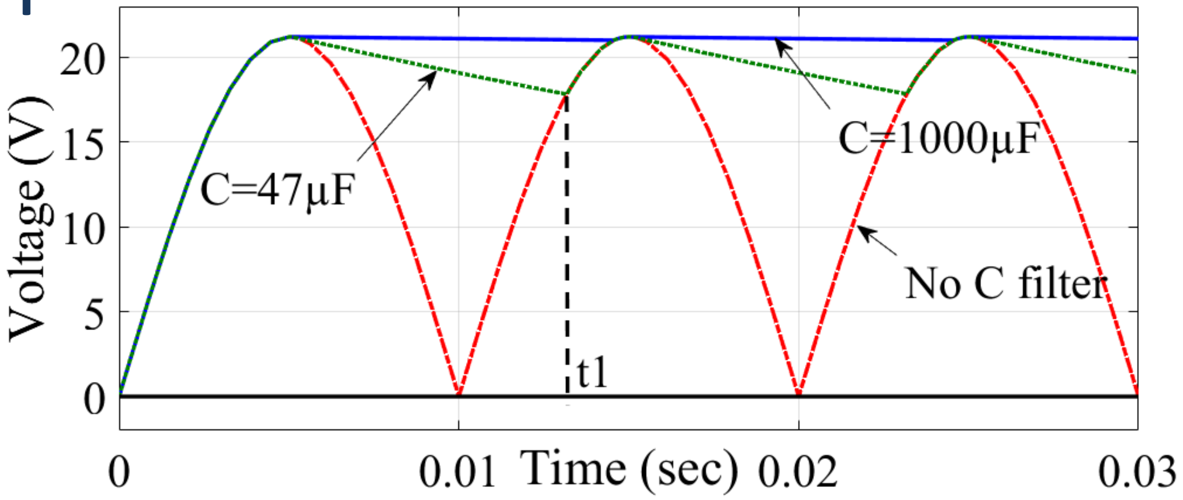
- ➢ Connect a Capacitor across the load
- ➢ V_o should remain ≈ constant.
- ➢ Therefore ‘ τ ’ should be large

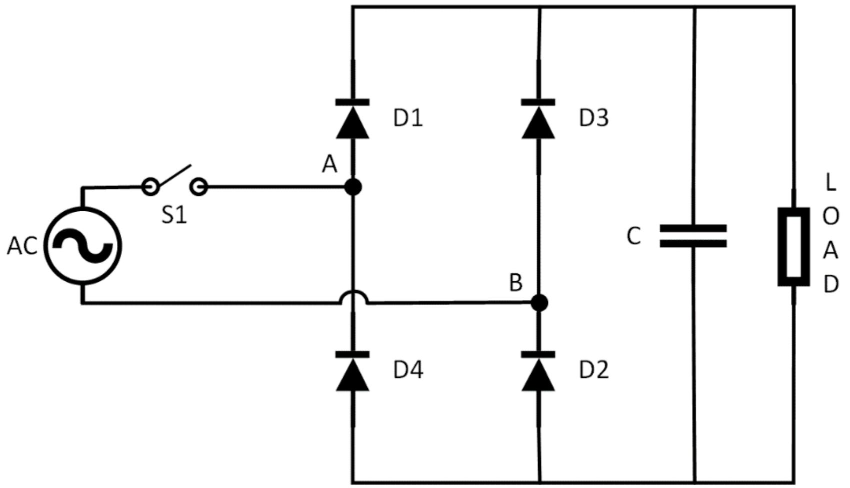
Diode Bridge Rectifier with Capacitor filter

Assume V_c=0 at t=0;

Switch is closed at t=0;

D_1- D_4 are ideal.



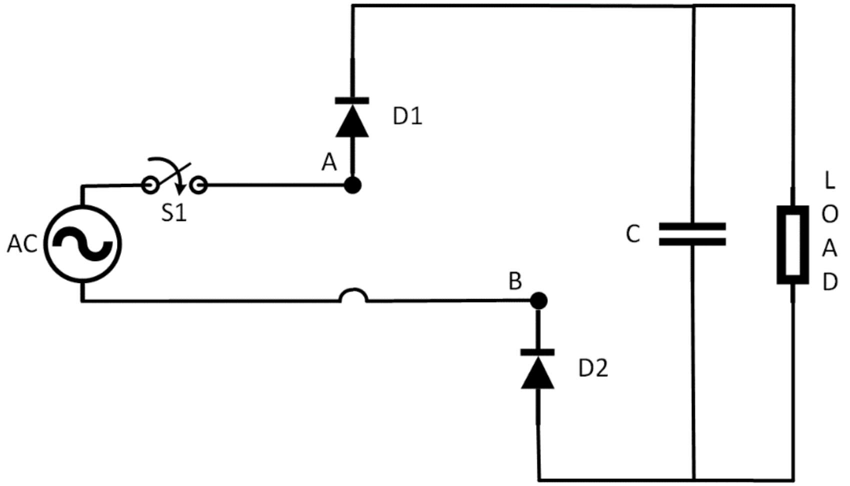


V_{AB}= V_o till ωt = π/2

at ωt = π/2$^+$

V_{AB}< V_m but

V_c =V_o =V_m



Cathode potential of D_1 >Anode potential of D_1.

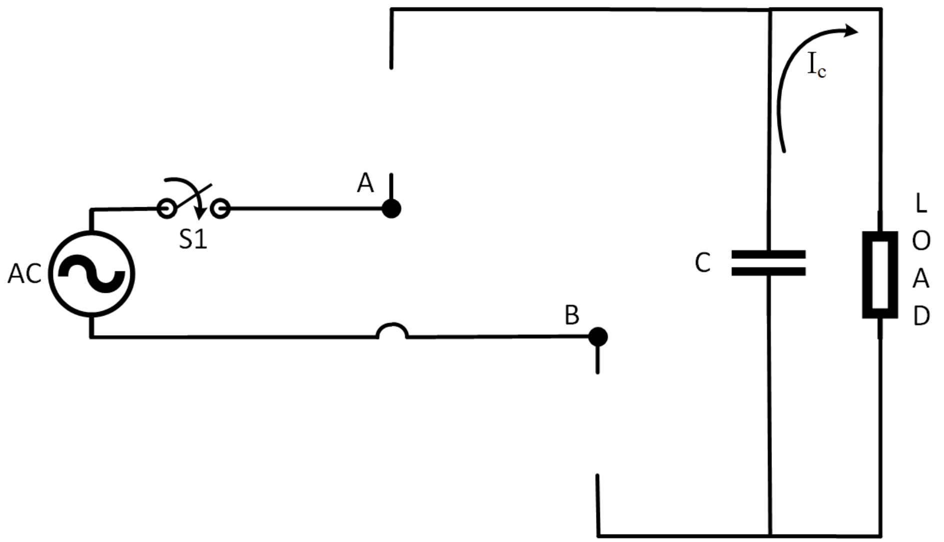
Diode is Reverse Biased.

