Electronic Devices and Circuits Lab (EE2301)
Experiment 4 : Rectifiers

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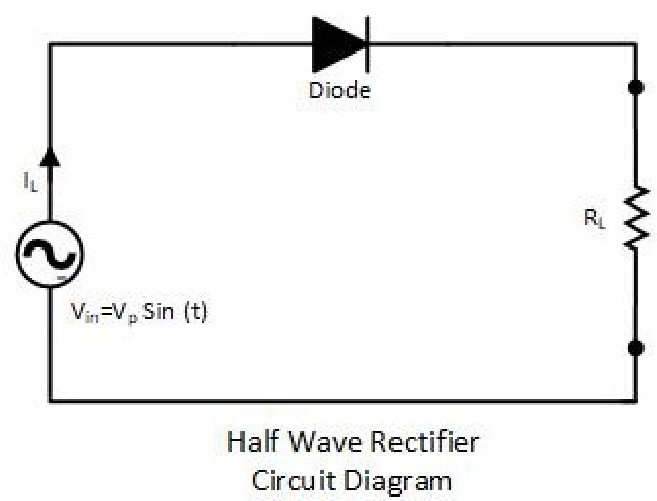
1 Aim

Our aim is to Understand rectifiers using ngspice simulation and plotting output with cut-in voltage and ideal diode and some parameters.

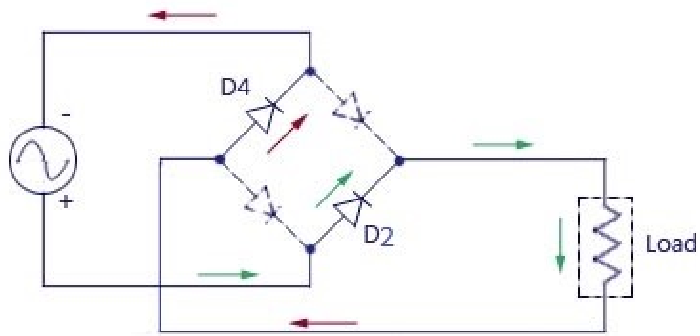
Rectifier
A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction.

Half wave rectifier



Half wave rectifier circuit diagram

Full wave rectifier



Full wave rectifier circuit diagram

Problem statement

1. Write SPICE scripts to simulate half and full wave rectifiers.

2. Use the rectifier scripts to perform the half-wave and full-wave rectification simulations with peak supply voltage of 1 V and 5 V. Comment on the results obtained.

3. From your simulations perform the calculate the following quantities for input signal, output of the half wave and output of the full wave rectifier. Assume the cut in voltage of 0.65V.

- Ripple frequency .

- Peak voltage ideal as well as accounting cut-in voltage.

- Average voltage .

2 Procedure

Steps

• First we need to write spice scripts for the above circuits of half wave and full wave rectifiers.

• Now we need to simulate the circuits for peak supply voltages of 1v and 5v and plot the output across the load resistance.

• We need to assign some input frequency for the sinusoidal voltage and use appropriate load resistance .

• Now we need to analyse the results obtained.

• Next from the simulations we need to find load output for both ideal and cut-in voltage diode.

• Given that we need to assume cut-in voltage to be 0.65V.

• Now we need to find the fundamental time period of the output plot and since frequency is inverse of time period we need to find that too which is ultimately the ripple frequency.

$$f = \frac{1}{T} \tag{1}$$

• Now we need to fine peak voltage of input and output for both ideal as well as accounting cutin voltage.

