Electronic Devices and Circuits Lab : Report-4

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Contents

1 Aim :

The aim of the experiment was to understand the process of rectification using diode and study its behaviour for different inputs.

2 Procedure

As we know that the diode is unilateral device, it allows conduction of current only in one direction. Using this characteristic of diode, rectification of a-c signal. When a sinusoidal voltage is applied across the diode through a resistor, the current can flow only in forward bias, so only positive half cycles can be observed.

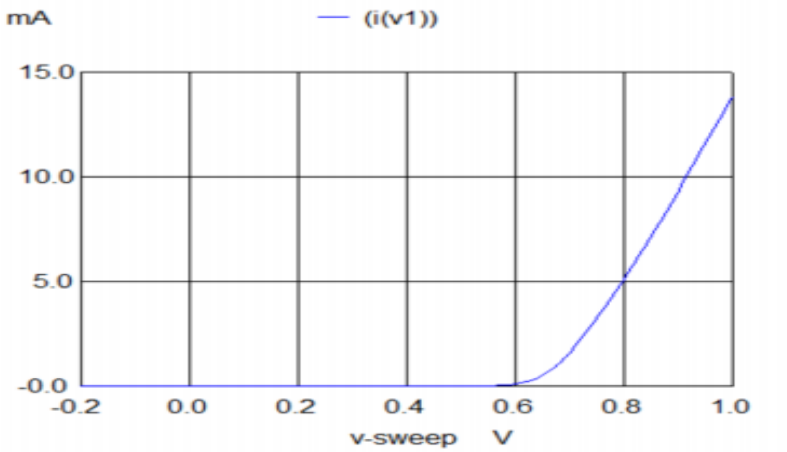


Figure 1: IV Characteristics

From the graph, it can be seen that the Current accordingly increases with increase in forward bias and almost negligible in the reverse bias. Even in the forward bias it can be seen that till 0.6 V the rise in current is meagre and increases rapidly there after. The voltage at this knee-like point, where after conduction begins to raise quickly is called cut-in voltage or knee-voltage. For Silicon, the cut-in voltage is around 0.7 V. Here, in the simulation we are assumed to take cut-in voltage as 0.65 V.

2.1 Half Wave Rectifier

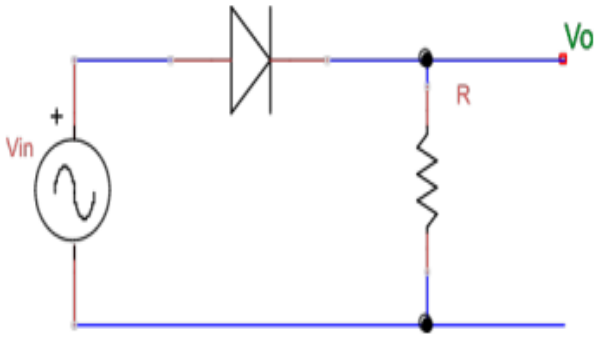


Figure 2: Half wave Rectifier

As said above, when the ac-signal is passed across the diode, the component which keeps the diode in forward bias passes the diode and hence we will be able to observe only the positive components of the signal across the load.

Here, when V_{in} is enough positive in forward across the diode, it appears across the load resistance as V_o and when the its negative, almost no voltage appears across the load. Hence, the signal is half-rectified . When the V_{in} is in forward bias, the current quantity is very less and hence the voltage across the load is also very less. So V_{in} should at least be greater than the cut-in voltage to seen across the load.