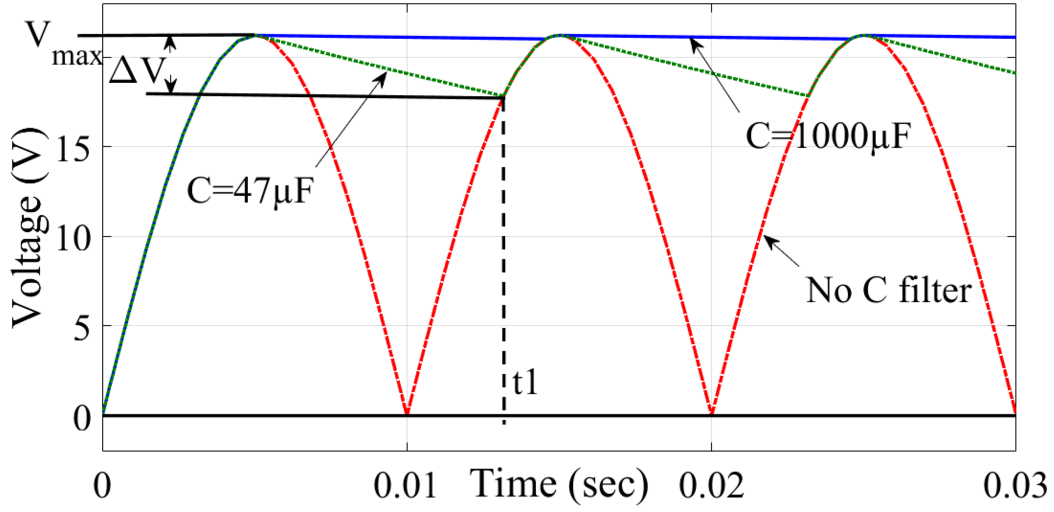
Source current = 0

Diode Bridge Rectifier with Capacitor filter

Source does not supply power.

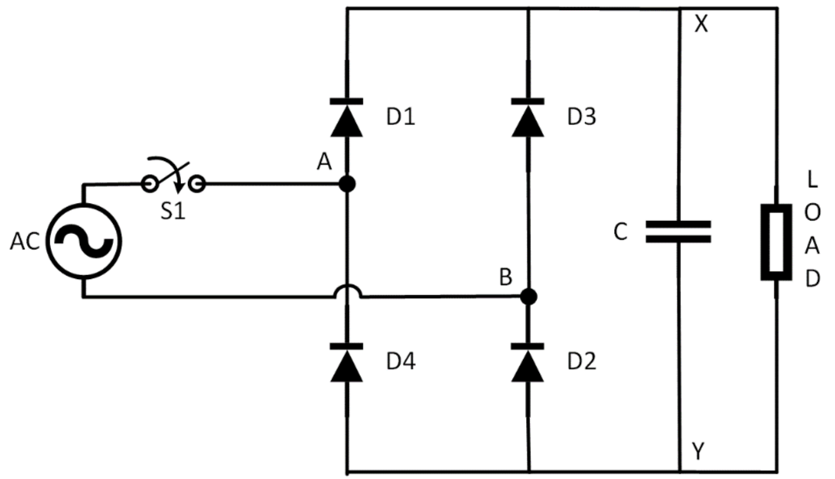
Capacitor supplies power to the load.





Because 'τ' is large, V_o gradually falls, this will continue till $D_3 - D_4$ starts conducting, this can happen as and when $V_B > V_X$.

It happens at t_1.



Unregulated DC Power Supply (using Capacitive Filter)

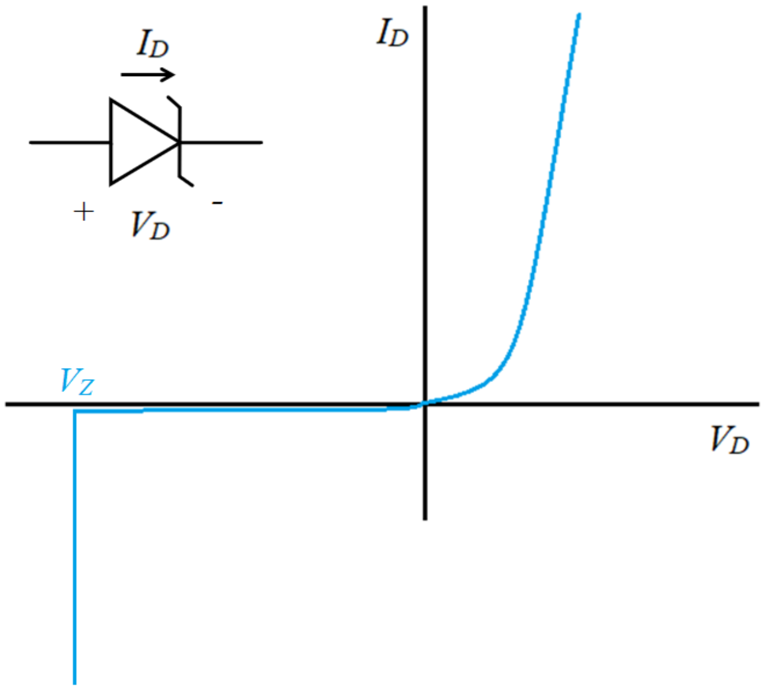
- Bridge rectifier followed by a large value Capacitor connected parallel to a load resistance

