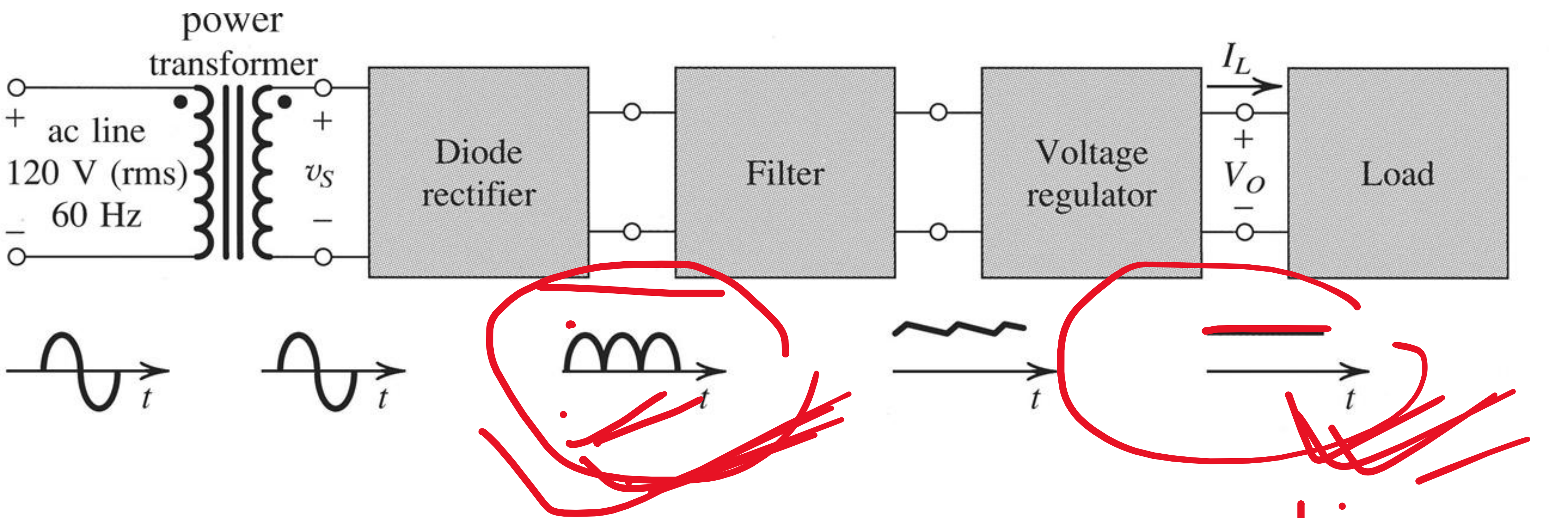
Rectifier with Filter

Semiconductor Devices and Circuits

(ECE 181302)