$$V_p = Max(V_{out}) \tag{2}$$

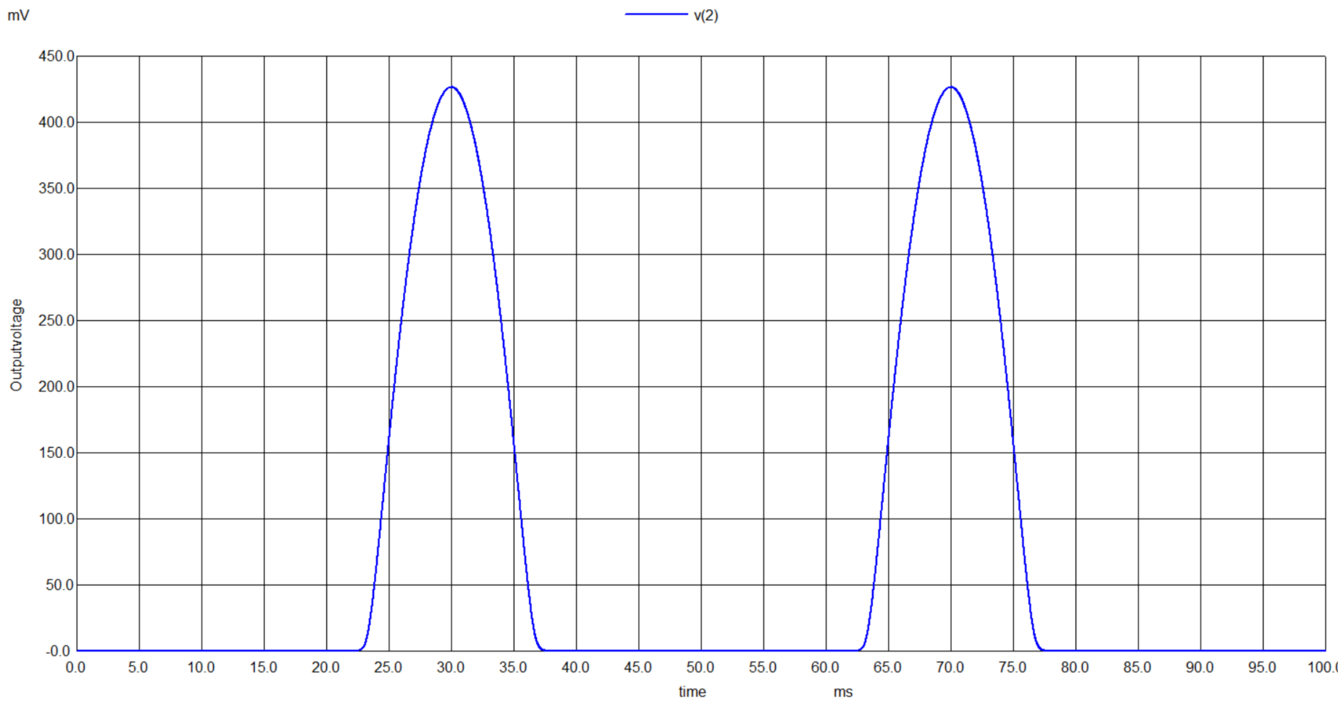
• Now we need to find average voltage which is given by below equation.

$$V_{avg} = \frac{\int_0^T V_{out}\, dt}{T} \tag{3}$$

3 Results and observations

Half wave rectifier plot

V=**1V** ($\mathbf{R}_L = 1k\Omega$)



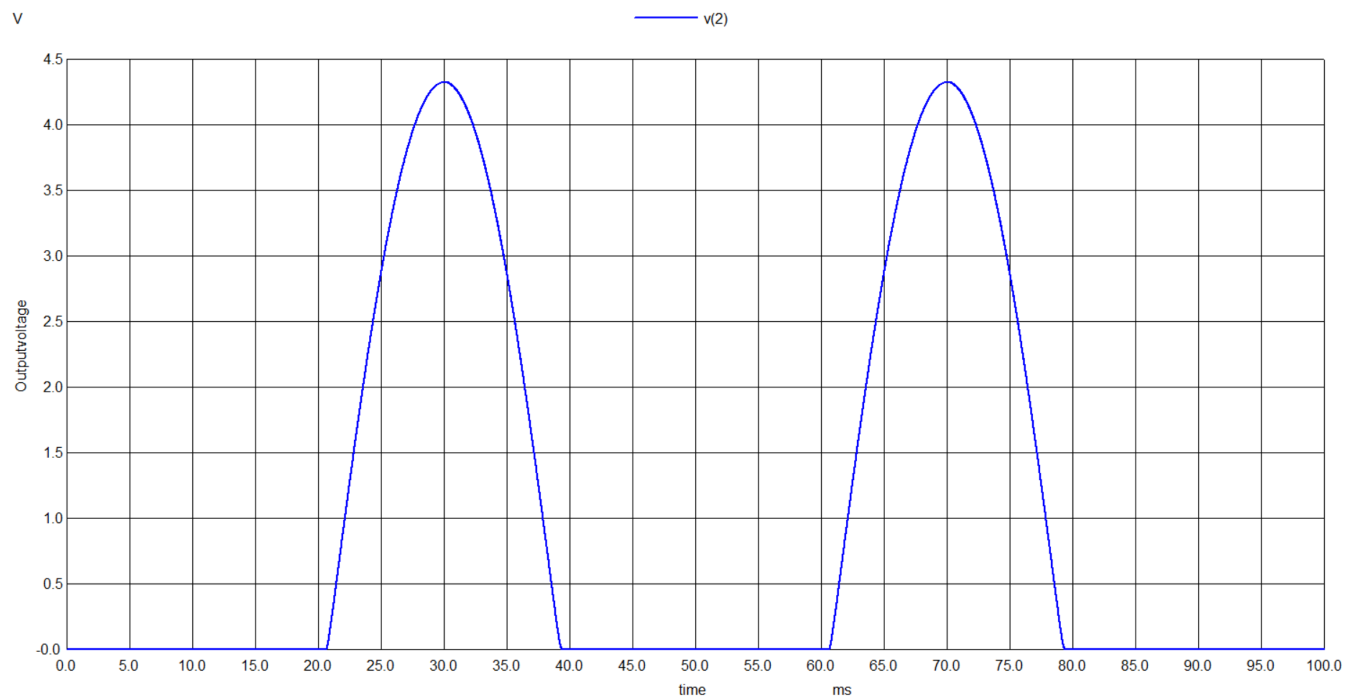
Plot: Output at 1V Vs Time(ms)

