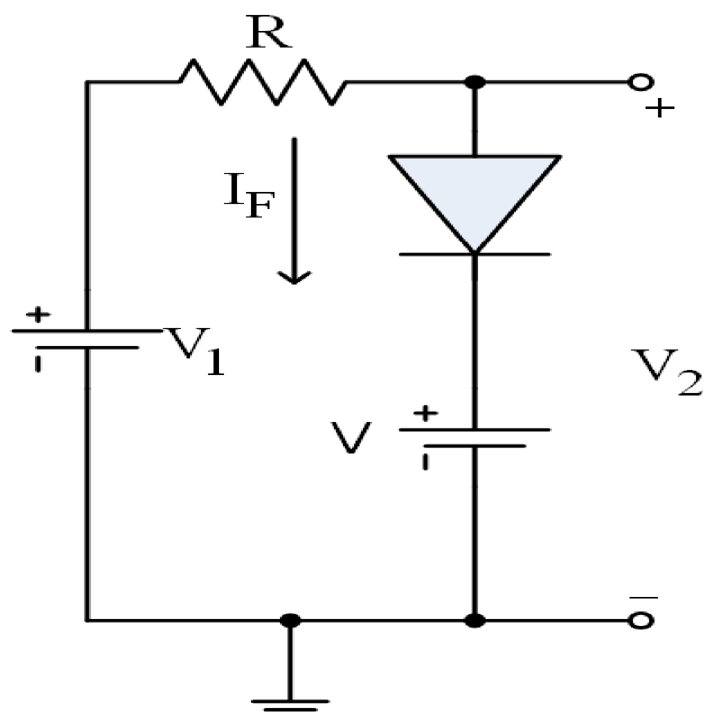
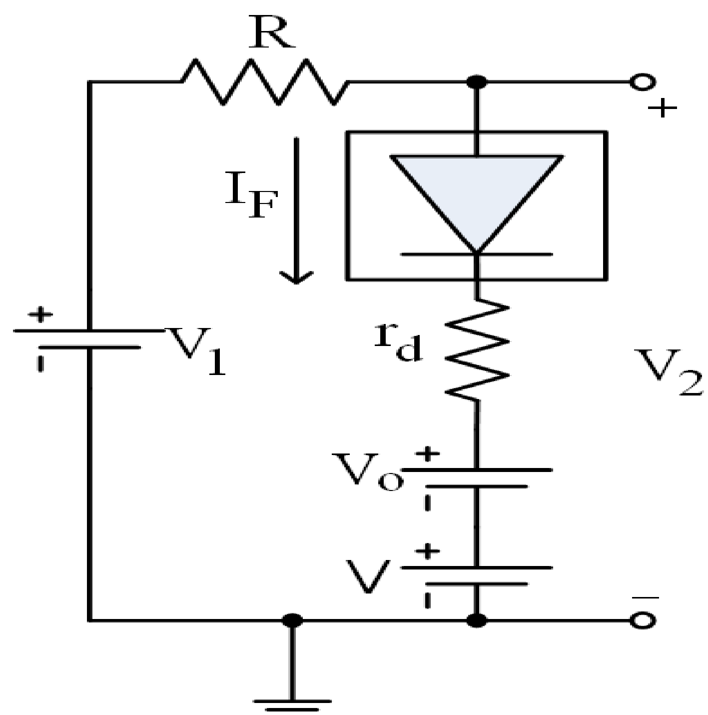
CLASS 9

Piecewise linear diode models and rectifiers

Example 2: Determine the transfer function of the circuit in Example 1 but with the potential barrier and forward resistance taken into consideration.

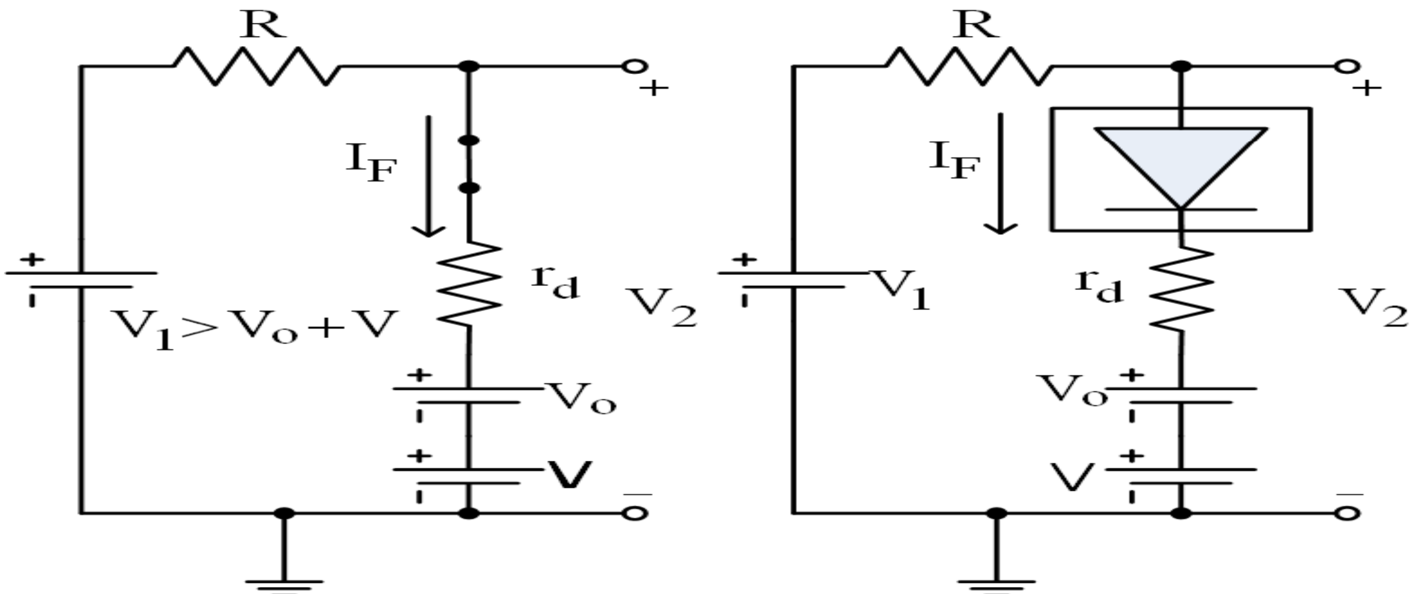




Case 1: What is the condition that will fb the diode?

Case 2: What is the condition that will rb the diode?

Case 1: To fb the diode, I_F is flowing from anode to cathode. For the current to flow in this direction, $V_1 > V_o + V$. For the fb ideal diode, it is represented by a s/c.

