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Date: 15/09/2021

Basic Electronics Laboratory

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EXPERIMENT-3
Title: Studies on Rectifier and Power Supply

Aim:

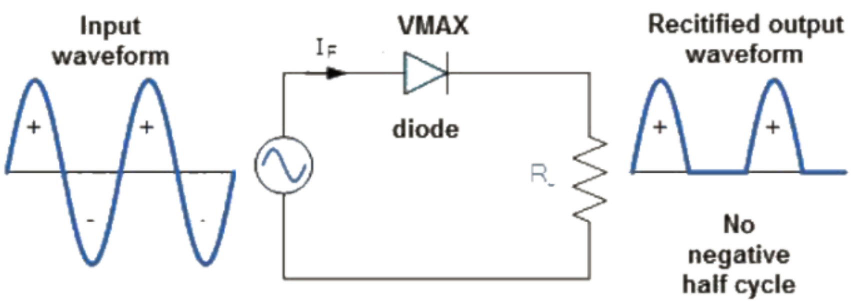
1. Explain half-wave rectification for positive and negative half-cycles
2. To explain the working of a centre-tapped full-wave rectification and to explain the working of a bridge full-wave rectification
3. To understand the concept of filtering of rectified signal and those of ripple voltage and ripple factor

Ⅰ. Explain half-wave rectification for positive and negative half-cycles

Tools Used: Lt Spice

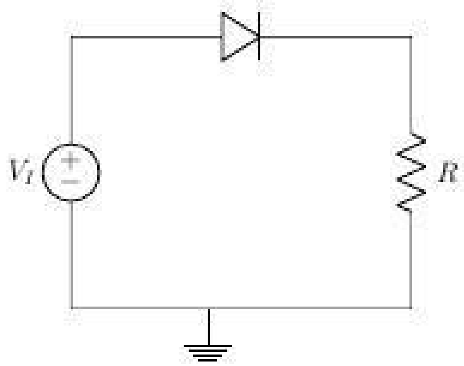
Background Knowledge (Brief):

- A rectifier is a device that converts alternating current (AC) to direct current (DC), a process known as rectification. Rectifiers are essentially of two types – a half-wave rectifier and a full-wave rectifier.
- Half Wave Rectification:
  - A half-wave rectifier is defined as a type of rectifier that only allows one half-cycle of an AC voltage waveform to pass, blocking the other half-cycle. Half-wave rectifiers are used to convert AC voltage to DC voltage, and only require a single diode to construct.
  - The mains power supply is applied at the primary of the step-down transformer. All the positive half cycles of the stepped down ac supply pass through the diode and all the negative half cycles get eliminated.

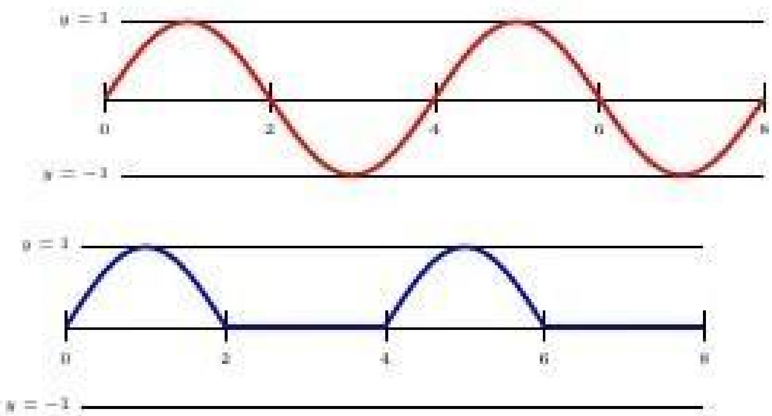


  - On the **positive cycle,** the diode is **forward biased** and on the **negative cycle,** the diode is **reverse biased**. By using a diode we have converted an AC source into a pulsating DC source. In summary, we have ‘rectified’ the AC signal.

- The simplest kind of rectifier circuit is the half-wave rectifier. The half-wave rectifier is a circuit that allows only part of an input signal to pass. The circuit is simply the combination of a single diode in series with a resistor, where the resistor is acting as a load.



- Half Wave Rectifiers – Waveforms:

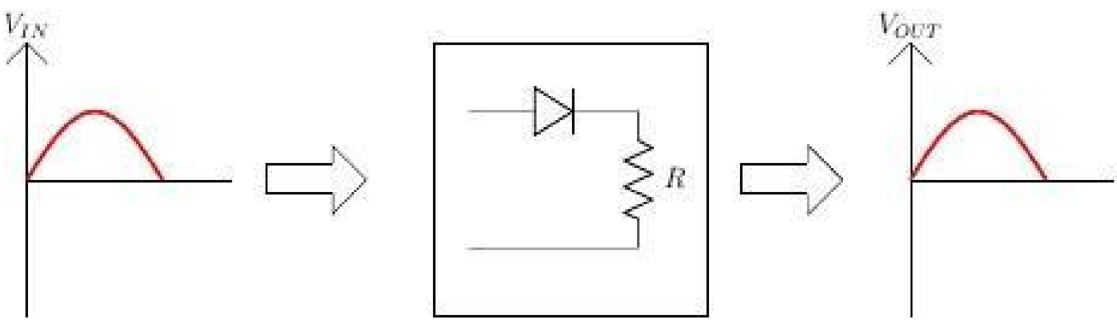


The output DC voltage of a half-wave rectifier can be calculated with the following two ideal equations-

$$V_{peak} = V_{rms} \times \sqrt{2}$$

$$V_{dc} = \frac{V_{peak}}{\Pi}$$

- Half Wave Rectification: For Positive Half Cycle:



When a diode is forward biased, acts as a short circuit, passes the waveform through.

For positive half-cycle:

$V_I - V_b - I \times r_d - I \times R = 0$

where,

V_I is the input voltage,

V_b is barrier potential,

r_d is diode resistance,

I is total current,

R is resistance

$$I = \frac{V_I - V_b}{r_d + R}$$

$$V_O = I \times R$$

$$V_O = \frac{V_I - V_b}{r_d + R} \times R$$

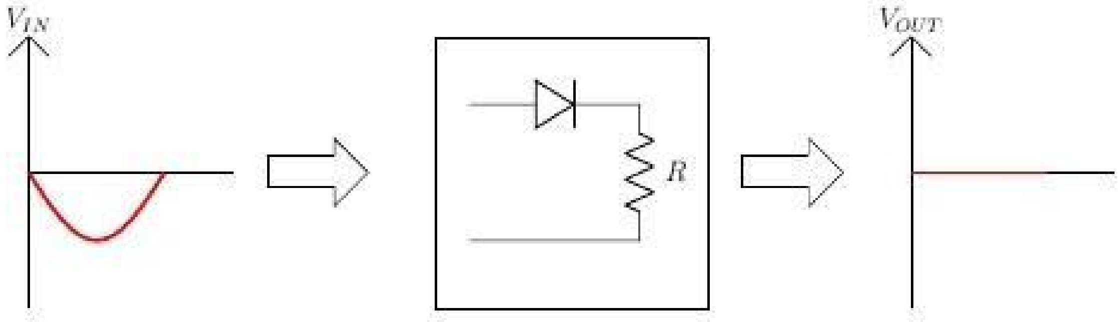
$$V_O = V_I - V_b$$

For $r_d << R$, $V_o = V_I - V_b$ and V_b is 0.3 Volts for Germanium and V_b is 0.7 V for Silicon.

For $V_I < V_b$, The diode will remain OFF. The output voltage will be, $V_O = 0$

For $V_I > V_b$, The diode will remain ON. The output voltage will be, $V_O = V_I - V_b$

- Half Wave Rectification: For Negative Half Cycle:



When a diode is reverse biased, acts as an open circuit, does not pass the waveform through.
For negative half-cycle- $V_O = 0$ since I = 0.

- Half-wave Rectification: For an Ideal Diode
  For the ideal diode, $V_b = 0$
  For positive half-cycle, $V_O = V_I$
  For negative half-cycle, $V_O = 0$
- Average output voltage:

$V_O = V_m \times \sin(wt)$ for $0 \leq wt \leq \pi$

$V_O = 0$ for $\pi \leq wt \leq 2\pi$

$$V_{av} = \frac{V_m}{\pi} = 0.318V_m$$

- RMS Load Voltage:

$$V_{rms} = I_{rms} \times R = \frac{V_m}{2}$$

- Average Load Current:

$$I_{av} = \frac{V_{av}}{R} = \frac{\frac{V_m}{\pi}}{R}$$

$$I_{av} = \frac{V_m}{\pi \times R} = \frac{I_m}{\pi}$$

- RMS Load current:

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

Form factor- It is defined as the ratio of RMS load voltage and average load voltage.

$$F.F = \frac{V_{rms}}{V_{av}}$$

$$F.F = \frac{\frac{V_m}{2}}{\frac{V_{av}}{2}} = \frac{\pi}{2} = 1.57$$

$F.F \geq 1$

$rms \geq av$

- Ripple Factor:

$$\gamma = \sqrt{(}F.F^2 - 1 \times 100\%$$

$$\gamma = \sqrt{(}1.57^2 - 1) \times 100\% = 1.21\%$$

Efficiency: It is defined as the ratio of dc power available at the load to the input ac power.

$$n\% = \frac{P_{load}}{P_{in}} \times 100\%$$

$$n\% = \frac{I_{dc}^2 \times R}{I_{rms}^2 \times R} \times 100\%$$

$$n\% = \frac{\frac{I_m^2}{\pi^2}}{\frac{I_m^2}{4}} \times 100\% = \frac{4}{\pi^2} \times 100\% = 40.56\%$$

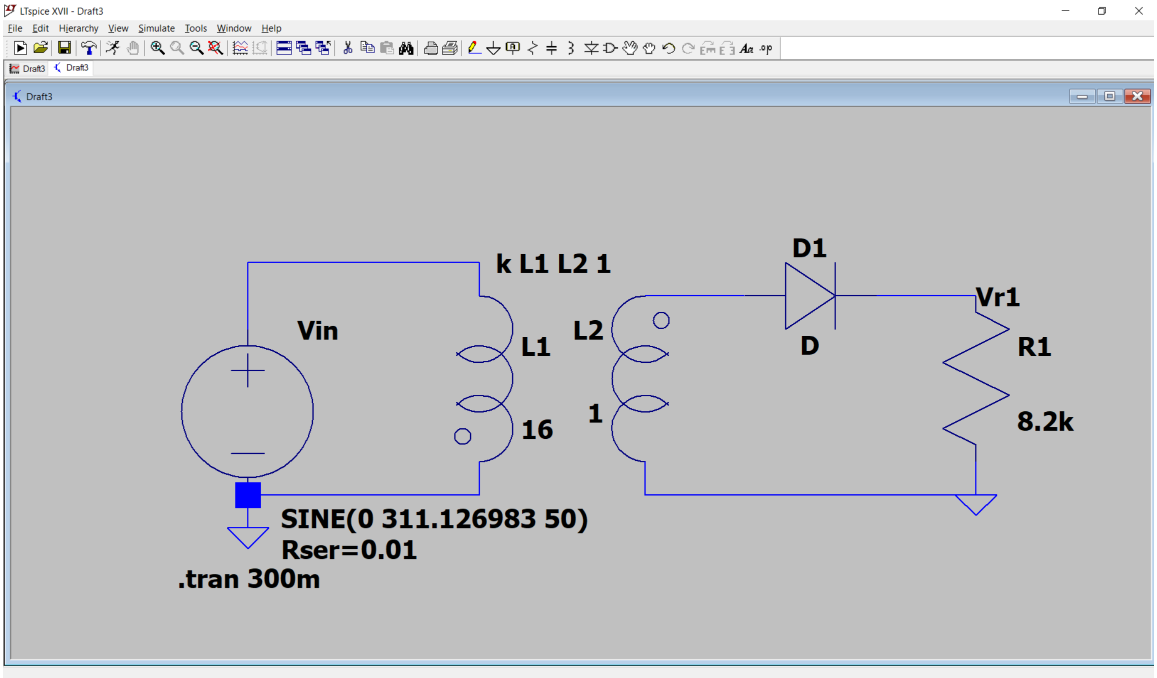
- Peak Inverse Voltage:
  For rectifier applications, peak inverse voltage (PIV) or peak reverse voltage (PRV) is the maximum value of reverse voltage which occurs at the peak of the input cycle when the diode is reverse-biased. The portion of the sinusoidal waveform which repeats or duplicates itself is known as the cycle. The part of the cycle above the horizontal axis is called the positive half-cycle, the part of the cycle below the horizontal axis is called the negative half cycle. With reference to the amplitude of the cycle, the peak inverse voltage is specified as the maximum negative value of the sine-wave within a cycle's negative half cycle.

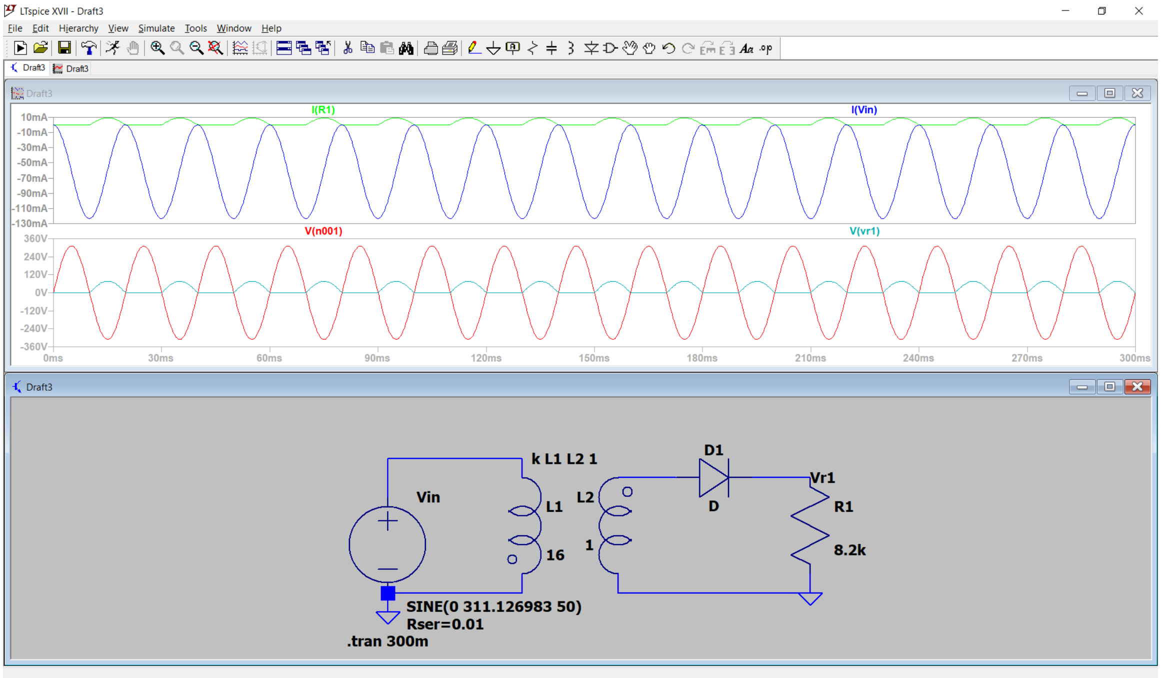
$$PIV = V$$
$$-V_m + V = 0$$
$$V_m = V$$
$$PIV \geq V_m$$

Circuit (hand-drawn/image):