26th November 2021

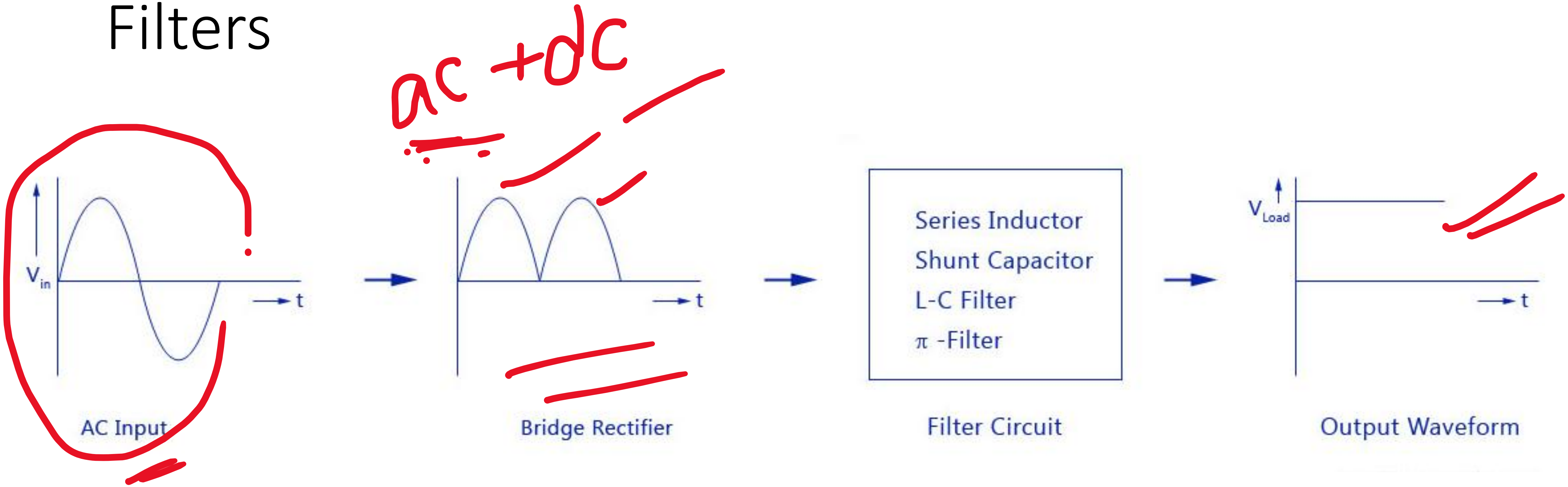


- The output from the rectifier section is a pulsating DC.

- The filter circuit reduces the peak-to-peak pulses to a small ripple voltage.

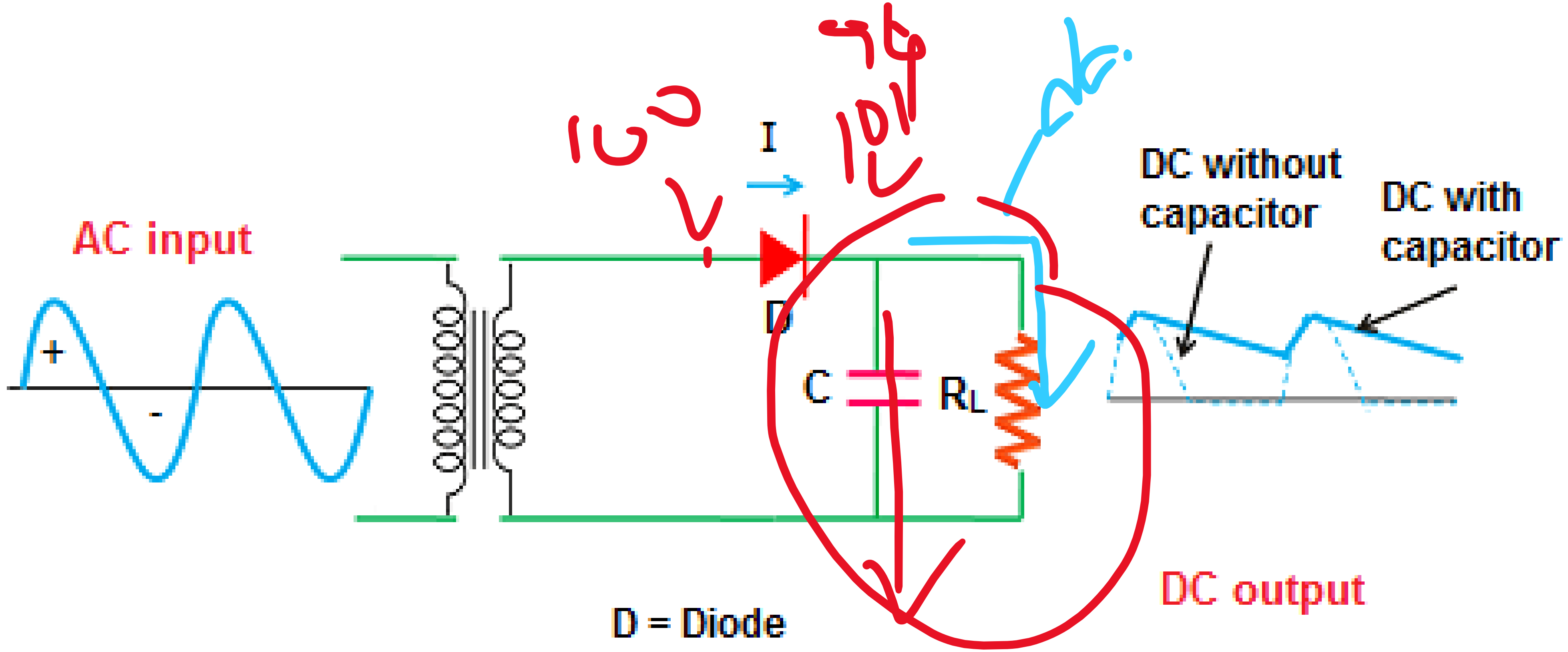
- The current at the output is not a pure Direct Current (DC) rather a pulsating current.
- The pulsating current fluctuates with respect to time.
- The pulsating DC contains both AC and DC components.
- A fluctuating DC is not useful in most of applications.
- DC component of the output is useful but AC component is not.
- We need a DC that does not fluctuate.
- We need to reduce or completely remove the AC components at the output.
- The solution is a filter.