- In the above plot we can see that the ouput is same as input when input is positive and zero when input is negative assuming ideal diode

- But if we consider cut-in voltage its like subtracting cut-in voltage from input and sending it through ideal diode and finding output voltage.

- Time is in milliseconds with Time period 40ms.

V=**5V** ($\mathbf{R}_L = 2k\Omega$)



Plot: Output at 5V Vs Time(ms)

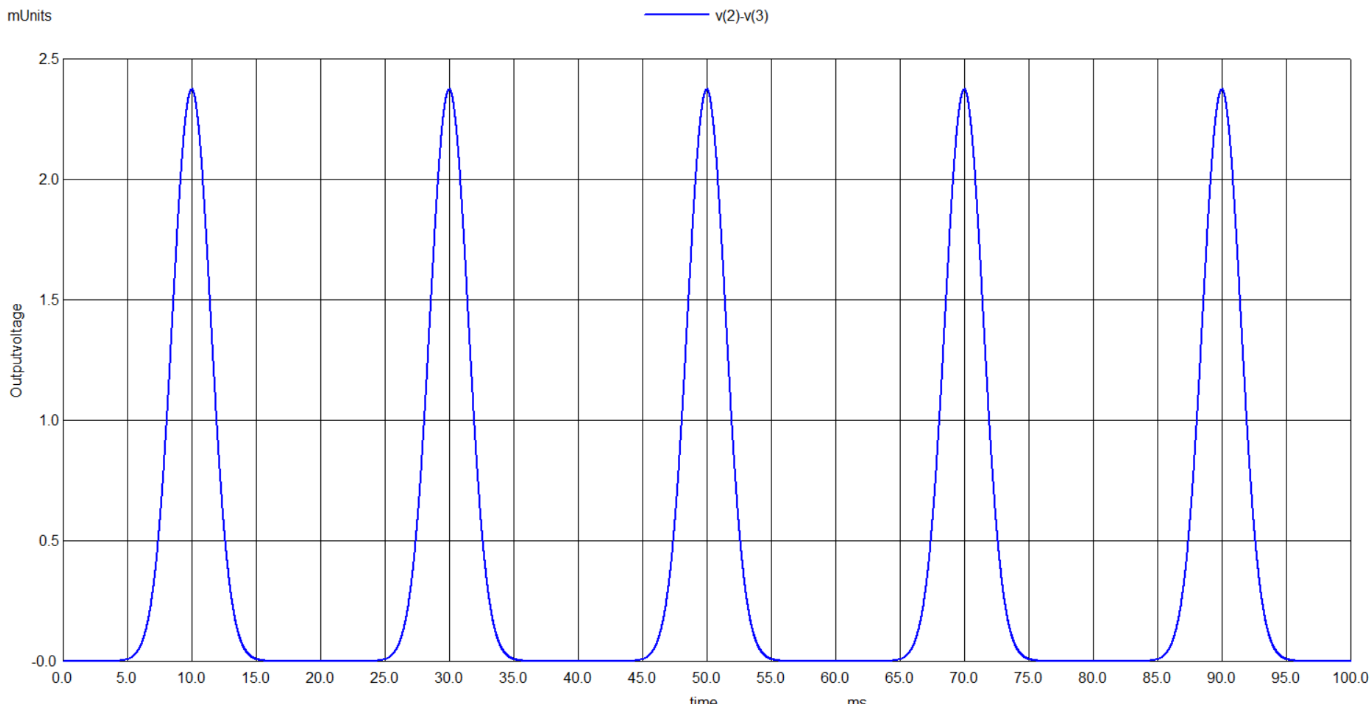
- In the above plot we can see that the ouput is same as input when input is positive and zero when input is negative assuming ideal diode

- But if we consider cut-in voltage its like subtracting cut-in voltage from input and sending it through ideal diode and finding output voltage.