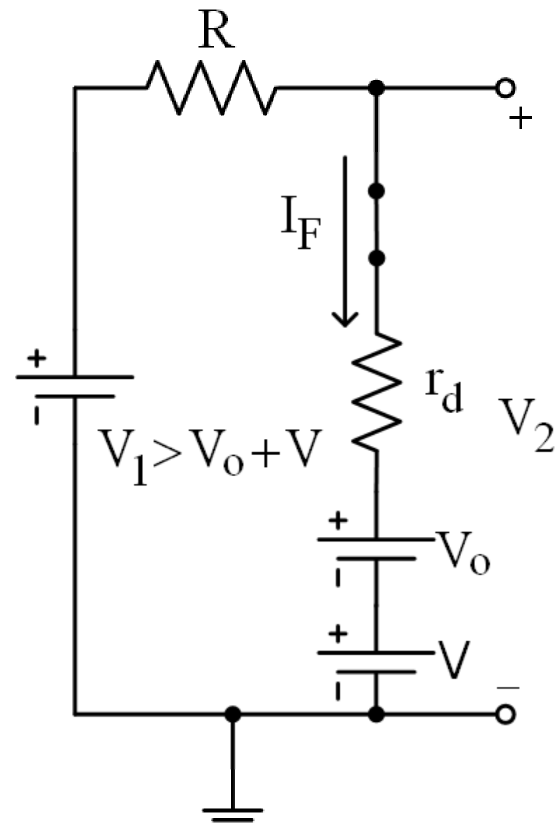


When $V_1 > V_o + V$, the diode is fb and

$$V_2 = V_o + V + I_F r_d \qquad (1)$$

$$-V_1 + I_F\left(R + r_d\right) + V_o + V = 0$$

$$I_F = \frac{V_1 - V_o - V}{R + r_d} \qquad (2)$$



Replace (2) into (1),

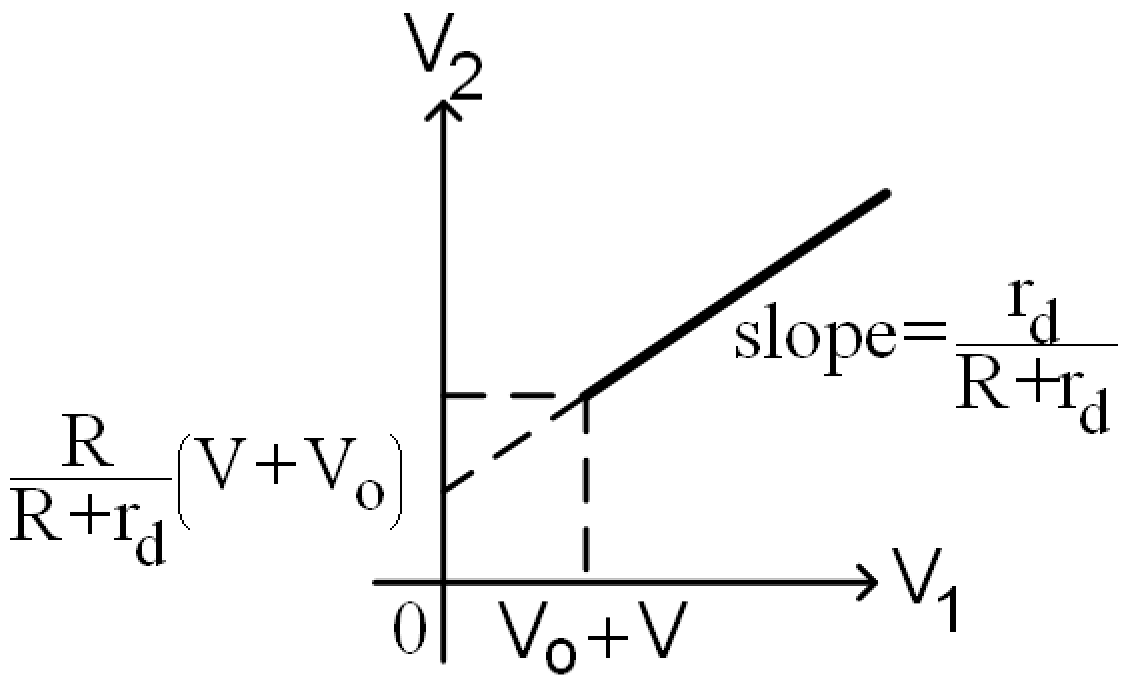
$$V_2 = \left(\frac{V_1 - V_o - V}{R + r_d}\right) r_d + V_o + V$$

$$= \left(\frac{r_d}{R + r_d}\right) V_1 - \left(\frac{r_d}{R + r_d}\right) V_o - \left(\frac{r_d}{R + r_d}\right) V + V_o + V$$

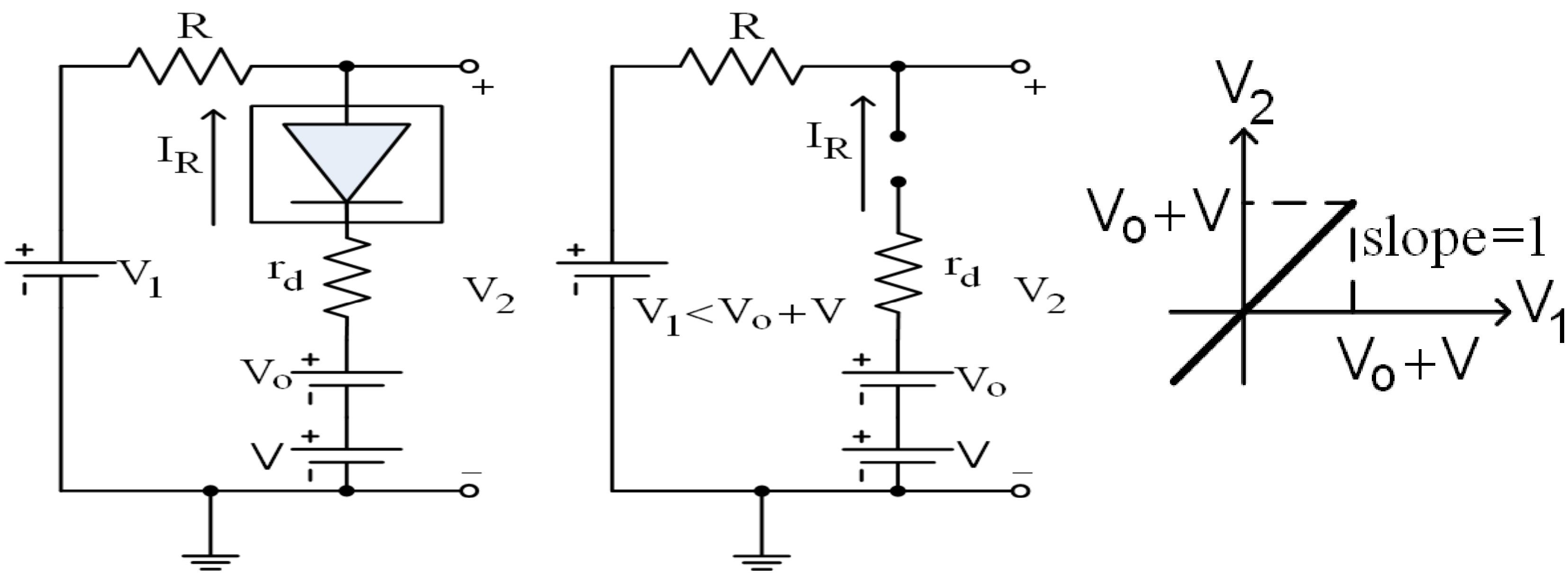
$$V_2=\left(\frac{r_d}{R+r_d}\right)V_1-\left(\frac{r_d}{R+r_d}\right)V_o-\left(\frac{r_d}{R+r_d}\right)V+V_o+V$$