Filters



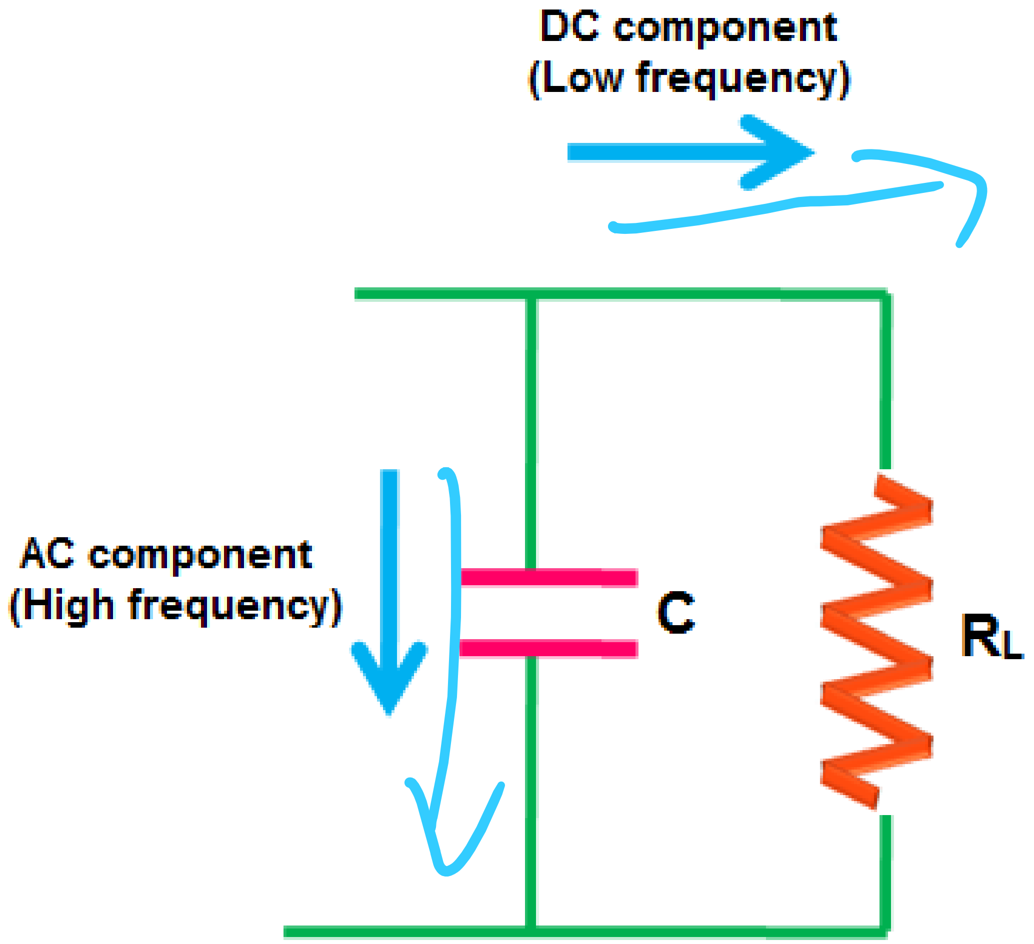
- Filter circuits are combination of capacitors, resistors, and inductors.
- A capacitor allows the ac component and blocks the dc component.
- An inductor allows the dc component and blocks the ac component.

