Basic Electrical Science Lab
Course Code: EE152

Laboratory Manual

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Section: B

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National Institute of Technology Goa

CERTIFICATE

This is to certify that Mr./ Ms. ______________________ of Class B.Tech 1st year (2nd Sem), Division Sec A/B, bearing Roll. No.______________, has satisfactorily completed the course experiments in the Laboratory Course Basic Electrical Science Lab (EE152) in the academic year 2020-2021 in the Institution of National Institute of Technology Goa.

Course Instructor

Table of Contents

Study of Diode Rectifier Circuits

1. A. Introduction:

This session makes students to understand Diode Rectifiers (Half wave, Full wave) and to verify its characteristics through a Simulation platform, MATLAB/Simulink.

1. B. Objectives:

a. Acquire a good knowledge on Diode Rectifier circuits.
b. Verification of the theoretical knowledge on Diode Rectifier circuits in MATLAB/Simulink Platform.

1. C. Theory:

Refer to the notes or necessary materials mentioned in EE151 course.

1. D. Statement of Experiments:

Fig. 6.1 represents a half wave rectifier diode circuit, where an ac sinusoidal voltage source ($v(t) = 230\sqrt{2}\sin(100\pi t)$) gets converted to DC waveform and feds power to a dc resistive load (R = 10 Ω). The transformer, T_1, is having turns ratio of 230/6 ($n_1 : n_2 = 230 : 6$). The following task has to be done theoretically and those have to be verified by simulation in matlab.

1. Derive the expression of vL(t) and iL(t). 2. Draw vL(t) and iL(t). 3. Find the value of average DC voltage VL across and current IL through load. 4. Find PIV of the diode, D1. 5. Find the rms value of output voltage and current. 6. Find rectification efficiency. 7. Check the output voltage waveform with a capacitor (with two values: 1μF and 1 mF) in parallel with load resistance.

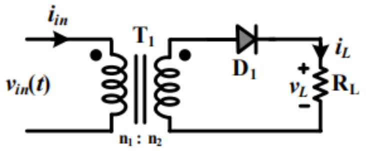


Fig. 6.1

1. E. Procedure:

Determine all the parameters asked in section- 5.3 theoretically and draw corresponding experimental circuit (necessary measuring instruments are to be incorporated in the circuit) of the circuit shown in Fig. 5.1. Construct the experimental circuits in Simulink domain, simulate it fill up the Table - 6.1. A brief procedure is mentioned below.

- Considering ideal diode (put on state voltage as zero), draw the circuit in *Simulink* and run it for 0.1 sec.
- Using "Mean" block, measure average values and using "RMS" block, measure rms values.

1. F. Assignments:

Consider Fig. 6.2 with $v(t) = 230\sqrt{2}\sin(100\pi t)$, R = 10 Ω and do the same as mentioned in Section - 1.D. Prepare an appropriate table and fill up it.

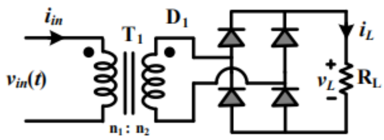


Fig. 6.2

Table - 6.1

Sl. No	Average DC Voltage (volt)		Average DC Current (Amp)		PIV of Diode (volt)		Output RMS Voltage (volt)		Output RMS Current (Amp)		Rectification efficiency (%)	
	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation
1												
2												
3												

Experiment 5

Study of Diode Rectifier Circuits

1. **Aim:** To verify the theoretical analysis of Diode rectifier circuits through a simulation platform.

2. **Simulink Blockset used:** Diode, Linear Transformer, Resistor, Capacitor, AC voltage source, current measurement, voltage measurement, product, divide, display, scope, constant, powergui, goto, from, RMS, mean

3. **Theory:**

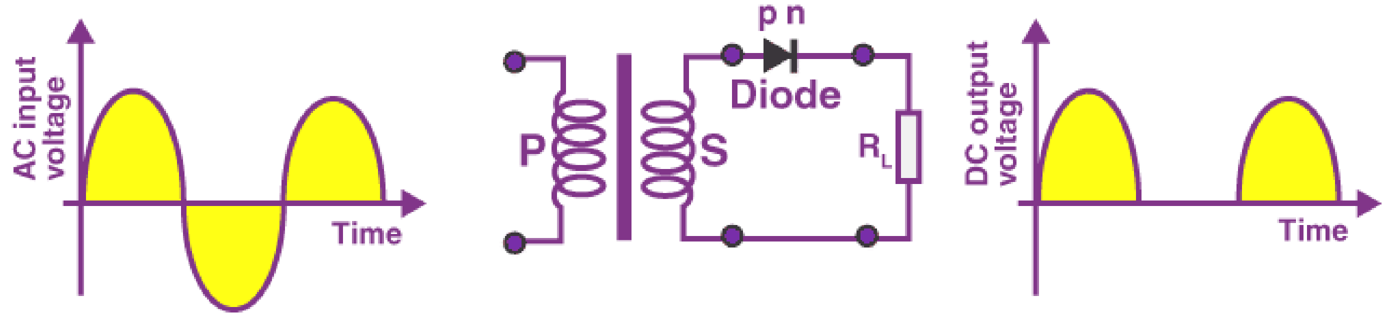
Full-Wave and Half-Wave Rectification

Rectification methods to convert AC (Alternating Current) to DC (Direct Current) include full-wave rectification and half-wave rectification. In both cases, rectification is performed by utilizing the characteristic that current flows only in the positive direction in a diode.