- Time is in milliseconds with Time period 40ms.

Full wave rectifier plot

V=**1V** ($\mathbf{R}_L = 1k\Omega$)



Plot: Output at 1V Vs Time(ms)

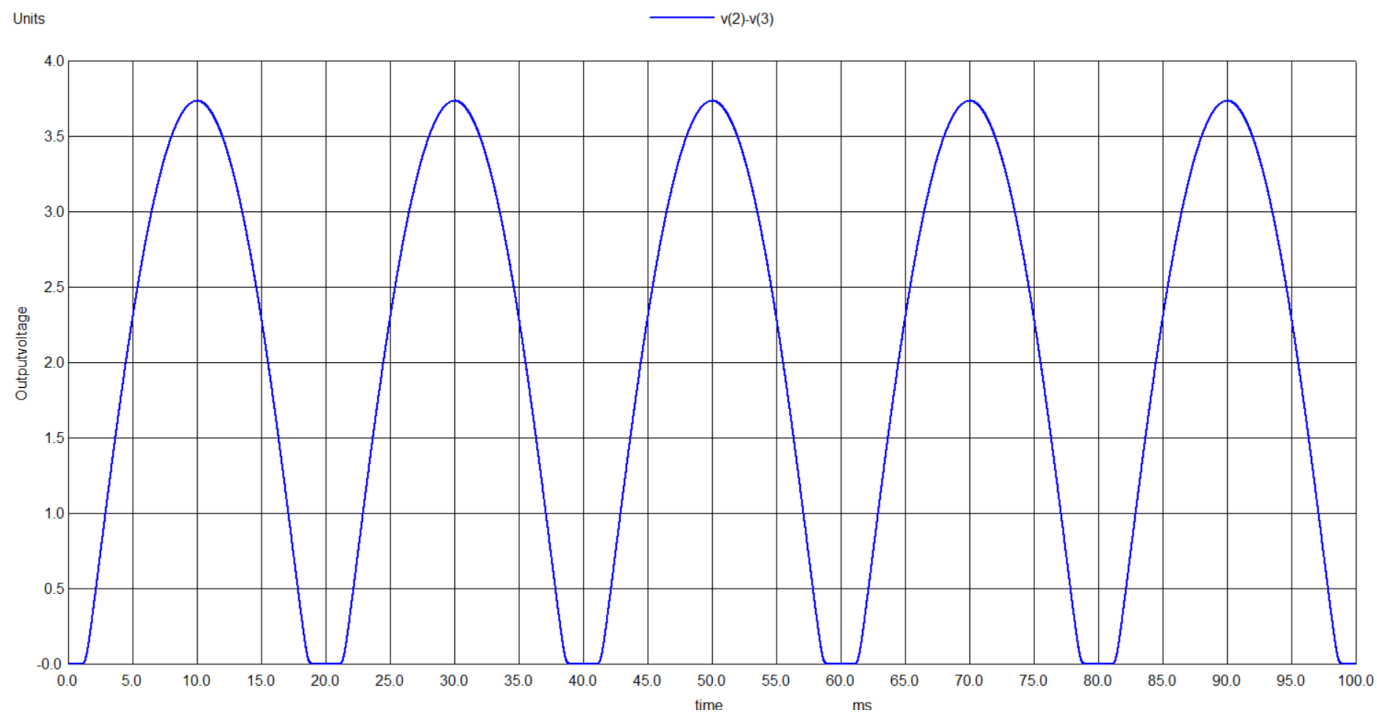
- In the above plot we can see that the output is same as input when input is positive and negative of input when input is negative assuming ideal diode

- But if we consider cut-in voltage its like subtracting twice of cut-in voltage from input(since two diodes are involved) and sending it through two ideal diode and finding output voltage only if Peak input is greater than twice of cut-in voltage.

- Time is in milliseconds with Time period 20ms.

- Here the output is practically zero.