$$=\left(\frac{r_d}{R+r_d}\right)V_1+\left(1-\frac{r_d}{R+r_d}\right)V_o+\left(1-\frac{r_d}{R+r_d}\right)V$$

$$V_2=\left(\frac{r_d}{R+r_d}\right)V_1+\left(\frac{R}{R+r_d}\right)(V_o+V)$$



<u>Case 2</u>: To rb the diode, I flows from cathode to anode. This happens when $V_1 < V_o + V$. Under this condition, $V_2 = V_1$.

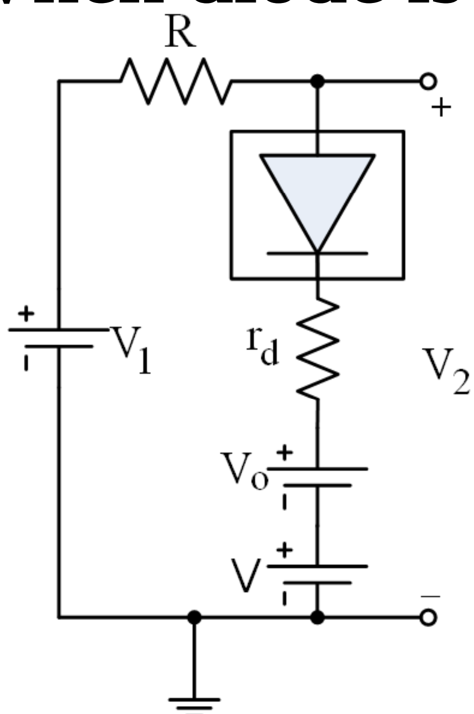


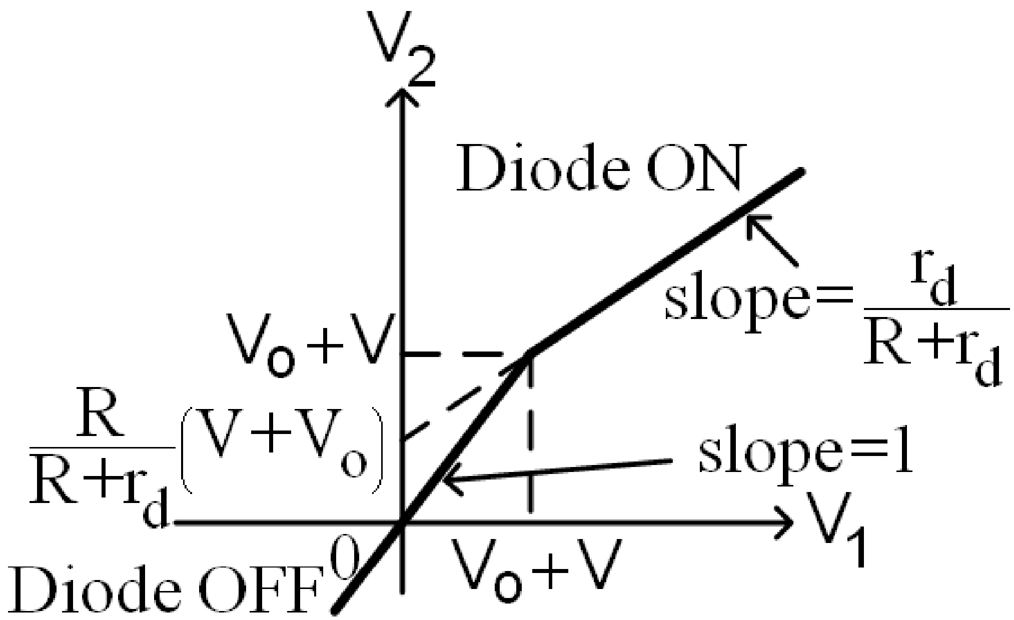
Overall transfer function plot:

When diode is ON ($V_1 > V_o + V$),

$$V_2 = \left(\frac{r_d}{R+r_d}\right)V_1 + \left(\frac{R}{R+r_d}\right)\left(V_o + V\right)$$

When diode is OFF ($V_1 < V_o + V$), $V_2 = V_1$

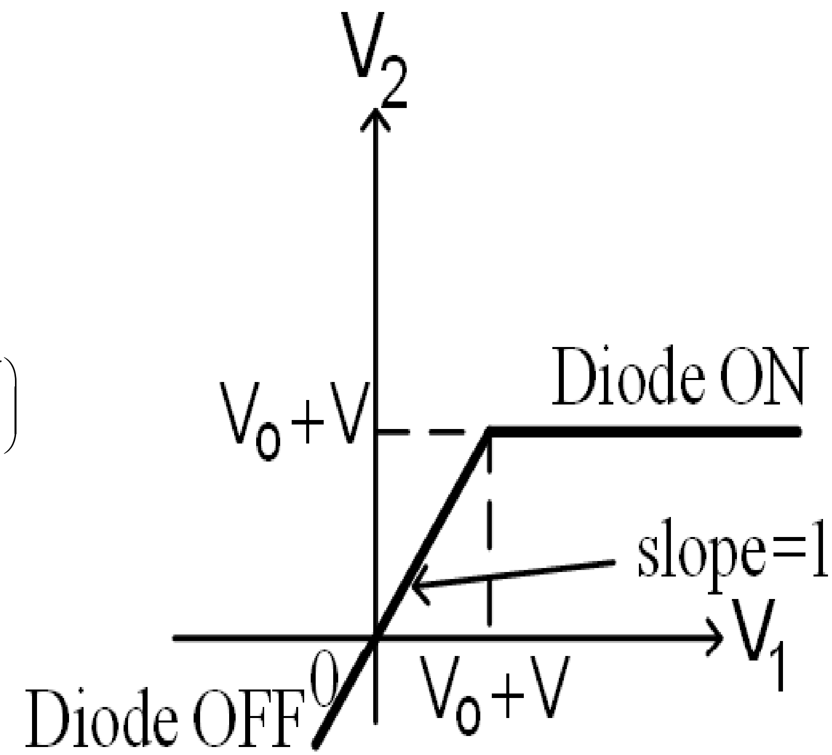




In practical, $r_d << R$. The equation when diode is ON:

$$V_2 = \left(\frac{r_d}{R+r_d}\right)V_1 + \left(\frac{R}{R+r_d}\right)(V_o + V)$$

With $r_d << R$, $V_2 = V_o + V$.