Half-wave Rectifier with Filter



D = Diode
C = Capacitor
R_L = Load resistor
I = Current

- Capacitor provides high resistive path to DC components (low-frequency signal) and low resistive path to AC components (high-frequency signal).
- Electric current always prefers to flow through a low resistance path.
- When diode D conducts during the positive half cycle, electric current reaches the filter and the DC components experience a high resistance from the capacitor while AC components experience a low resistance from the capacitor.
- The DC components find the path of low resistance and flows through the load resistor (RL).

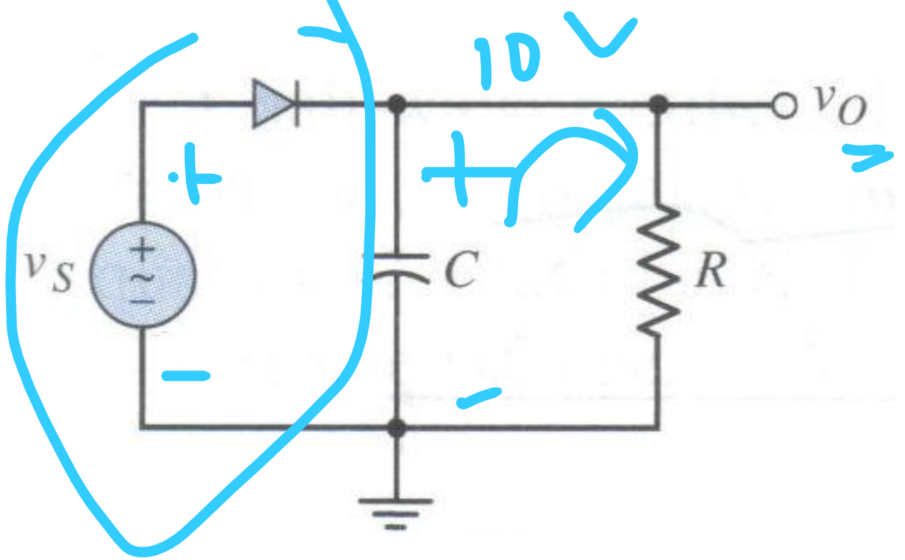