V=**5V** ($\mathbf{R}_L = 3k\Omega$)



Plot: Output at 5V Vs Time(ms)

- In the above plot we can see that the output is same as input when input is positive and zero when input is negative assuming ideal diode

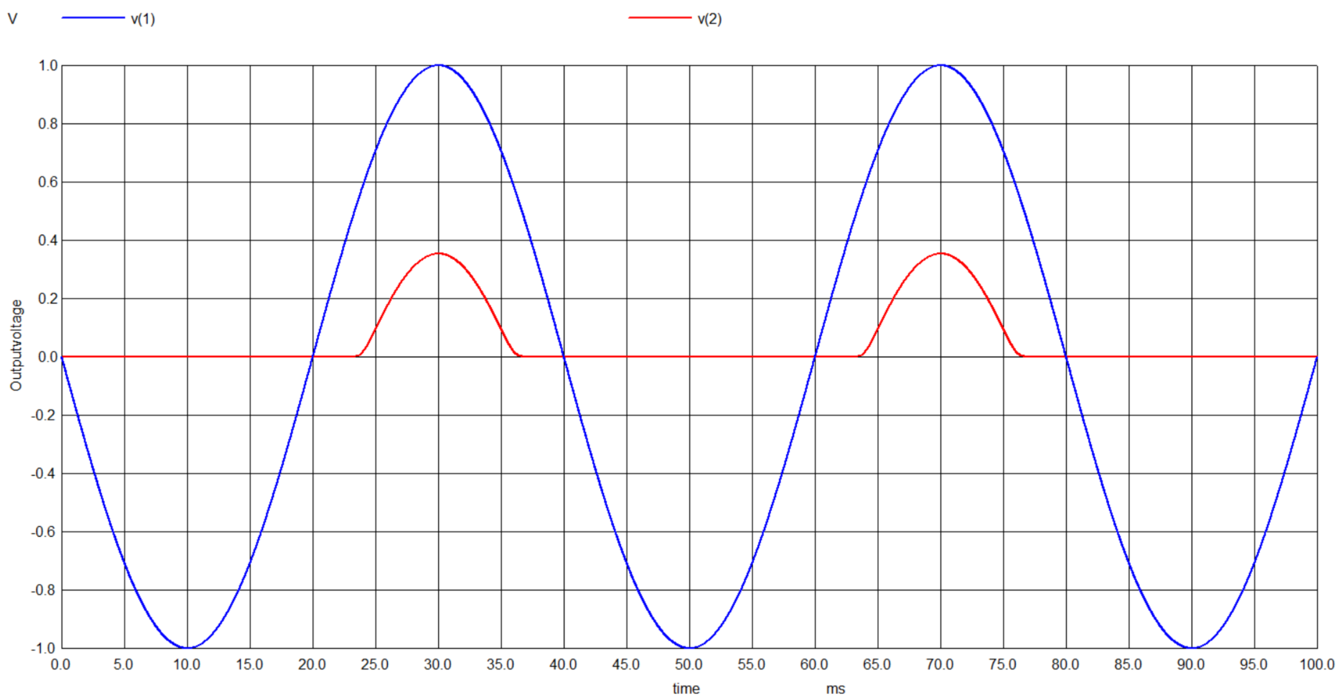
- But if we consider cut-in voltage its like subtracting twice of cut-in voltage from input and sending it through 2 ideal diodes and finding output voltage.

- Time is in milliseconds with Time period 20ms.

Calculation from simulations

Half wave rectifier at 1V

V=**1V**



Plot:Input and Output Vs time

Input Signal

Ripple frequency:

$$f_{ripple} = \frac{1}{T} = \frac{1}{40ms} = 25Hz. \tag{4}$$

Peak voltage:

$$V_p = 1V. \tag{5}$$

Average voltage:

$$V_{avg} = \frac{\int_0^T V_{in}\, dt}{T} = \frac{\int_0^T V_p sin(2\pi ft)\, dt}{T} = 0. \tag{6}$$

Output Signal

Ripple frequency:

$$f_{ripple} = \frac{1}{T} = \frac{1}{40ms} = 25Hz. \tag{7}$$

Peak voltage ideal:

$$V_p = 1V. \tag{8}$$

Peak voltage with cut-in:

$$V_p = 0.37V \ at \ R_L = 1k\Omega \tag{9}$$

- Note that the peak voltage changes with load resistance.

Average voltage ideal:

$$V_{avg} = \frac{\int_0^T V_{Out}\, dt}{T} = \frac{\int_0^{T/2} V_p sin(2\pi ft)\, dt}{T} = \frac{V_p}{\pi} = 0.318V. \tag{10}$$