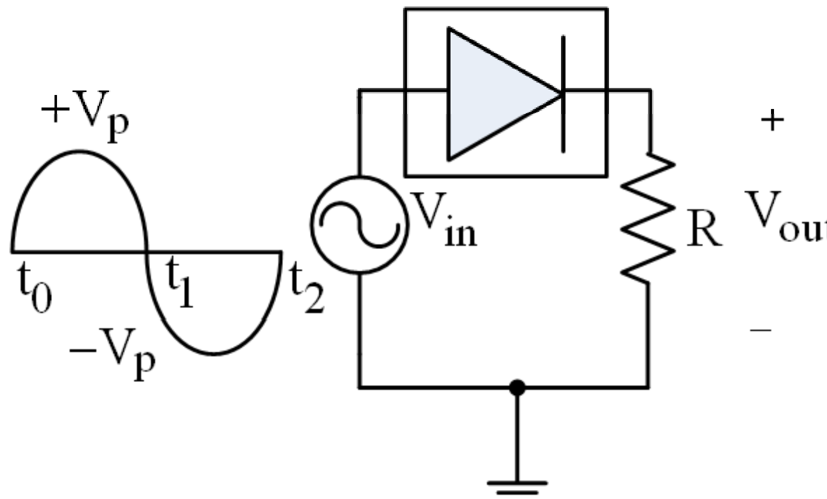


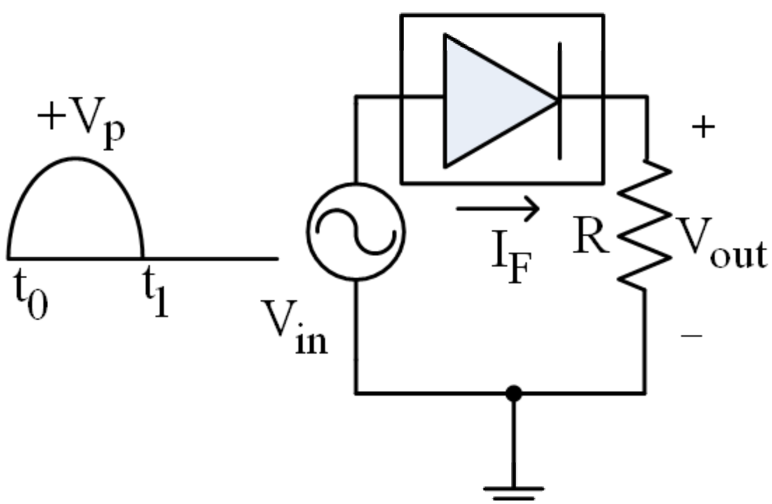
RECTIFYING DIODE

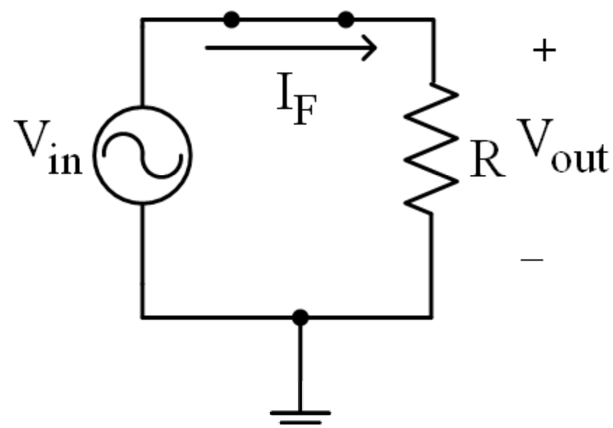
- **It is the main application of semiconductor diodes.**
- **This diode converts AC voltage to DC voltage. The diode's ability to let current flow in one direction (when fb) and preventing current flow in the opposite direction (when rb) is the basis of the rectifying circuit.**
- **Rectifying circuits are available in all DC power supply that operates from an AC voltage source.**
- **2 types of rectifying circuits:**
  - half-wave rectifier
  - full-wave rectifier

HALF-WAVE RECTIFIER

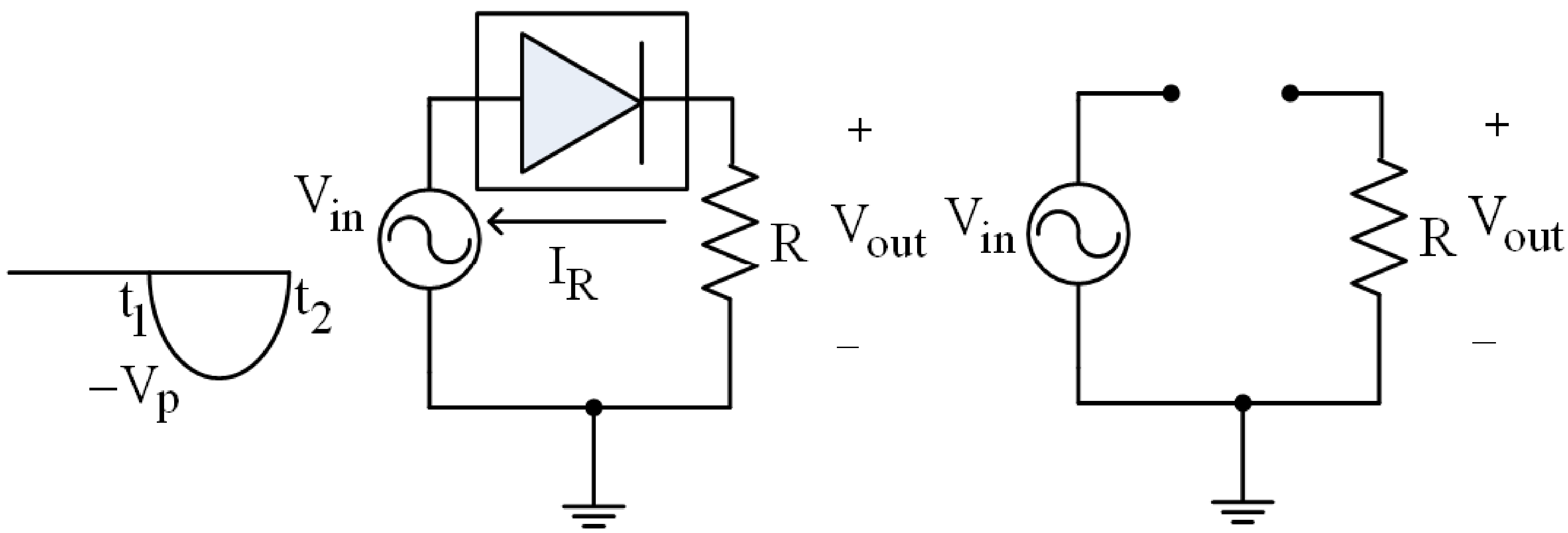
During the 1st half cycle, $V_{out} = V_{in}$



