

UNIVERSITY OF Hilla		LECTURE : 5
ENGINEERING FACULTY		SUBJECT : power Electronics
Medical Device Technology Engineering		LECTURE'S TITLE: 1 PH FWUCR
Asst. Lec. Morteza Abbas Imran		DATE : 2024/2025

AC-DC Conversion (Single Phase Full Uncontrolled Rectification)

1-Single-phase **center tap** full-wave rectifier

(Single-phase Full-Wave Bi-phase (Center tapped) Uncontrolled Rectifier with R- Load

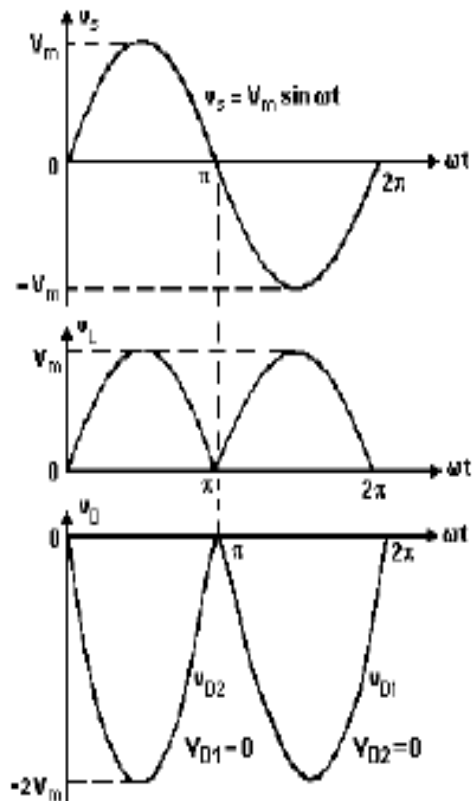
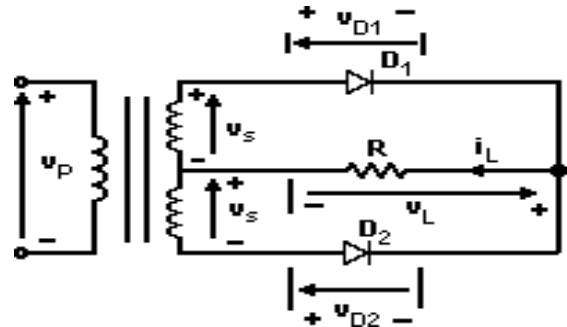
Each half of transformer constitutes a half-wave rectifier .

There is no dc current flowing through the transformer (no dc saturation prob.)

The average output voltage is

$$V_{dc} = \frac{2}{T} \int_0^{T/2} V_m \sin \omega t \, dt = \frac{2V_m}{\pi}$$

PIV of the diodes is $2V_m$



2- Single-phase full-wave **bridge** rectifier with **R-(resistive)** load

Full utilization of transformer

Requires four diodes

PIV of the diodes is V_m

The average output voltage is

$$V_{dc} = \frac{2}{T} \int_0^{T/2} V_m \sin \omega t \, dt = \frac{2V_m}{\pi}$$

PIV of the diodes is V_m

$$V_{o \, mean} = \frac{2}{2\pi} \left[\int_0^\pi V_m \sin \theta \, d\theta \right] = \frac{2V_m}{\pi}$$

$$V_{mean} = 0.6366 V_m$$

$$I_{o \, mean} = \frac{V_{mean}}{R} = \frac{2V_m}{\pi R} = \frac{0.6366 V_m}{R}$$

$$V_{o \, rms} = \left[\frac{2}{2\pi} \int_0^\pi (V_m \sin \theta)^2 \, d\theta \right]^{1/2} = \frac{V_m}{\sqrt{2}}$$