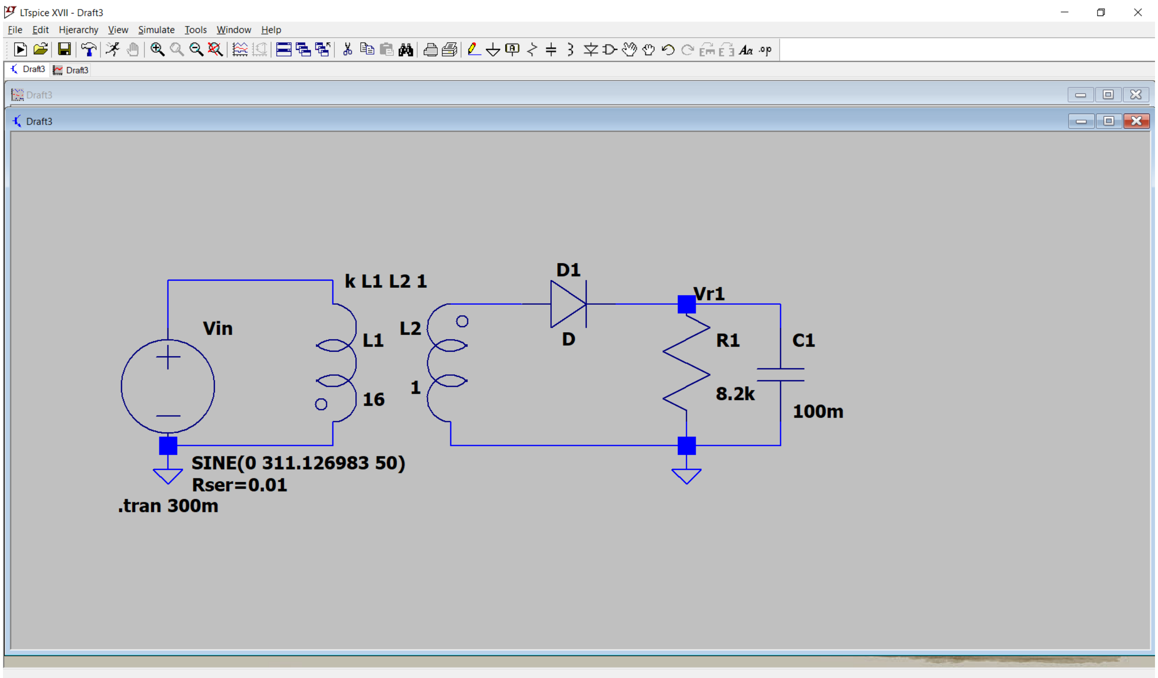
Half-wave rectifier-

- Circuit-1: Pulsatile DC-

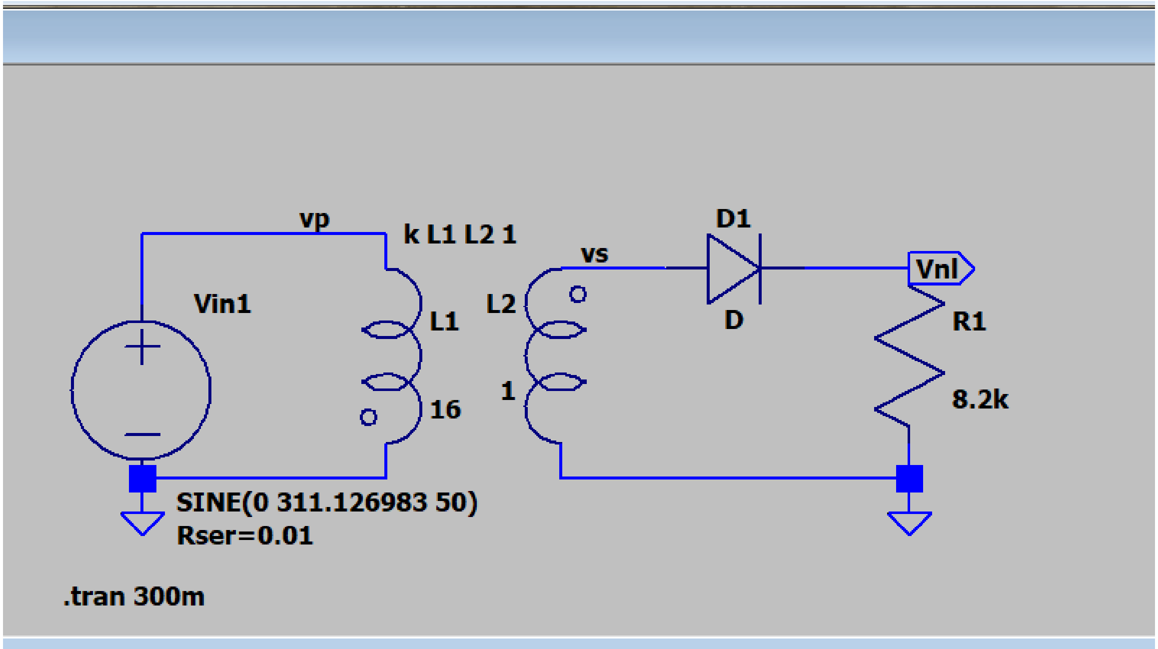




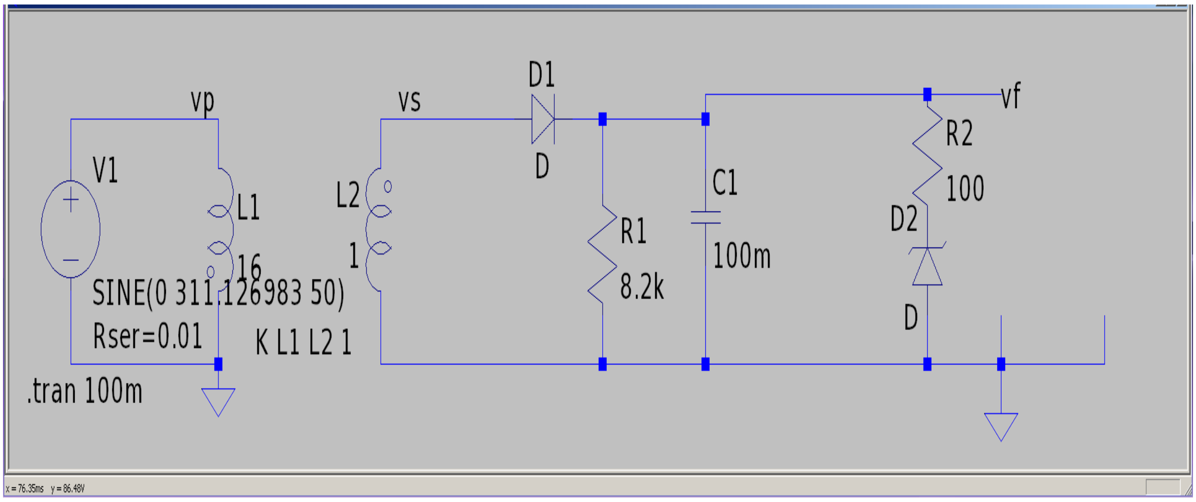
- Circuit-2: When a low pass filter is included-



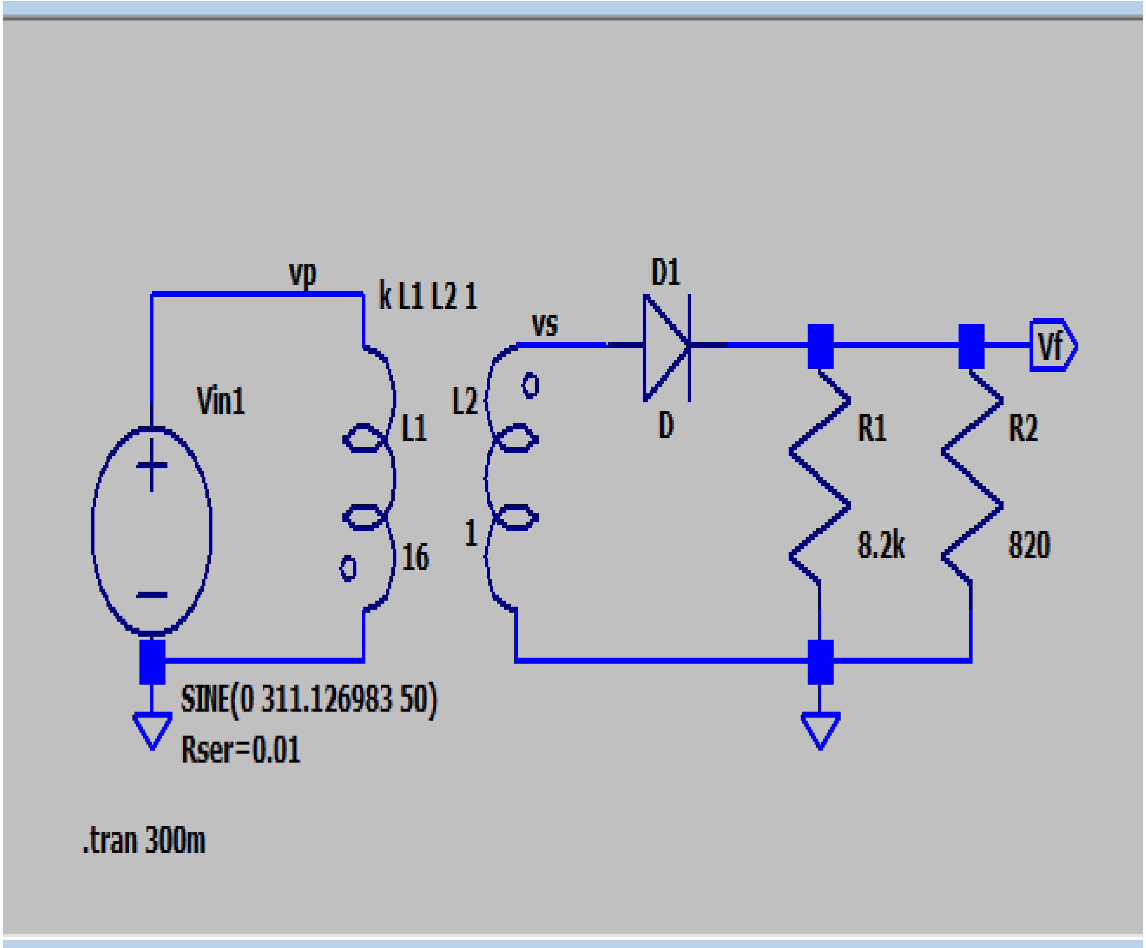
- Circuit-3: Voltage regulator-
  - When no load is connected-
    - Circuit-4: Without a filter-



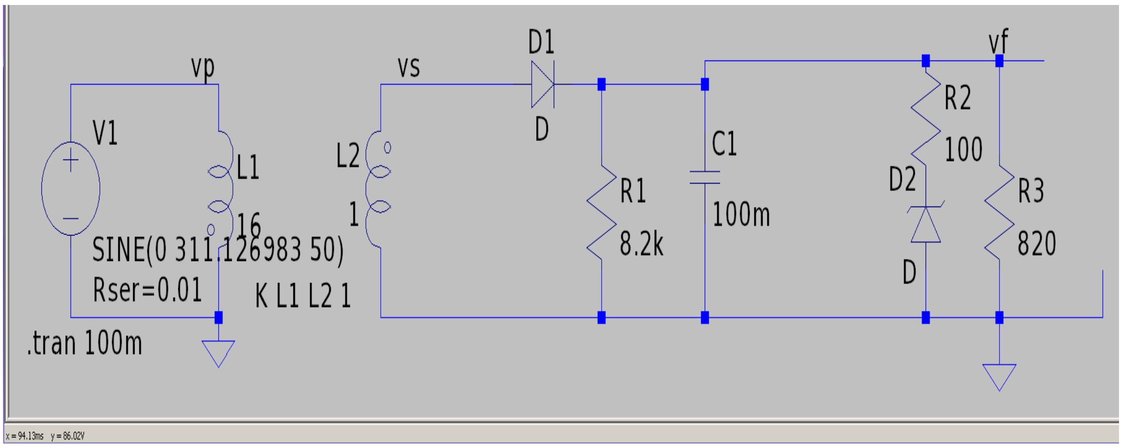
- Circuit-5: With a filter-



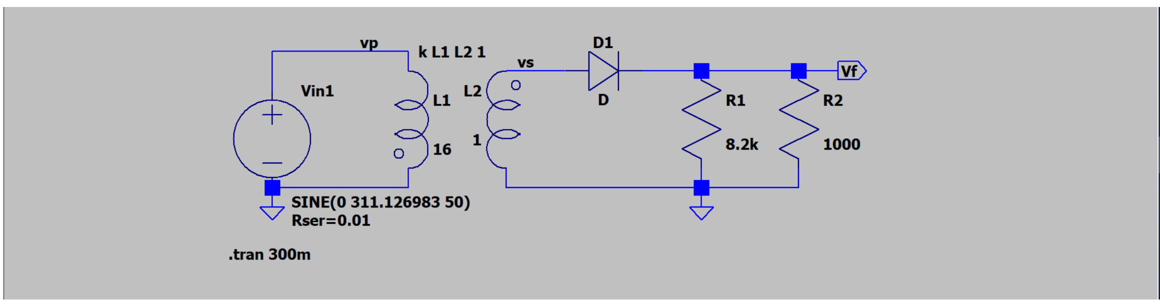
- When load-1 is connected-
  - Circuit-6: Without a filter-



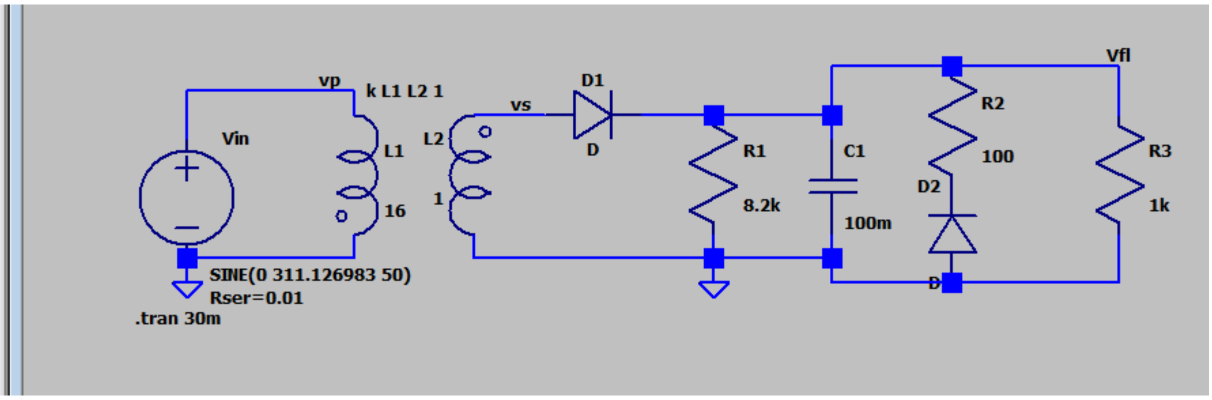
- Circuit-7: With a filter-



- When load-2 is connected-
    - Circuit-8: Without a filter-

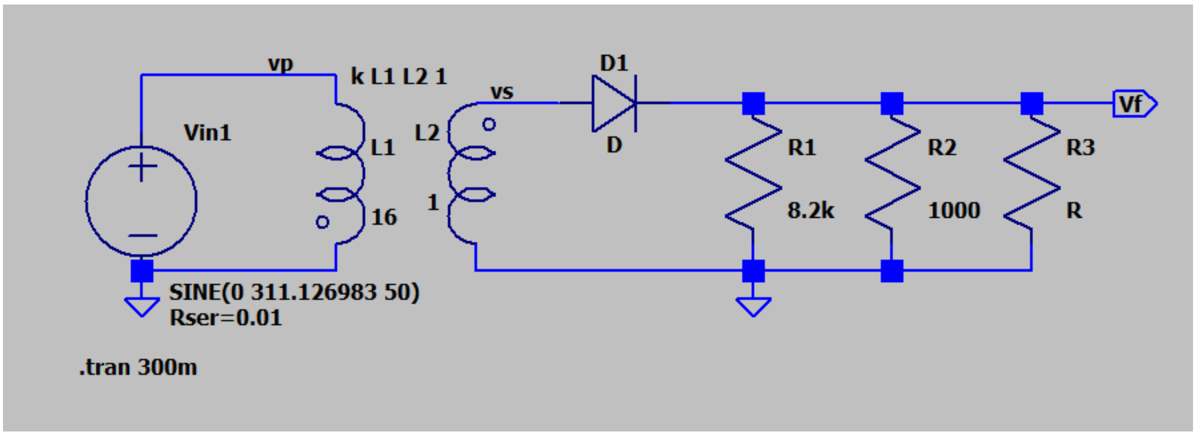


■ Circuit-9: With a filter-

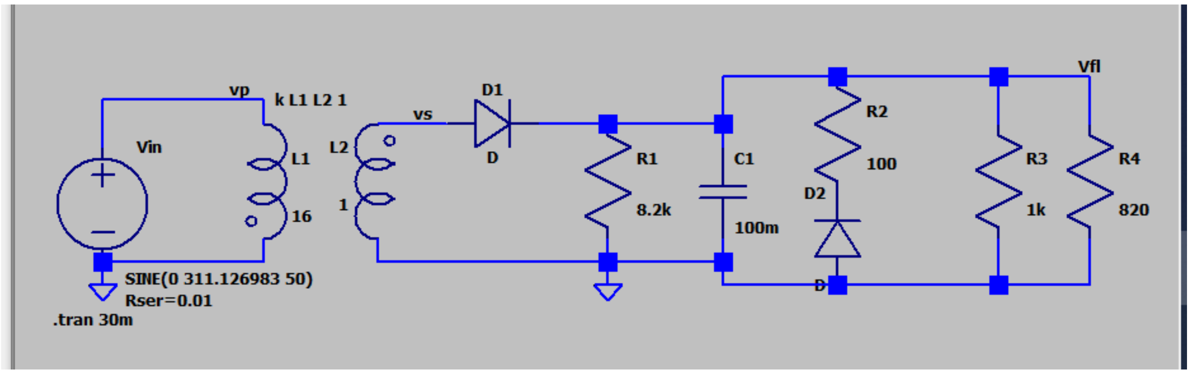


○ When load-1 and load-2 are connected-

■ Circuit-10: Without a filter-



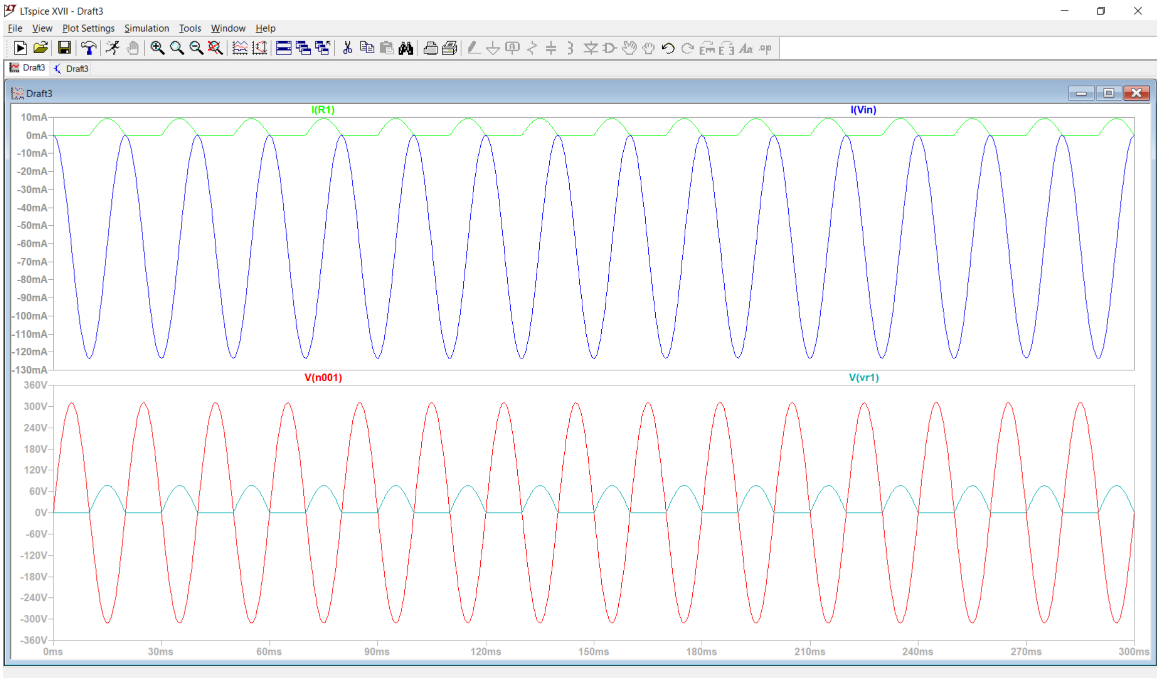
■ Circuit-11: With a filter-



Graphs (Image/Screenshots):