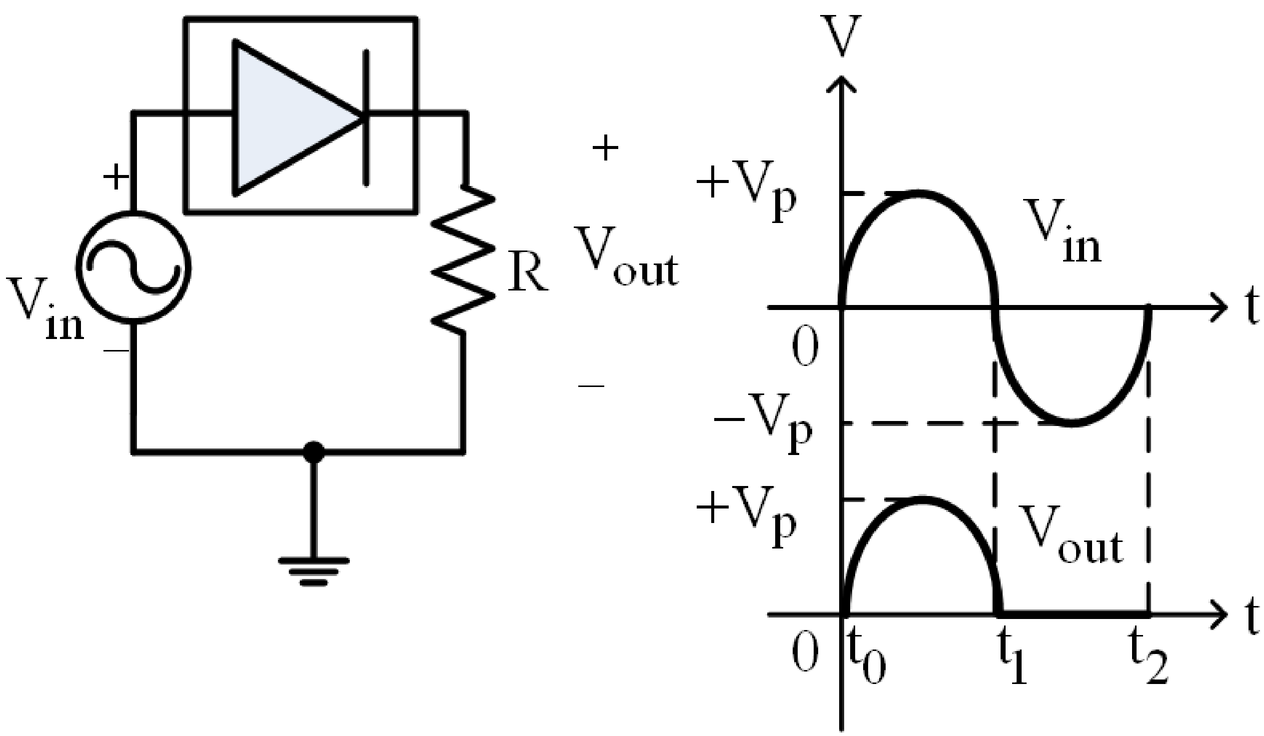




During the 2nd half cycle, $V_{out} = 0$.



Overall output signal:



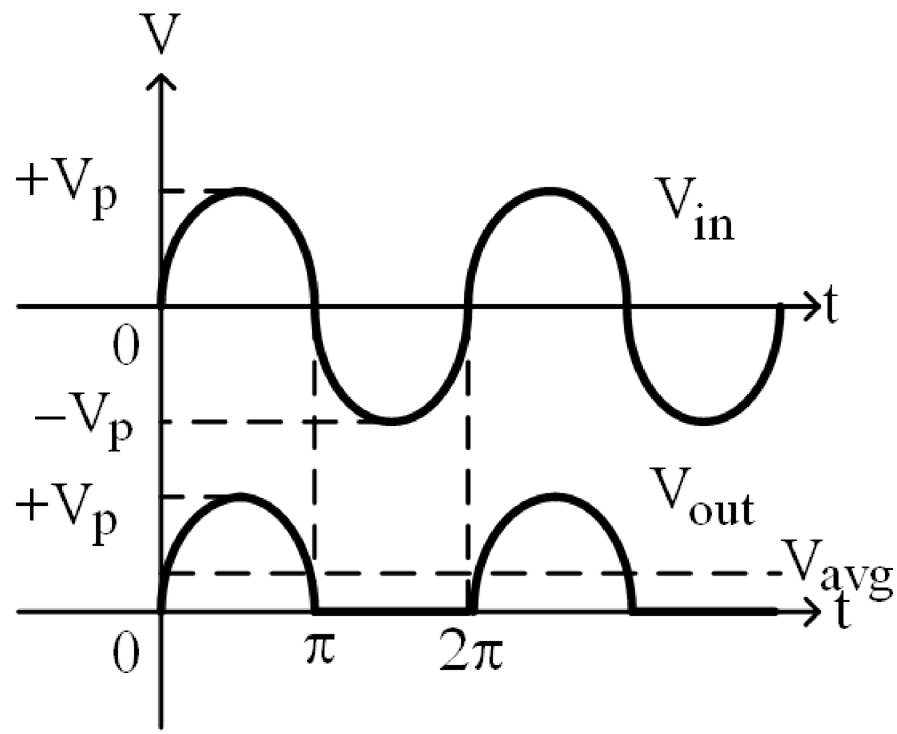
$$V_{avg} = \frac{1}{T}\int_0^{2\pi} V_p \sin\theta \; d\theta$$

$$\pi \rightarrow 2\pi, \; V_{out} = 0$$

$$V_{avg} = \frac{1}{T}\int_0^{\pi} V_p \sin\theta \; d\theta$$

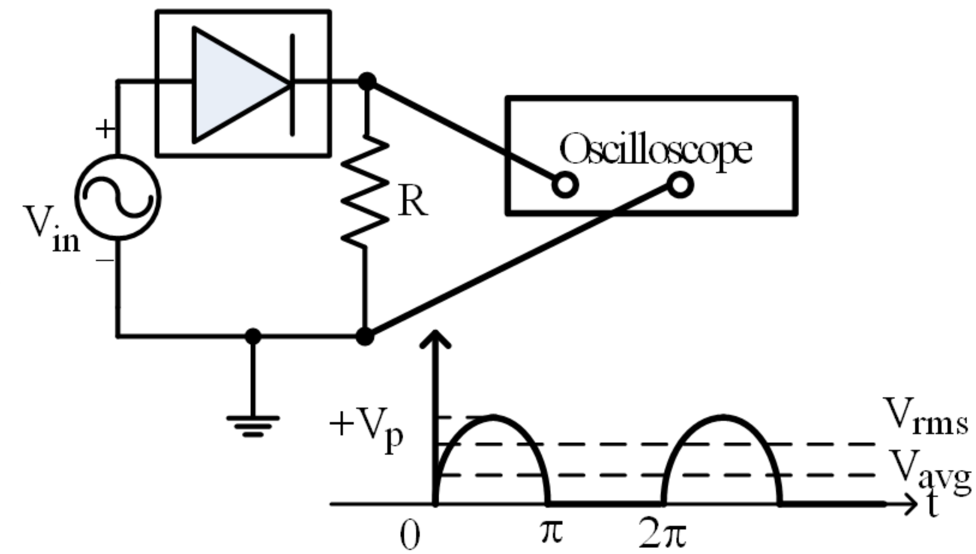
$$= \frac{V_p}{2\pi}\left[-\cos\theta\right]_0^{\pi}$$