$$\mathrm{C} \approx \frac{\mathrm{V_{max}}}{2 * \mathrm{R} * \Delta V * f}$$

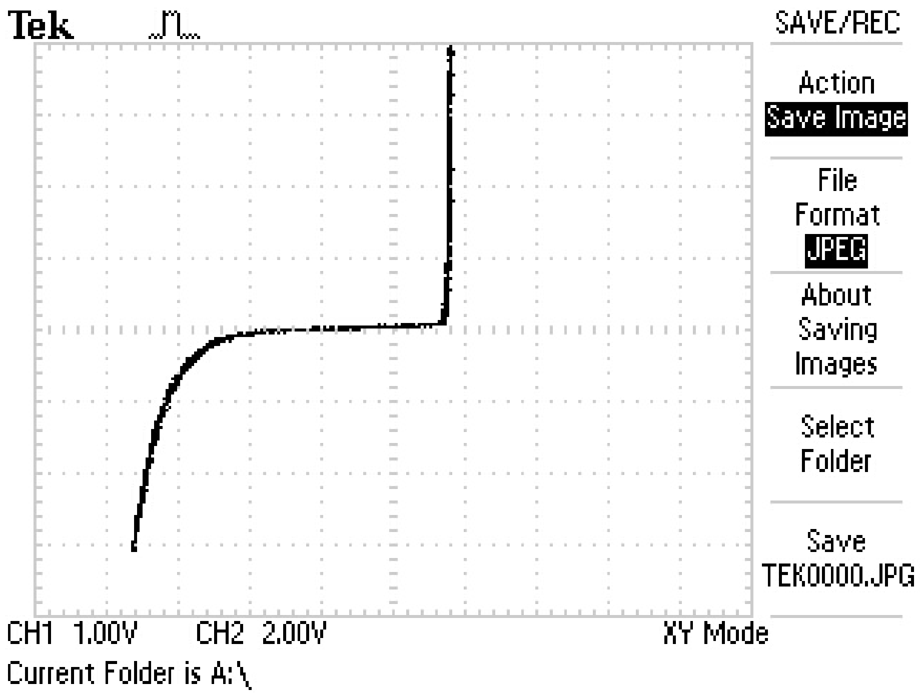
- Ripple voltage and its reduction
  - Keep on increasing the Capacitor value – not a good solution
  - Use voltage regulator circuits (Zener regulator or Voltage regulator ICs)

Zener Diode

- Normal diodes operate in forward biased state, but Zener diode is operated in reverse biased state
- It has very sharp V-I characteristic in reversed direction

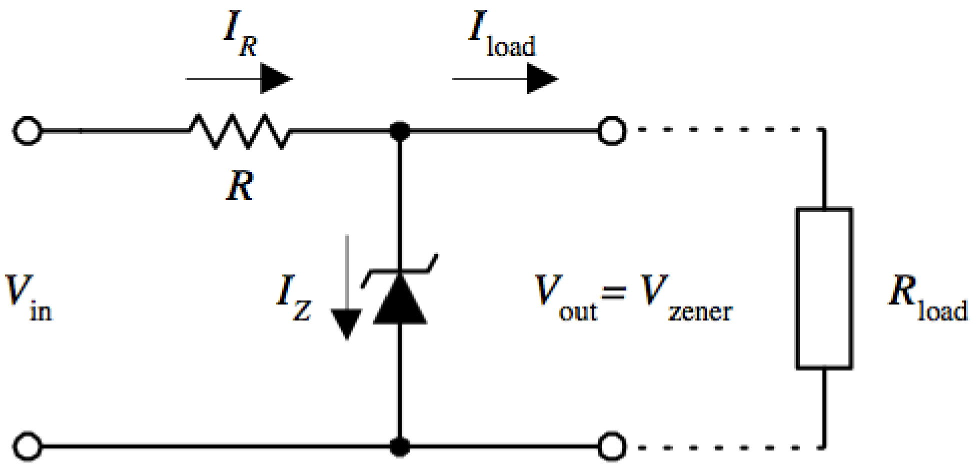


Ideal zener characteristics



Actual zener characteristics

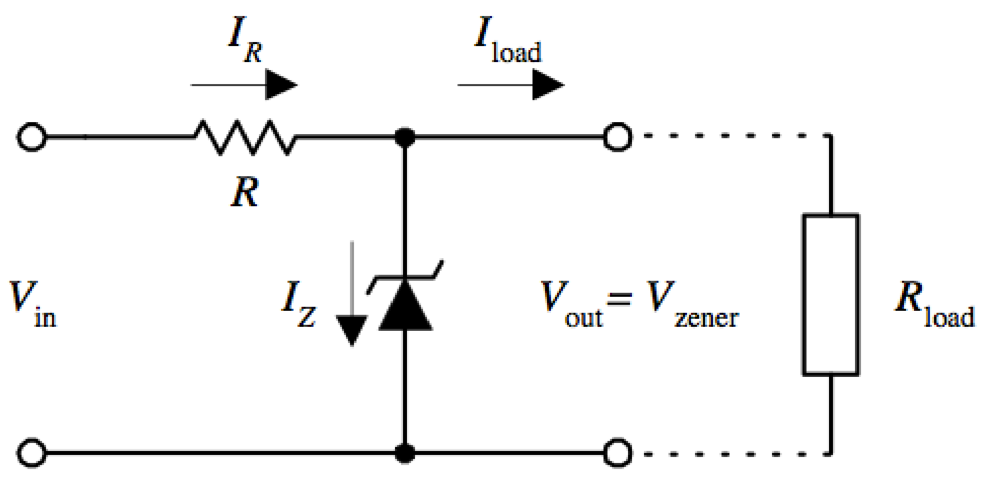
Zener Diode as a Voltage Regulator

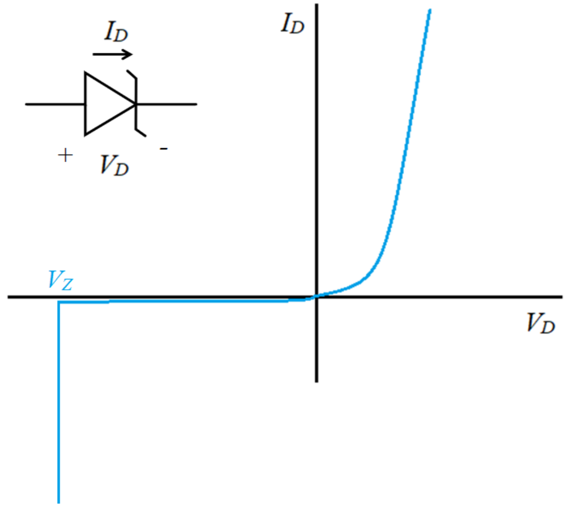


In reverse breakdown range, Zener diode maintains constant voltage across it.