Half-wave rectifier-

- Graph of Circuit-1: Pulsatile DC-



Voltage Waveforms-

a) Input Voltage is represented by V(n001)- red coloured waveform

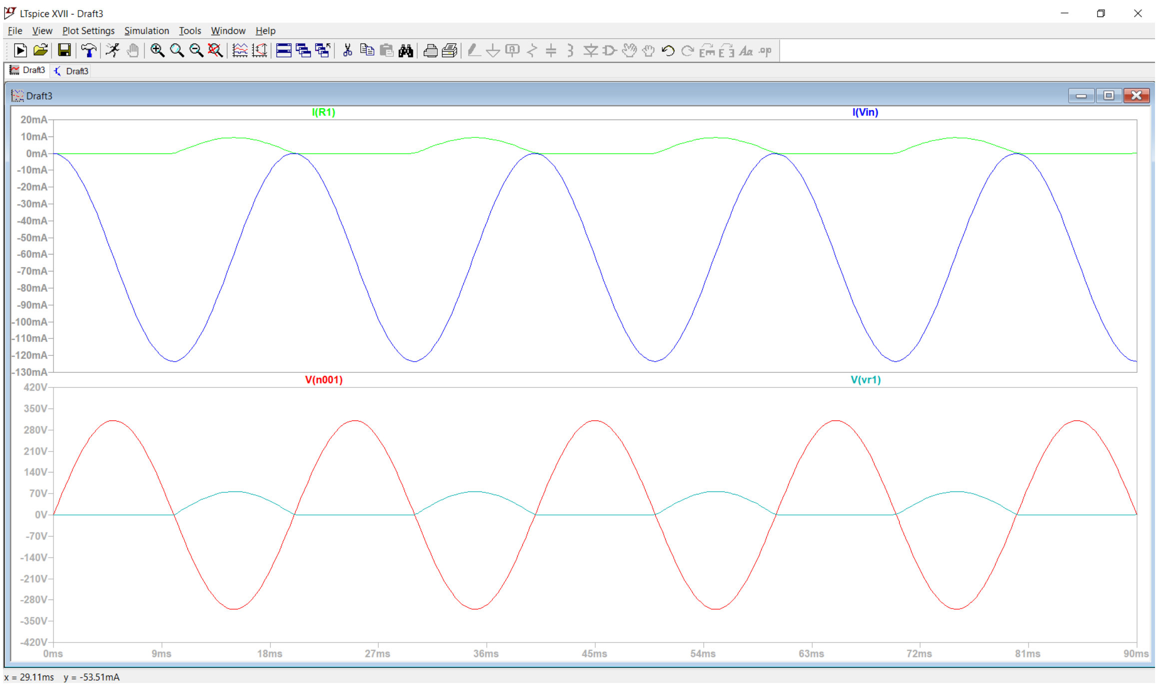
b) Rectified Voltage is represented by V(vr1)- cyan coloured waveform

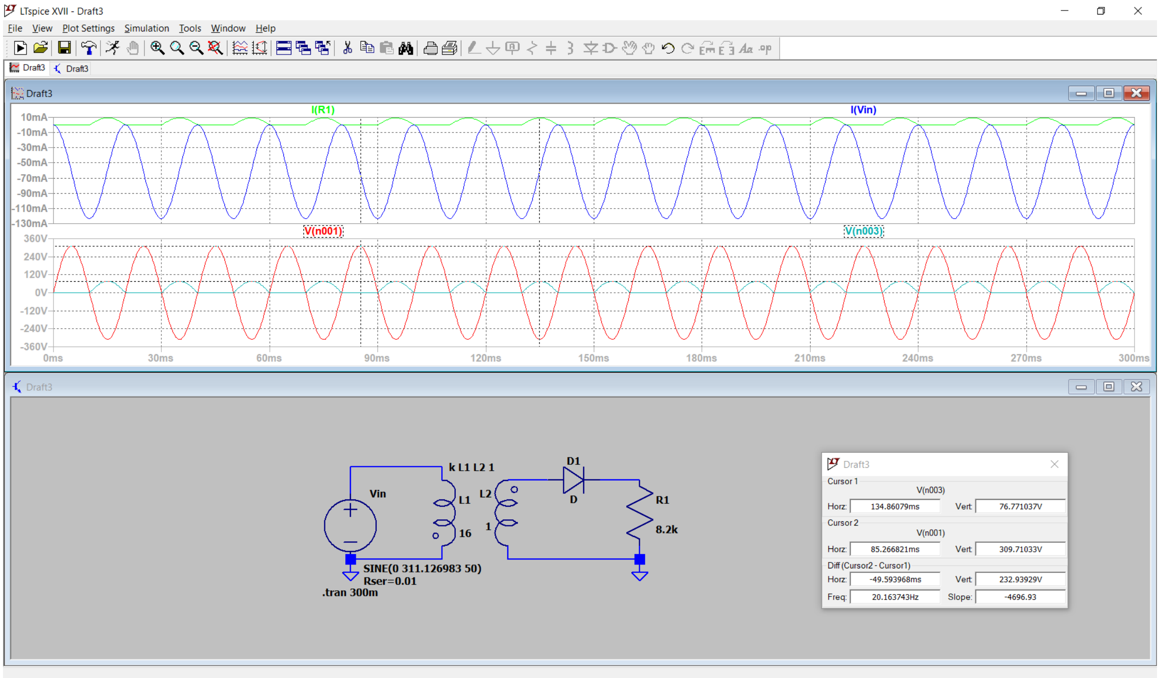
[Observation: only positive half cycles of the AC voltage is passed to the output side]

Current Waveforms-

a) Input Current is represented by I(Vin)- blue coloured waveform

b) Current through R1 is represented by I(R1)- green coloured waveform





Calculations-

Theoretical Calculations -

$V_m = 76.771037$ V

$$V_{DC} = \frac{V_M}{\pi} = 24.437\ Volts$$

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

$$I_{RMS} = \frac{I_M}{2}$$

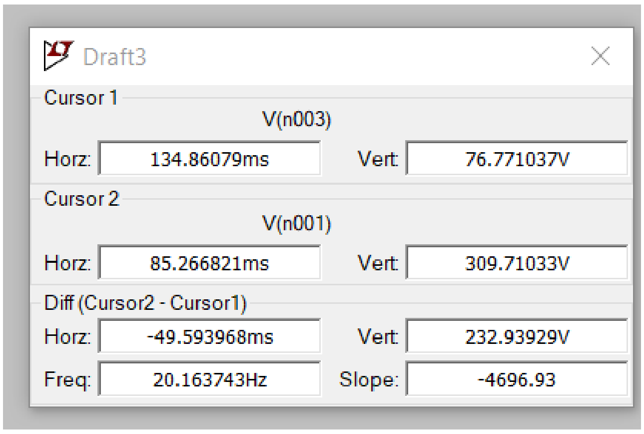
Ripple factor = $\sqrt{\left(\frac{I_{RMS}}{I_{DC}}\right)^2 - 1} = 1.21$

Clearly, from the graph, $V_m = 76.771037$V

$$V_{DC} = \frac{V_M}{\pi} = 24.437\ Volts$$

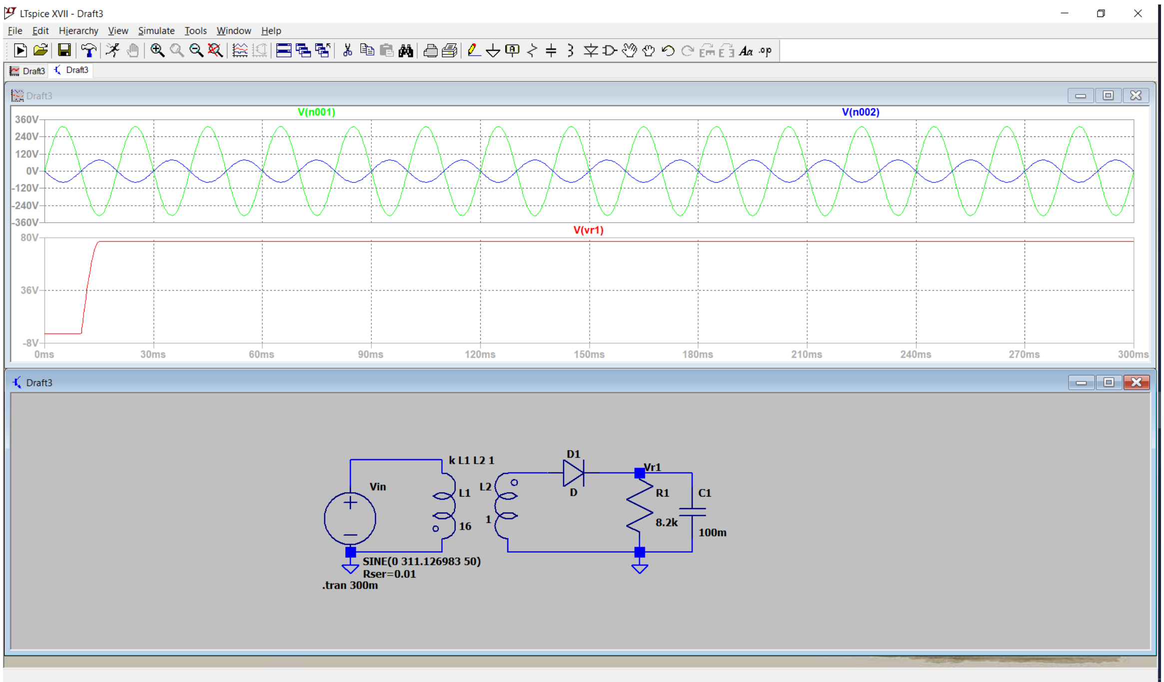
$$V_{RMS} = \frac{V_M}{2}$$

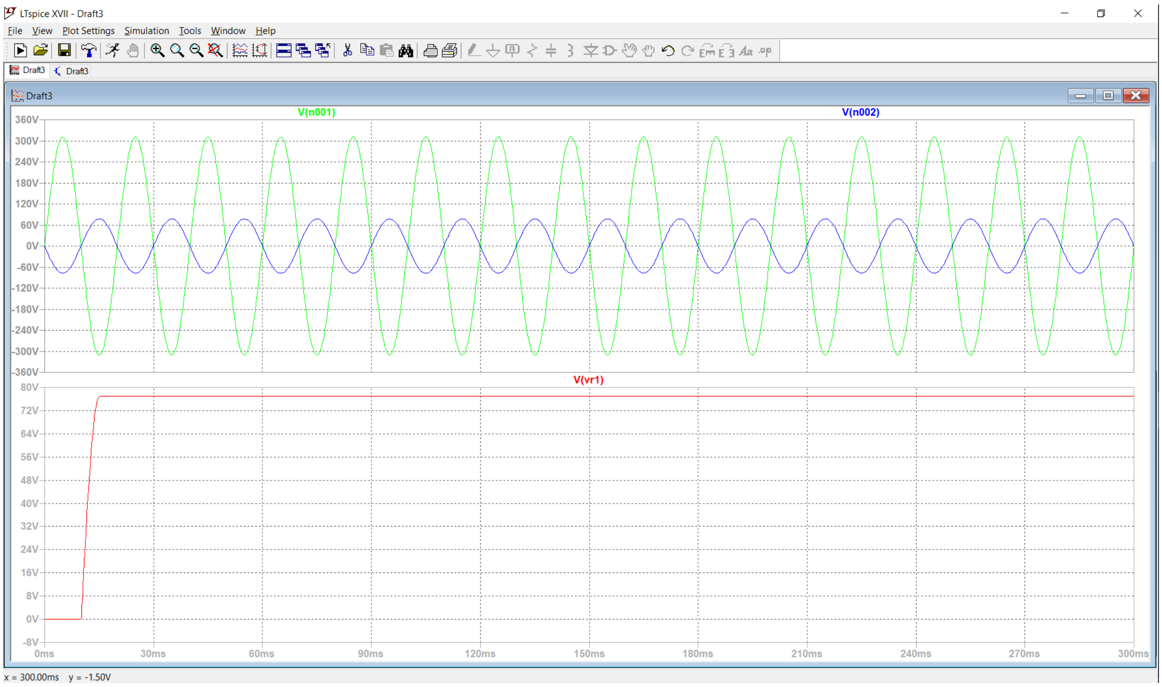
Ripple factor = $\frac{V_{RMS}}{V_{DC}} = 1.21$



Therefore, the theoretical value of the ripple factor is 1.21 which is the calculated value of the ripple factor using the values of voltages obtained from the graph.

- Graph of Circuit-2: When a low pass filter is included-





Voltage Waveforms-

The final output voltage is represented by V(vr1), a red coloured waveform as shown in the second plot.

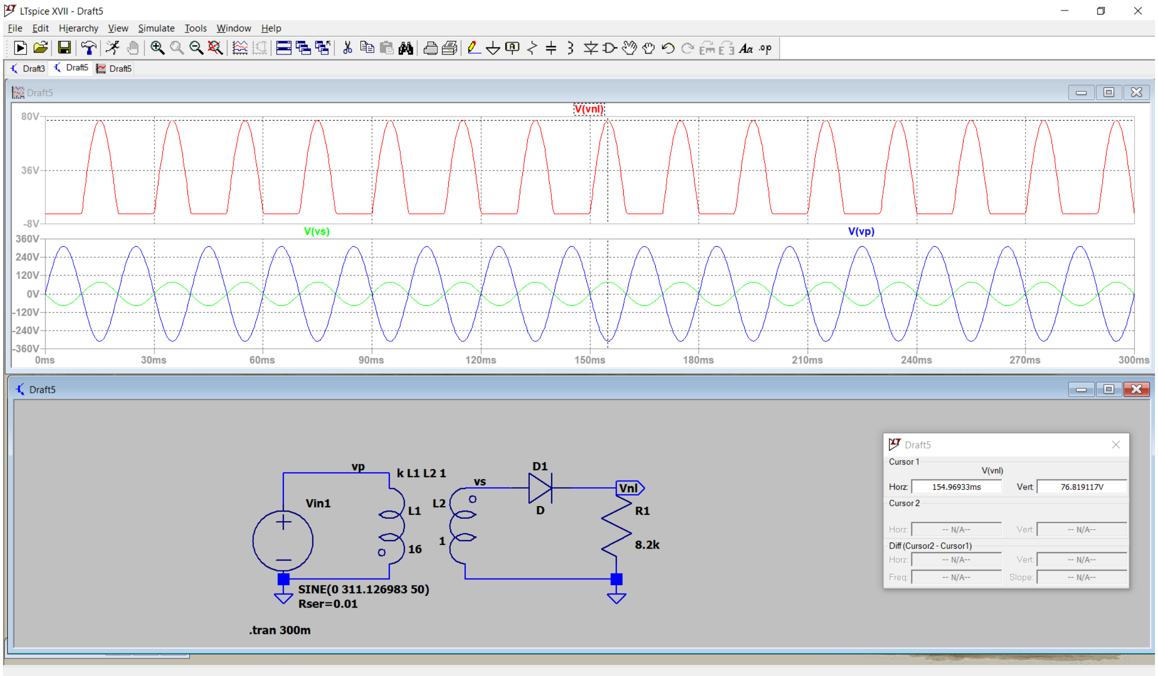
Including a low pass filter, the output voltage is a steady DC voltage.