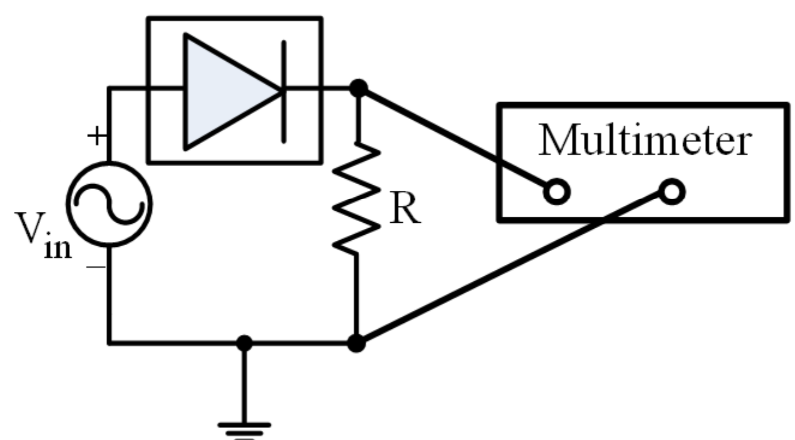
$$= \frac{V_p}{\pi}$$



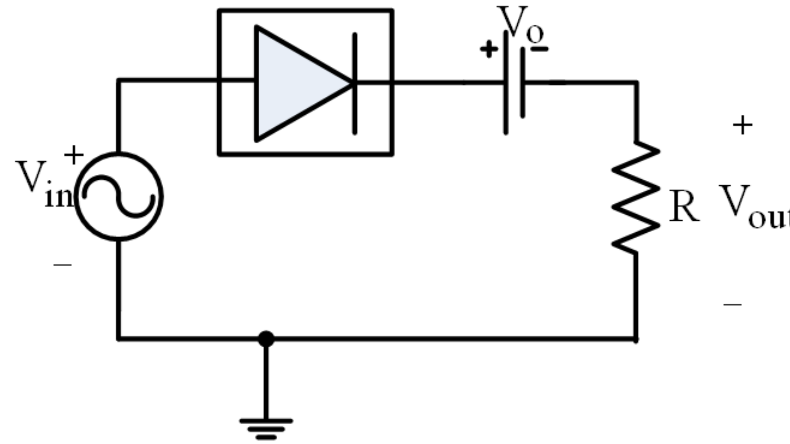
V_{avg} is also known as V_{dc}

- **V_{avg} is the reading that will be obtained if the multimeter's knob is at the VDC range.**
- **V_{rms} is the reading that will be obtained if the multimeter's knob is at the VAC range.**





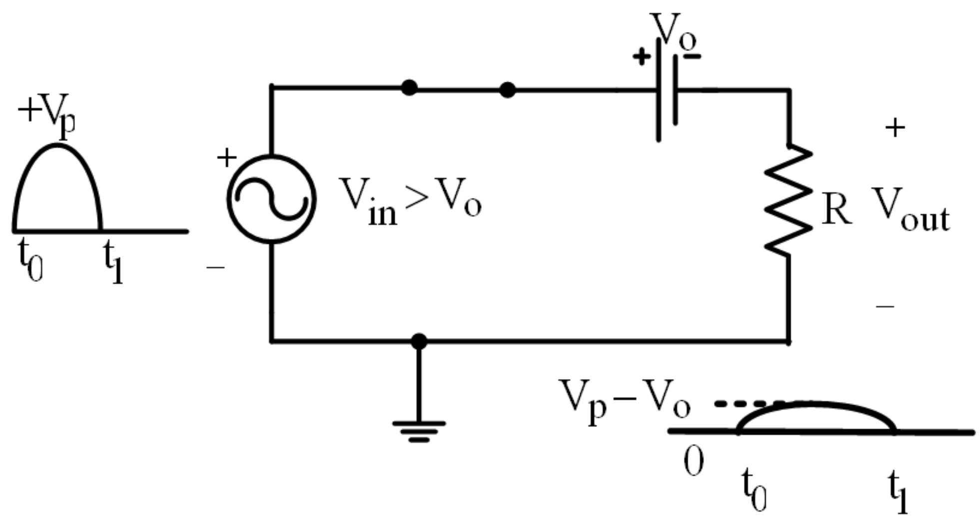
Rectifier circuit with diode's potential barrier taken into consideration



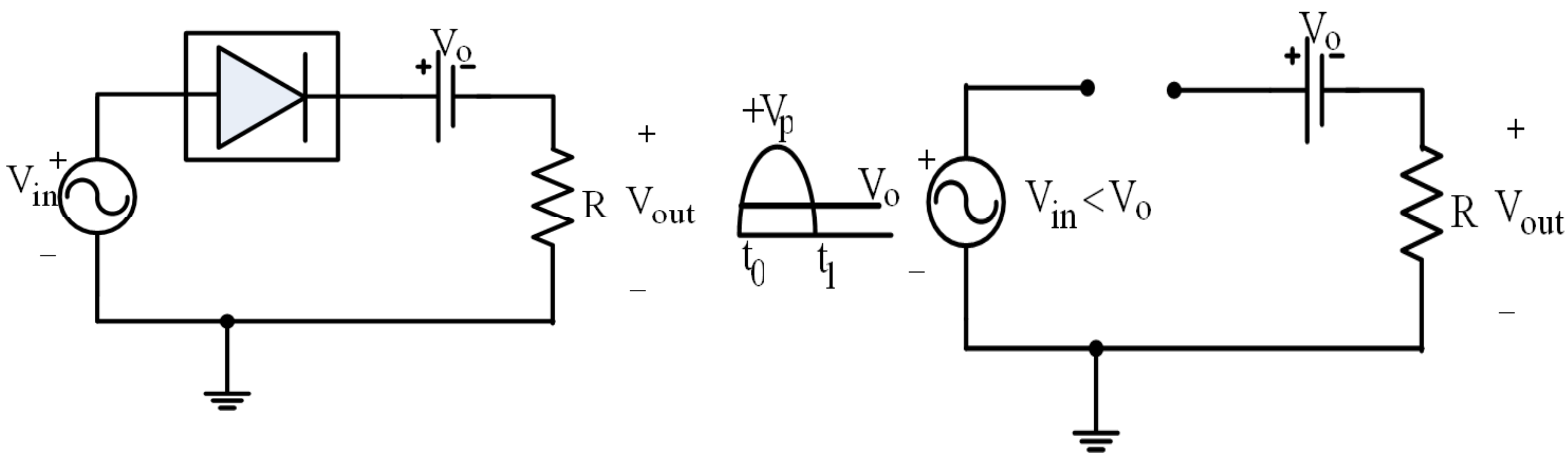
The diode will be fb if $V_{in} > V_o$. During fb, the diode is represented by a s/c. Using KVL,