1. Zener diode should be reverse biased and R should be chosen such that Iz should be within its rating.
2. $I_R = I_{load} + I_Z$

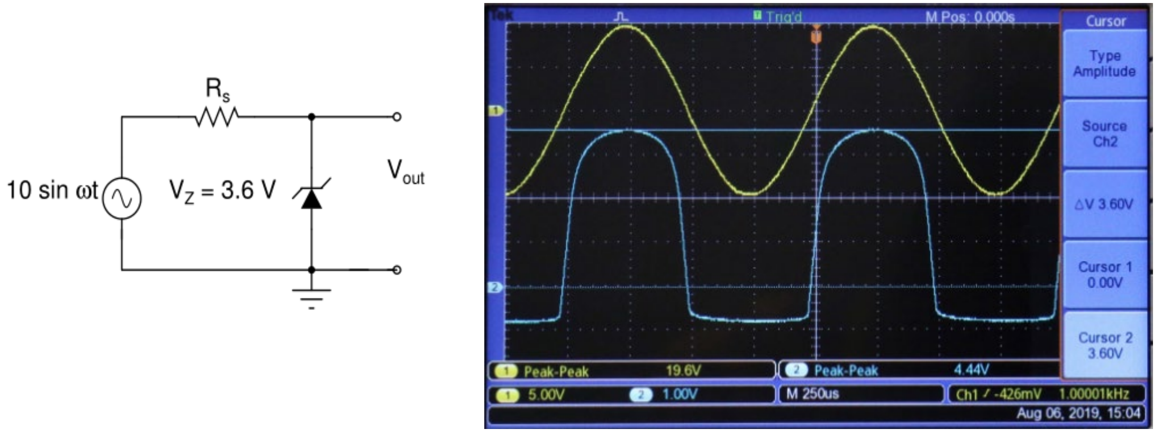
Zener Diode as a Voltage Regulator (Design)



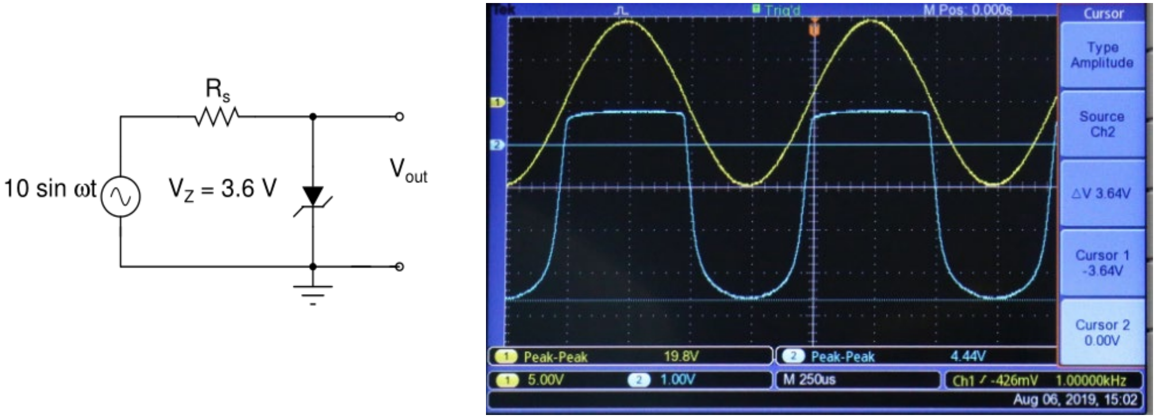


- Assuming Zener diode to be ideal, V_{out} = V_{Zener}
- Current through R is $\boldsymbol{I_Z + I_{load}}$
- When I_{load} = 0 (or R_{Load} is open), Zener diode will have maximum current,
- $I_{Zmax} = \frac{V_{in} - V_{zener}}{R}$
- Choose R such that I_{Zmax} is within the permissible range
- For finite values of R_{load}, load current is, $I_{Load} = \frac{V_{Zener}}{R_{Load}}$

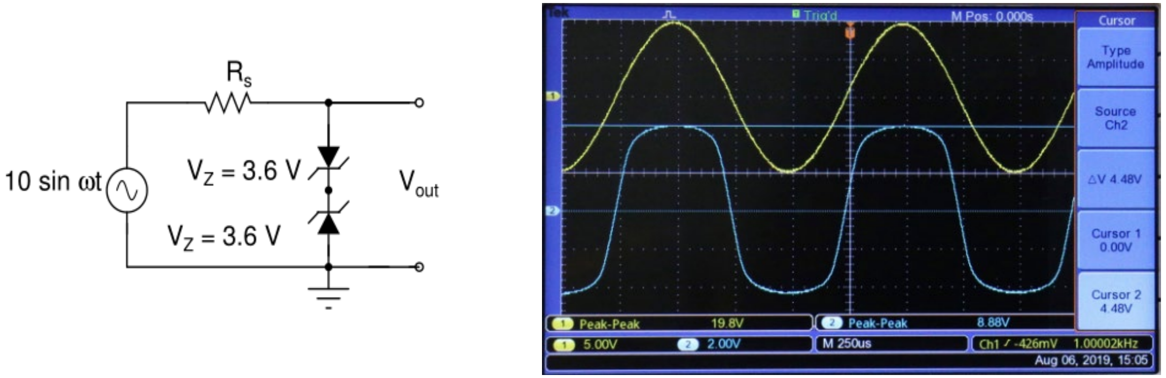
Zener Diode Clipping Circuits



Zener diode clipping circuit 1 and the observed V_{out} waveform



Zener diode clipping circuit 2 and the observed V_{out} waveform



Zener diode clipping circuit 3 and the observed V_{out} waveform

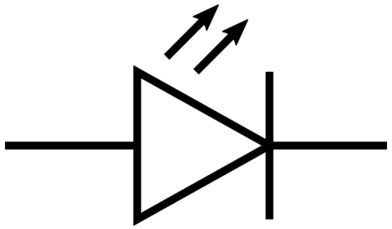
Zener Diode as a Voltage Regulator (Design)

- Used for regulating the output voltage of a DC Power supply against variations in the input voltages.