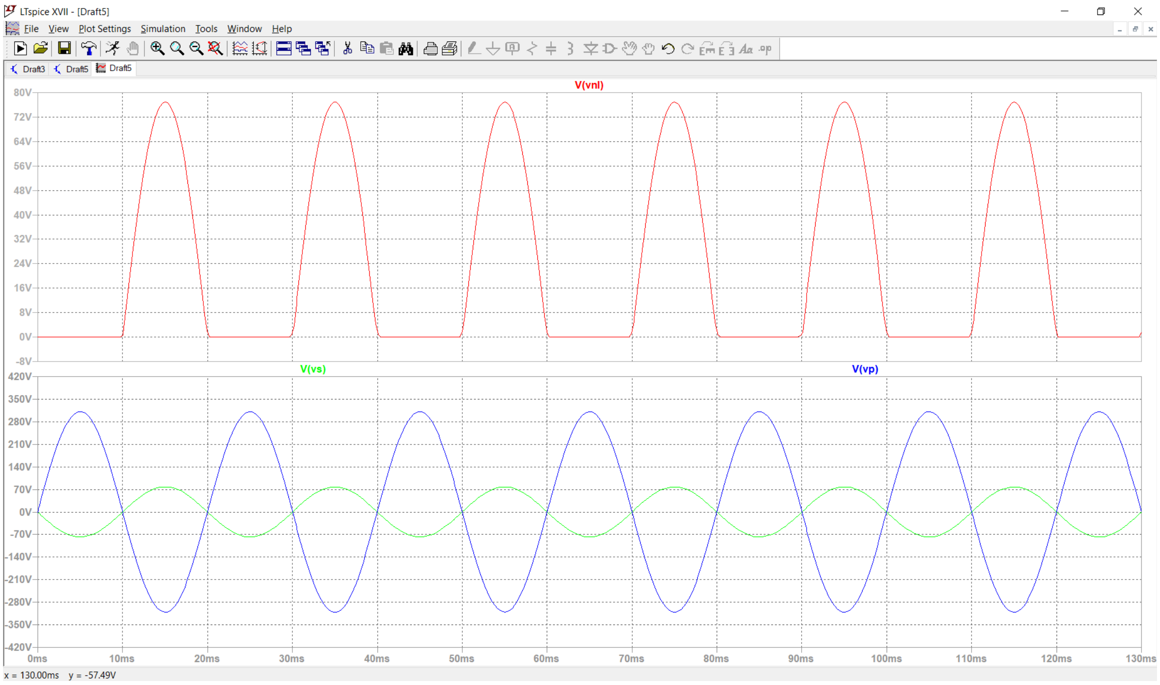
Calculations-

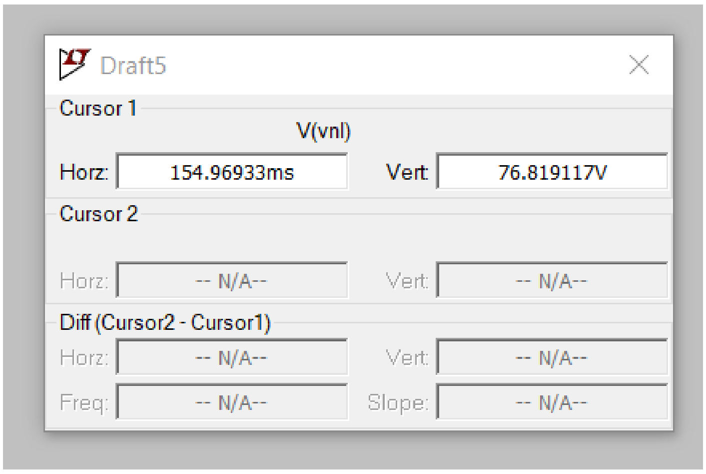
$f = 50Hz, R = 8.2k, C = 100mF$

Ripple factor $= \frac{1}{2\sqrt{3}fCR} = 7.04 \times 10^{-6}$

- Graph of Circuit-3: Voltage regulator-
    - When no load is connected-
        - Graph of Circuit-4: Without a filter-

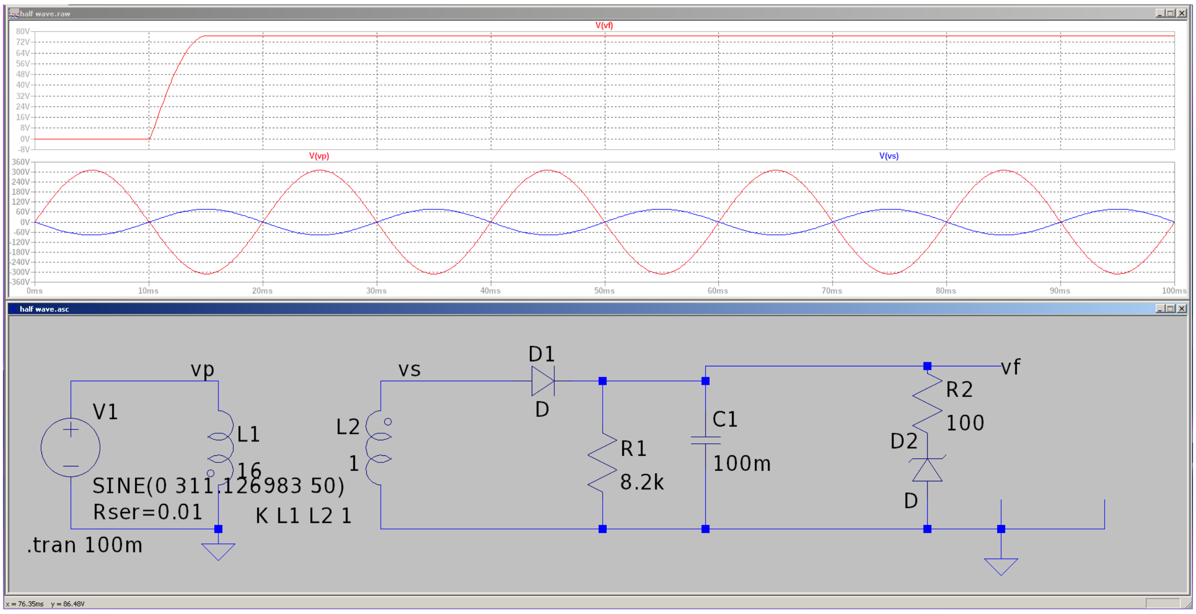

LTspice XVII - Draft5
File Edit Hierarchy View Simulate Tools Window Help
Draft3 Draft5 Draft5
V(vnl)
80V
36V
-8V
V(vs)
V(vp)
360V
240V
120V
0V
-120V
-240V
-360V
0ms 30ms 60ms 90ms 120ms 150ms 180ms 210ms 240ms 270ms 300ms
vp
k L1 L2 1
vs
D1
Vnl
Vin1
L1
L2
D
R1
16
1
8.2k
SINE(0 311.126983 50)
Rser=0.01
.tran 300m
Cursor 1
V(vnl)
Horz: 154.96933ms
Vert: 76.819117V
Cursor 2
Diff (Cursor2 - Cursor1)

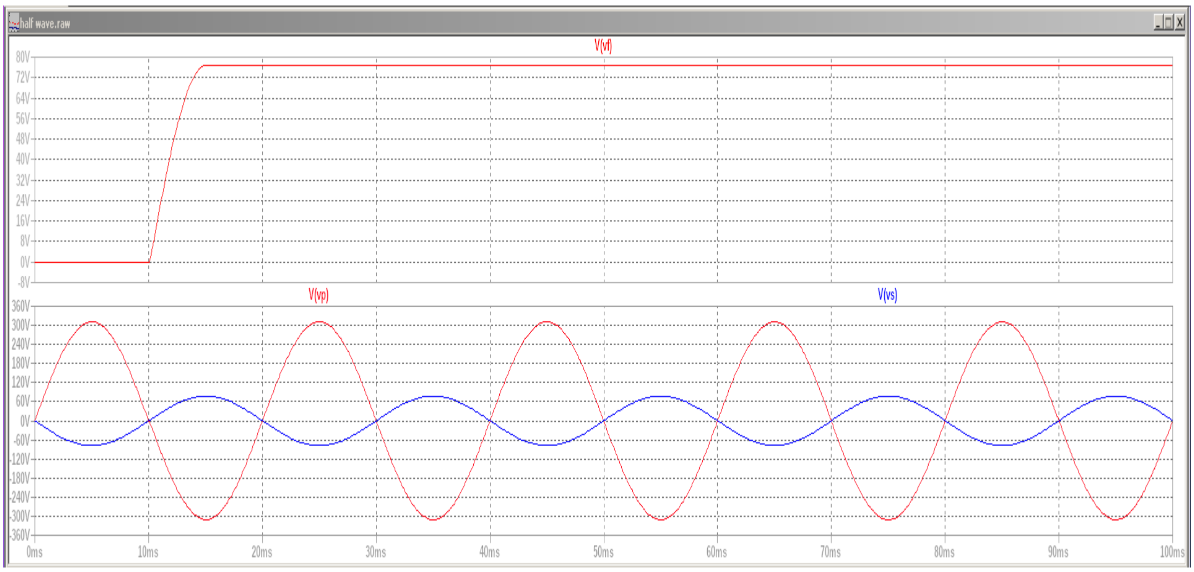

LTspice XVII - [Draft5]
File View Plot Settings Simulation Tools Window Help
Draft3 Draft5 Draft5
V(vnl)
80V
72V
64V
56V
48V
40V
32V
24V
16V
8V
0V
-8V
V(vs)
V(vp)
420V
350V
280V
210V
140V
70V
0V
-70V
-140V
-210V
-280V
-350V
-420V
0ms 10ms 20ms 30ms 40ms 50ms 60ms 70ms 80ms 90ms 100ms 110ms 120ms 130ms
x = 130.00ms y = -57.49V



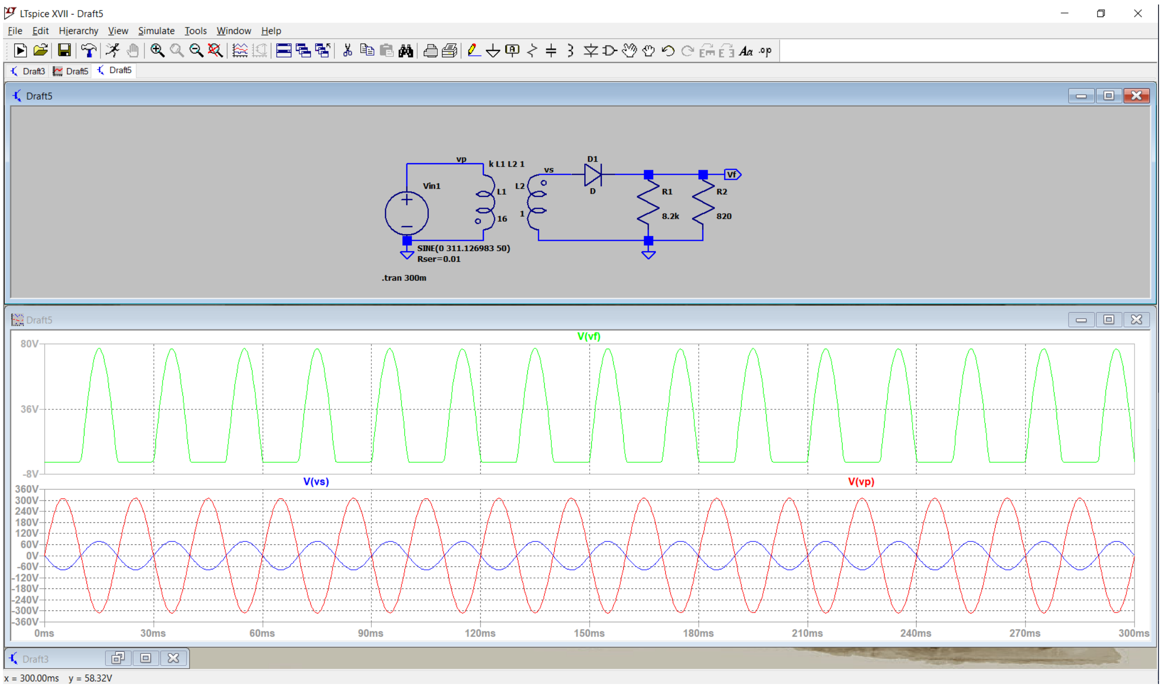
From the graph, it's clear that V_{NL} = 76.819117 V. ---> 1