2.2 Full Wave Rectifier

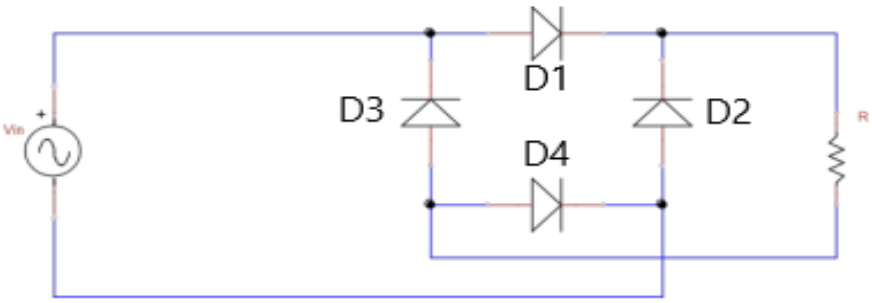
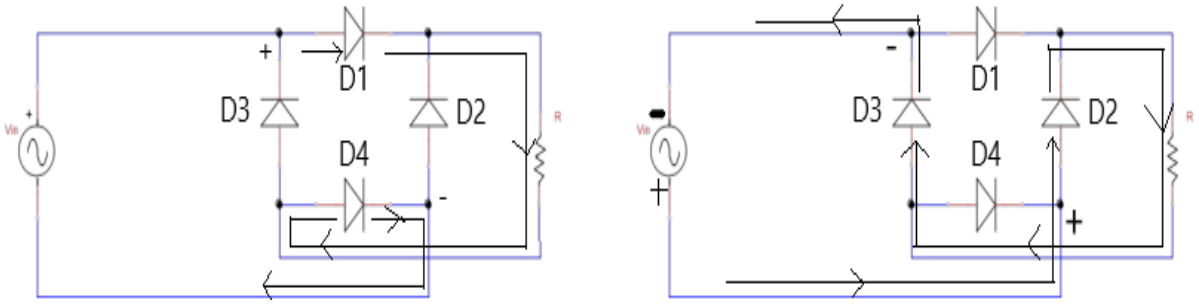


Figure 3: Full wave rectifier

The above circuit is known as the full wave rectifier. Here, it can be observed that the four diodes are connected in such a way that both the positive and the negative components of the input signal appears across the load as positive signal.

The below shown figures tell the behaviour of a full wave rectifier. When



(a) V_{in} is positive (b) V_{in} is negative

the V_{in} is positive, D1 diode is in forward bias, so current flows through it. In D2 diode, negative bias is at p-side, so almost no current flows through it, entire current flows through the load. After passing through load, D4 is in forward bias, and hence current leaves from it. Similar analysis happens when V_{in} is negative. D2 and D3 will be in forward bias and D1 and D4 while be in reverse bias. So current enters through D2 and leaves through D3.

Here, effectively the current direction does not change across the load, hence V_o is always positive. And also note that, here as in any case, the current passes any two diodes, so the bias across them should be applied such that it is greater than its cut-in voltage. Else, current would not pass through the load.

3 Results and Discussion

3.1 Half Wave Rectifier

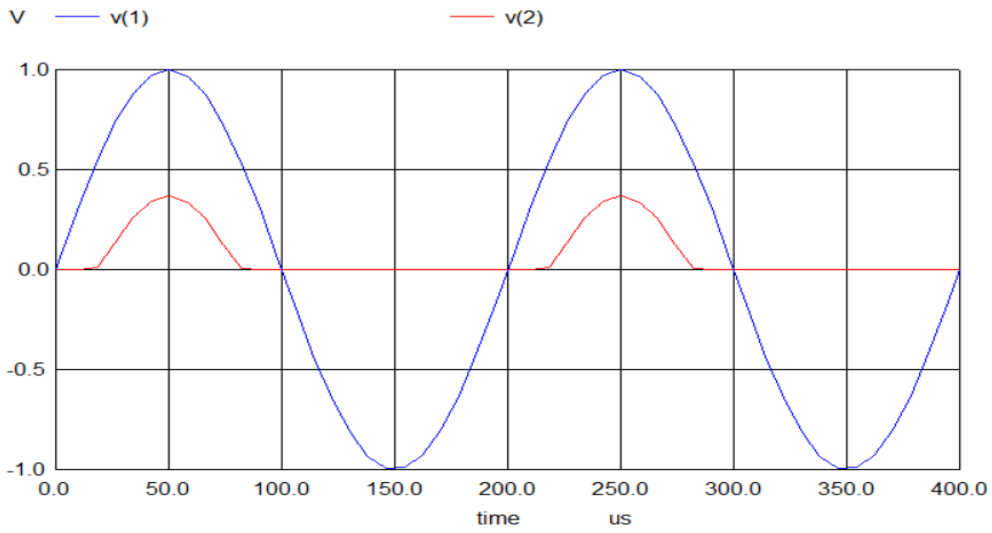


Figure 5: Output for 1V sinusoidal input (Input(blue),Output(red))