$V_{out} = V_{in} - V_o$

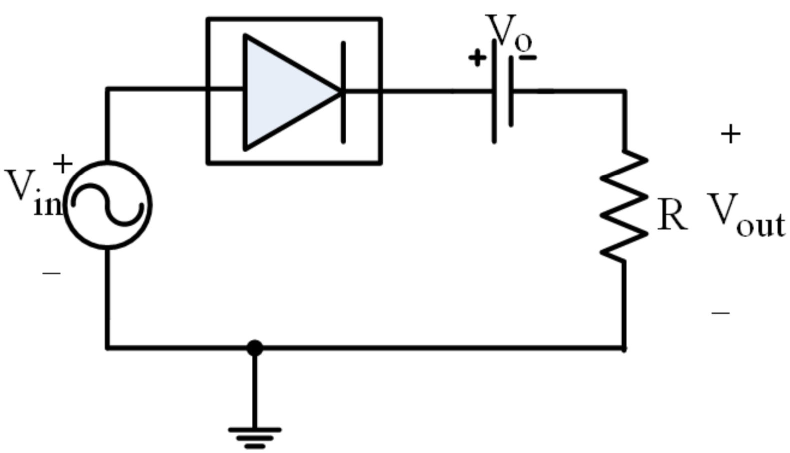
If $V_{in} = V_p$, $V_{out} = V_p - V_o$.

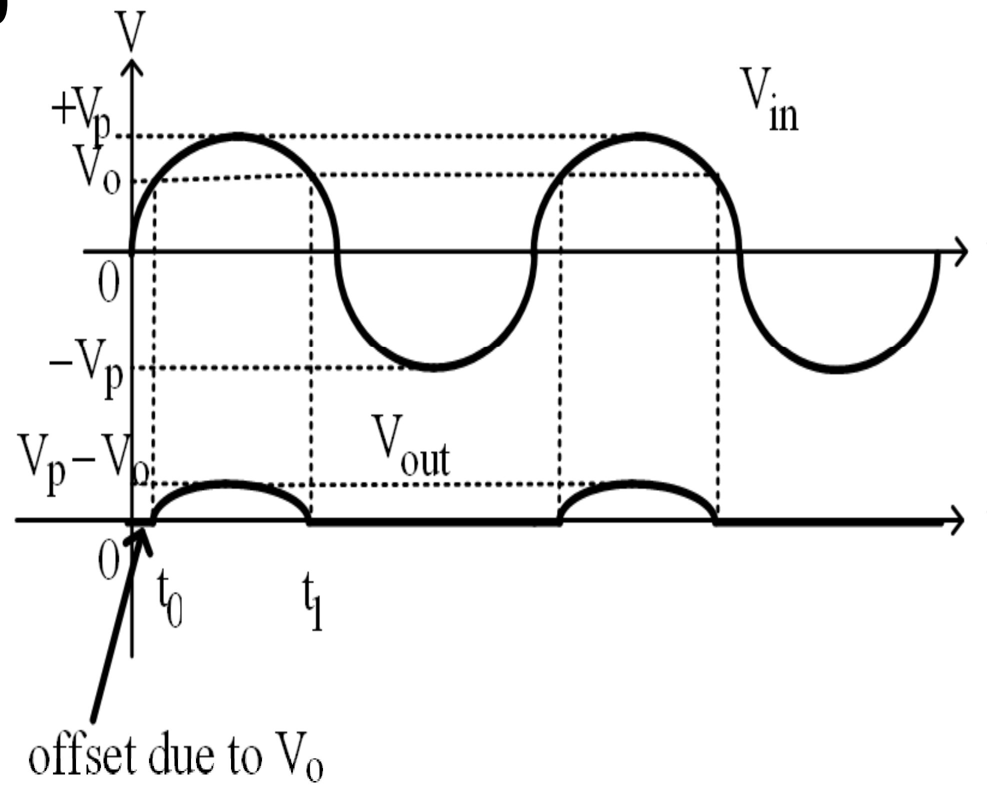


If V_{in}<V_o , then current will be flowing from the cathode to the anode. Hence, diode is rb. Diode is represented by an o/c. Current is 0. V_{out} = 0.



- **Diode fb (ON), $V_{out} = V_{in} - V_o$. If $V_{in} = V_p$, $V_{out} = V_p - V_o$**
- **Diode rb (OFF), $V_{out} = 0$**





PEAK INVERSE VOLTAGE (PIV)

- **The maximum peak voltage that can be across the diode during rb.**
- **The PIV is specified by the diode's manufacturer**
- **The PIV of a diode in a circuit needs to be known as it should not be more than the PIV specified by the manufacturer.**

PIV of a half-wave rectifier

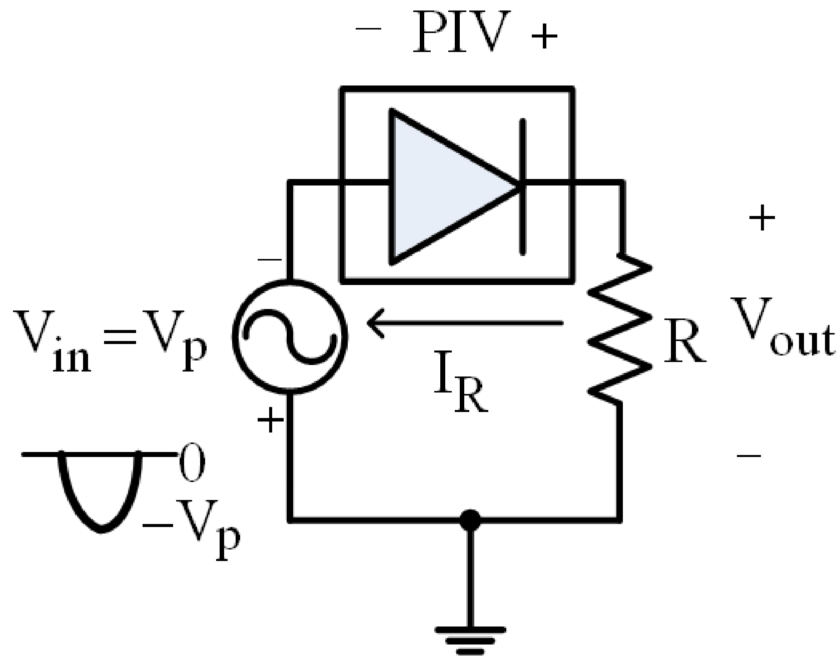
To determine the PIV of the diode, the V_{in} needs to be at its maximum negative peak, $-V_p$. KVL gives:

V_p – PIV + V_{out} = 0

PIV = V_p + V_{out}

But during rb, V_{out} = 0.