Full-wave rectification rectifies the negative component of the input voltage to a positive voltage, then converts it into DC (pulse current) utilizing a diode bridge configuration. In contrast, half-wave rectification removes just the negative voltage component using a single diode before converting to DC.
Afterward, the waveform is smoothed by charging/discharging a capacitor, resulting in a clean DC signal.
From this, it can be said that full-wave rectification is a more efficient method than half-wave rectification since the entire waveform is used.
Also, a ripple voltage that appears after smoothing will vary depending on the capacitance of this capacitor and the load.
Given the same capacitance and load, ripple voltage is smaller with full-wave rectification than haif-wave rectification. Of course, it goes without saying that the smaller the ripple voltage the better the stability.

Working of Half Wave Rectifier

The half-wave rectifier has both positive and negative cycles. During the positive half of the input, the current will flow from positive to negative which will generate only a positive half cycle of the AC supply. When AC supply is applied to the transformer, the voltage will be decreasing at the secondary winding of the diode. All the variations in the AC supply will reduce, and we will get the pulsating DC voltage to the load resistor.



In the second half cycle, the current will flow from negative to positive and the diode will be reverse biased. Thus, at the output side, there will be no current generated, and we cannot get power at the load resistance. A small amount of reverse current will flow during reverse bias due to minority carriers.

DC Current

DC current is given as:

$$I_{DC} = \frac{I_{max}}{\pi}$$

Where,

- I_{max} is the maximum DC load current

DC Output Voltage

The output DC voltage appears at the load resistor R_L which is obtained by multiplying output DC voltage with the load resistor R_L. The output DC voltage is given as:

$$V_{DC} = \frac{V_{Smax}}{\pi}$$

Where,

- V_{Smax} is the maximum secondary voltage

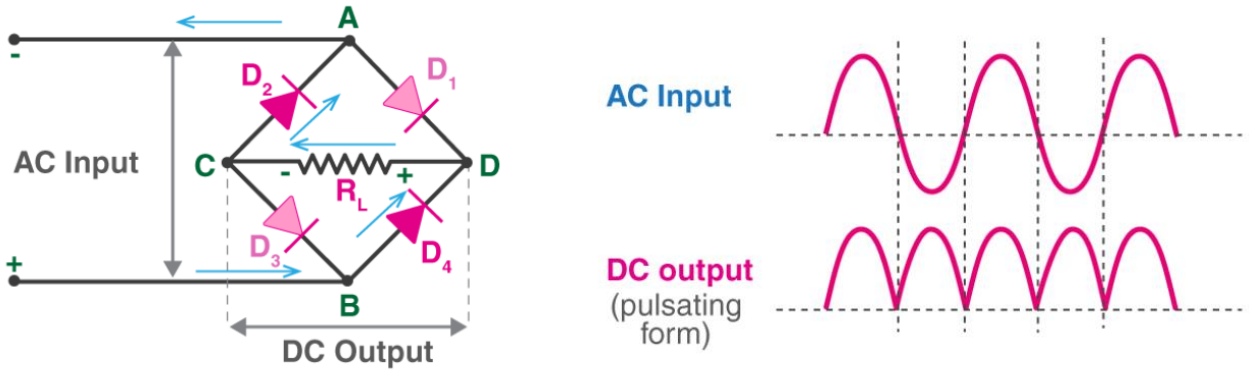
RMS value of Half Wave Rectifier

The RMS value of the load current for a half-wave rectifier is given by the formula:

$$I_{rms} = \frac{I_m}{2}$$

Working of Full Wave Rectifier

The full-wave rectifier utilizes both halves of each a.c input. When the p-n junction is forward biased, the diode offers low resistance and when it is reversing biased it gives high resistance. The circuit is designed in such a manner that in the first half cycle if the diode is forward biased then in the second half cycle it is reverse biased and so on.



DC Current

Currents from both the diodes D_1 and D_2 are in the same direction when they flow towards load resistor R_L. The current produced by both the diodes is the ratio of I_{max} to π, therefore the DC current is given as:

$$I_{DC} = \frac{2I_{max}}{\pi}$$

Where,

- I_{max} is the maximum DC load current

DC Output Voltage

DC output voltage is obtained at the load resistor R_L and is given as:

$$V_{DC} = \frac{2V_{max}}{\pi}$$

Where,

- V_{max} is the maximum secondary voltage

RMS Value of Current

The RMS value of the current can be calculated using the following formula:

$$I_{rms} = \frac{I_{max}}{\sqrt{2}}$$

Peak Inverse Voltage:

In semiconductor diodes, peak reverse voltage or peak inverse voltage is the maximum voltage that a diode can withstand in the reverse direction without breaking down or avalanching. If this voltage is exceeded the diode may be destroyed. Diodes must have a peak inverse voltage rating that is higher than the maximum voltage that will be applied to them in a given application.