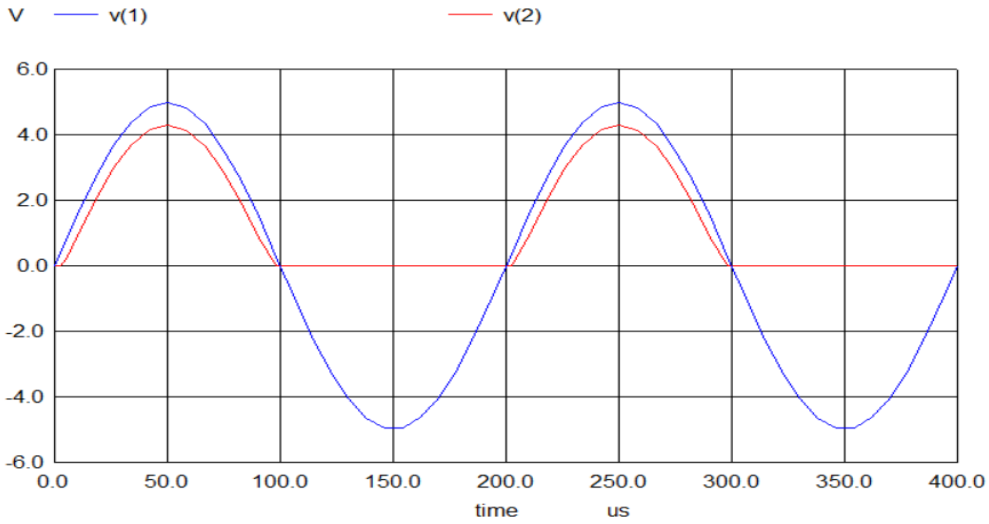


Figure 6: Output for 5V sinusoidal input (Input(blue),Output(red))

The observations that can be drawn from the above graphs are

- The voltage across the load has only the positive halves of the input.
- **Ripple Frequency** : The frequency of the rectified ac-input signal is called the ripple frequency. In the half wave rectifier's case, it can be observed that the frequency of the output is same as the input. The output wave, in the first half cycle, it mimics the input signal and in the second half cycle, it remains null. Hence the ripple frequency for both the above simulated outputs is same as input i.e, 5kHz.
- **Peak Voltage :** Actually in a half wave rectifier, the bias across the diode must be greater than the cut-in voltage for the current to pass through the diode. So the difference between V_{in} and V_o must at least be greater than the cut-in voltage. And also the, peak voltage varies with load resistance. It can be seen from the voltage of diode,

  $$V_d = V_{in} - V_o = V_{in} - IR_L \implies I = (\frac{-1}{R_L})V_d + \frac{V_{in}}{R_L}$$

  Comparing the intersection point with the IV characteristics of diode, we can see for higher load, the bias voltage required is less and hence, V_o will be higher.But this variation can be safely ignored in small variation of resistance.
- Note that if V_{in} is less than cut-in(0.65V), then amount of current passing would be negligible, and V_o remains almost zero as seen.
- V_p for 1V sinusoidal input ideally is 1V and for 5V sinusoidal input it should be 5V but actually is differing with around 0.7 V for 1kΩ load.The observed values of peak voltage are 0.37V for 1V input, 4.30V for 5V input.
- **Average Voltage :** In an ac sinusoidal signal the average voltage is zero. But after rectification, the negative half cycles disappear, leading to a dc component and hence the output has a non zero finite average voltage. Hence the average value of the output is 0.318*V_{in} ideally.
- So V_{avg} for 1V sinusoidal input ideally are 0.318V and for 5V sinusoidal input it should be 1.59V but actually is less than expected as observed values are 0.07V and 1.3V respectively.