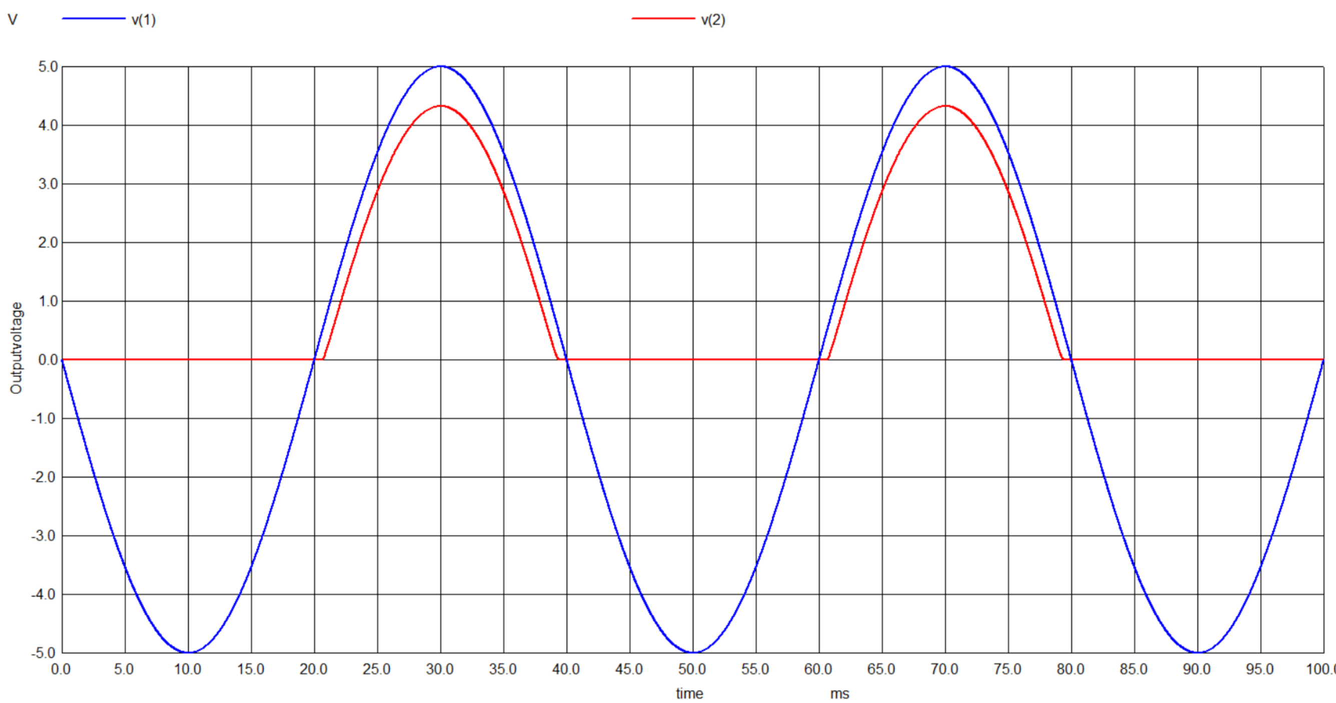
Average voltage with cut-in:

$$V_{avg} = 0.0735V. \tag{11}$$

- Note that the average voltage including cut-in is less than ideal case.

Half wave rectifier at 5V

V=**5V**



Plot:Input and Output Vs time

Input Signal

Ripple frequency:

$$f_{ripple} = \frac{1}{T} = \frac{1}{40ms} = 25Hz. \tag{12}$$

Peak voltage:

$$V_p = 5V. \tag{13}$$

Average voltage:

$$V_{avg} = \frac{\int_0^T V_{in}\, dt}{T} = \frac{\int_0^T V_p sin(2\pi ft)\, dt}{T} = 0. \tag{14}$$

Output Signal

Ripple frequency:

$$f_{ripple} = \frac{1}{T} = \frac{1}{40ms} = 25Hz. \tag{15}$$

Peak voltage ideal:

$$V_p = 5V. \tag{16}$$

Peak voltage with cut-in:

$$V_p = 4.34V \;\; at \;\; R_L = 2k\Omega \tag{17}$$

- Note that the peak voltage changes with load resistance.

Average voltage ideal:

$$V_{avg} = \frac{\int_0^T V_{Out}\, dt}{T} = \frac{\int_0^{T/2} V_p sin(2\pi ft)\, dt}{T} = \frac{V_p}{\pi} = 1.591V. \tag{18}$$

