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Royal Commission for Jubail & Yanbu

EEN 313 : Power Electronics Circuits

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Lecture 2

Uncontrolled Rectifiers

AC → DC

- Outline
  - Part 01 : Half-Wave Rectifiers
  - Part 02: Full-Wave Rectifiers

Part 01

Half-Wave Uncontrolled Rectifiers

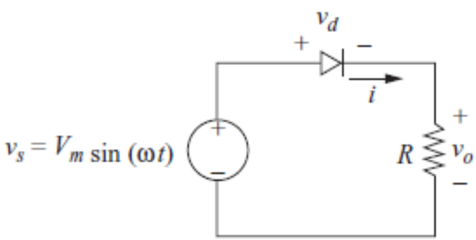
•Outline

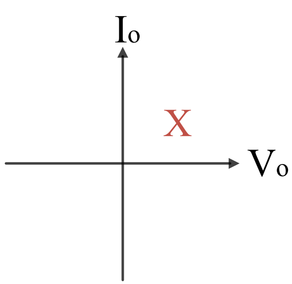
- Half-Wave Diode Rectifier with ***R*** Load
- Half-Wave Diode Rectifier with ***RL*** Load
- Half-Wave Diode Rectifier with **freewheeling Diode**
- Half-Wave **Battery Charger**

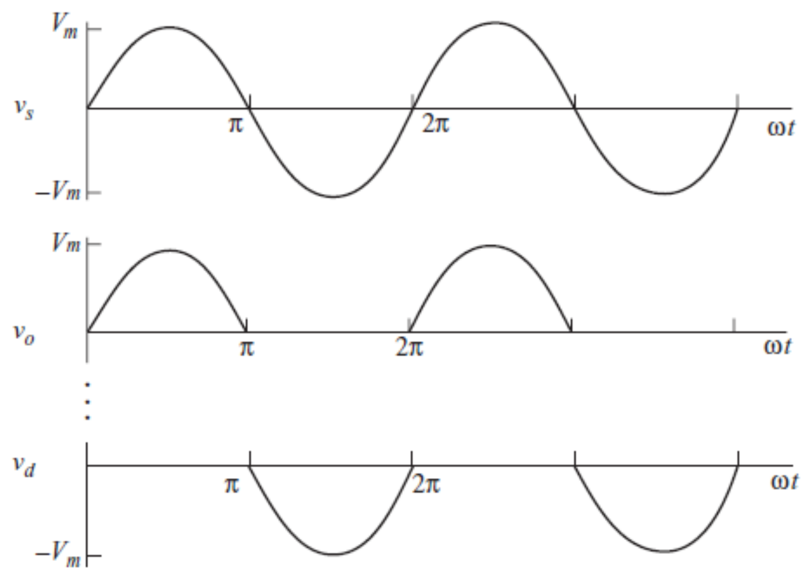
Half-Wave Diode Rectifier with *R* Load-1

- Half-Wave Diode Rectifier is the simplest PEC circuit.
- It is not normally used in industrial applications. However, it is very useful in understanding the basic of rectification process.
- A basic half-wave diode rectifier with a resistive load is shown below. It delivers a half-cycle of dc output for every full cycle of the applied ac voltage.