$$V_{o \, rms} = 0.707 V_m$$

$$I_{rms} = I_o = \frac{V_{rms}}{R} = \frac{0.707 V_m}{R}$$

$$P_{mean} = \frac{(0.6366 V_m)^2}{R}$$

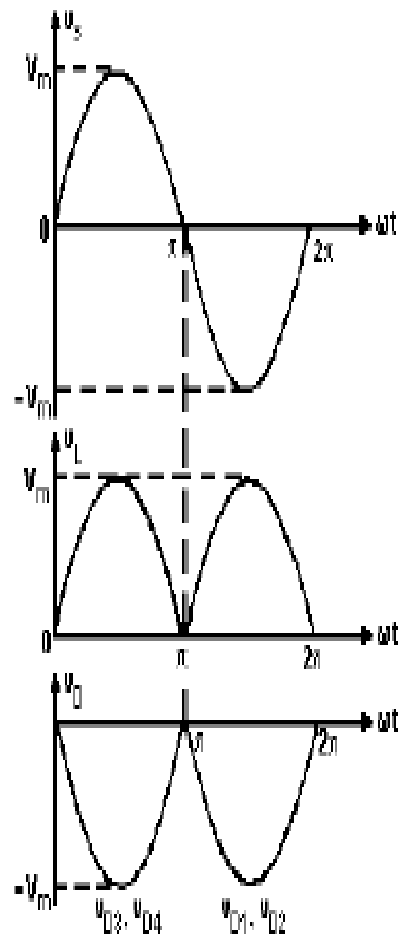
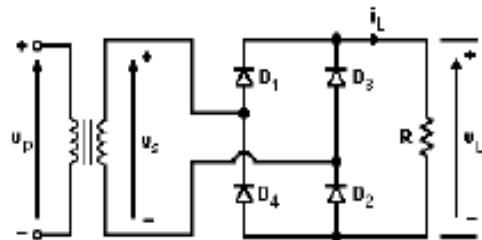
$$P_{rms} = \frac{(0.707 V_m)^2}{R}$$

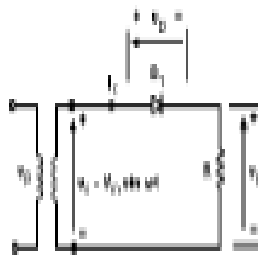
$$a) \, \eta = \frac{(0.6366 V_m)^2}{(0.707 V_m)^2} = 81 \%$$

$$b) \, FF = \frac{0.707 V_m}{0.6366 V_m} = 1.11 = 111 \%$$

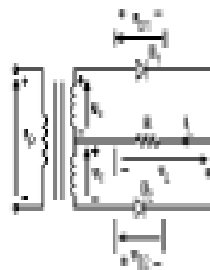
$$c) \, RF = \sqrt{(1.11)^2 - 1} = 0.482 = 48.2\%$$

The performance of a bridge rectifier is improved compared to that a half wave rectifier

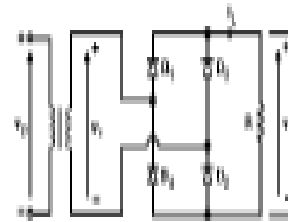




Rectifier
(R Load)