- Effective when the load currents are fairly small. (in the mA range)

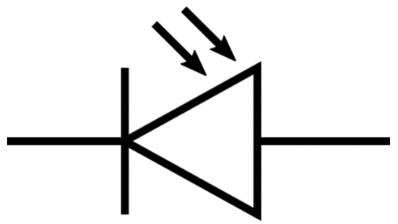
- For high currents, voltage regulator ICs are available
  - e.g.: LM7805 5V regulator; LM7812 12V regulator;
  - LM7905 -5V regulator, LM7912 -12V regulator

Light Emitting Diode (LED)

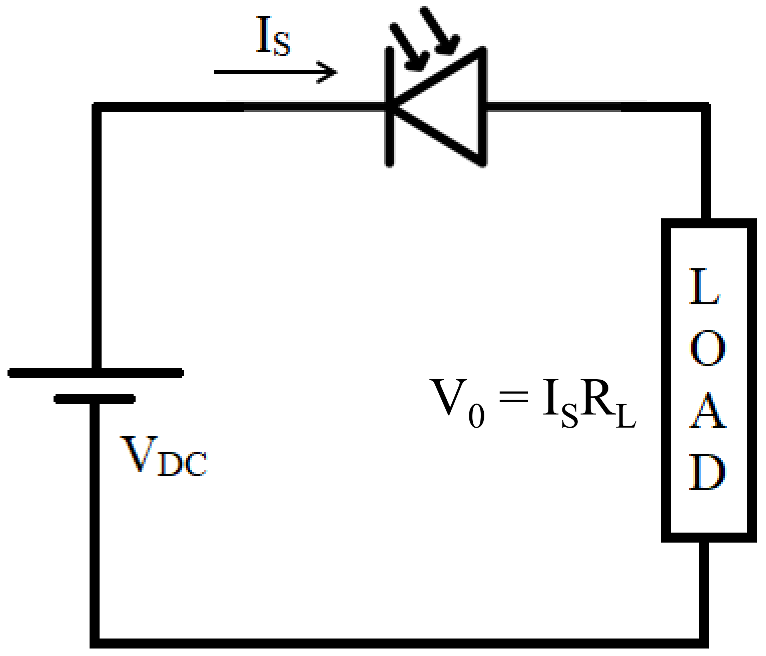


- When electron jumps from conduction band to valence band, it losses energy
- This energy can appear as heat or light
- In silicon, it appears as heat
- In Gallium Arsenide, lost energy appears as light
- When Gallium Arsenide p-n junction is forward biased, it emits light

Photodiode



- Photodiode is operated in reverse biased state
- Functioning is opposite to that of LED
- I_S , reverse saturation current is a function of incident radiation
- When light is incident on the photodiode (junction), electrons absorb energy and jump to conduction band
- Reverse current through the diode increases



Electric power capacity in India

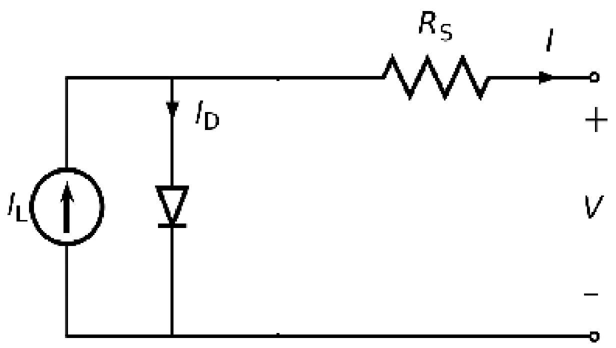
Total Installed Capacity (31st Oct, 2021)	390.791 GW[†]
Total wind power installations (31st Oct, 2021)	39.990[†], (10.23%)
Cumulative solar installations (31st Oct, 2021)	47.665[†], (12.19%)

National Solar Mission -> **100 GW** Solar Capacity by **2022** [‡]

[†] https://cea.nic.in/wp-content/uploads/installed/2021/10/installed_capacity.pdf
[‡] https://mnre.gov.in/solar/current-status/

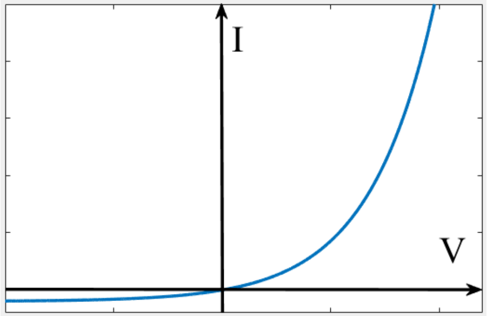
Diodes vs Solar Cells

- Normal diodes used for rectification are encapsulated in dark epoxy material. Therefore, no light enters the P-N junction.
- Solar cells are also (large area) diodes, but in their case, the junction is intentionally kept bare, (or encapsulated in transparent materials) so that the light enters the P-N junction.
- The light that enters P-N junction of solar cells results in photon-generated current, which is constant for a given light intensity and flows in the opposite direction to that of diode current.
- This current is then passed through the load connected to the solar cell to extract electrical energy from the cell.

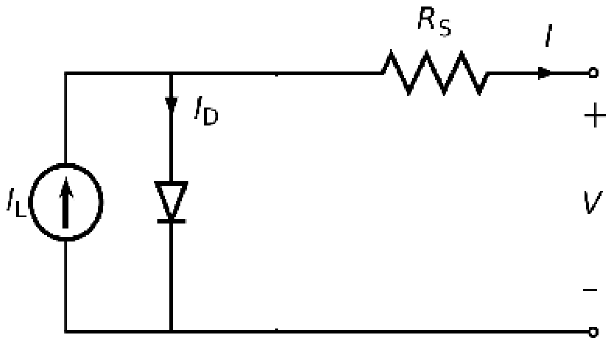


Current, Equivalent Circuit, I-V Curves

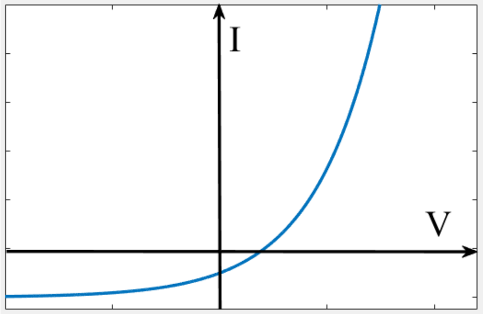
- Diode Current Equation is : $$I = I_s(e^{\frac{qV}{kT}} - 1)$$

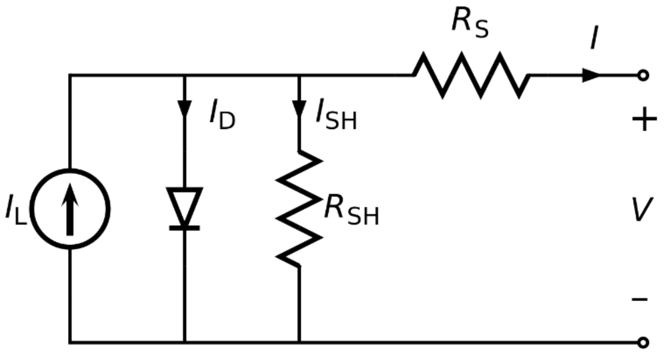


- Considering light generated current in solar cell, it becomes:



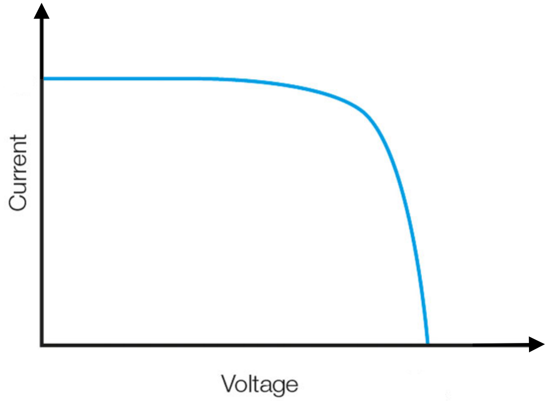
$$I = I_s\left(e^{\frac{qV}{kT}} - 1\right) - I_L$$





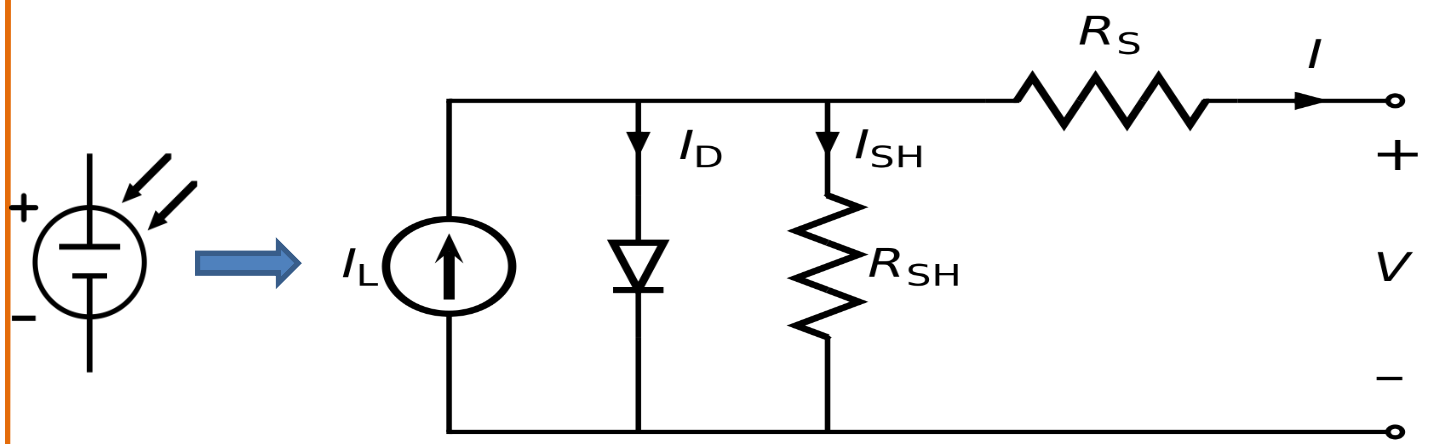
I-V Curve is inverted for convenience. So that we don't have to deal with negative currents

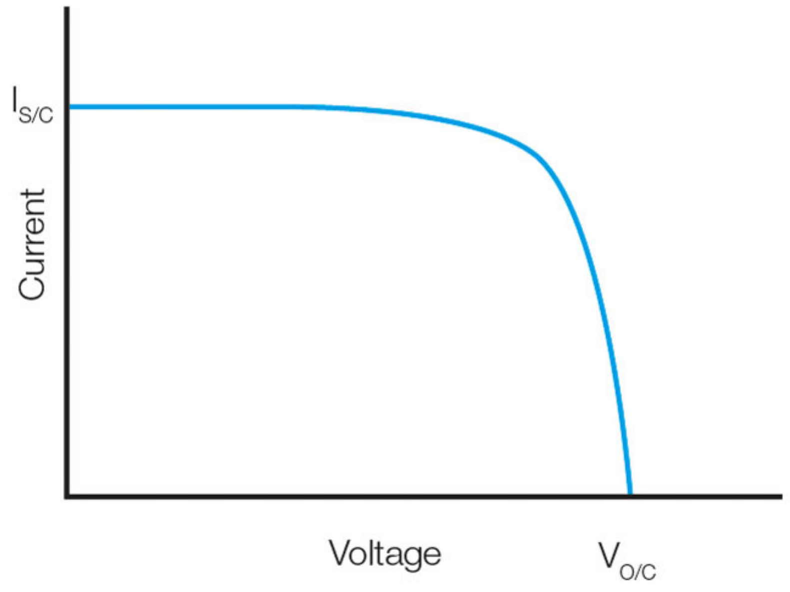
$$I = I_L - I_s\left(e^{\frac{qV}{kT}} - 1\right) - \frac{V - IR_s}{R_{sh}}$$



R_{SH} ⟹ some defects in the solar cell

Solar cell





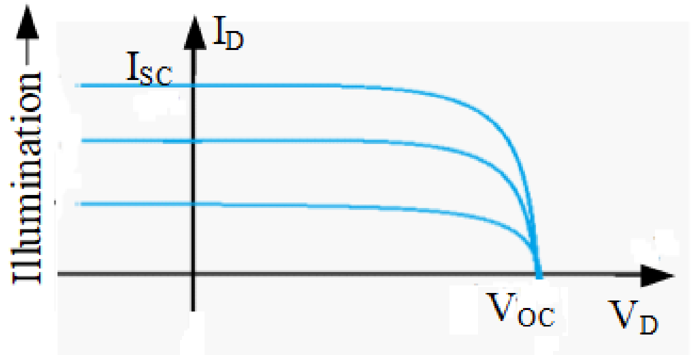
$I_L = I_D + I_{SH} + I,$ $\qquad$ $I_D = I_S e^{\frac{kV_D}{T}} - I_S$

For a good quality solar cell, its open-circuit voltage (V_{OC}) and short-circuit current (I_{SC}) are given as follows

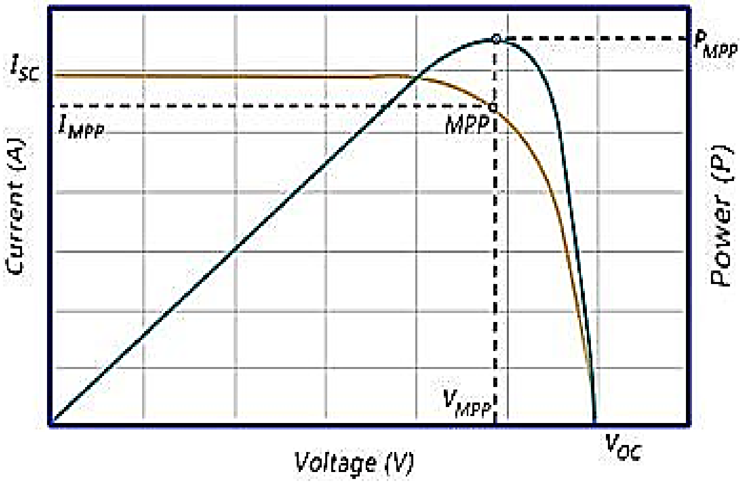
$$V_{OC} \approx \frac{nkT}{q} \ln\left(\frac{I_L}{I_S} + 1\right)$$