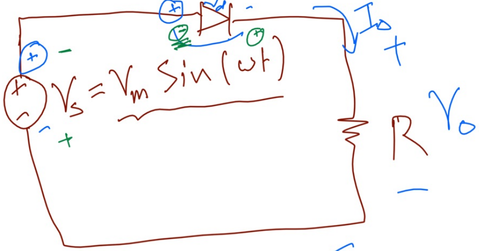
Diode Conduction angle is π



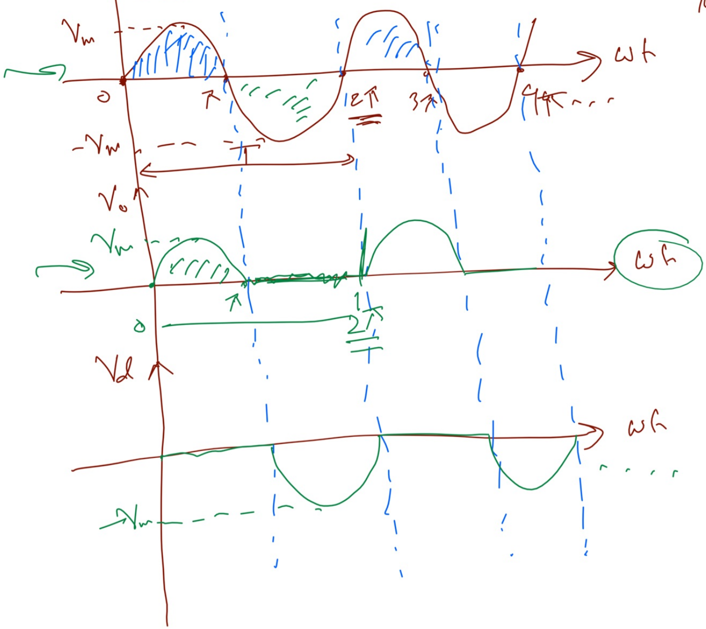


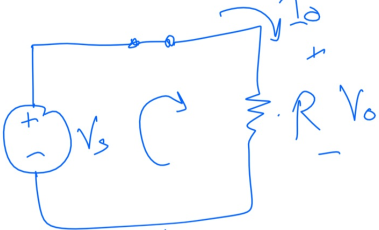


The output ripple frequency is same as the source frequency.



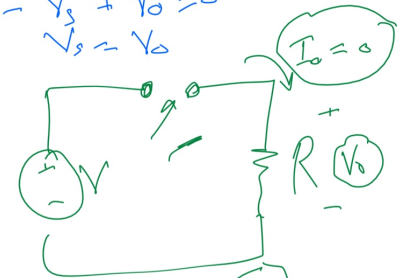
$V_s = V_m \sin(\omega t)$ $\quad \omega = 2\pi f$ rad/s $\quad f = \frac{1}{T}$





$-V_s + V_o = 0$

$V_s = V_o$



$V_o = R I_o$
$= 0$

$$V_o = V_{avg} = V_{dc} = \frac{1}{2\pi}\int_0^{\pi} V_m \sin(\omega t)\, d\omega t = \frac{V_m}{2\pi}\int_0^{\pi} \sin\omega t \, d\omega t$$

$$= \frac{V_m}{2\pi}\Big[-\cos(\omega t)\Big]_0^{\pi}$$

$$= \frac{V_m}{2\pi}\Big[-(-1-1)\Big]$$

$$= \frac{V_m}{\pi}$$

$$I_{o\,avg} = I_{dc} = \frac{V_{avg}}{R} = \frac{V_m}{\pi R}$$

$$P_{avg} = P_{dc} = V_{o\,avg} I_{o\,avg} = \frac{V_m}{\pi} * \frac{V_m}{\pi R}$$

$$= \frac{V_m^2}{\pi^2 R}$$

$$V_{rms} = \sqrt{\frac{1}{2\pi} \int_0^{\pi} (V_m \sin(\omega t))^2 \, d\omega t}$$

$$= \frac{V_m}{2}$$

$$I_{rms} = \frac{V_{rms}}{R} = \frac{V_m}{2R}$$

$$P_{ac} = V_{o\,rms} I_{o\,rms}$$

$$= \frac{(V_{o\,rms})^2}{R}$$

$$= (I_{o\,rms})^2 R$$

$$\eta_{\text{ल}} = \frac{P_{dc}}{P_{ac}}$$

Half-Wave Diode Rectifier with R Load-2

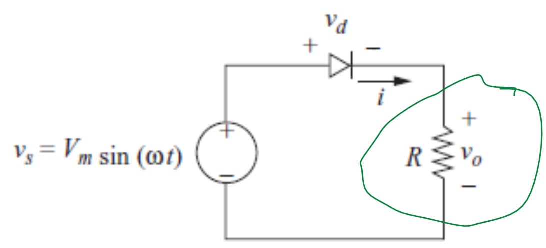
- The output voltage is composed of two components: **dc** component and **ac** component.

- The **dc** component or average value of the output is

$$V_{dc} = V_{o,avg} = \frac{Peak\ of\ sinusoidal\ input\ voltage}{\pi} = \frac{V_m}{\pi}$$

- The **dc** component of the current through the resistive load is

$$I_{dc} = I_{o,avg} = \frac{V_m}{\pi\ R}$$



- The output **dc** power is $P_{dc} = P_{o,avg} = V_{dc}\ I_{dc}$

Half-Wave Diode Rectifier with R Load-3

- The **rms** value of the output voltage is $V_{o,rms} = \frac{V_m}{2}$
- The **rms** value of the current through the resistive load is

$$I_{o,rms} = \frac{V_m}{2\,R}$$

- The output **ac** power is $P_{ac} = V_{o,rms}\, I_{o,rms} = \frac{V_{o,rms}^2}{R} = I_{o,rms}^2\, R$
- The rectification ratio is $\eta = \frac{P_{dc}}{P_{ac}}$