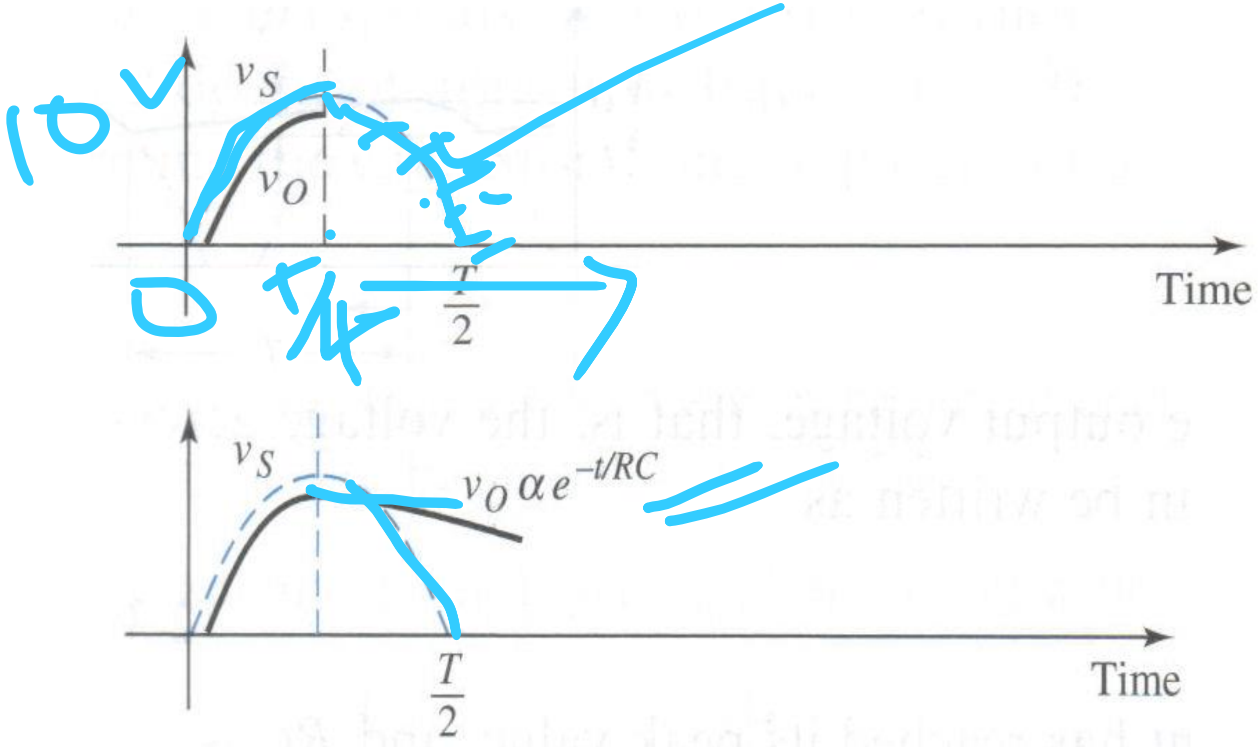
How the Filter Works

- A capacitor is added in parallel with the load resistor of a half-wave rectifier to form a simple filter circuit. At first there is no charge across the capacitor

- During the 1st quarter positive cycle, **diode is forward biased**, and C charges up.
- **$V_C = V_O = V_S - V\gamma$.**

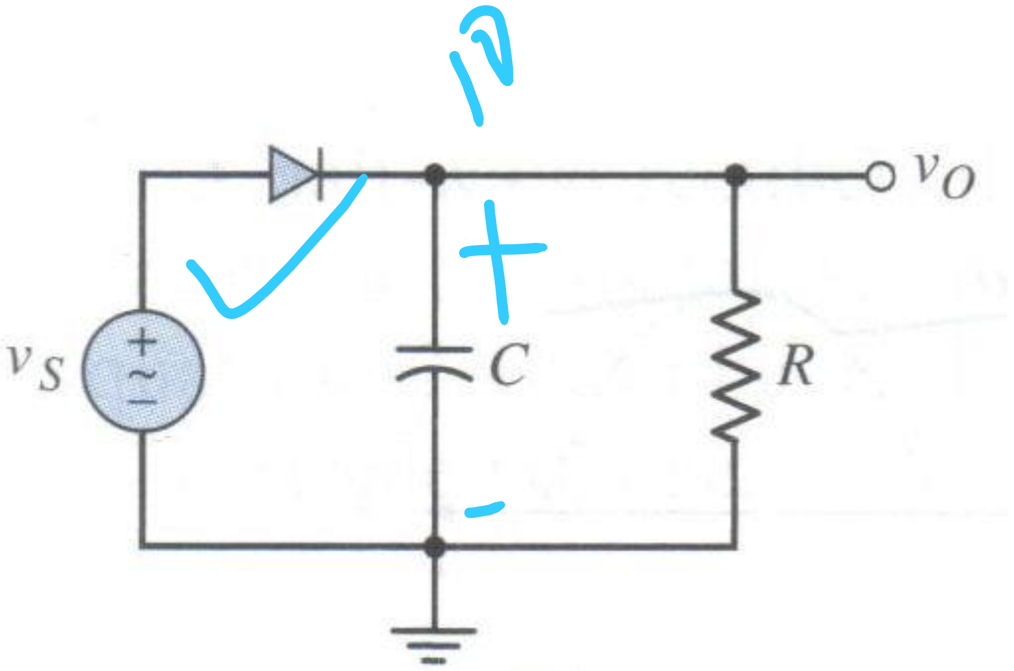
- As V_S falls back towards zero, and into the negative cycle, the capacitor discharges through the resistor R. The diode is reversed biased (turned off)
- If the *RC* time constant is large, the voltage across the capacitor discharges exponentially.