Rectifier Efficiency

Rectifier efficiency is used as a parameter to determine the efficiency of the rectifier to convert AC into DC. It is the ratio of DC output power to the AC input power

$$\eta = \frac{\text{DC Output Power}}{\text{AC Output Power}}$$

4. Statement of Experiments:

Fig. 6.1 represents a half wave rectifier diode circuit, where an ac sinusoidal voltage source (v(t) = 230√ 2sin(100πt)) gets converted to DC waveform and feds power to a dc resistive load (R = 10 Ω).

The transformer T1, is having turns ratio of 230/6 (n1: n2= 230: 6). The following task has to be done theoretically and those have to be verified by simulation in MATLAB.

1. Derive the expression of vL(t) and iL(t).
2. Draw vL(t) and iL(t).
3. Find the value of average DC voltage VL across and current IL through load.
4. Find PIV of the diode, D1.
5. Find the rms value of output voltage and current.
6. Find rectification efficiency.
7. Check the output voltage waveform with a capacitor (with two values: 1μF and 1 mF)

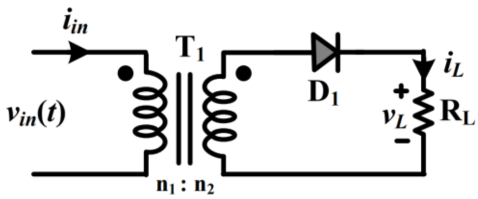


Fig. 6.1

5. Procedure:

Determine all the parameters asked in section-5.3 theoretically and draw corresponding experimental circuit (necessary measuring instruments are to be incorporated in the circuit) of the circuit shown in Fig. 5.1. Construct the experimental circuits in Simulink domain, simulate it fill up the Table -6.1. A brief procedure is mentioned below.

- Considering ideal diode (put on state voltage as zero), draw the circuit in Simulinkand run it for 0.1 sec.
- Using “Mean” block, measure average values and using “RMS” block, measure rms values.

❖ Circuit Diagram:

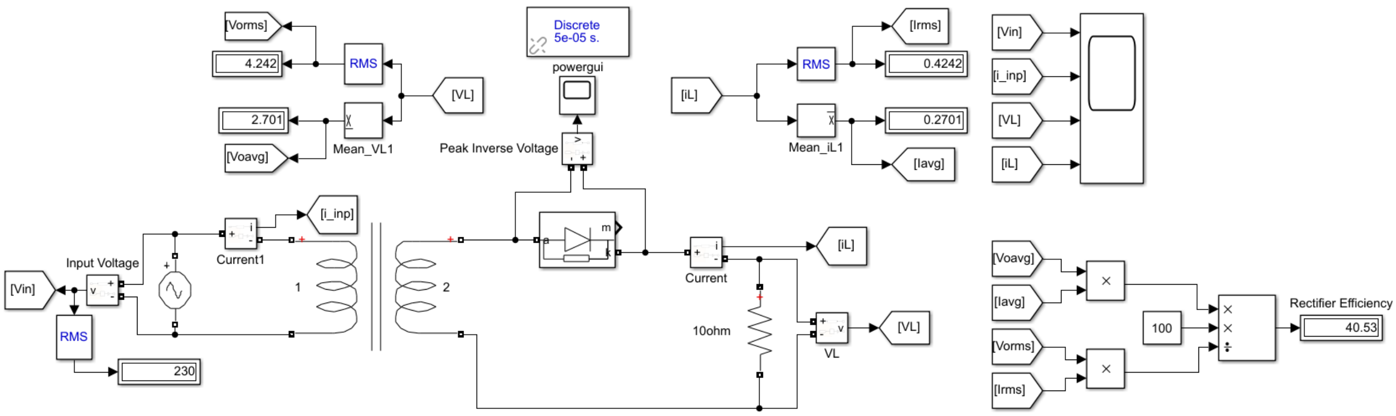


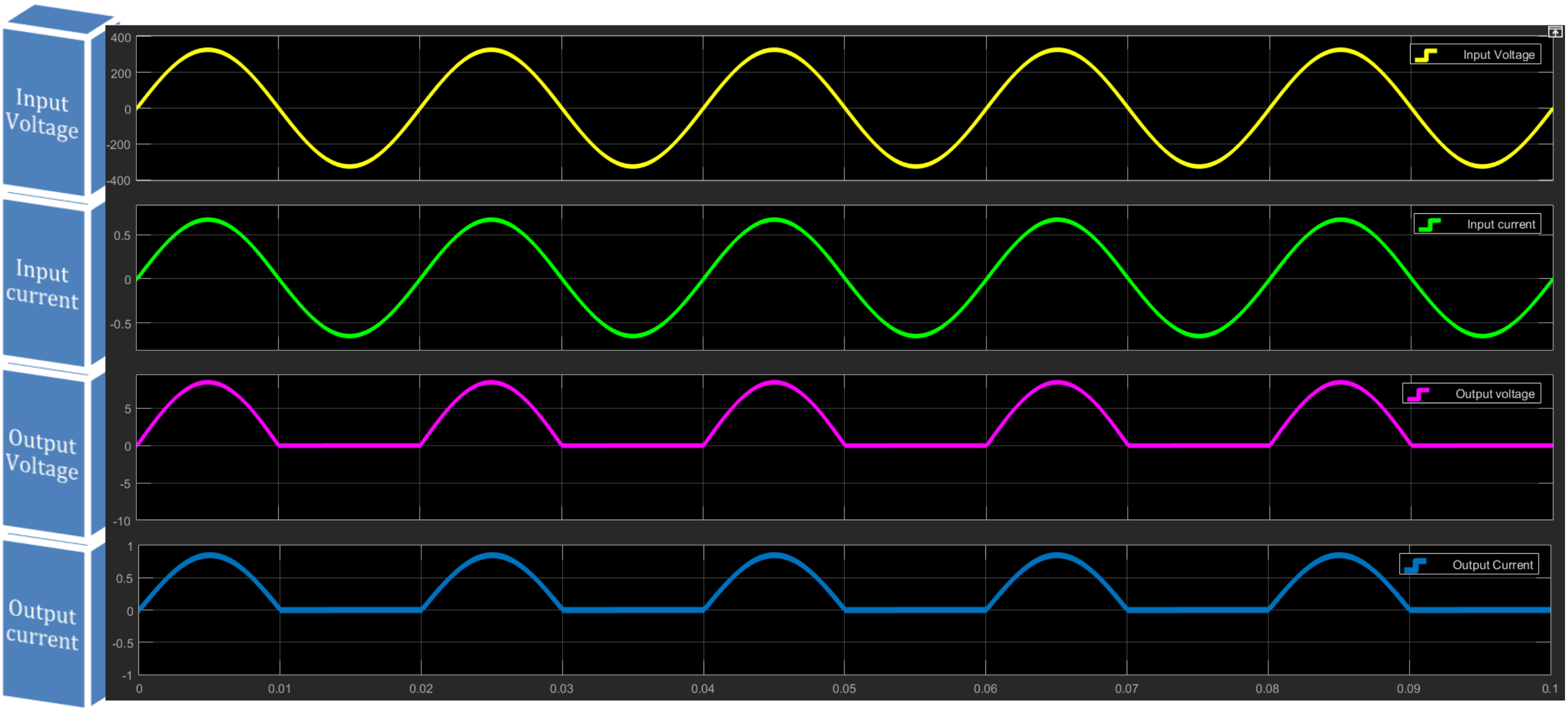
Fig1b: Circuit connections in Simulink

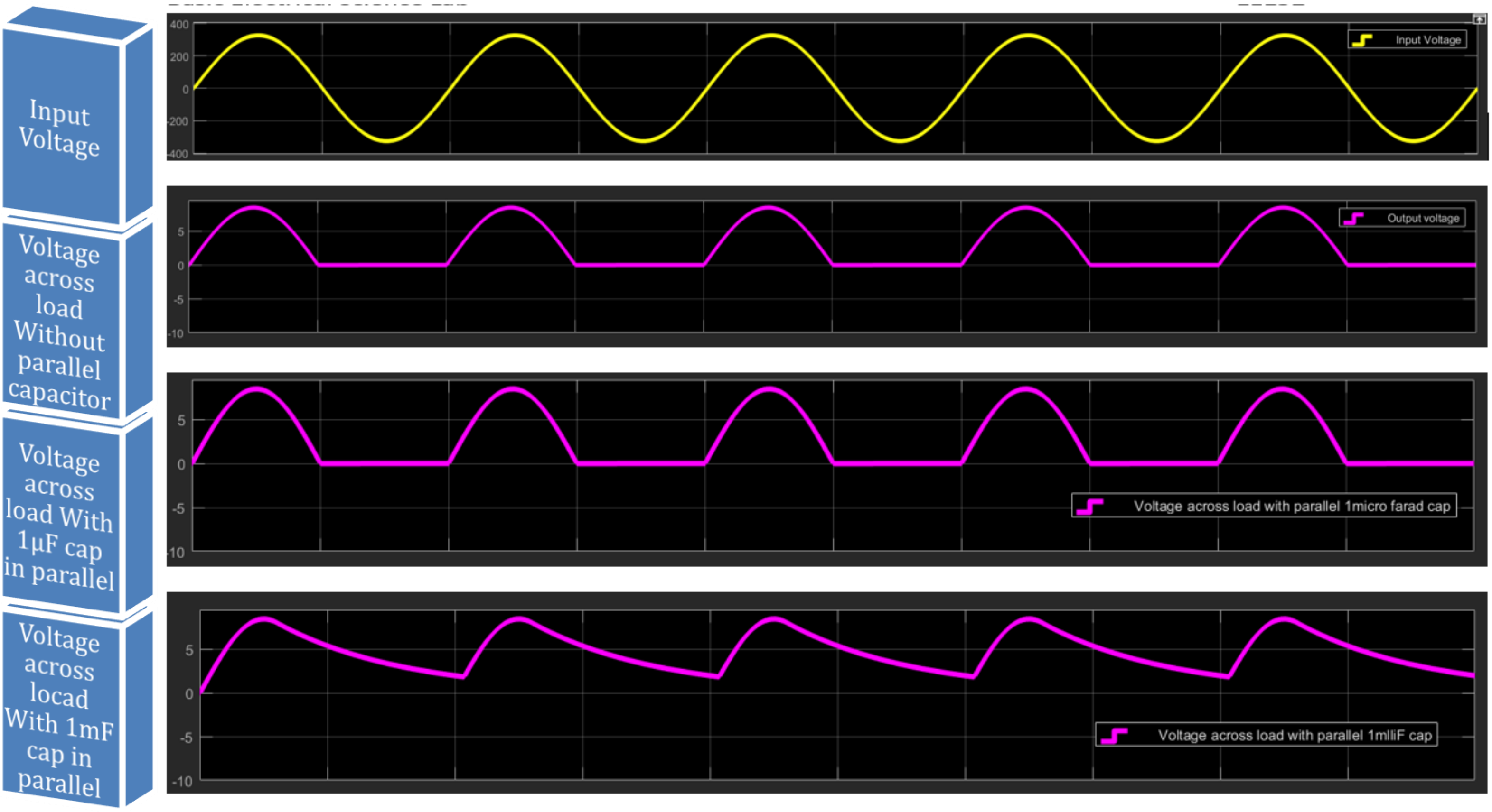
6. Observations:

Sl. No	Average DC Voltage (volt)		Average DC Current (Amp)		PIV of Diode (volt)		Output RMS Voltage (volt)		Output RMS Current (Amp)		Rectification efficiency (%)	
	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation
1	2.7	2.7	0.27	0.27	8.485	8.485	4.242	4.242	0.4242	4.242	40.53	40.53

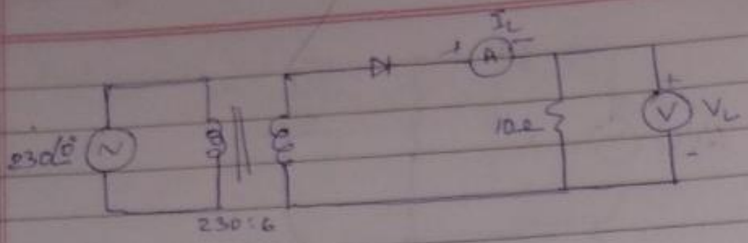
Table 6.1: Comparison between theoretical and simulation rectifier analysis

Graphical Results:





Theoretical Calculations:



Transformer turns ratio $\frac{n_1}{n_2} = \frac{230}{6}$

$$\frac{V_{in}}{V_{op}} = \frac{n_1}{n_2}$$

$$V_{op} = \frac{V_{in}\, n_2}{n_1}$$

$$= \frac{230\angle 0 \times 6}{230}$$

$$V_{op} = 6\angle 0^\circ$$

Considering diode is ideal, pd across diode is 0

In positive half cycle diode conducts hence

$$V_{op} = V_L$$

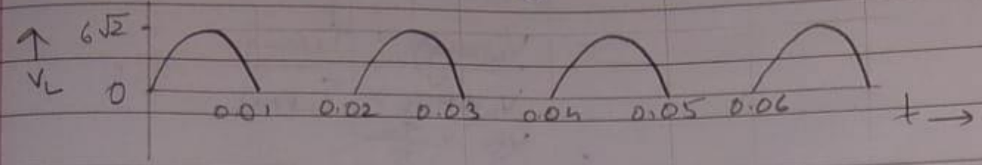
$\therefore$ Voltage across load $V_L = 6\angle 0$ $I_L = 0.6\angle 0^\circ$ in +ve half cycle.

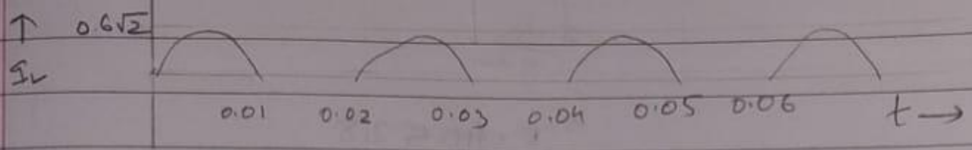
In negative half cycle diode do not conduct

$$V_L = 0$$

$$I_L = 0$$

V_L and I_L waveforms.





In negative half cycle the maximum potential apperaring across diode is V_m.

$$V_{piv} = V_m = 6\sqrt{2}$$

$$V_{piv} = 8.485 \text{ Volts}$$

PIV of diode is 8.485 Volts

RMS value of voltage across load $= \frac{V_{Lm}}{2} = \frac{6\sqrt{2}}{2}$

$$V_{L(RMS)} = 4.242 \text{ Volts}$$

RMS value of current through load $= \frac{I_{Lm}}{2} = \frac{0.6\sqrt{2}}{2}$

$$I_{L(RMS)} = 0.4242 \text{ A}$$

$$V_{L(avg)} = \frac{V_m}{\pi} = \frac{6\sqrt{2}}{\pi} = 2.7 \text{ V}$$

$$I_{L(avg)} = \frac{I_m}{\pi} = \frac{0.6\sqrt{2}}{\pi} = 0.27 \text{ V}$$

$$\text{Rectifier efficiency} = \frac{\text{DC output power}}{\text{AC output power}}$$

$$= \frac{V_{L(avg)} \times I_{L(avg)}}{V_{L(RMS)} \times I_{L(RMS)}}$$

$$= \frac{\frac{V_m}{\pi} \times \frac{I_m}{\pi}}{\frac{V_m}{2} \times \frac{I_m}{2}}$$

$$= \frac{4}{\pi^2}$$

$$= 0.40528$$

$$= 40.528$$

Rectifier efficiency = 40.53%

7. **Precautions:**

a) Ensure that 'powergui' block set is included in the Simulink file
b) Ensure that connections are properly made
c) Ensure that the scale of the graphs should be adjusted to the range in which the readings vary.
d) Ensure that the correct RMS and MEAN block is used.
e) Ensure that all the parameters in the linear transformer and diode block are correct.