Hence, PIV = V_p.



Half-wave rectifier with input from the transformer

Transformer is used to couple the AC input voltage to the rectifier circuit.

<u>Advantages:</u>

- **The supply voltage to the rectifier can be varied (by utilizing the step-up or step-down transformer).**
- **AC power supply can be isolated from the rectifier circuit. The danger of electrical shock can be reduced.**

Half-wave rectifier with transformer coupled input

N_1 = number of winding in the primary coil

N_2 = number of winding in the secondary coil

V_1 = voltage across the primary coil

V_2 = voltage across the secondary coil

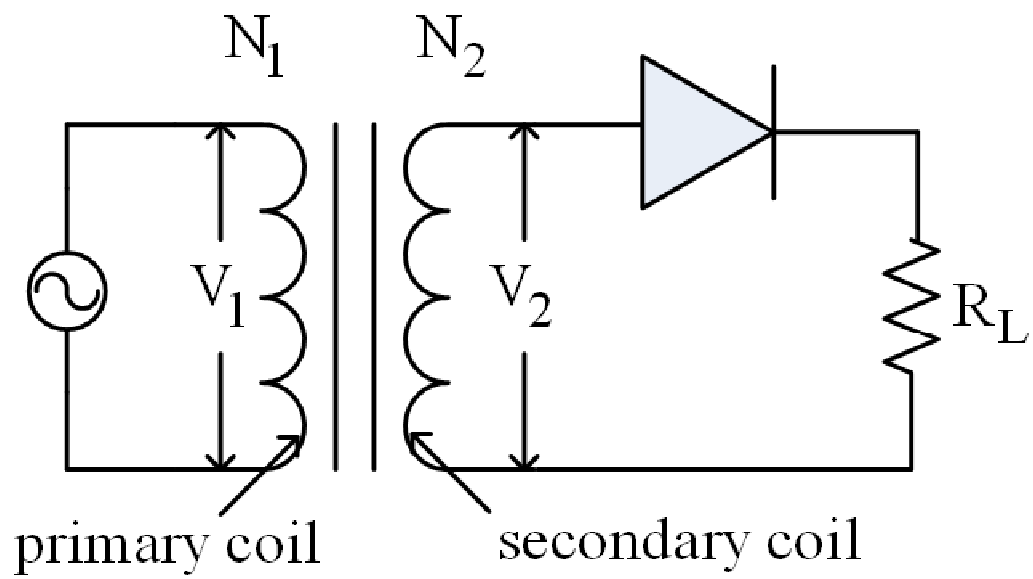
$V_2 = (N_2 / N_1)\ V_1$

$N_2 > N_1$, $V_2 > V_1$

$N_2 < N_1$, $V_2 < V_1$

$N_2 = N_1$, $V_2 = V_1$

Hence, the AC supply voltage to the rectifier circuit is adjustable.



FULL-WAVE RECTIFIERS

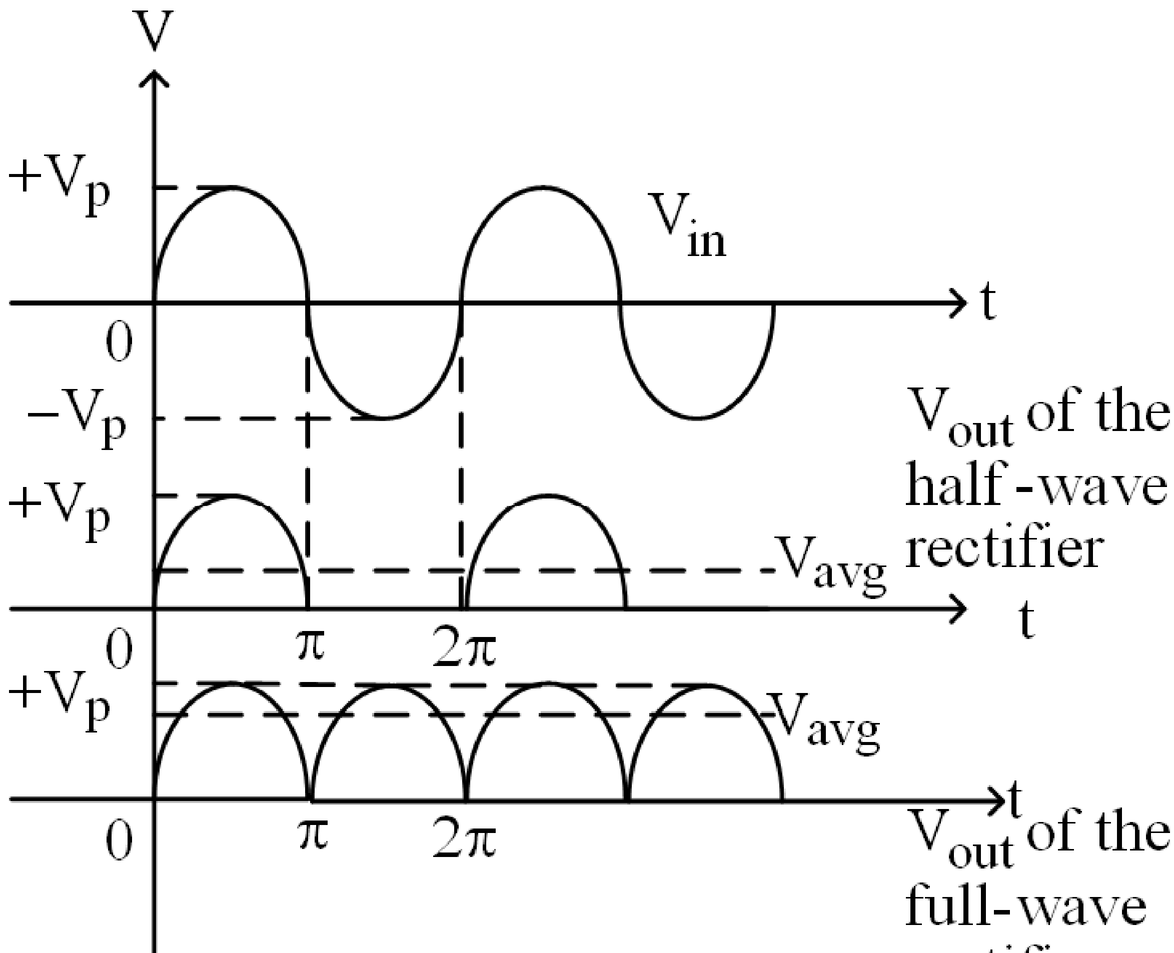
Two types:

- Centre-tap full-wave rectifier
- Bridge full-wave rectifier

  Difference between the half-wave and the full-wave rectifiers:

- Full-wave rectification enables current in one direction to reach the load for 1 full cycle of the input signal.

Difference between the half-wave and full-wave output signals



Centre-tapped transformer

The output voltages wrt to the centre tap is 180° out of phase and having ½ the magnitude of the voltage across the secondary coil.