- In summary:

DC components	AC components
$V_{dc} = \frac{V_m}{\pi}$	$V_{o,rms} = \frac{V_m}{2}$
$I_{dc} = \frac{V_m}{\pi\,R}$	$I_{o,rms} = \frac{V_m}{2\,R}$
$P_{dc} = V_{dc}\, I_{dc}$	$P_{ac} = V_{o,rms}\, I_{o,rms}$

Half-Wave Diode Rectifier with *R* Load-4

$f = 60\ Hz$

$\omega = 2\pi f$

$= 2\pi * 60 = 377$

Example

- A 120V rms , 60Hz power source supplies a 5*Ω* resistive load through a half-wave diode rectifier. Draw the circuit of the question and determine

(a) The average of the output voltage.

(b) The average load current.

(c) The dc power delivered to the load.

(d) The rms value of the output voltage.

(e) The rms value of the load current.

(f) The ac power delivered to the load.

(g) The rectification ratio of the rectifier.

(h) The power factor of the circuit.

$V_{rms} = 120$

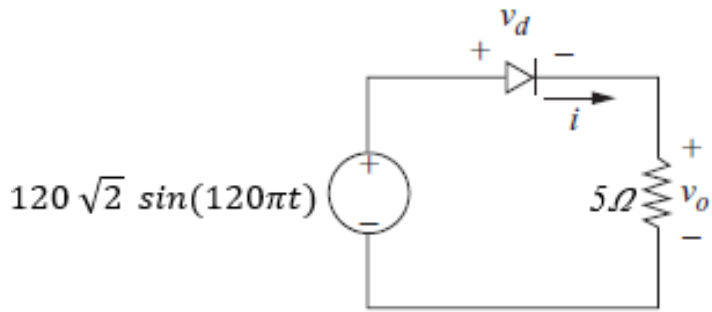
$V_m = 120\sqrt{2}$

$= 169.7$

$R = 5\ \Omega$

$V_s = V_m \sin(\omega t)$

Solution



Vrms Value

(a) $V_{dc} = \frac{V_m}{\pi} = \frac{120\sqrt{2}}{\pi} = 54\ V$

(b) $I_{dc} = \frac{V_m}{\pi R} = \frac{120\sqrt{2}}{\pi\ (5)} = 10.8\ A$

(c) $P_{dc} = V_{dc}\ I_{dc} = 583.4\ W$ $= 54 * 10.8$

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

(d) $V_{o,rms} = \frac{V_m}{2} = \frac{120\sqrt{2}}{2} = 84.9\ V$

(e) $I_{o,rms} = \frac{V_m}{2\ R} = \frac{120\sqrt{2}}{2\ (5)} = 17\ A$

(f) $P_{ac} = V_{o,rms}\ I_{o,rms} = 1443\ W$

$P.F = \frac{P_{ac}}{S}$

(g) $\%\eta = \frac{P_{dc}}{P_{ac}} = \frac{583.4}{1443} x\ 100 = 40\%$

(h) $PF = \frac{P_{ac}}{|S|} = \frac{1443}{V_{s,rms}\ I_{s,rms}} = \frac{1443}{(120)(17)} = 0.707$