8. **Inferences**:

- From the output, it can be inferred that in half wave rectifier, negative cycles of input are blocked and the load experiences only the positive regulated cycles. Thus, the AC signal is converted into DC signal.
- Attaching a capacitor in parallel to the load, lowers the ripple factor of the output signal.

9. **Conclusion:**

- The PIV of diode in half wave rectifier is 8.485V.
- Half wave rectifier efficiency is 40.53%.
- Theoretical analysis of half wave rectifier circuits is verified through simulation platform.

Assignment:

Consider Fig. 6.2 with $v(t) = 230\sqrt{2}\sin(100\pi t)$, $R = 10\ \Omega$ and do the same as mentioned in Section - 1.D. Prepare an appropriate table and fill up it.

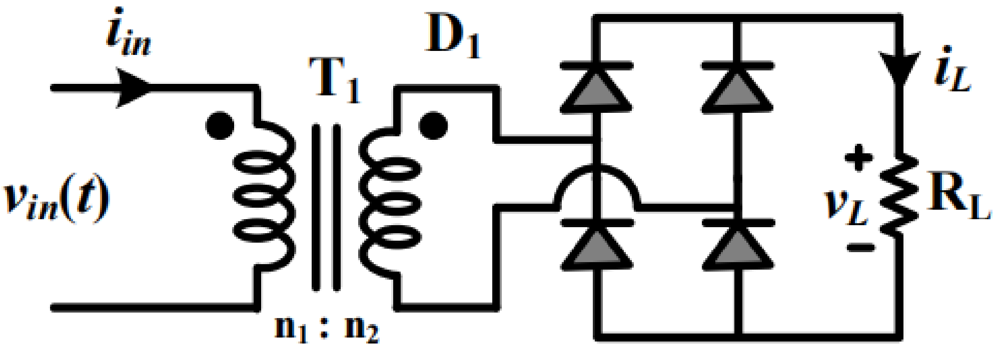


Fig. 6.2

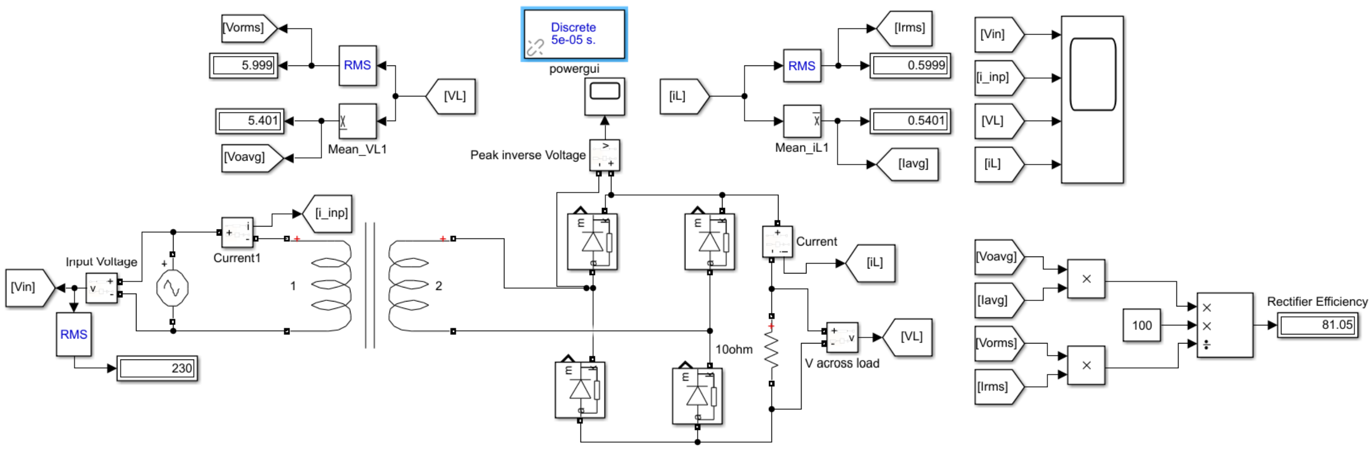
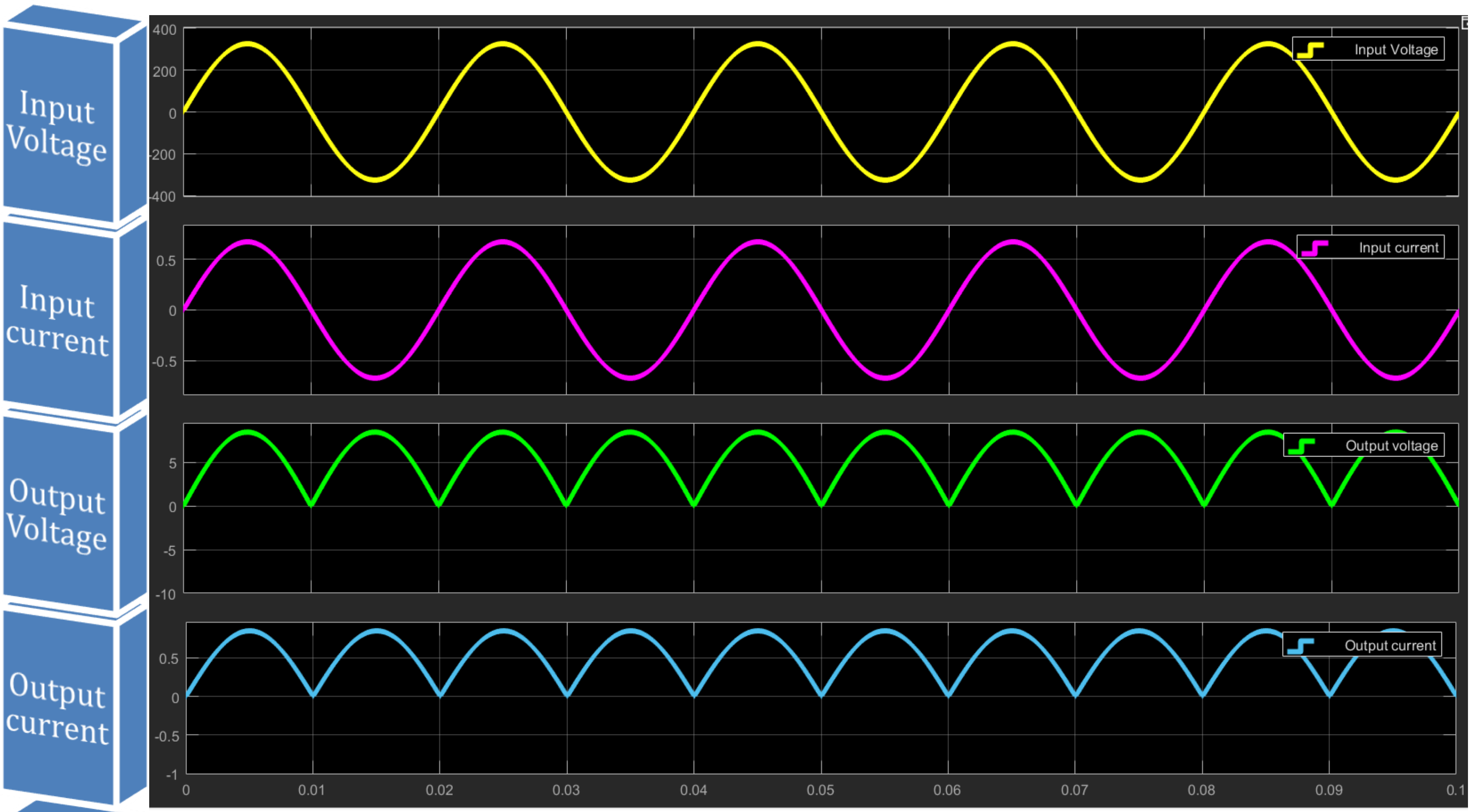


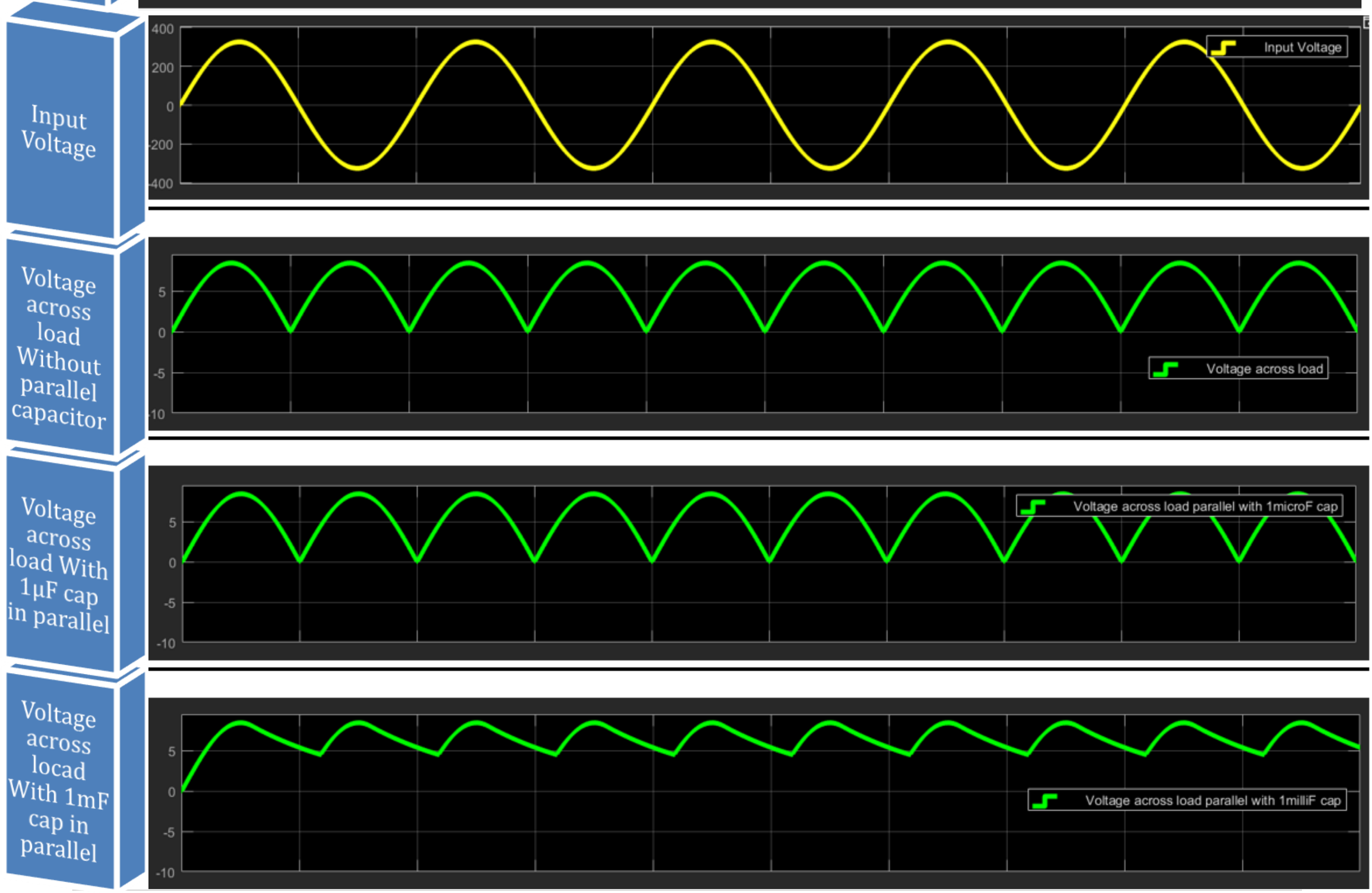
Fig1b: Circuit connections in Simulink for the given circuit in fig6.2