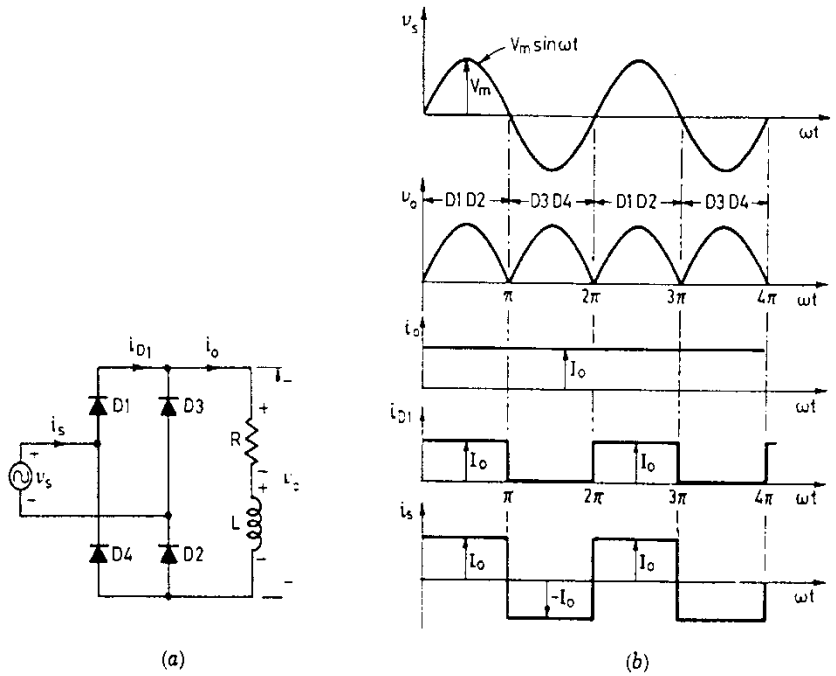
Full-Wave Transformer Rectifier
(R Load)



Performance Parameter	Half-Wave	Center-Tapped	Bridge
Efficiency (η)	40.5%	81%	81%
Form Factor (FF)	157%	111%	111%
Ripple Factor (RF)	121%	48.2%	48.2%
Transformer Utilization Factor (TUF)	28.6%	57.32%	81.1%
Peak Inverse Voltage (PIV)	V_m	$2V_m$	V_m
Crest Factor (CF)	2	1.414	1.414

3. Single-phase Full-wave rectifier with R-L (inductive) load

A single-phase bridge rectifier supplies power to a highly inductive load such as a DC motor.



When L is very high the change of current and the ripple can be assumed to be zero. The load current can be assumed to be pure dc or the load current will be approximately pure dc.

4- Single-phase Full-wave rectifier with R-L-E load

Case 1: continues load current (cont.)

In practice, most loads are inductive

A battery is added to develop generalized equations.

Input ac voltage source

$$v_s = V_m \sin \omega t = \sqrt{2}V_s$$

- The load current i_L can be found from

$$L \frac{di_L}{dt} + Ri_L + E = \sqrt{2}V_s \sin \omega t$$

The differential equation has a solution of the form

$$i_L = \frac{\sqrt{2}V_s}{Z} \sin(\omega t - \theta) + A_1 e^{-\frac{R}{L}t} - \frac{E}{R}$$

$$Z = \sqrt{R^2 + (\omega L)^2} \quad \theta = \tan^{-1} \frac{\omega L}{R}$$

The constant A_1 can be determined from condition: at $\omega t = \pi$, $i_L = I_1$

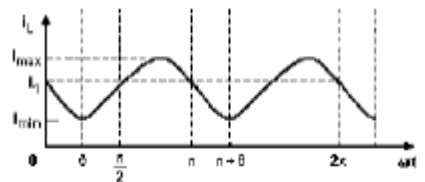
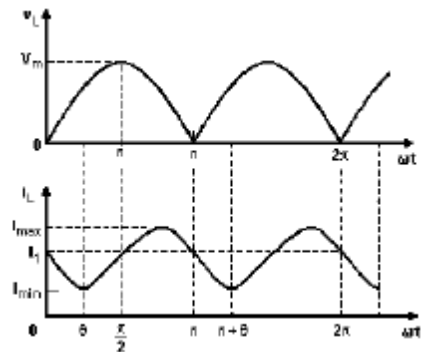
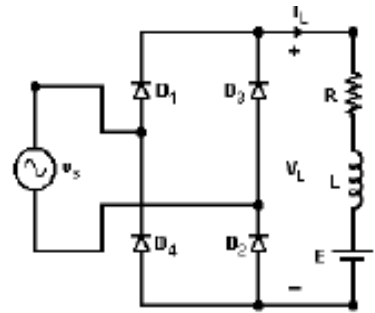
$$A_1 = \left(I_1 + \frac{E}{R} - \frac{\sqrt{2}V_s}{Z} \sin \theta \right) e^{\frac{R\pi}{L\omega}}$$