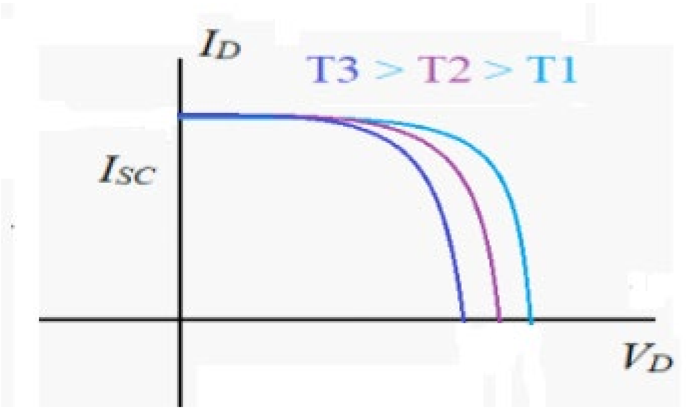
$$I_{SC} = I_L$$

Solar Cell Characteristic



Effect of illumination intensity on
V-I characteristic





Effect of temperature on
V-I characteristic

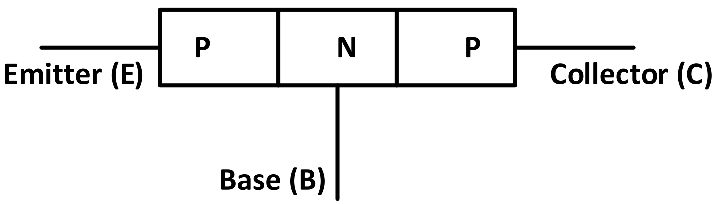
- Illumination intensity affects I_{SC}
- Temperature affects V_{OC}

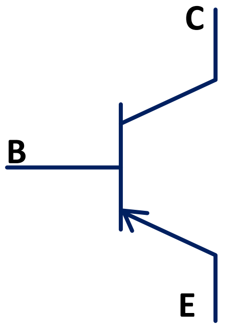
Transistor

Diode: 2 terminal device → Uncontrolled Switch → Device starts conducting when $V_{AK} > 0.7$ V

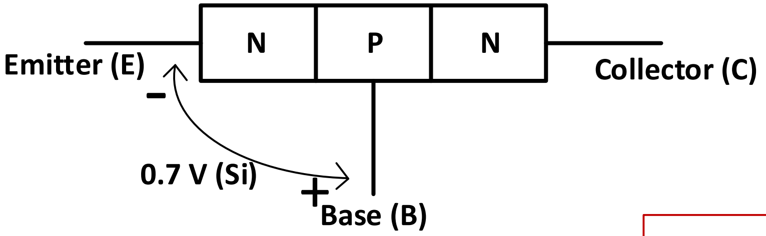
Transistor: 3 terminal device → Controlled Switch → Two types.

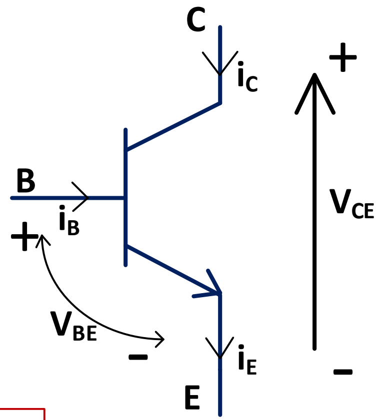
PNP Transistor





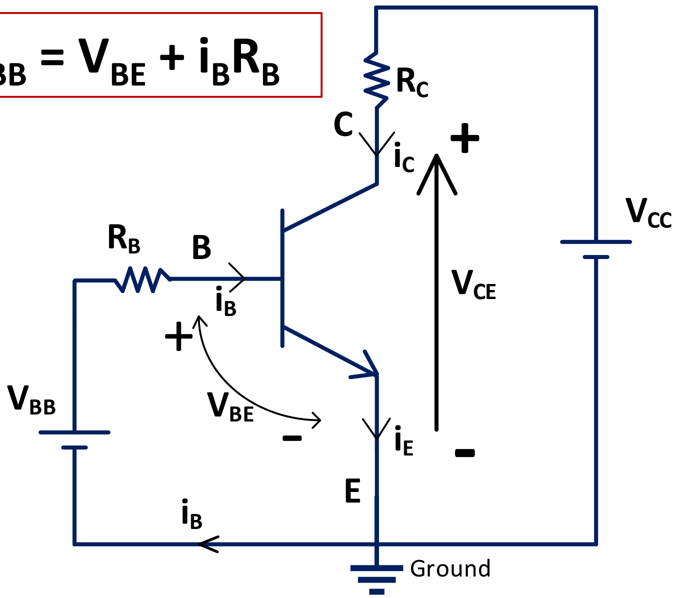
NPN Transistor





$$\boxed{I_E = I_C + I_B}$$

$$\boxed{V_{BB} = V_{BE} + i_B R_B}$$



When $V_{BE} < 0.7$; Transistor is off → "**Cut-off**"

In **ON state**, there are TWO modes.