Sl. No	Average DC Voltage (volt)		Average DC Current (Amp)		PIV of Diode (volt)		Output RMS Voltage (volt)		Output RMS Current (Amp)		Rectification efficiency (%)	
	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation
1	5.4	5.4	0.54	0.54	8.485	8.485	6	6	0.6	0.6	81.05	81.05

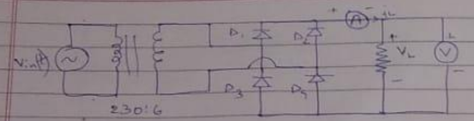
Table 6.2: Comparison between theoretical and simulation rectifier analysis

Graphical Results:





Theoretical Calculations:



Voltage output across transformer $= \frac{6}{230} \times V_{in}$

$= \frac{6}{230} \times 230\angle 0$

$V_{o/p} = 6\angle 0$

Considering diodes are ideal pd across diode is 0.

In +ve half cycle D_1 D_4 conduct D_3 D_2 do not hence Voltage across load $V_L = 6\angle 0°$

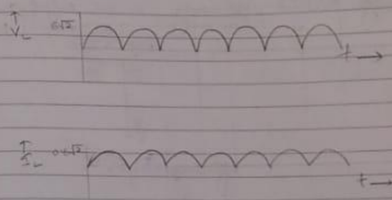
In -ve half cycle D_2 D_3 conduct $D_1 D_4$ do not hence voltage across load $V_L = 6\angle 0°$

$\therefore$ Voltage across load $V_L = 6\sqrt{2}|\sin(100\pi t)|$

Similarly current across load $i_L = \frac{V_L}{R}$

$= \frac{6\sqrt{2}|\sin 100\pi t|}{10}$

$= 0.6\sqrt{2}\,|\sin 100\pi t|$



In negative half cycle maximum potential across any diode is $V_{piv} = V_m$

$= 6\sqrt{2}$

$V_{piv} = 8.485$ Volts

RMS Voltage across load $= \frac{V_m}{\sqrt{2}}$

$= \frac{6\sqrt{2}}{\sqrt{2}}$

$V_{L\,RMS} = 6$ volt

RMS current through load $= \frac{I_m}{\sqrt{2}}$

$= \frac{0.6\sqrt{2}}{\sqrt{2}}$

$i_{L\,RMS} = 0.6A$

DC voltage across load $V_{L\,avg} = \frac{2V_m}{\pi} = \frac{2 \times 6\sqrt{2}}{\pi}$

$V_{L\,avg} = 5.4V$

DC average current through load $i_{L\,avg} = \frac{2I_m}{\pi} = \frac{2 \times 0.6\sqrt{2}}{\pi} = 0.54A$

Bridge Rectifier efficiency $= \frac{\text{DC output power}}{\text{AC output power}}$

$$= \frac{\frac{2V_m}{\pi} \times \frac{2I_m}{\pi}}{\frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}}}$$

$$= \frac{8}{\pi^2}$$

efficiency $= 81.05\%$

Inferences:

- From the output, it can be inferred that in full wave bridge rectifier, in both positive and negative cycles of input, the load experiences positive cycles. Thus, the AC signal is converted into DC signal throughout the waveform.
- Attaching a capacitor in parallel with the load, lowers the ripple factor of the output signal.

Conclusion:

- The PIV of diode in full wave bridge rectifier is 8.485V.
- Full wave bridge rectifier efficiency is 81.05%.
- Theoretical analysis of full wave bridge rectifier circuits is verified through simulation platform.