LAB Experiment 4
Rectifiers

S.V.Harshith EE19BTECH11018

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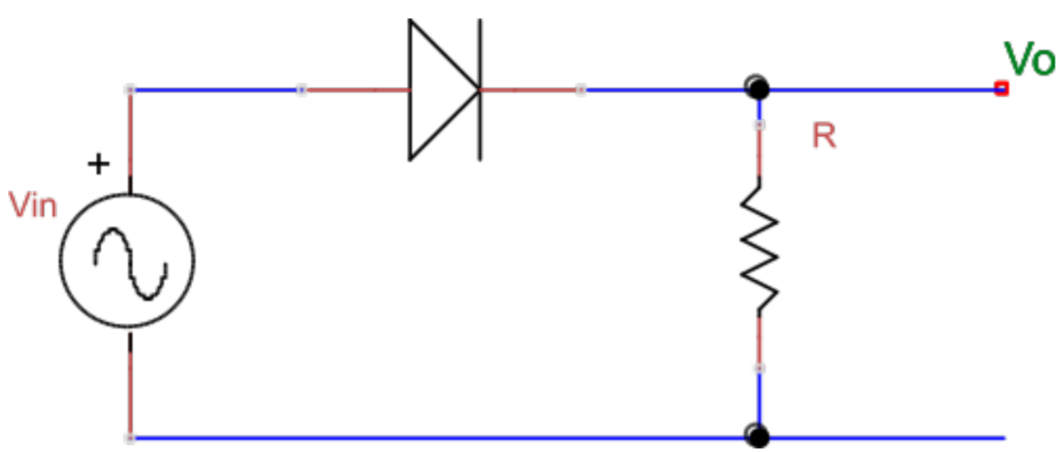
1 Aim

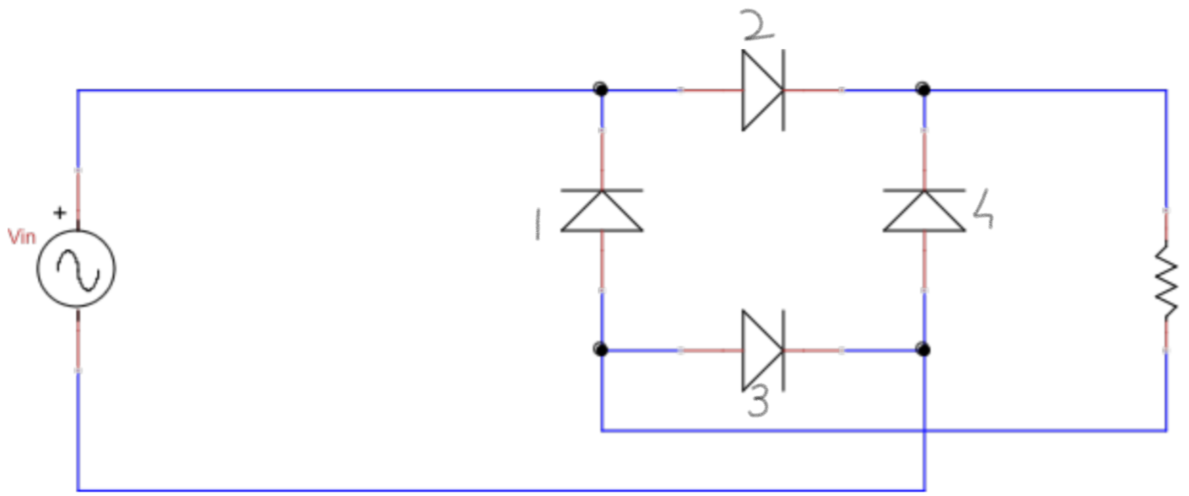
Write SPICE scripts to perform the half-wave and full-wave rectification simulations with peak supply voltage of 1 V and 5 V and comment on the results obtained.
From the simulations performed calculate the following quantities for input signal, output of the half wave and output of the full wave rectifier.(Assume the cut in voltage of 0.65 V)
• Ripple frequency
• Peak voltage ideal as well as accounting cut-in voltage.
• Average voltage

2 Procedure

2.1 Half wave rectifier



2.2 Full wave rectifier



Write the NGspice scripts for the above circuits and take the input voltage as a sin wave with peak voltage 1V,5V for each circuit respectively(4 cases) and let the frequency of the sin wave be 100Hz.Let resistance be $1k\Omega$

3 Results and observations

Important points-
We know that the peak voltage of input signal are 1V and 5V respectively and its average voltage is zero.
Ripple frequency is the output frequency , so for a half wave rectifier ripple frequency is same as the input signal frequency and for full wave rectifier it is twice the input signal frequency(Since the negative cycle of the input signal becomes positive and doubles the frequency).
Ideal peak voltage for each case will be equal to the peak voltage of the input signal.