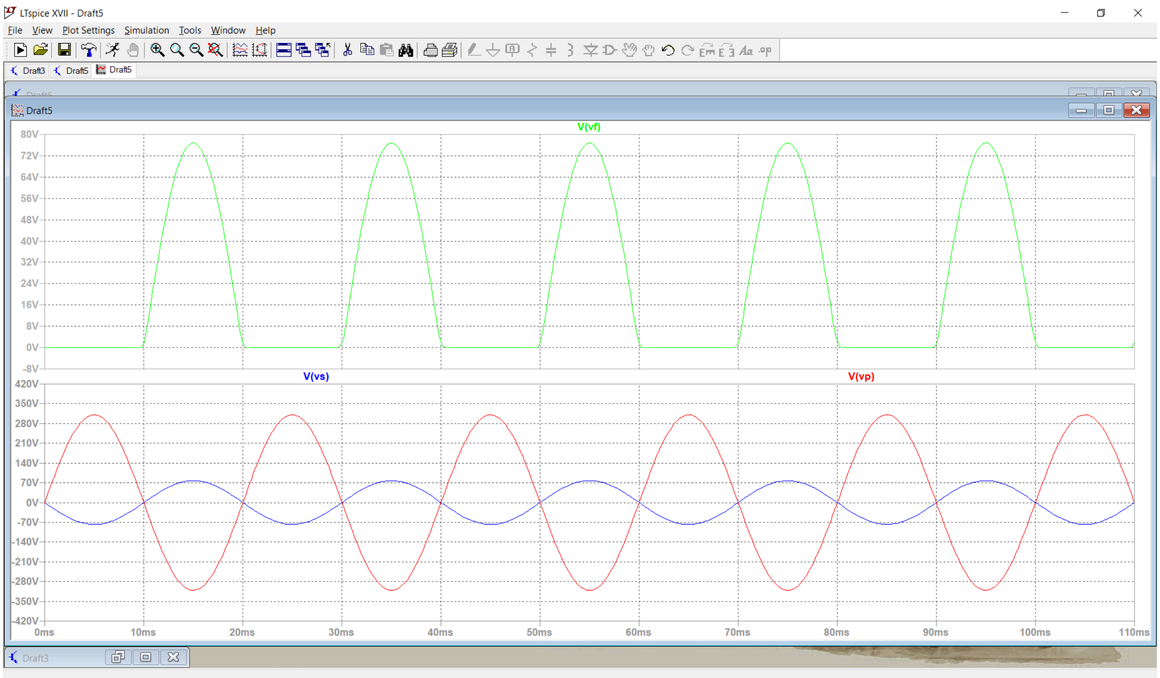
- Graph of Circuit-5: With a filter-



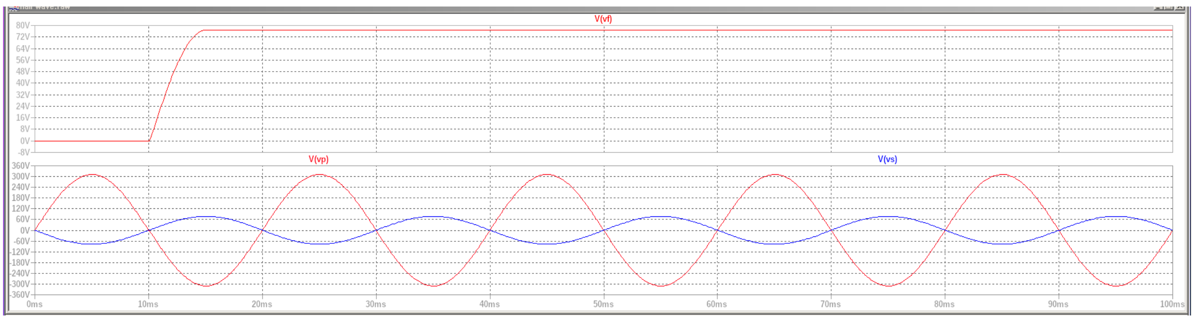


- When load-1 is connected-
    - Graph of Circuit-6: Without a filter-

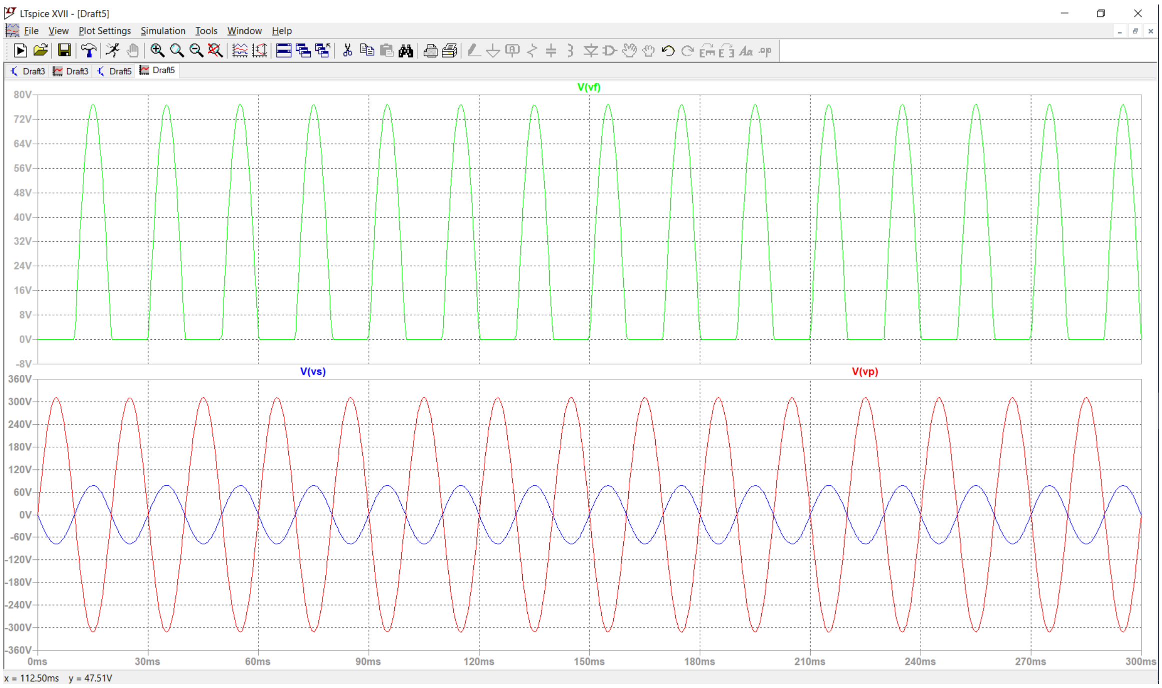




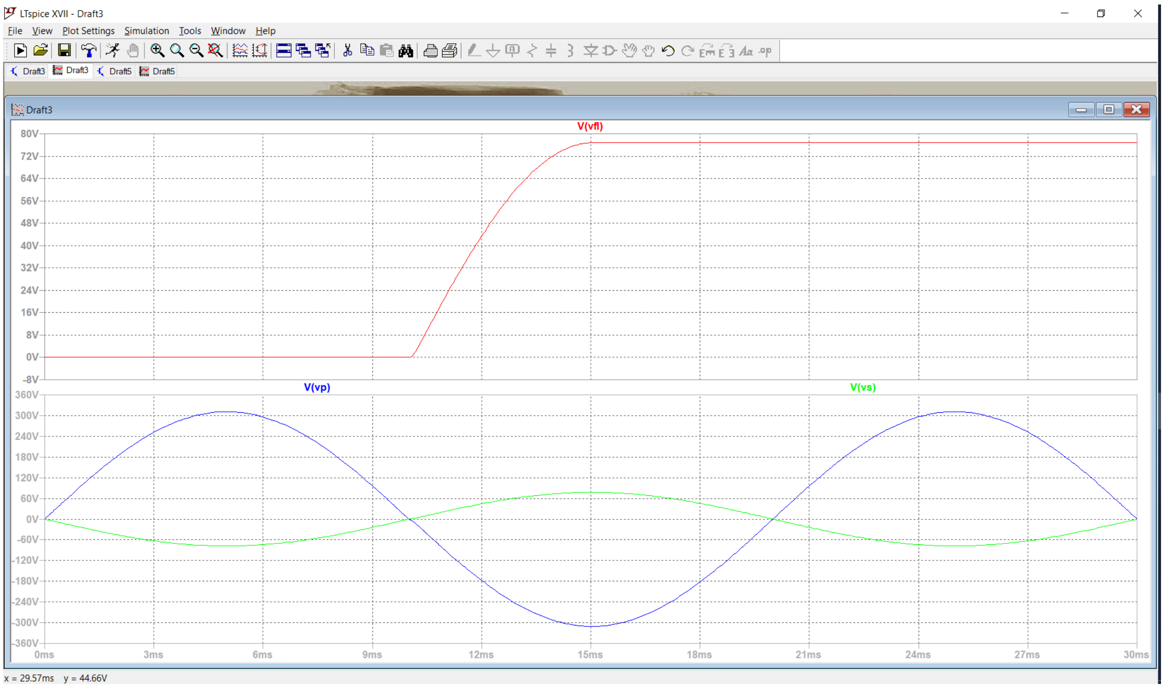
- Graph of Circuit-7: With a filter-



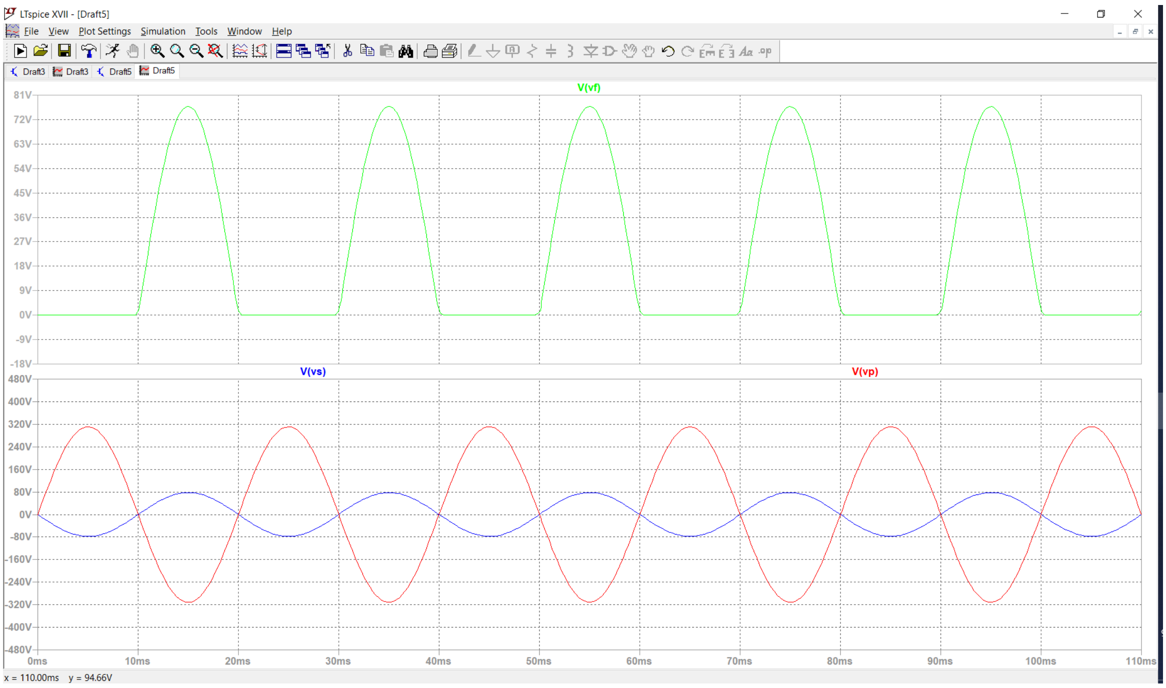
- When load-2 is connected-
  - Graph of Circuit-8: Without a filter-

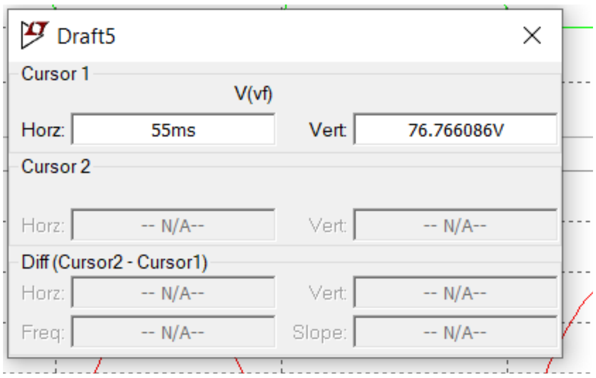


  - Graph of Circuit-9: With a filter-



- When load-1 and load-2 are connected-
  - Graph of Circuit-10: Without a filter-



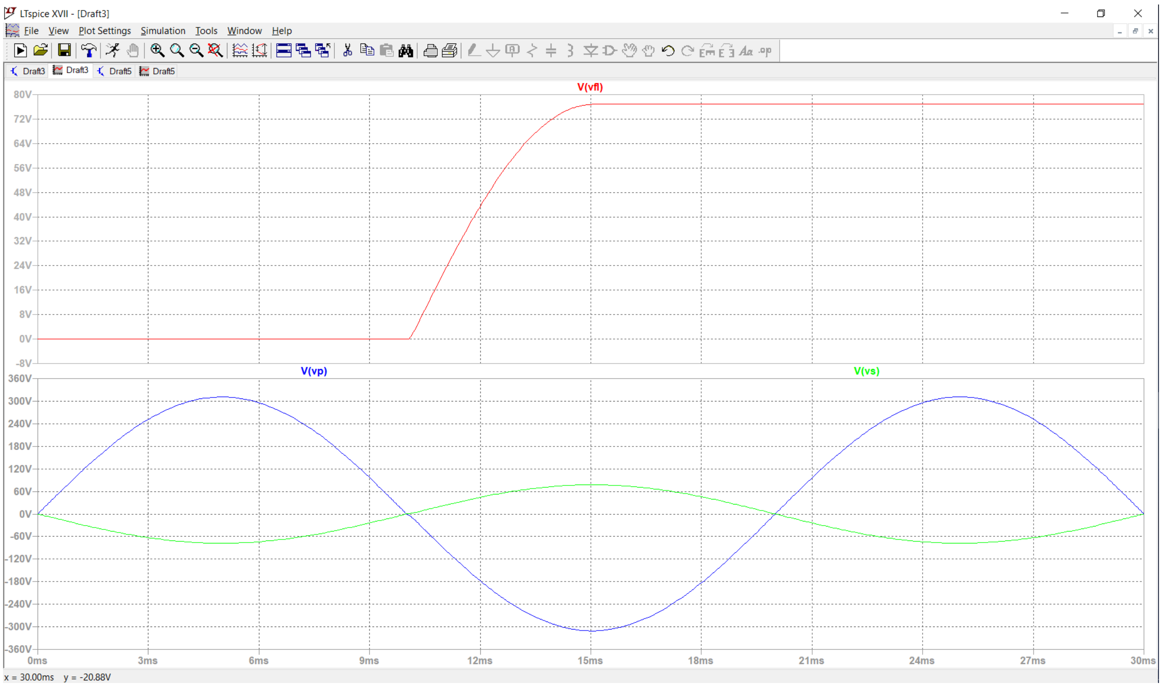


Calculations-

From the graph, it's clear that V_{FL} = 76.766086V

$$\text{Voltage Regulation} = \frac{V_{NL} - V_{FL}}{V_{FL}} = \frac{76.819117 - 76.766086}{76.766086} = 6.908 \times 10^{-4}$$

- Graph of Circuit-11: With a filter-



Conclusion:

In a half-wave rectifier, the first half cycle of a sinusoidal waveform is positive, and the inclusion of a reverse-biased diode makes the current not flow to the negative side of the wave. Using a capacitor as a filter helped to smoothen out the output signal, reducing the ripple effect. Finally, using a Zener diode in a voltage-regulated DC circuit, we were able to observe the properties of a Zener diode and its behaviour in the break-down region. The output voltage for Zener Diode - Line Regulator became constant and was equal to the Zener voltage, for all input values greater than or equal to the Zener voltage. All this behaviour is a result of the special property of semiconductor diodes which allows current to flow when forward biased but not as easy when reversing biased.

It can be made at a low cost. It is easy to use and understand the circuit. They only allow a half cycle through per sine wave, and the other half cycle is wasted. This leads to power loss. They produce a low output voltage.

The theoretical principles of rectifiers and diodes have been verified in this experiment.

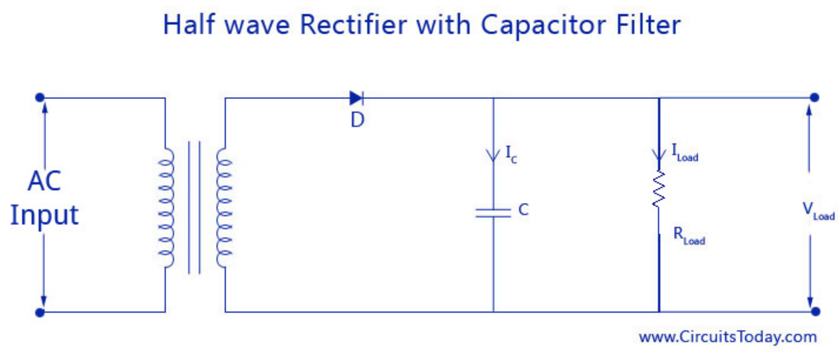
Discussions:

1. Peak inverse voltage of a half-wave rectifier: It is defined as the maximum voltage that the diode can withstand during the reverse bias condition. If a voltage is applied more than the PIV then the diode will be destroyed.

2. Advantages and disadvantages of a half-wave rectifier: The main advantage is that it's a simple circuit with fewer components and hence very economical. But it has a major disadvantage in that it converts only one cycle of the sinusoidal input given to it and the other cycle gets wasted, thus giving more power loss.

3. Half-wave rectifiers are not as commonly used as full-wave rectifiers. Despite this, they still are used in soldering, AM radio, pulse generated circuits, etc.
4. In the forward biasing of a diode, the positive terminal of the battery is connected to the P side and the negative terminal of the battery is connected to the N side of the diode. The diode will conduct in forward biasing because the forward biasing will decrease the depletion region width and overcome the barrier potential. In order to conduct, the forward biasing voltage should be greater than the barrier potential. During forward biasing the diode acts like a closed switch with a potential drop of nearly 0.6 V across it for a silicon diode (0.3 V across it for a germanium diode). From the graph, you may notice that the diode starts conducting when the forward bias voltage exceeds around 0.6 volts (for Si diode) and 0.3 volts (for Ge diode). This voltage is called cut-in voltage.
5. In reverse biasing, the positive terminal of the battery is connected to the N side and the negative terminal of the battery is connected to the P side of a diode. In reverse biased, the diode does not conduct electricity, since reverse biasing leads to an increase in the depletion region width; hence current carrier charges find it more difficult to overcome the barrier potential. The diode will act as an open switch and there is no current flow.
6. The V-I characteristics of the P-N junction diode in forwarding bias are nonlinear. Using the slope of the graph we can conclude that the resistance of the diode is very low in forward bias. A large amount of current starts to flow above the knee point with a small amount of external potential applied.
7. The output signal for Low pass filters lags in phase, i.e, there's a negative phase shift.
8. In rectifier circuits about converting a sinusoidal ac voltage into its corresponding pulsating dc. Apart from the dc component, this pulsating dc voltage will have unwanted ac components like the components of its supply frequency along with its harmonics (together called ripples). These ripples will be the highest for a single-phase half-wave rectifier and will reduce further for a single-phase full-wave rectifier. The ripples will be minimum for 3-phase rectifier circuits. Such supply is not useful for driving complex electronic circuits. For most supply purposes constant dc voltage is required than the pulsating output of the rectifier. For most applications, the supply from a rectifier will make the operation of the circuit poor. If the rectifier output is smoothened and steady and then passed on as the supply voltage, then the overall operation of the circuit becomes better. Thus, the output of the rectifier has to be passed through a filter circuit to filter the ac components.
9. The filter is a device that allows passing the dc component of the load and blocks the ac component of the rectifier output. Thus the output of the filter circuit will be a steady dc voltage. Finally, using a Zener diode in a voltage-regulated DC circuit, we were able to observe the properties of a Zener diode and its behaviour in the break-down region. The output voltage for Zener Diode - Line Regulator became constant and was equal to the Zener voltage, for all input values greater than or equal

to the Zener voltage. All this behaviour is a result of the special property of semiconductor diodes which allows current to flow when forward biased but not as easy when reversing biased.



10. The primary application of rectifiers is to derive DC power from an AC supply (AC to DC converter). Rectifiers are used inside the power supplies of virtually all electronic equipment. Rectifiers are used in mobile and laptop chargers, TVs, kitchen appliances, car alternators, and in many more areas. To smoothen the output waveform filters are used here we have used capacitors. If the capacitor values are very low, there will be huge 'gaps' and the ripple effect will be much more prominent. However, for large enough values of capacitors, the output signal will be much more smoothened out and the observed ripple effect will be reduced. Ripple Factor is inversely proportional to Capacitor Value in the case of capacitive circuits. Zener Diode Voltage Regulator has a thinner depletion region. When we apply a voltage more than the Zener breakdown voltage (can range from 1.2 volts to 200 volts), the depletion region vanishes, and a large current starts to flow through the junction. Also, Zener diodes are bi-directional whereas, normal p-n junction diodes are uni-directional.

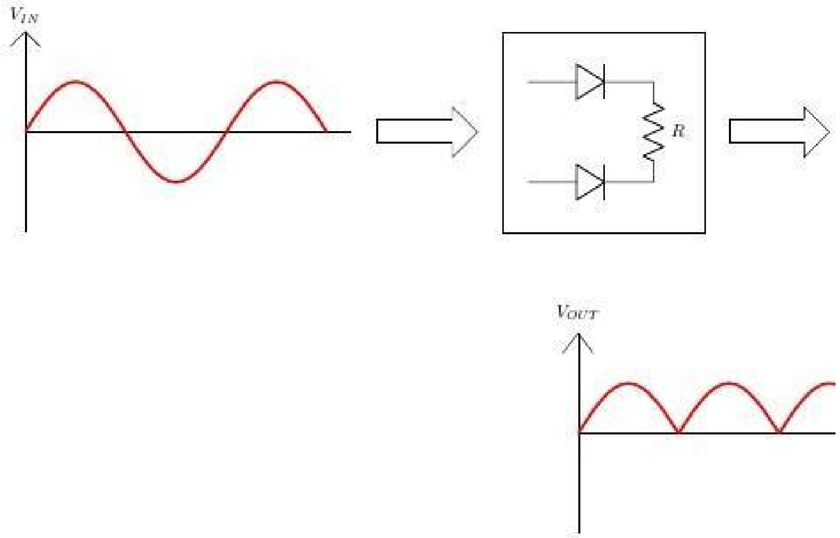
Ⅰ Ⅰ. To explain the working of a centre-tapped full-wave rectification and to explain the working of a bridge full-wave rectification

Tools Used: Lt Spice
Background Knowledge (Brief):

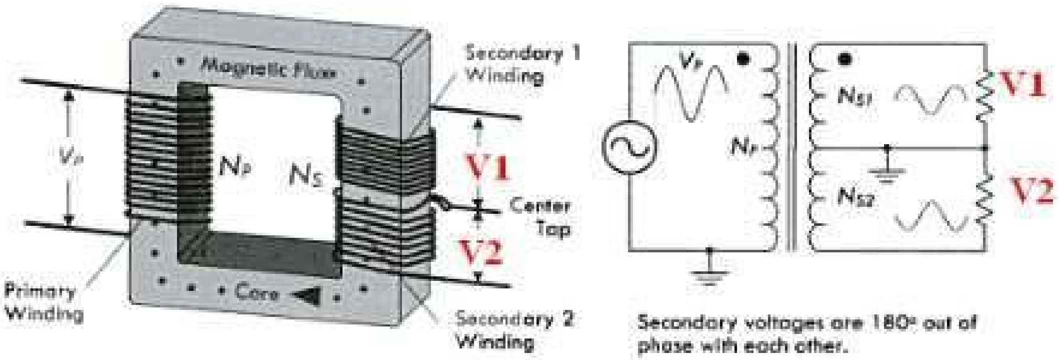
- A rectifier is a device that converts alternating current (AC) to direct current (DC), a process known as rectification. Rectifiers are essentially of two types – a half-wave rectifier and a full-wave rectifier.
- Full Wave Rectification:
  - A full-wave rectifier is exactly the same as the half-wave, but allows unidirectional current through the load during the entire sinusoidal cycle (as opposed to only half the cycle in the half-wave). A full-wave rectifier converts

the whole of the input waveform to one of constant polarity (positive or negative) at its output.