Substituting of A_1 to diff. Equation yields

$$i_L = \frac{\sqrt{2}V_s}{Z} \sin(\omega t - \theta) + \left(I_1 + \frac{E}{R} - \frac{\sqrt{2}V_s}{Z} \sin \theta \right) e^{\frac{R}{L}(\frac{\pi}{\omega} - t)}$$

Under steady-state condition $i_L(\omega t=0) = i_L(\omega t=\pi) = I_1$. applying this condition

$$I_1 = \frac{\sqrt{2}V_s}{Z} \sin \theta \frac{1 + e^{\frac{R\pi}{L\omega}}}{1 - e^{\frac{R\pi}{L\omega}}} - \frac{E}{R} \quad \text{for } I_1 \geq 0$$



Substituting I_1 and simplification gives

$$i_L = \frac{\sqrt{2}V_s}{Z} \left[\sin(\omega t - \theta) + \frac{2}{1 - e^{-\frac{R\pi}{L\omega}}} \sin \theta e^{-\frac{R}{L}t} \right] - \frac{E}{R} \quad \text{for } 0 \leq \omega t \leq \pi \text{ and } i_L \geq 0$$

RMS diode current can be found

$$I_r = \sqrt{\frac{1}{2\pi} \int_0^\pi i_L^2 d(\omega t)}$$

And the RMS output current can then be determined by combining the RMS current of each diode

$$I_{rms} = \sqrt{I_r^2 + I_r^2} = \sqrt{2}I_r$$

Average diode current

$$I_d = \frac{1}{2\pi} \int_0^\pi i_L d(\omega t)$$

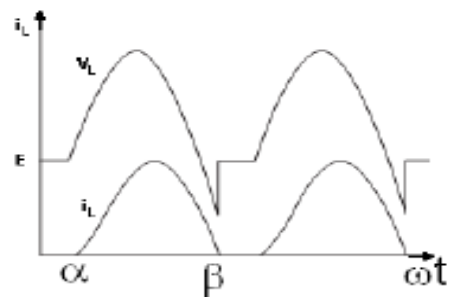
Case 2: discontinues load current

The load current flows only during the period $\alpha \leq \omega t \leq \beta$. The diodes start to conduct at $\omega t = \alpha$ given by

$$\alpha = \sin^{-1} \frac{E}{V_m}$$

The constant A_1 can be determined from condition at $\omega t = \alpha$, $i_L(\omega t) = 0$

$$A_1 = \left(\frac{E}{R} - \frac{\sqrt{2}V_s}{Z} \sin(\alpha - \theta) \right) e^{\frac{R\alpha}{L\omega}}$$



Substituting it to diff. equation

$$i_L = \frac{\sqrt{2}V_s}{Z} \sin(\omega t - \theta) + \left(\frac{E}{R} - \frac{\sqrt{2}V_s}{Z} \sin(\alpha - \theta) \right) e^{\frac{R}{L}(\frac{\alpha}{\omega} - t)}$$

At $\omega t = \beta$, the current falls zero, and $i_L(\omega t = \beta) = 0$. That is,

$$0 = \frac{2\sqrt{V_s}}{Z} \sin(\beta - \theta) + \left(\frac{E}{R} - \frac{2\sqrt{V_s}}{Z} \sin(\alpha - \theta) \right) e^{-\frac{R}{L}(\frac{\beta}{\omega} - \frac{\alpha}{\omega})}$$

β can be found from this transcendental equation by using an iterative (trial and error) method.

After β found, the RMS diode current can be calculated as

$$I_r = \sqrt{\frac{1}{2\pi} \int_{\alpha}^{\beta} i^2 d(\omega t)}$$

The average diode current

$$I_d = \frac{1}{2\pi} \int_{\alpha}^{\beta} i_L d(\omega t)$$