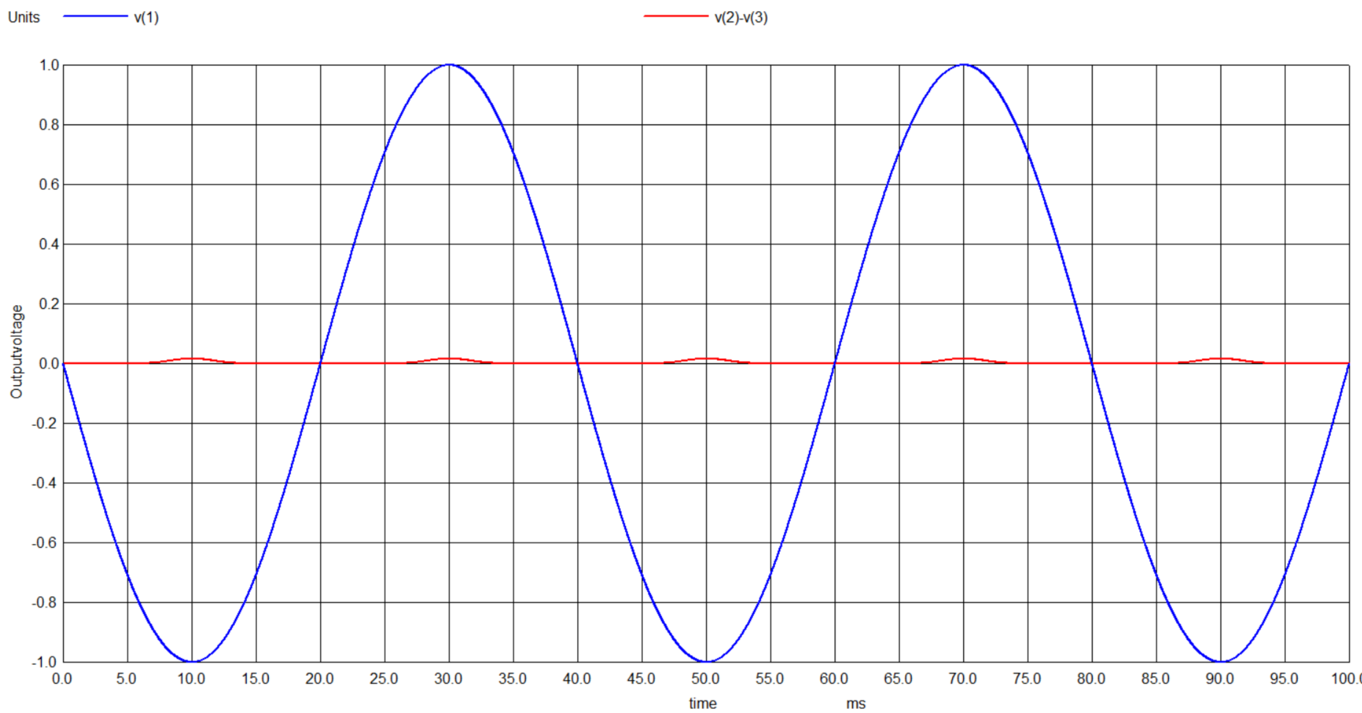
Average voltage with cut-in:

$$V_{avg} = 1.276V. \tag{19}$$

- Note that the average voltage including cut-in is less than ideal case.

Full wave rectifier at 1V

V=**1V**



Plot:Input and Output Vs time

Input Signal

Ripple frequency:

$$f_{ripple} = \frac{1}{T} = \frac{1}{40ms} = 25Hz. \tag{20}$$

Peak voltage:

$$V_p = 1V. \tag{21}$$

Average voltage:

$$V_{avg} = \frac{\int_0^T V_{in}\,dt}{T} = \frac{\int_0^T V_p sin(2\pi ft)\,dt}{T} = 0. \tag{22}$$

Output Signal

Ripple frequency:

$$f_{ripple} = \frac{1}{T} = \frac{1}{20ms} = 50Hz. \tag{23}$$

Peak voltage ideal:

$$V_p = 1V. \tag{24}$$

Peak voltage with cut-in:

$$V_p = 2.6mV \approx 0V \ at \ R_L = 1k\Omega \tag{25}$$

- Note that the peak voltage changes with load resistance.

Average voltage ideal:

$$V_{avg} = \frac{\int_0^T V_{Out}\,dt}{T} = \frac{\int_0^{T/2} V_p sin(2\pi ft)\,dt}{T/2} = \frac{2V_p}{\pi} = 0.636V. \tag{26}$$