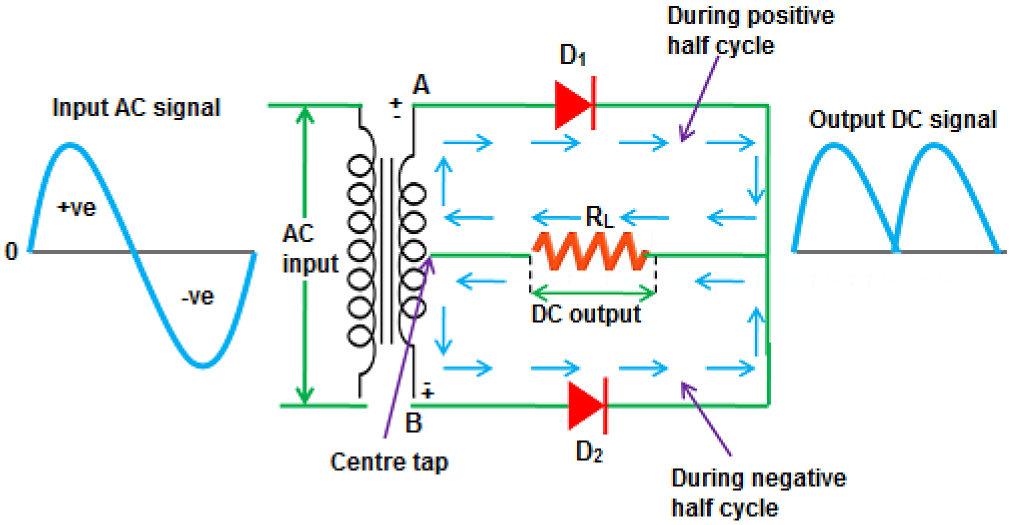
- Full Wave Rectification:



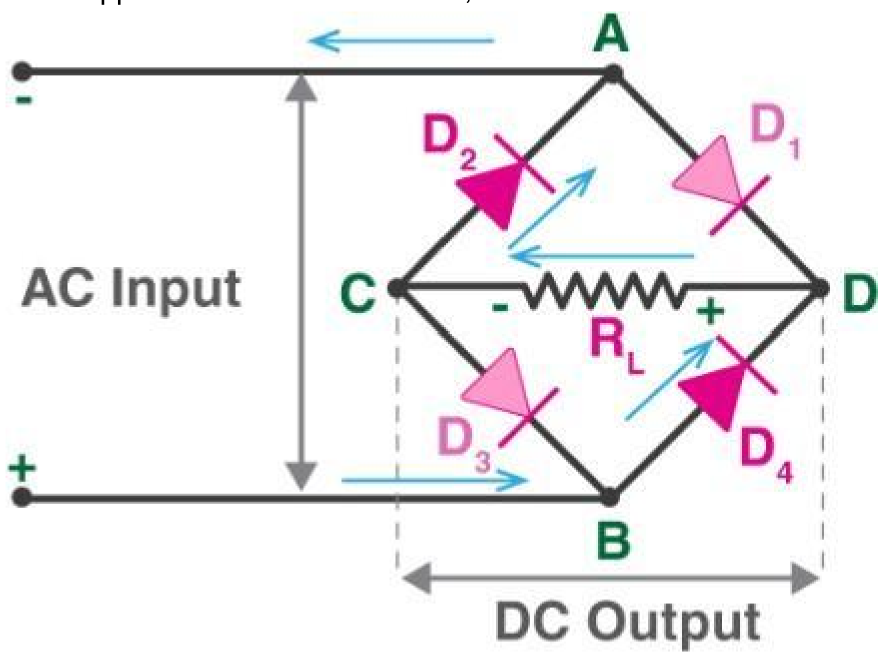
- Full wave with center-tapped transformer:
    - A center tapped full wave rectifier is a type of rectifier that uses a center tapped transformer and two diodes to convert the complete AC signal into a DC signal.



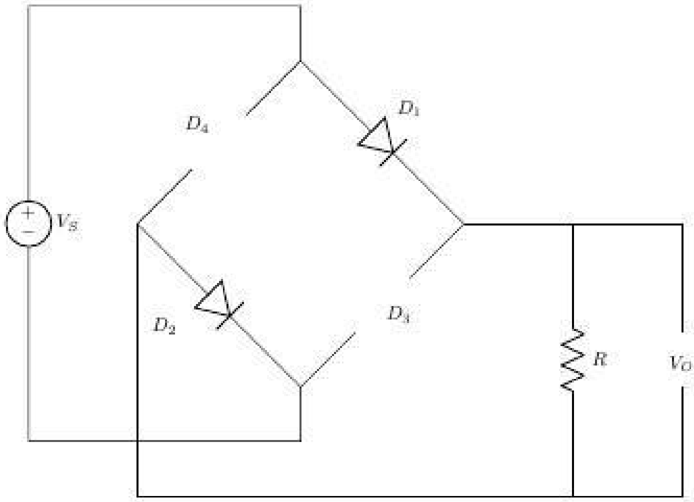
    - When an additional wire is connected across the exact middle of the secondary winding of a transformer, it is known as a center-tapped transformer. The upper part of the secondary winding produces a positive voltage V1, and the lower part has center-tapped a negative voltage V2. When we combine these two voltages at output load, we get a complete AC signal.



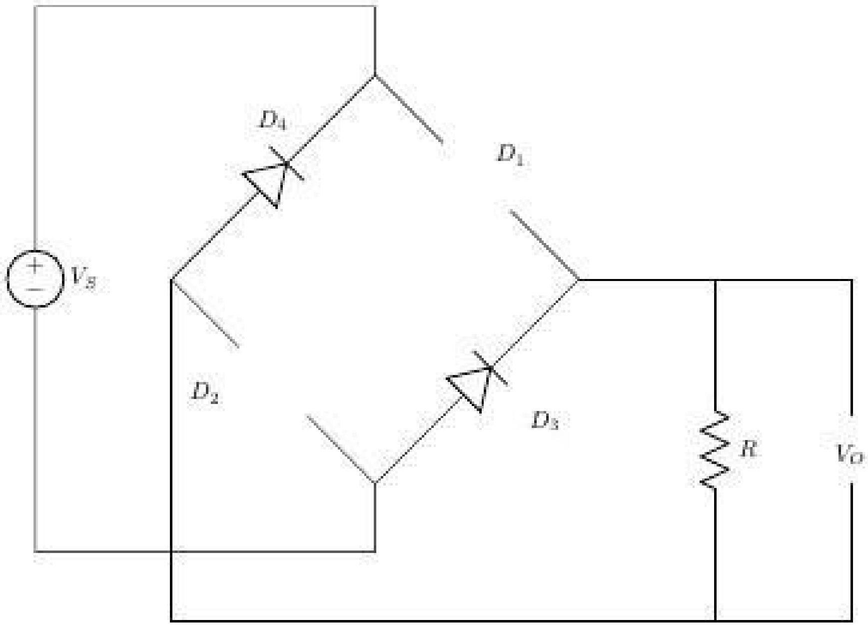
- <u>Full wave Bridge rectifier:</u>
  - Bridge rectifier circuit comprises four diodes D1, D2, D3, D4, and a load resistor RL. The four diodes are connected in a closed-loop configuration to efficiently convert the alternating current (AC) into Direct Current (DC). The main advantage of this configuration is the absence of the expensive center-tapped transformer. Therefore, the size and cost are reduced.



  - <u>Bridge Rectifier – Positive Half Cycle:</u> During the positive half cycle of the supply diodes D1 and D2 conduct in series while diodes D3 and D4 are reverse biased (ideally they can be replaced with open circuits) and the current flows through the load as shown below.



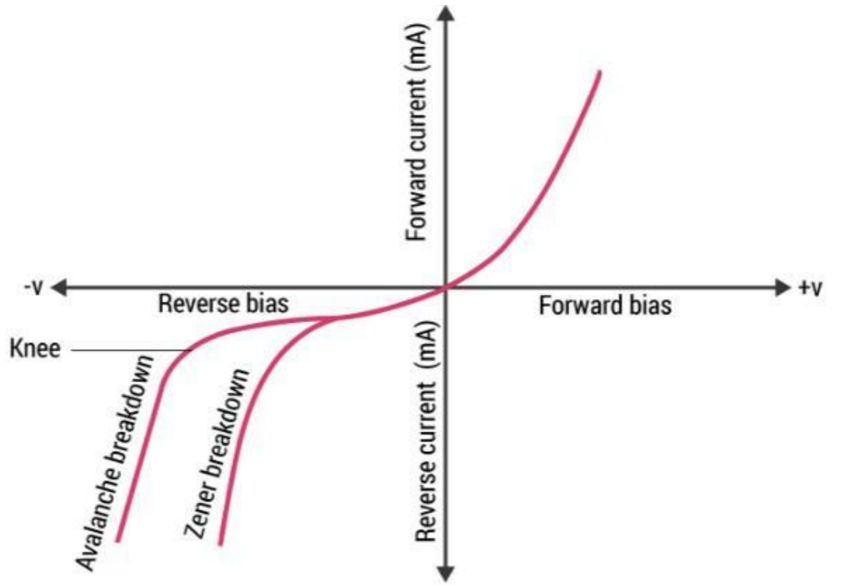
- Bridge Rectifier – Negative Half Cycle: During the negative half cycle of the supply, diodes D3 and D4 conduct in series, but diodes D1 and D2 switch off as they are now reverse biased. The current flowing through the load is the same direction as before.



- The efficiency of the bridge rectifier is higher than the efficiency of a half-wave rectifier. However, the rectifier efficiency of the bridge rectifier and the center-tapped full-wave rectifier is the same.

- Zener Diode: is also known as a breakdown diode, is a heavily doped semiconductor device designed to operate in the reverse direction. When the voltage across the terminals of a Zener diode is reversed, and the potential reaches the Zener Voltage (knee voltage), the junction breaks down, and the current flows in the reverse direction.
- Avalanche Breakdown: When a high value of reverse voltage is applied to the PN junction, the free electrons gain sufficient energy and accelerate at high velocities. These free electrons moving at high velocity collide with other atoms and knock off more electrons. Due to this continuous collision, a large number of free electrons are generated due to the electric current in the diode rapidly increasing.
- Zener Breakdown: When the applied reverse bias voltage reaches closer to the Zener voltage, the electric field in the depletion region gets strong enough to pull

electrons from their valence band. The valence electrons that gain sufficient energy from the strong electric field of the depletion region break free from the parent atom. At the Zener breakdown region, a slight increase in the voltage results in a rapid rise of the electric current.

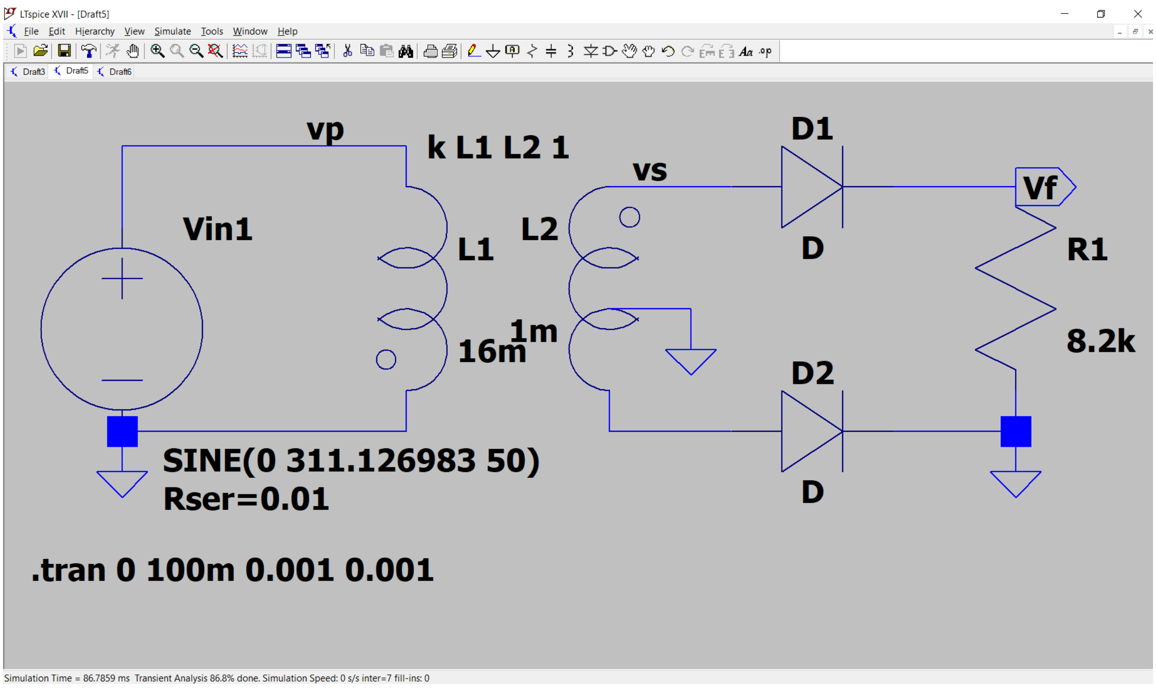


When reverse-biased voltage is applied to a Zener diode, it allows only a small amount of leakage current until the voltage is less than Zener voltage.

Circuit (hand-drawn/image):

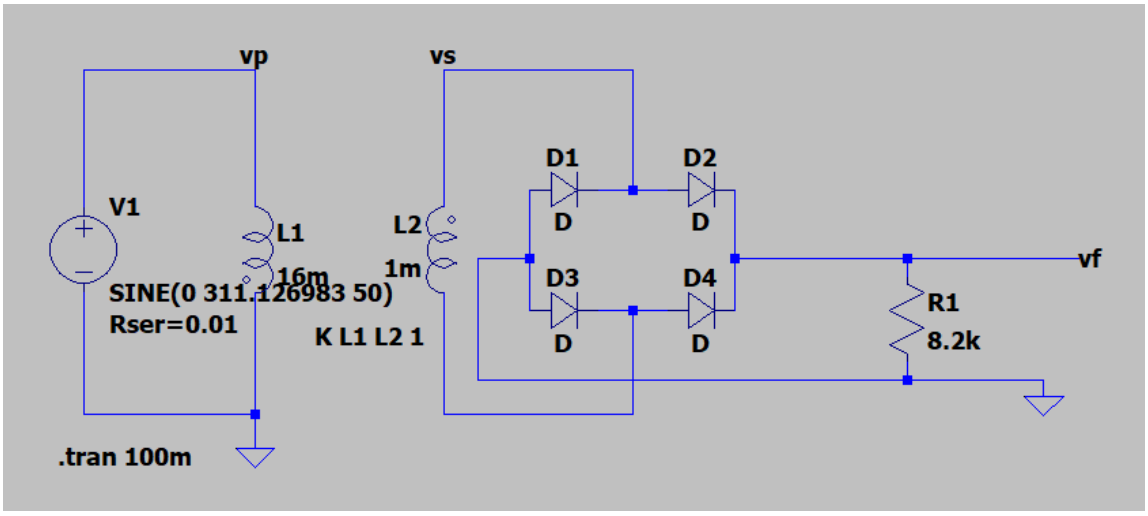
Full-wave with center-tapped transformer-

- Circuit-1: Pulsatile DC-

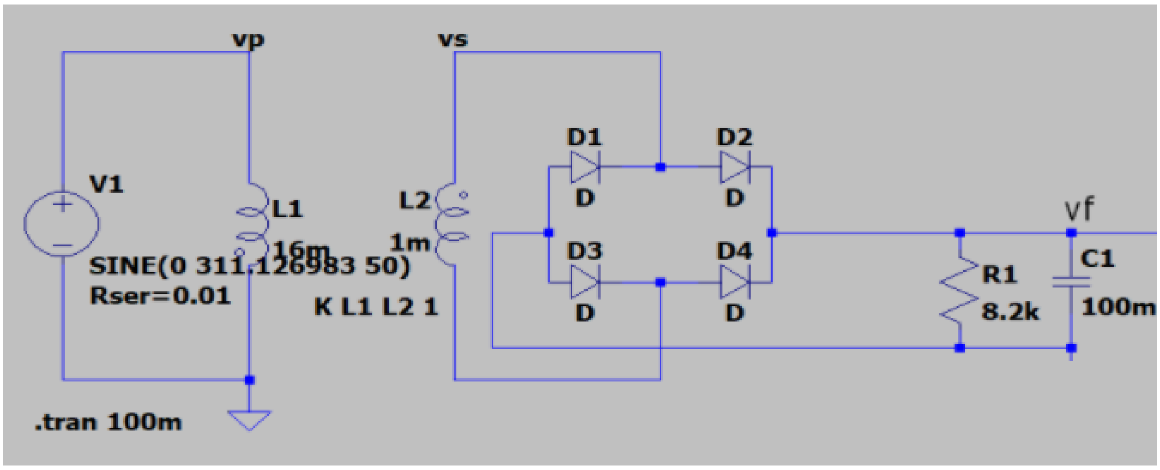


Full-wave rectifier-

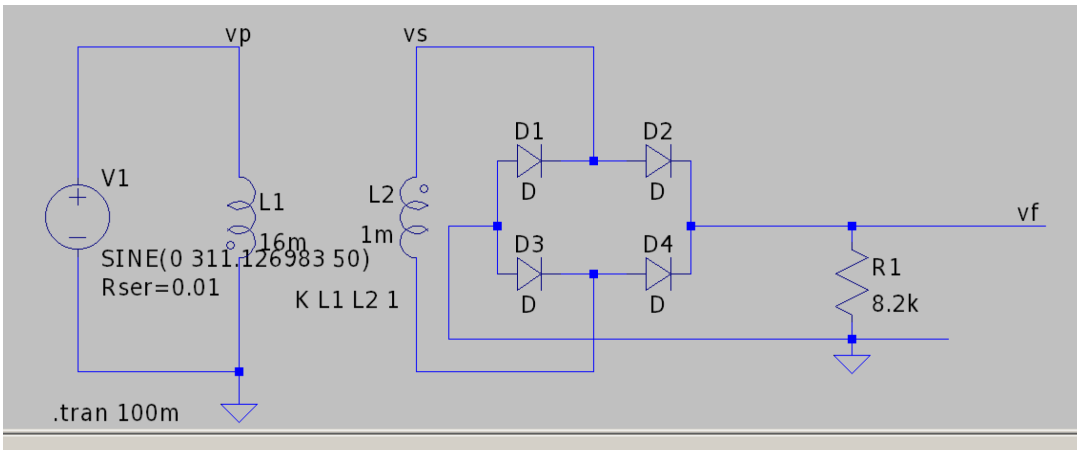
- Circuit-1: Pulsatile DC-



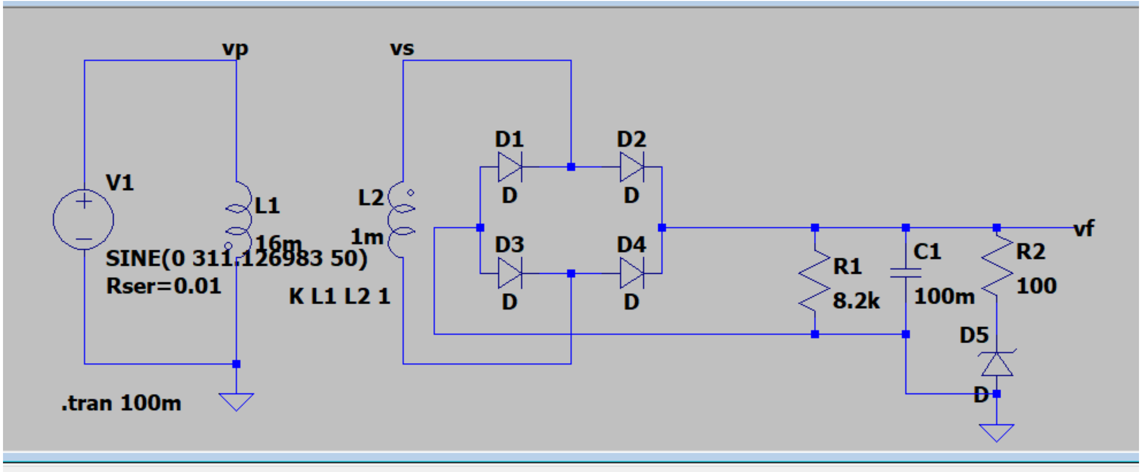
- Circuit-2: When a low pass filter is included-