The average voltage of the output signal of a halfwave rectifier is given by

$$V_{Av} = \frac{1}{T}\int_0^T V_{out}dt$$

But diode conducts after crossing junction potential(VJ = 0.65)

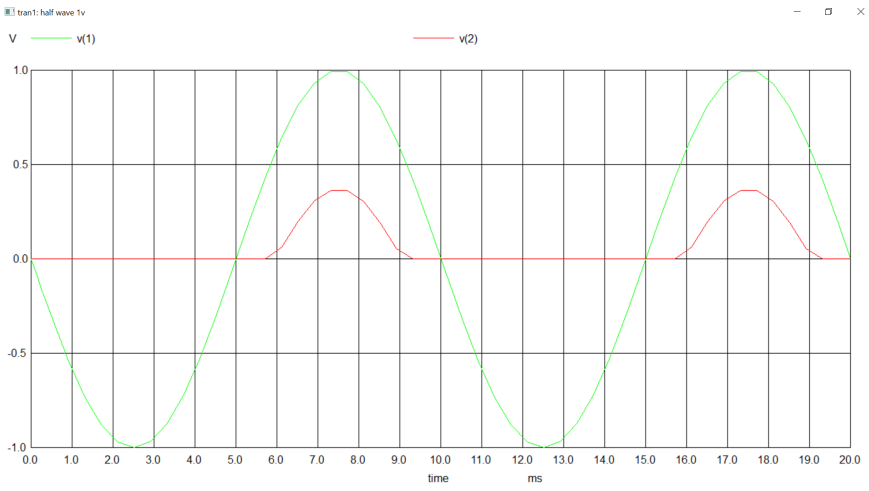
$$\implies V_{Av} = \frac{1}{T}\int_{\frac{\pi}{\omega}-\frac{1}{\omega}sin^{-1}\left(\frac{VJ}{VP_{in}}\right)}^{\frac{1}{\omega}sin^{-1}\left(\frac{VJ}{VP_{in}}\right)} (VP_{in}sin(\omega t) - VJ)dt$$

Where VP_{in} is the input signal peak voltage and ω is the input signal angular frequency. Similarly for a full wave rectifier it is

$$V_{Av} = \frac{2}{T}\int_{\frac{\pi}{\omega}-\frac{1}{\omega}sin^{-1}\left(\frac{2VJ}{VP_{in}}\right)}^{\frac{1}{\omega}sin^{-1}\left(\frac{2VJ}{VP_{in}}\right)} (VP_{in}sin(\omega t) - 2VJ)dt$$

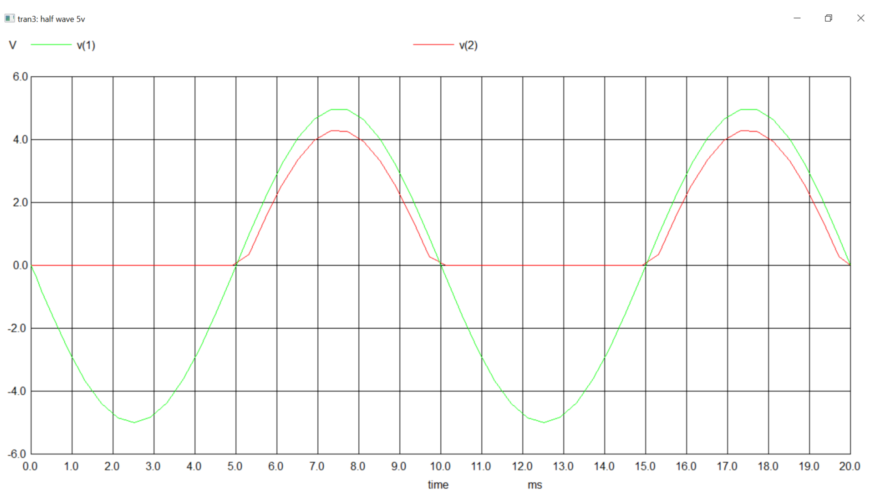
After using the above points and substituting the values in the above equations we get the following results -

3.1 Half wave rectifier(Peak supply voltage 1V)



Ripple frequency = 100Hz(same as input frequency)
Peak voltage-
For ideal case 1V and if we account cut-in voltage and the resistor it is close to 0.36V(From the plot above)
Average voltage ≈ 0.06V