3.2 Full Wave Rectifier

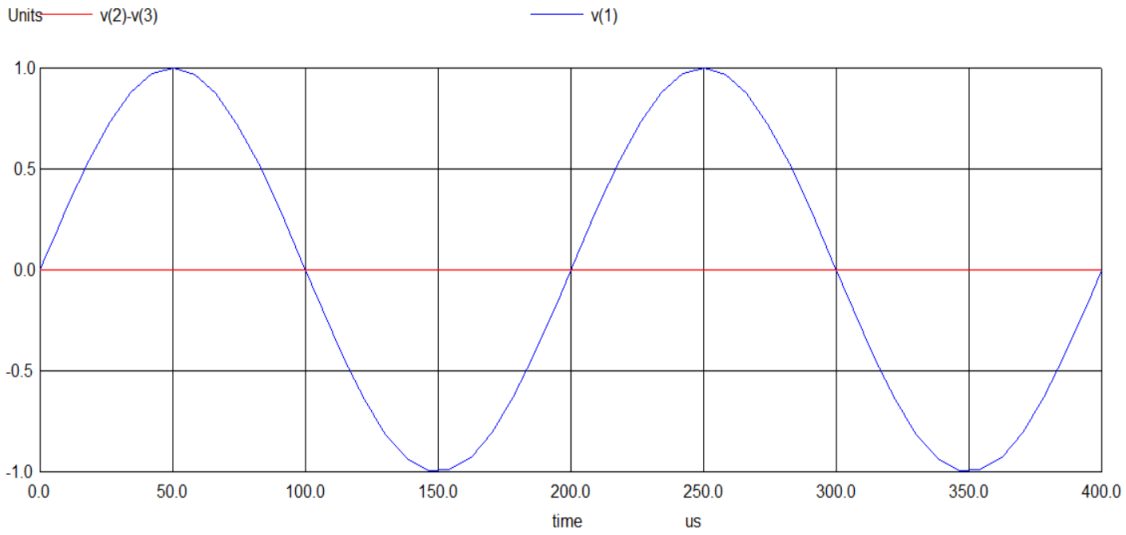


Figure 7: Output for 1V sinusoidal input (Input(blue),Output(red))

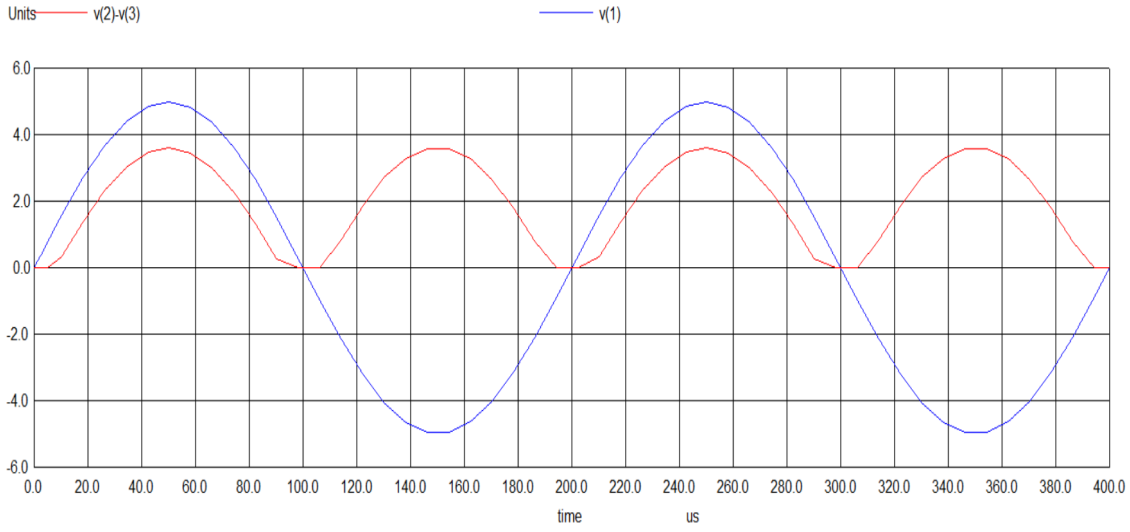


Figure 8: Output for 5V sinusoidal input (Input(blue),Output(red))