Active : $I_C = \beta I_B$; where $\beta = h_{FE}$ = current gain → >>1

$V_{CE} = V_{CC} - i_C R_C > V_{CE(Sat)}$ min(V_{CE}) = $V_{CE(Sat)} \approx$ 0.2V

Saturation : $I_C \neq \beta I_B$; $i_C = \dfrac{V_{CC} - V_{CE(Sat)}}{R_C}$

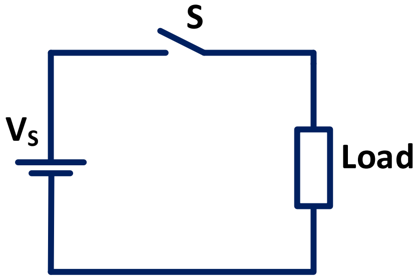
Transistor

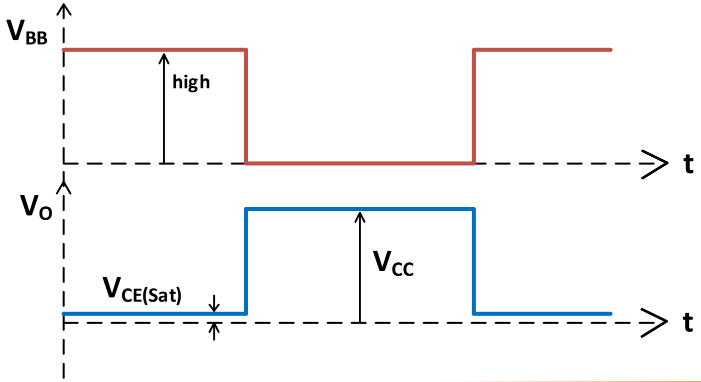
Conclusions:

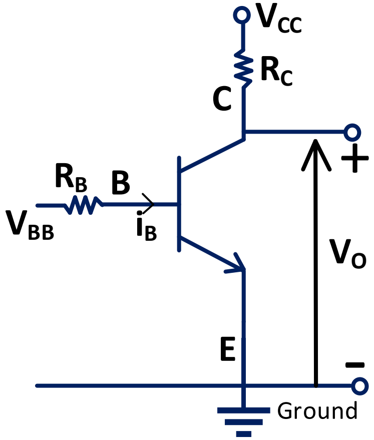
- When $V_{BE} < 0.7$; Transistor is off → "**Cut-off**" mode
- In **Active** region, $\mathbf{I_C = \beta I_B}$; $\mathbf{V_{CE} = V_{CC} - i_C R_C}$ → used as an **AMPLIFIER**
- In **Saturation** region, $\mathbf{i_C} = \dfrac{V_{CC} - V_{CE(Sat)}}{R_C}$ → used as a **SWITCH**

As a Switch:

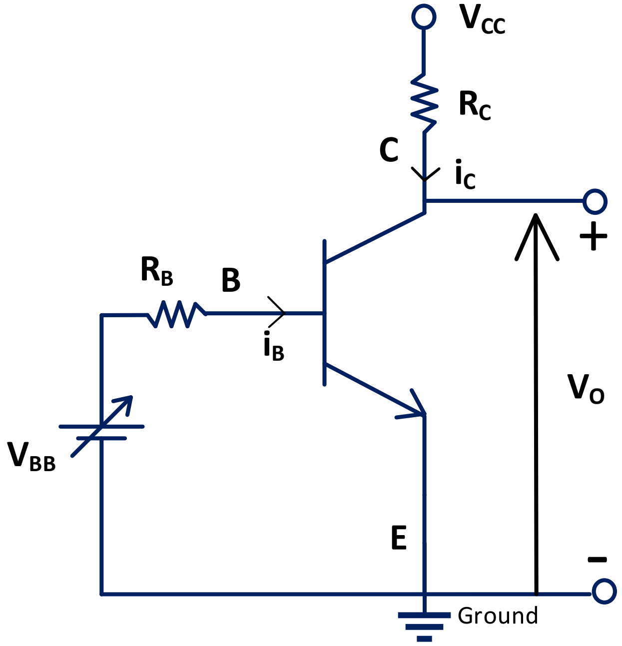
- When OFF, voltage across switch = V_s
- When ON, voltage across switch = 0 ≈ $V_{CE(Sat)}$
- Assumed that resulting i_B saturates the transistor
- V_O = voltage across the transistor (V_{CE}) is the complimentary of the signal applied at the base circuit → **INVERTER**



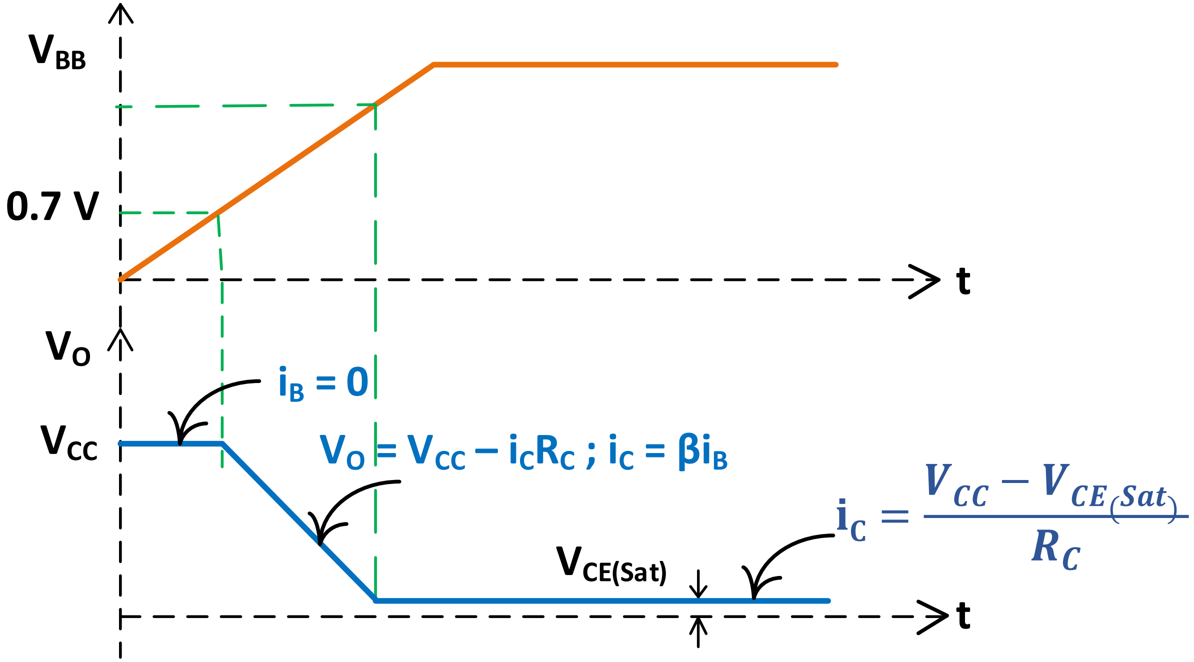




Transistor



V_{CC}
R_C
C
i_C
R_B
B
i_B
+
V_O
V_{BB}
E
-
Ground



V_{BB}
0.7 V
t
V_O
$i_B = 0$
V_{CC}
$V_O = V_{CC} - i_C R_C\ ;\ i_C = \beta i_B$
$i_C = \dfrac{V_{CC} - V_{CE(Sat)}}{R_C}$
$V_{CE(Sat)}$
t