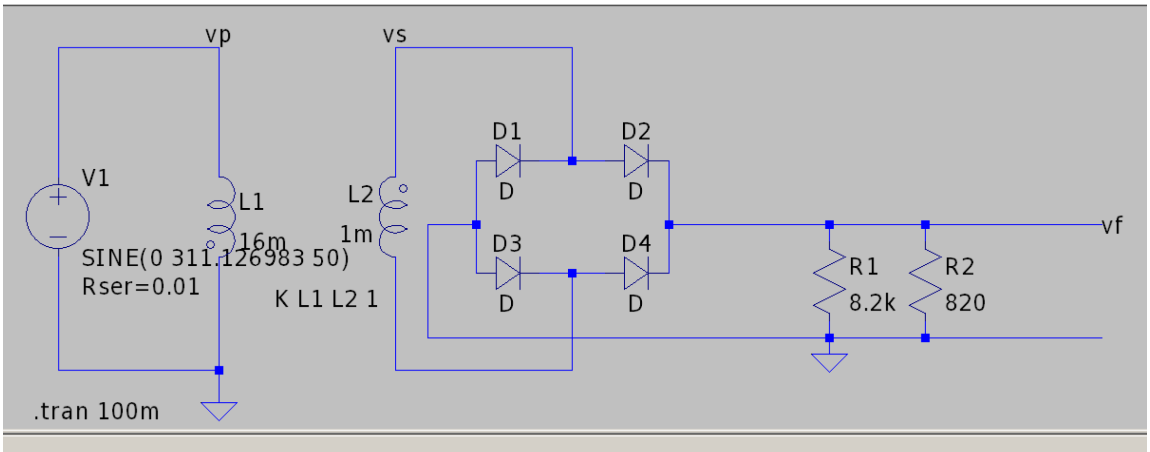
- Circuit-3: Voltage regulator-
    - When no load is connected-
        - Circuit-4: Without a filter-



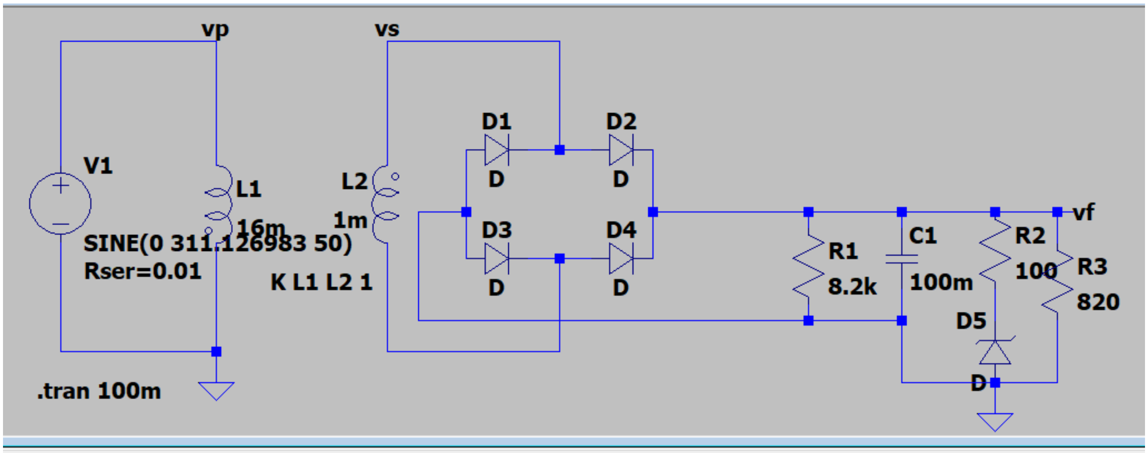
- Circuit-5: With a filter-



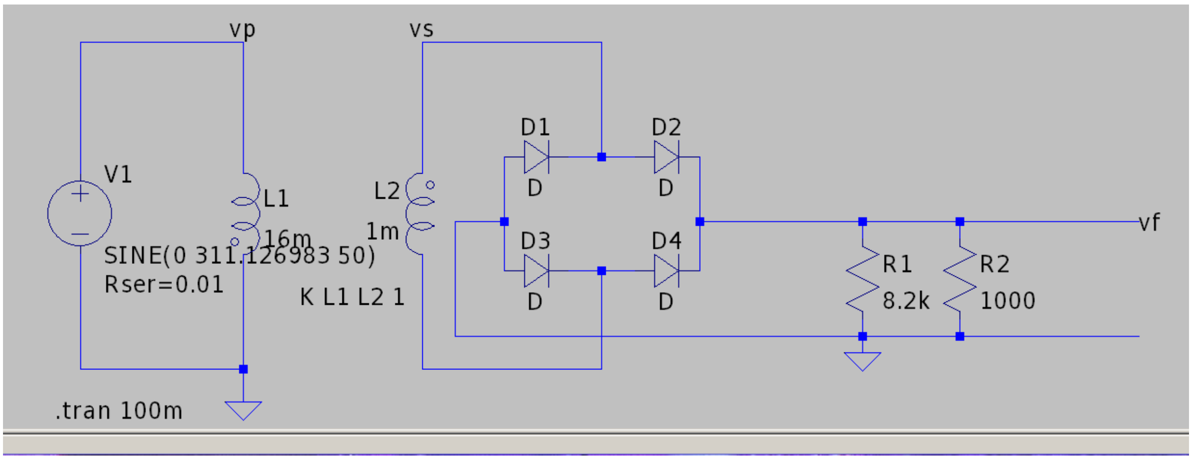
- When load-1 is connected-
  - Circuit-6: Without a filter-



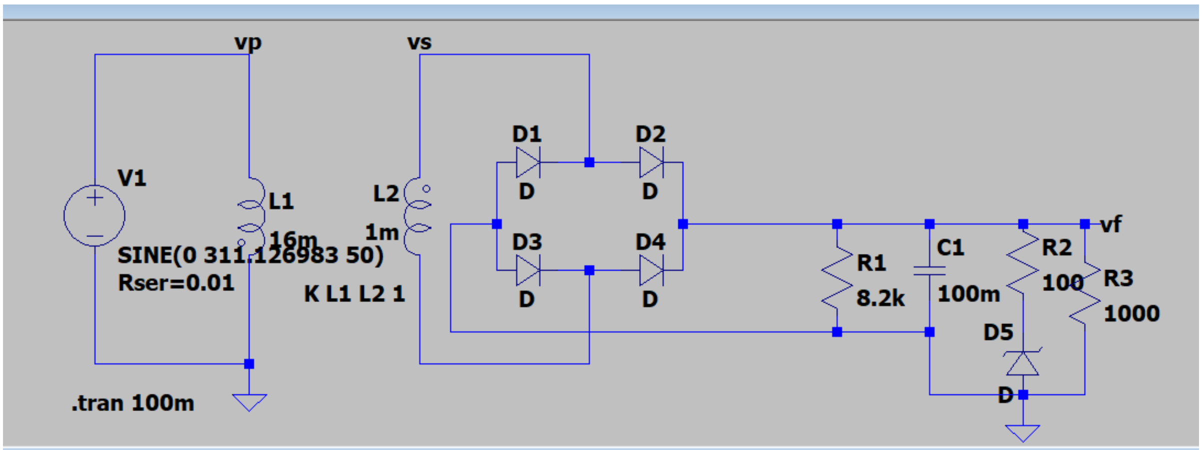
- Circuit-7: With a filter-



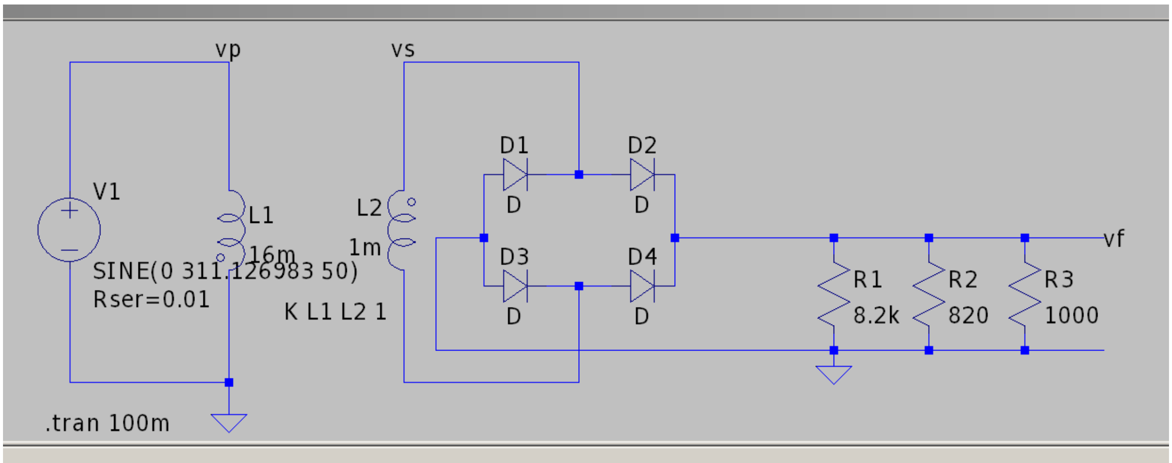
- When load-2 is connected-
  - Circuit-8: Without a filter-



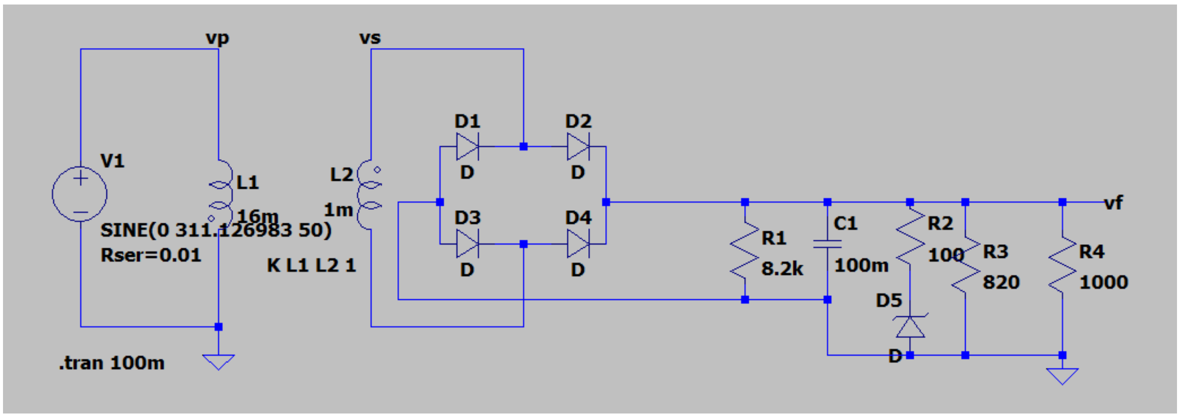
- Circuit-9: With a filter-



- When load-1 and load-2 are connected-
  - Circuit-10: Without a filter-



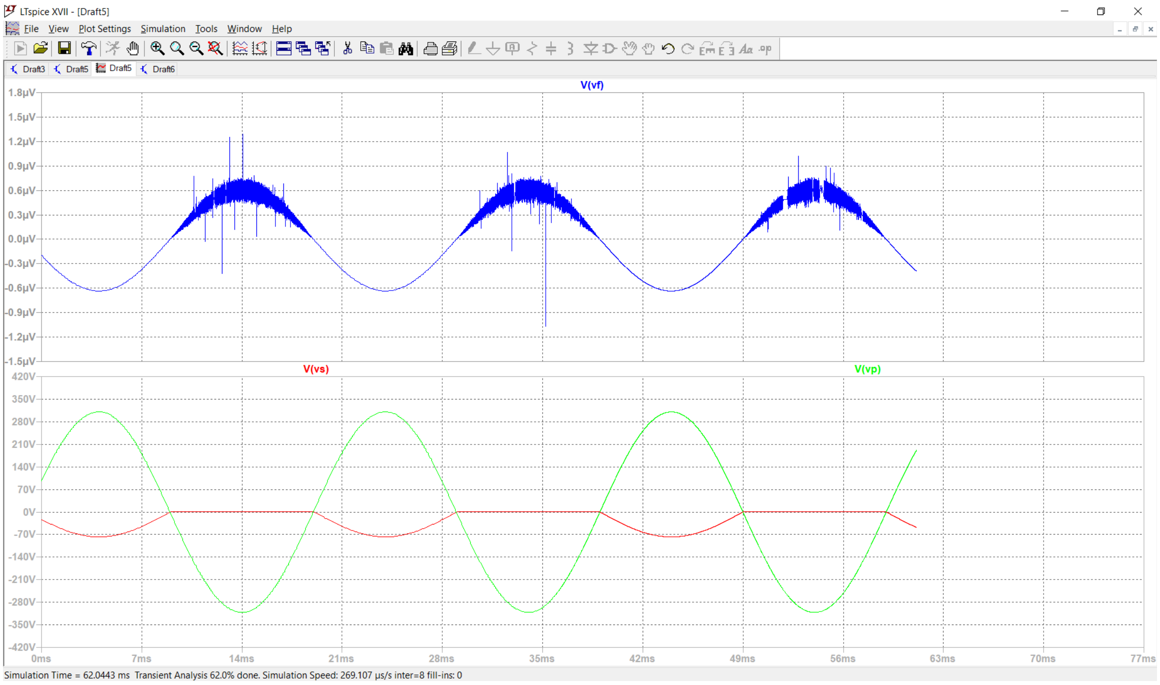
- Circuit-11: With a filter-



Graphs (Image/Screenshots):

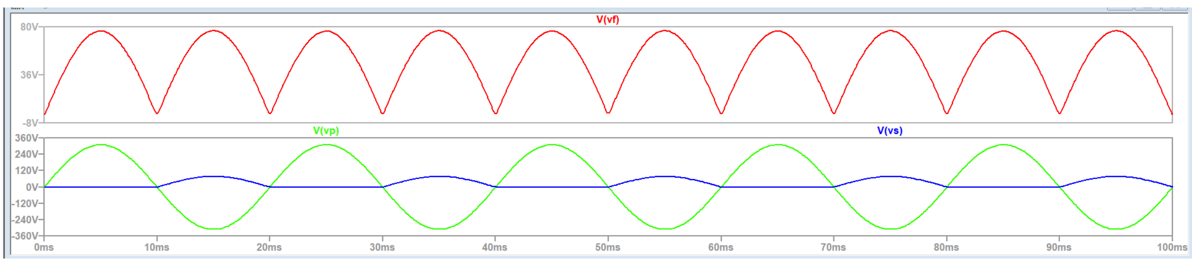
Full-wave with center-tapped transformer-

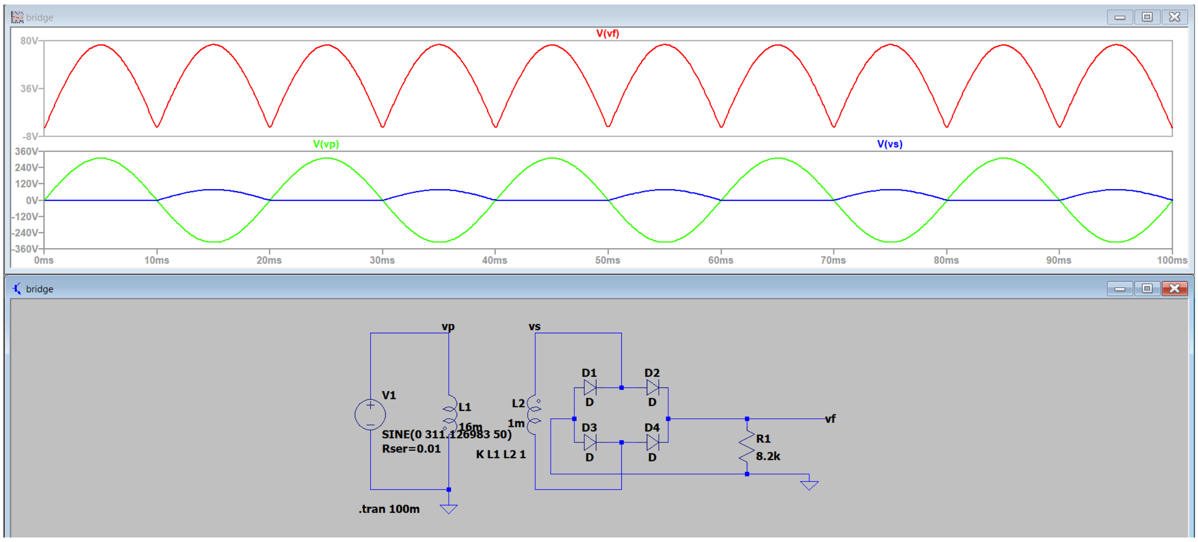
- Circuit-1: Pulsatile DC-



Full-wave rectifier-

- Graph of Circuit-1: Pulsatile DC-





Voltage Waveforms-
The final output waveform is represented by V(vf), a red colored waveform.