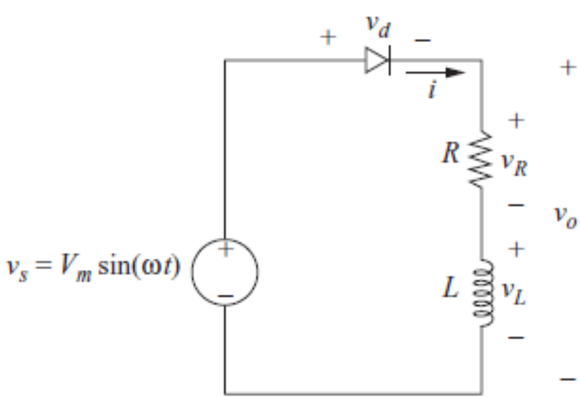
$S = V_{s\,rms} * I_{s\,rms}$

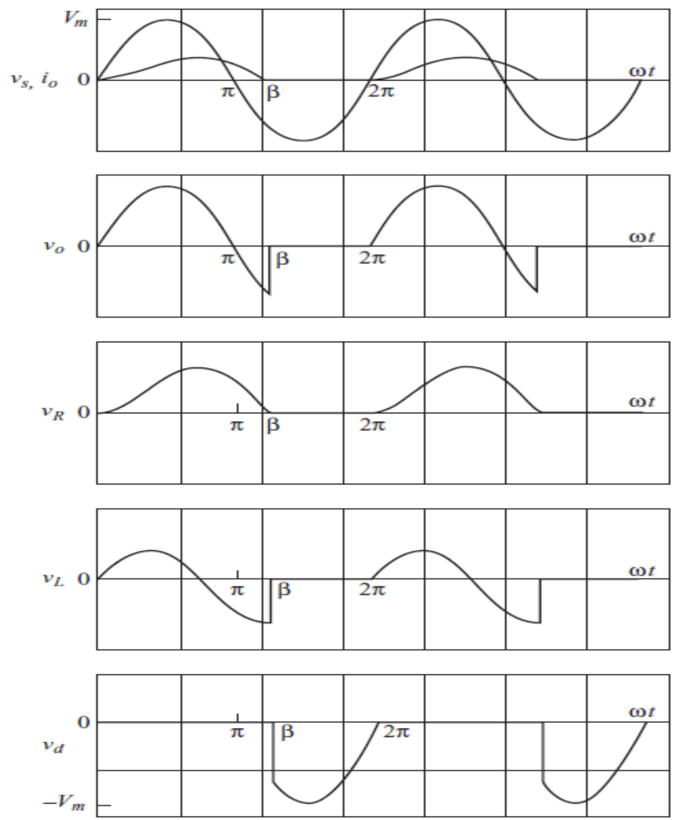
$= \frac{1443}{120 * 17} = 0.707$

Half-Wave Diode Rectifier with ***RL*** Load

- The conduction period of the diode will extend beyond π (180°) until the current becomes zero at $\omega t = \pi + \beta$. Explain why?
- Would you expect average output voltage to increase or decrease ?

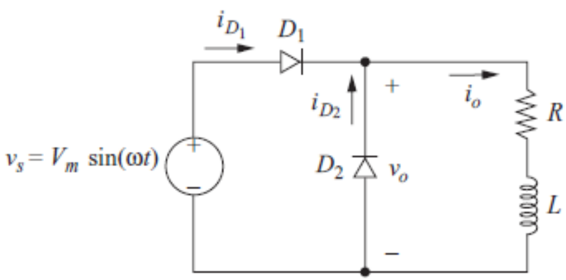
- $V_{dc} = V_{o,avg} = \frac{V_m}{2\pi}[1 - \cos(\pi + \beta)]$
- $I_{dc} = \frac{V_{dc}}{R}$

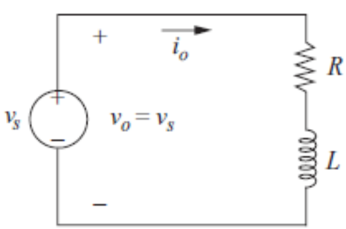




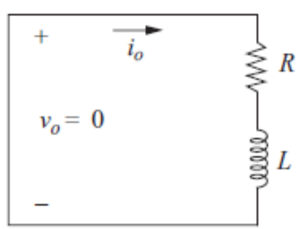
Half-Wave Diode Rectifier with ***RL*** Load and **Freewheeling** Diode

- To prevent the output voltage from going negative, a freewheeling diode (D_2) can be placed in parallel with the RL load. This will make $\beta = 0$.
- D_1 and D_2 can never conduct at the same time. Why?
- i_o can be continuous or discontinuous depending on $\tau = L/R$.

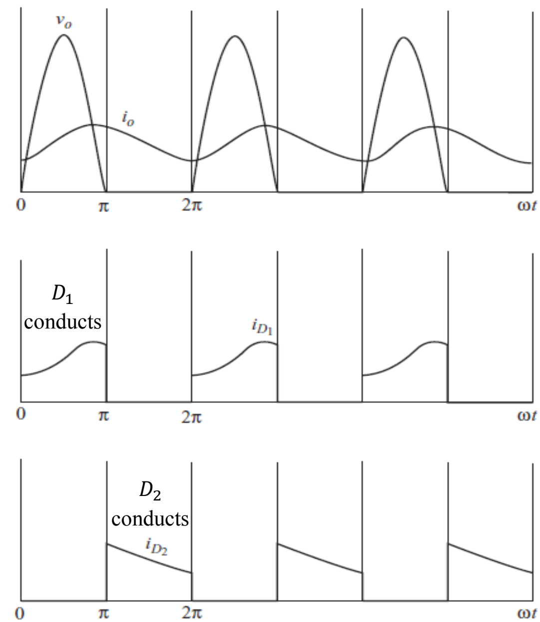




$v_s > 0$



$v_s < 0$



Steady-state load voltage and current waveforms with freewheeling diode.