3.2 Half wave rectifier(Peak supply voltage 5V)

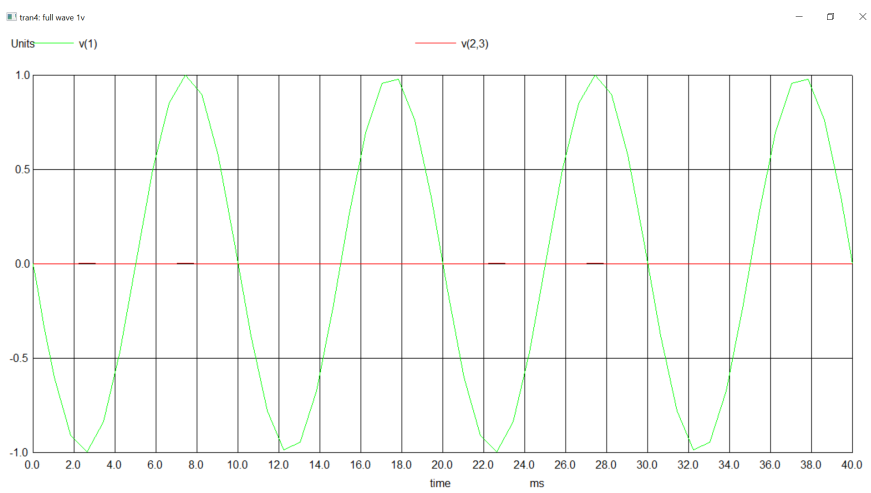


Ripple frequency = 100Hz(same as input frequency)
Peak voltage-
For ideal case 5V and if we account cut-in voltage and the resistor it is close to 4.23V(From the plot above)
Average voltage ≈ 1.28V

3.2.1 Understanding

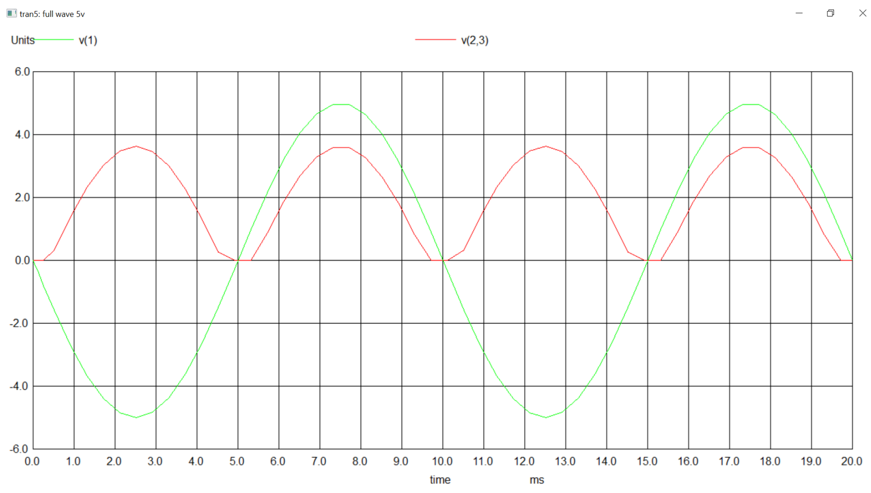
As the sin wave passes through the diode only the positive cycle is allowed since the negative negative cycle makes the diode reverse biased and the current flowing becomes negligible. From the I-V characteristics of a p-n junction diode in forward bias we see that the current varies linearly after voltage reaches a threshold value called as cut-in voltage and below that the current is almost zero.Thus in the output signal there is a slight delay along with the reduction of peak voltage i.e $V_{P_{out}} = V_{P_{in}} - 0.65$
But if we increase the resistance in NGspice script we see that the output peak voltage also increases.This is due to the fact that, as resistance increases the current in the loop also decreases and the peak output voltage also varies accordingly with the I-V characteristics of the diode.So $V_{P_{out}}$ is not exactly equal to $V_{P_{in}} - 0.65$

3.3 Full wave rectifier(Peak supply voltage 1V)



Ripple frequency = 0Hz
Peak voltage-
For ideal case 1V and if we account cut-in voltage and the resistor it is close to 0V(From the plot above)
Average voltage ≈ 0V

3.4 Full wave rectifier(Peak supply voltage 5V)



Ripple frequency = 200Hz (2 x input frequency)
Peak voltage-
For ideal case 5V and if we account cut-in voltage and the resistor it is close to 3.54V(From the plot above)
Average voltage ≈ 1.99V

3.4.1 Understanding

The four diodes labelled D1 to D4 are arranged in series pairs with only two diodes conducting current during each half cycle duration. During the positive half cycle , D2 and D3 diodes conduct in a series while diodes D1 and D4 are reverse biased and the current flows through the load. During the negative half cycle, D1 and D4 diodes conduct in a series and diodes D2 and D3 switch off as they are now reverse biased configuration.
Current flowing through the load is unidirectional so the voltage developed across the load is also unidirectional voltage and we get the above plots.
Same as the case in half wave rectifier the diodes have a cut-in voltage and here the signal flows through two diodes so the decrease in peak voltage is twice as the case in halfwave(2 x VJ = 1.3).In the case of input peak voltage 1V there is no output as we require a minimum of 1.3V for conduction
And due to the resistance we have a similar variance in peak voltage as explained before.

4 Conclusion

The half wave rectifier is not as efficient as a full wave rectifier which can be seen from the calculated average voltage.
These circuits after some slight modifications like adding a capacitor and a voltage regulator can be used to create an AC to DC converter.
The primary application of rectifiers is to derive DC power from an AC supply and they are used in almost all the electronic devices and transformers.