[Observation: Both positive and negative half cycles of the AC voltage is passed to the output side]

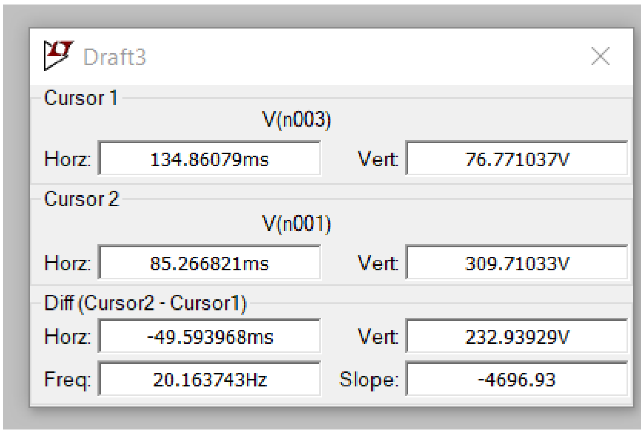
<u>Calculations-</u>
Theoretical Calculations -
$V_m = 76.771037$ V

$$V_{DC} = \frac{2 \bullet V_M}{\pi} = 24.437\ Volts$$

$$I_{DC} = \frac{2 \bullet I_M}{\pi}$$

$$I_{RMS} = \frac{I_M}{\sqrt{2}}$$

Ripple factor = $\sqrt{\left(\frac{I_{RMS}}{I_{DC}}\right)^2 - 1} = 0.48$



Clearly, from the graph, V_m = 76.771037V

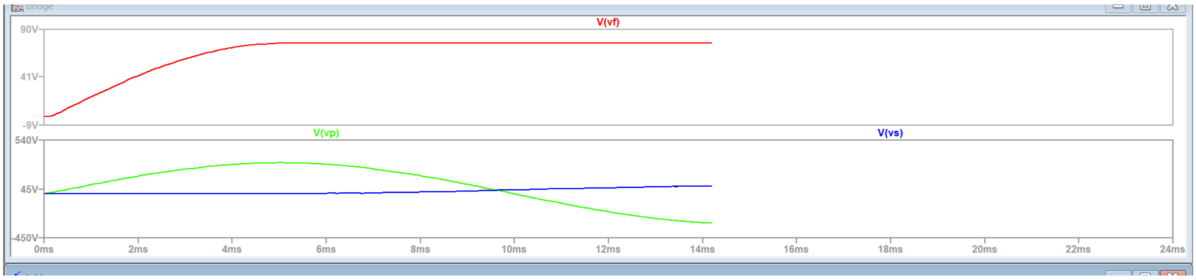
$$V_{DC} = \frac{2 \bullet V_M}{\pi} = 48.87396\,Volts$$

$$V_{RMS} = \frac{V_M}{2}$$

Ripple factor = $\frac{V_{RMS}}{V_{DC}} = 0.48$

Therefore, the theoretical value of the ripple factor is 0.48 which is the calculated value of the ripple factor using the values of voltages obtained from the graph.

- Graph of Circuit-2: When a low pass filter is included-



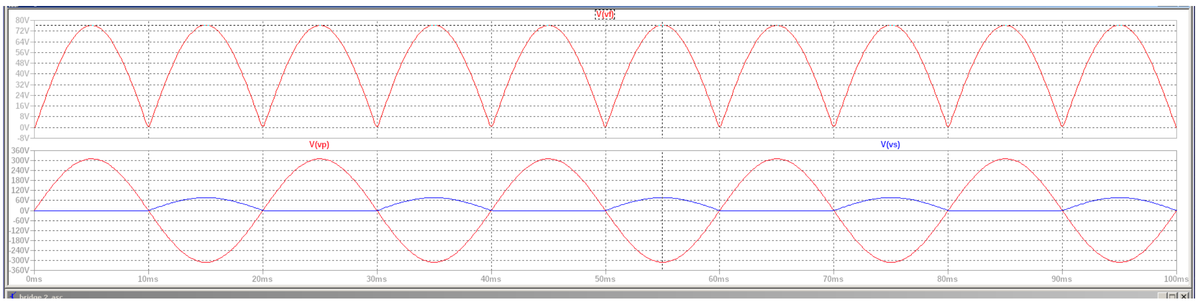
Voltage Waveforms-
The final output voltage is represented by V(vf), a red coloured waveform as shown in the second plot.
Including a low pass filter, the output voltage is a steady DC voltage.

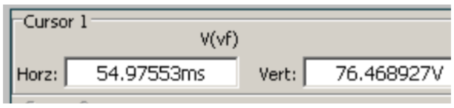
Calculations-

$f = 50Hz, R = 8.2k,\ C = 100mF$

Ripple factor $= \frac{1}{4\sqrt{3}fCR} = 3.52 \times 10^{-6}$

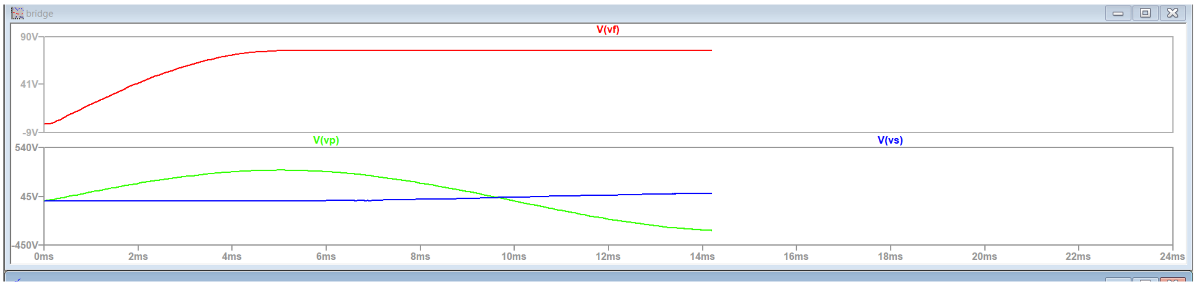
- Graph of Circuit-3: Voltage regulator-
  - When no load is connected-
    - Graph of Circuit-4: Without a filter-



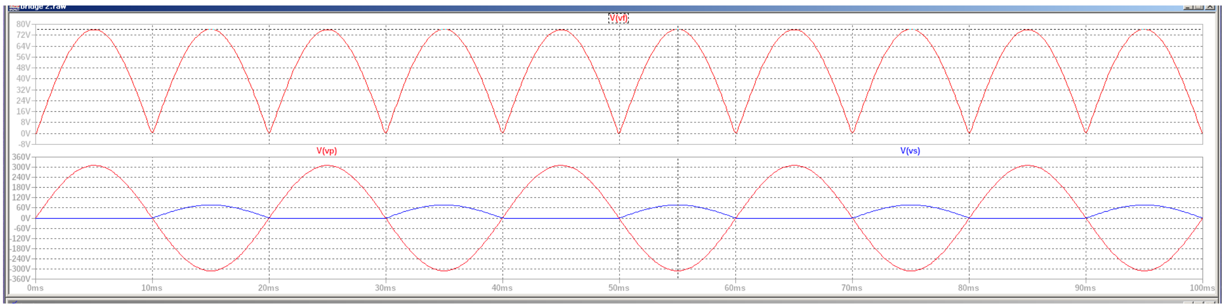


From the graph, it's clear that V_{NL} = V(vf) = 76.468927 V.

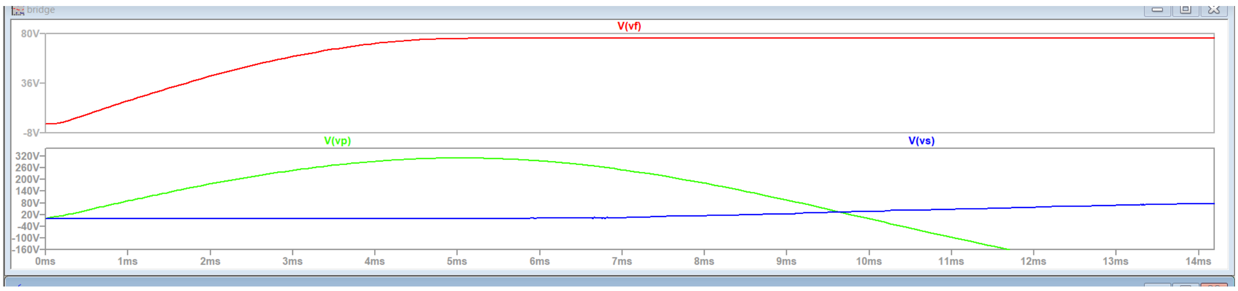
- Graph of Circuit-5: With a filter-



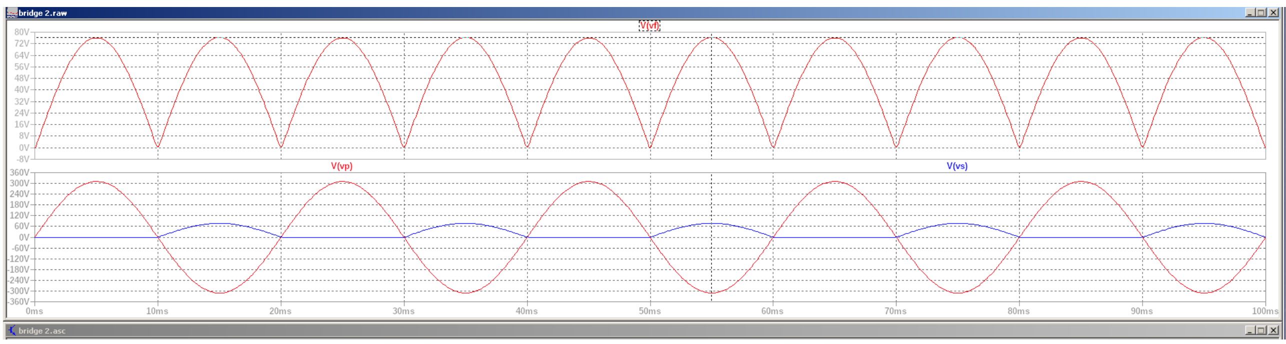
- When load-1 is connected-
  - Graph of Circuit-6: Without a filter-



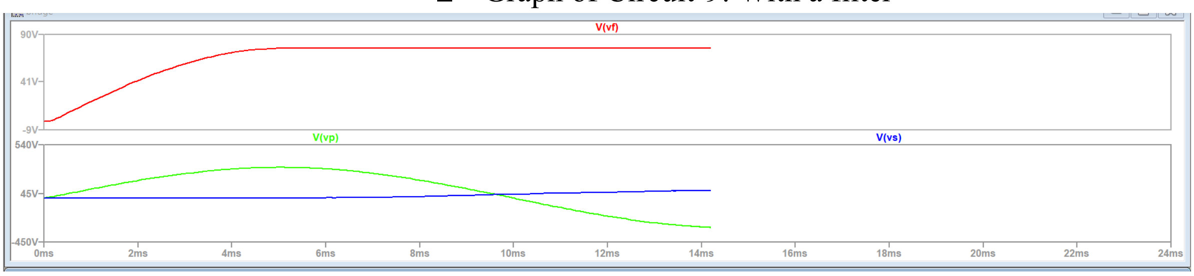
- Graph of Circuit-7: With a filter-



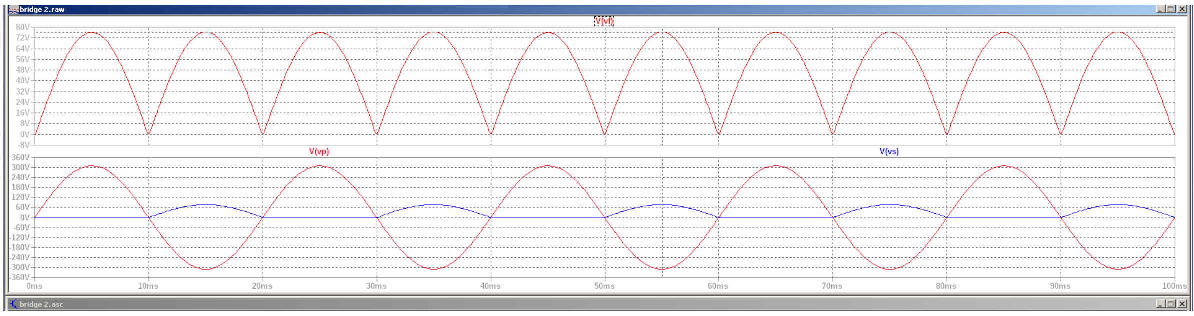
- When load-2 is connected-
  - Graph of Circuit-8: Without a filter-

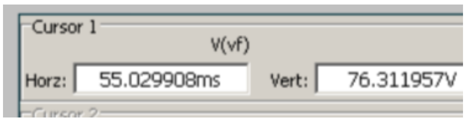


- Graph of Circuit-9: With a filter-



- When load-1 and load-2 are connected-
    - Graph of Circuit-10: Without a filter-



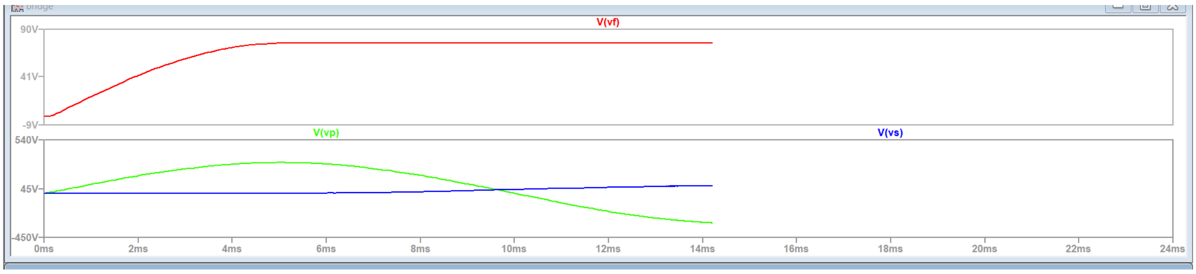


Calculations-

From the graph, it's clear that V_{FL} = 76.311957V

Voltage Regulation = $\frac{V_{NL}-V_{FL}}{V_{FL}} = \frac{76.468927 - 76.311957}{76.311957} = 0.0151$

- Graph of Circuit-11: With a filter-



Conclusion:

Full wave with center-tapped transformer is the same as Bridge Wave Rectifier. Both center tap and bridge have their own merits and demerits. In case of a full-wave with center tapped transformer, the ripple factor is much less than that of a half-wave rectifier. It is expensive to manufacture a center-tapped transformer that produces an equal voltage on each half of the secondary windings. The output voltage is half of the secondary voltage, as each diode utilizes only one-half of the transformer's secondary voltage.

Full-wave Bridge rectifier - It is evident that the output is obtained for both the positive and negative half-cycles. It is also observed that the output across the load resistor is in the same direction for both the half cycles. The need for a center-tapped transformer is eliminated. If stepping up or stepping down of AC voltage is not needed, it does not even require any transformer. The transformer is less costly as it is necessary to provide only half the voltage of an equivalent center-tapped transformer used in a full-wave rectifier. It requires four semiconducting diodes. Two diodes in series conduct at a time on alternate half-cycles. This creates a problem when low DC voltages are required. This leads to poor voltage regulation.

In the case of full-wave rectifiers, a complete input signal was allowed to pass through and both parts were transformed to the same polarity. Using a capacitor as a filter helped to smoothen out the output signal, reducing the ripple effect. Finally, using a Zener diode in a voltage-regulated DC circuit, we were able to observe the properties of a Zener diode and its behaviour in the break-down region. The output voltage for Zener Diode - Line Regulator became constant and was equal to the Zener voltage, for all input values greater than or equal to the Zener voltage. All this behaviour is a result of the special property of semiconductor diodes which allows current to flow when forward biased but not as easy when reversing biased.

The theoretical principles of rectifiers and diodes have been verified in this experiment.

Discussions:

1. When a standard AC waveform is passed through a full-wave rectifier, It rectifies both positive and negative half cycles. 2 paths of diodes will be used in the circuit and one of them will be forward biased during each half cycle giving a continuous, positive DC output.
2. As seen in the graph, the amplitude of the output waveform is slightly less than the amplitude of the input waveform because the diode is not ideal and has a nonzero barrier potential.
3. The ripple factor of the full wave rectifier is 0.482. This value matches with that of the value calculated using values from the graph, and the theoretical values.
4. Full wave rectifiers have higher rectifying efficiency than half-wave rectifiers. This means that they convert AC to DC more efficiently. They have low power loss because no voltage signal is wasted in the rectification process. But, a main disadvantage is that, The centre-tapped rectifier is more expensive than half-wave rectifier and tends to occupy a lot of space.
5. The Centre tapped Rectifier consists of two diodes which are connected to the centre tapped secondary winding of the transformer as well as with the load resistor.
6. Bridge rectifier comprises 4 diodes which are connected in the form of Wheatstone bridge and thus provide full wave rectification.
7. The advantage of using Bridge rectifier is that no centre tapping is required. Thus, we can eliminate the transformer from the circuit, if the step-down voltage is not required. Although, a bridge rectifier also possesses some drawbacks, among which one of the drawbacks is the voltage drop across four diodes.
8. Full wave rectifiers are mainly used in soldering, in AM radio and also for detecting the amplitude of a modulating signal.
9. When capacitive filtering is applied to a rectifier, for the first quarter of the positive cycle of the input voltage, the capacitor will charge up to the supply maximum voltage Vp. For the second quarter of the positive cycle, the diode will become reverse biased So, for the rest of the cycle, the capacitor will provide current to the load and discharge until the supply voltage becomes more than that of capacitor voltage. As the input voltage becomes greater than the capacitor voltage the capacitor will again start charging.
10. Capacitor is used in rectifier circuits to get constant DC signal(ideally) but in practical less fluctuating DC rather than pulsating DC. It is really important in circuitry because highly fluctuating DC may bring harm to many electrical components. If capacitance value is large, due to which the discharging time constant of capacitor load resistance circuit will be more and hence falling part(discharging part) of the curve will tend to

be flat which indicates less fluctuation as DC signal is almost flat signal.

11. For low-frequency signals, the capacitor offers extremely high resistance and for high-frequency signals, it proves less resistance. The line filter capacitor is applicable in several industrial loads as well as appliances in order to defend the appliance from the noise of line voltage noise and to defend other devices on a similar line from the generated noise within the circuit.