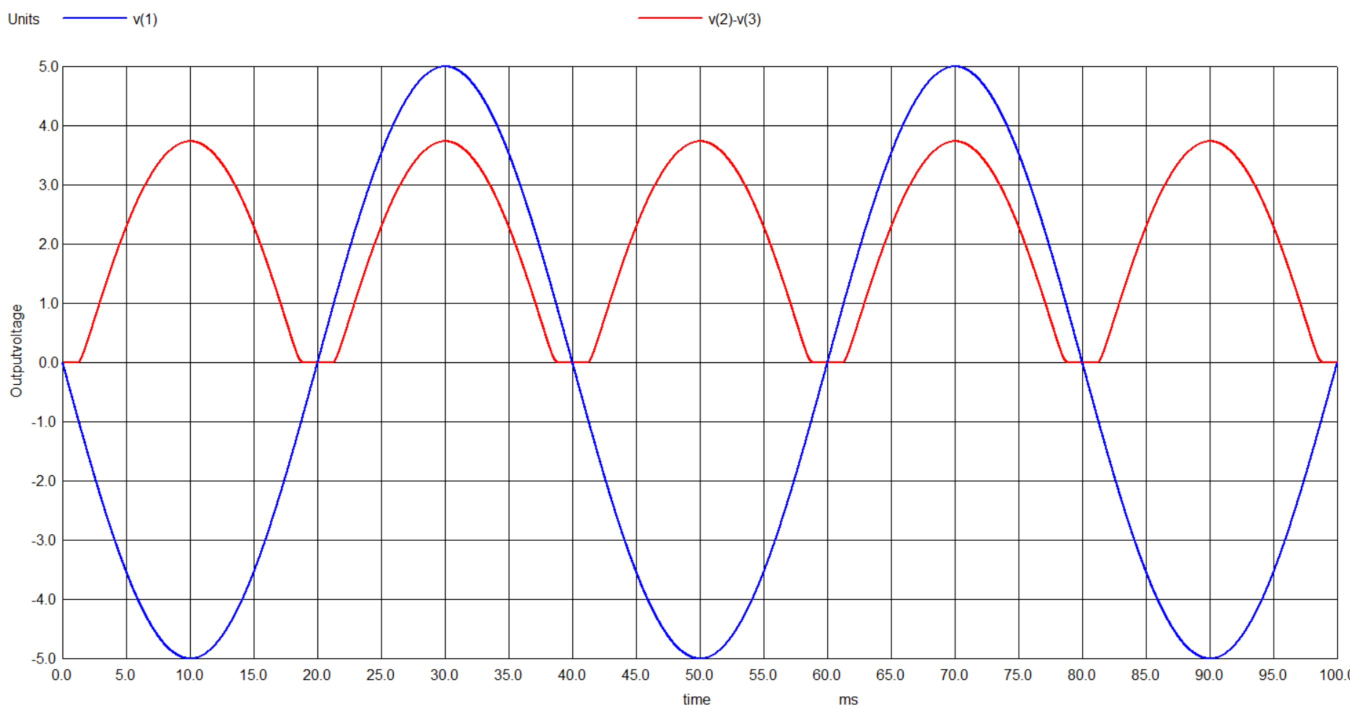
Average voltage with cut-in:

$$V_{avg} = 0.0V. \tag{27}$$

- Note that the average voltage including cut-in is less than ideal case.

Full wave rectifier at 5V

V**=5V**



Plot:Input and Output Vs time

Input Signal

Ripple frequency:

$$f_{ripple} = \frac{1}{T} = \frac{1}{40ms} = 25Hz. \tag{28}$$

Peak voltage:

$$V_p = 5V. \tag{29}$$

Average voltage:

$$V_{avg} = \frac{\int_0^T V_{in}\,dt}{T} = \frac{\int_0^T V_p sin(2\pi ft)\,dt}{T} = 0. \tag{30}$$

Output Signal

Ripple frequency:

$$f_{ripple} = \frac{1}{T} = \frac{1}{20ms} = 50Hz. \tag{31}$$

Peak voltage ideal:

$$V_p = 5V. \tag{32}$$

Peak voltage with cut-in:

$$V_p = 3.707V \ at \ R_L = 3k\Omega \tag{33}$$

- Note that the peak voltage changes with load resistance.

Average voltage ideal:

$$V_{avg} = \frac{\int_0^T V_{Out}\,dt}{T} = \frac{\int_0^{T/2} V_p sin(2\pi ft)\,dt}{T/2} = \frac{2V_p}{\pi} = 3.183V. \tag{34}$$

Average voltage with cut-in:

$$V_{avg} = 2.002V. \tag{35}$$

- Note that the average voltage including cut-in is less than ideal case.

4 Conclusions

Half wave rectifier

• we can conclude that the output of half wave rectifier depends on both cut-in voltage and load resistance .

• We need to ensure that peak voltage is much greater than cut-in voltage to get expected results.

• when input peak voltage is less than or close to cut-in voltage then there is no output voltage.

• The frequency of output is same as the frequency of input.

Full wave rectifier

• we can conclude that the output of full wave rectifier depends on both cut-in voltage and load resistance .

• We need to ensure that peak voltage is much greater than twice of the cut-in voltage to get expected results.

• when input peak voltage is less than or close to twice cut-in voltage then there is no output voltage.

• The frequency of output is same as the twice as the frequency of input.

Thank you