The observations that can be made from the graphs are

- The output voltage is always greater than or equal to 0, and its value depends on the just magnitude of of V_{in} and is independent of direction(sign).
- The output for the 1V sinusoidal input is zero throughout and for a 5V input sinusoidal, output is similar to modulus of the input sinusoidal

with smaller amplitude. Te reason being, the current flows through the load only when the two diodes(D1,D4 or D2,D3) are in forward bias and bias is enough to be more than the cut-in voltage. Taking V_{cut-in}=0.65V, we would at least require the input voltage to be greater than 2× V_{cut-in} i.e, 1.3V.Hence the 1V sinusoidal almost has zero output. Even in the 5V output, we can see the voltage across the load is zero,when the input voltage is not sufficient to create the bias.

- As said above, the variation in load resistance can affect the output voltage. For higher loads, the output curve's peak almost touches the input's curve peak.

- **Ripple Frequency :** The frequency of the output, for a high enough input, generally is twice the inputs frequency as the negative half cycle would be reflected in output and are effectively similar to positive half cycle. Hence, the frequency of output for 5V input sinusoidal is twice the frequency as the input, here 2*5=10kHz. Whereas, for 1V input sinusoidal, as we get zero all time, the frequency is 0Hz.

- **Peak Voltage :** Ideally, the peak of output voltage must be same as the peak of input voltage, but due to potential drop across diodes we get small difference between peaks of input and output.In this 1V peak sinusoidal case it is zero(observed 0.03V), and for 5V peak sinusoidal, output peak is lowered by 1.3V approximately for 1kΩ load as observed value is 3.7V .

- **Average Voltage :** In full wave rectifier, along with positive cycles, the negative cycles also get rectified and hence the DC component observed would be twice than that observed for half wave rectifier. Hence the average value of the output is 0.636*V_{in} ideally.

- Hence here we observe the average output voltage for 1V sinusoidal is zero(0.00046V) whereas the average output voltage ideally for 5V is 3.18V but practically is less than expected as observed value is 2.11V.

- Though it can be seen that the rectification process has improved, but it happens at cost of more expenditure in diodes and more complexity in working. Hence there is a trade off when we want to do rectification of a signal.

4 Conclusions

1. The IV characteristics of a diode are such that it allows conduction of current only in one direction and is negligible in other direction. Even in the forward direction, a the bias across diode should be greater than cut-in voltage for significant amount of current to pass.

2. The characteristics of diode can used to build a half wave rectifier which passes the positive half cycles of the ac signal and blocks the negative half cycles.

3. The output of the half wave rectifier has ripple frequency same as the input ac frequency,has average voltage or a dc component , has peak voltage almost but less than the input peak voltage.

4. The difference between the peaks of the voltage can be reduced by increasing the load resistance adequately . However the variation can be ignored for small range variation in load resistance.

5. The full wave rectifier is constructed with the help of 4 diodes in a manner such that the voltage across the load is always positive. Hence, it rectifies both positive and negative half cycles.

6. In either direction of current from source, it has to pass across two diodes and hence the input voltage should be greater twice the cut-in voltage for current to pass across the load.

7. The output of the full wave rectifier has ripple frequency twice the inputs frequency, has average voltage or dc component twice to that that observed in half wave rectifier, has peak voltage slightly smaller than the input peak voltage.

8. The implementation of half wave rectifier is simpler and cheap than full wave rectifier but the performance of rectification in full wave rectifier is quite better than the half wave rectifier.