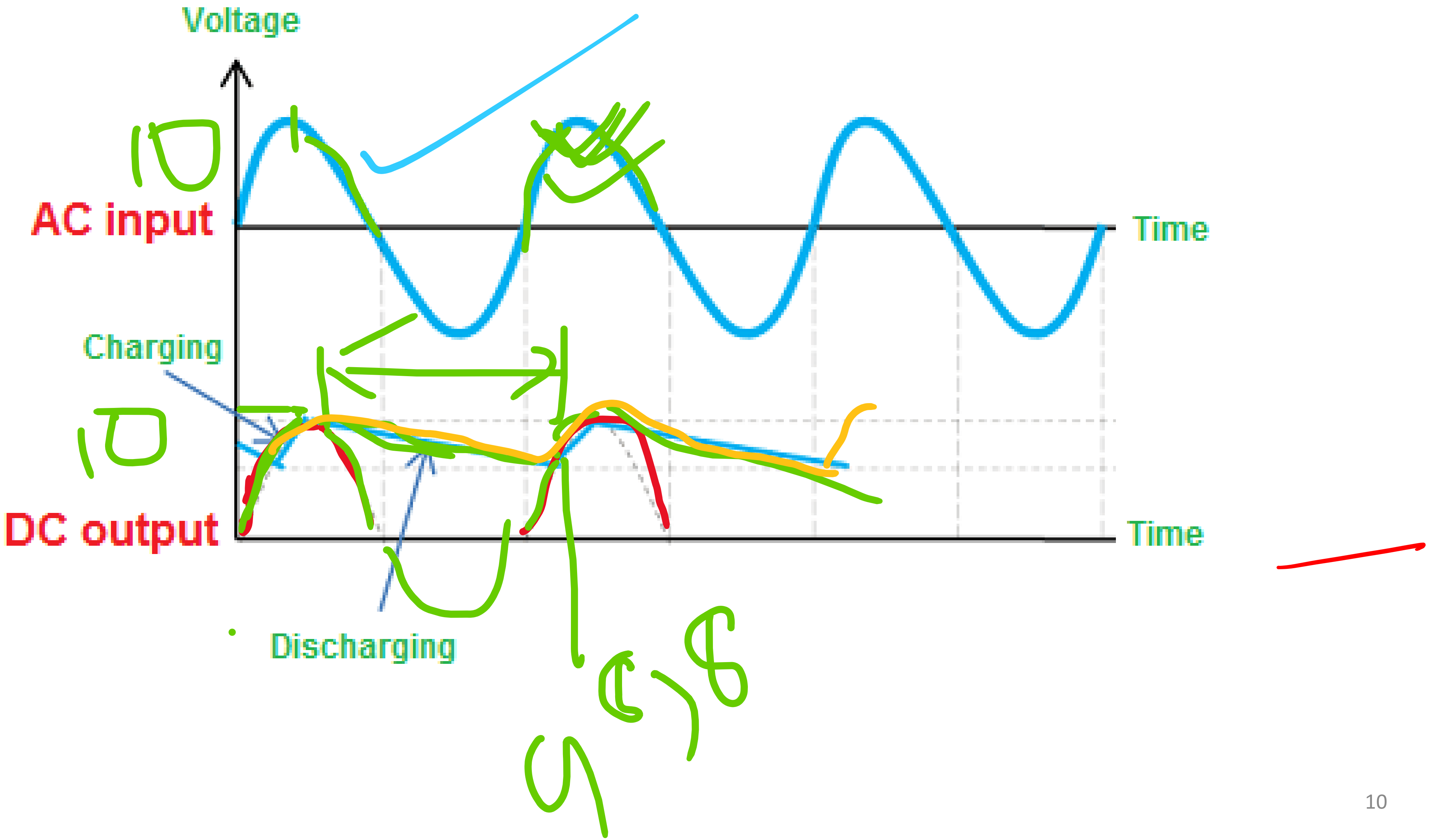


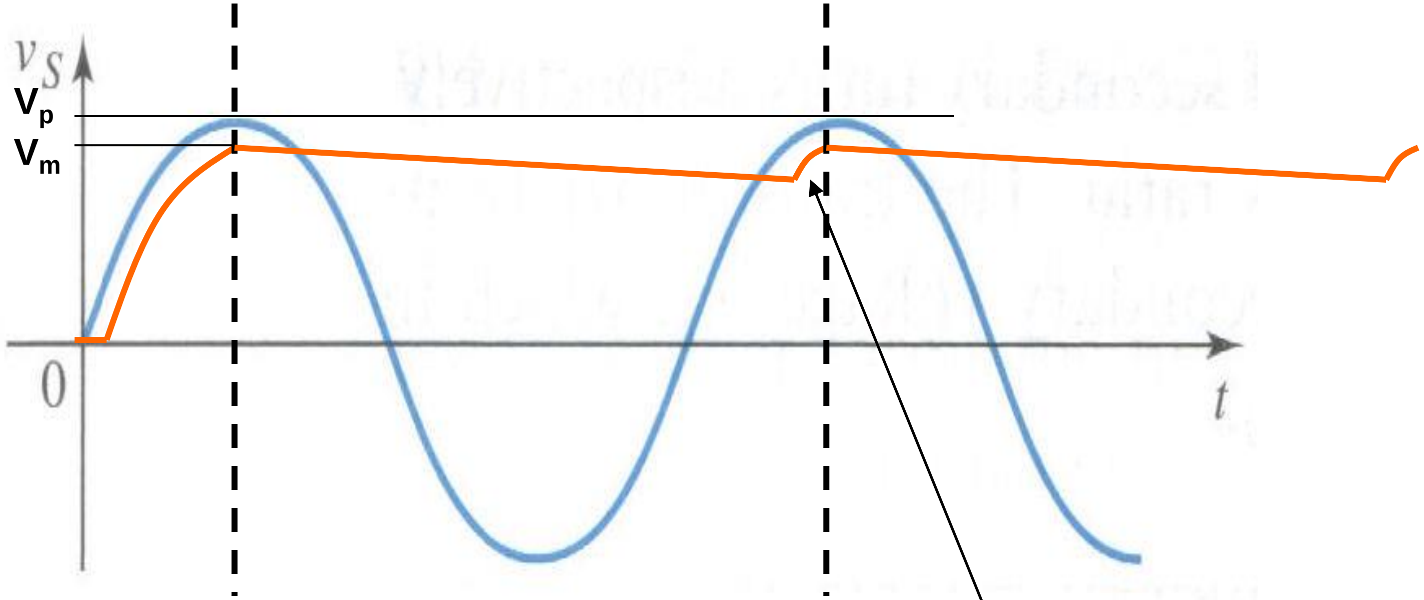
- During the next positive cycle of the input voltage, **there is a point at which the input voltage is greater than the capacitor voltage, diode turns on**.

- The diode remains **on** until the input reaches its peak value and the **capacitor voltage is completely recharged.**



- AC components experience a low resistance from the capacitor and passes easily passes through the capacitor.
- Only a small part of the ac components passes through the load resistor (R_L) producing a small ripple voltage at the output.
- The passage of AC components through the capacitor charges the capacitor.
- The AC component is nothing but an excess current that flows through the capacitor, charges it and prevents any sudden change in the voltage at the output.
- The capacitor charges to the maximum value of the supply voltage: voltage between the plates of the capacitor is equal to the supply voltage.


Voltage
10
AC input
Time
Charging
10
DC output
Time
Discharging



Quarter cycle; capacitor charges up

Capacitor discharges through R since diode becomes off

$$\boxed{V_C = V_m e^{-t/RC}}$$

Input voltage is greater than the capacitor voltage; recharge before discharging again

NOTE: V_m is the <u>peak value</u> of the capacitor voltage = V_P - $V\gamma$

Since the capacitor filters out a large portion of the sinusoidal signal, it is called a **filter capacitor**.

Ripple Voltage, and Diode Current

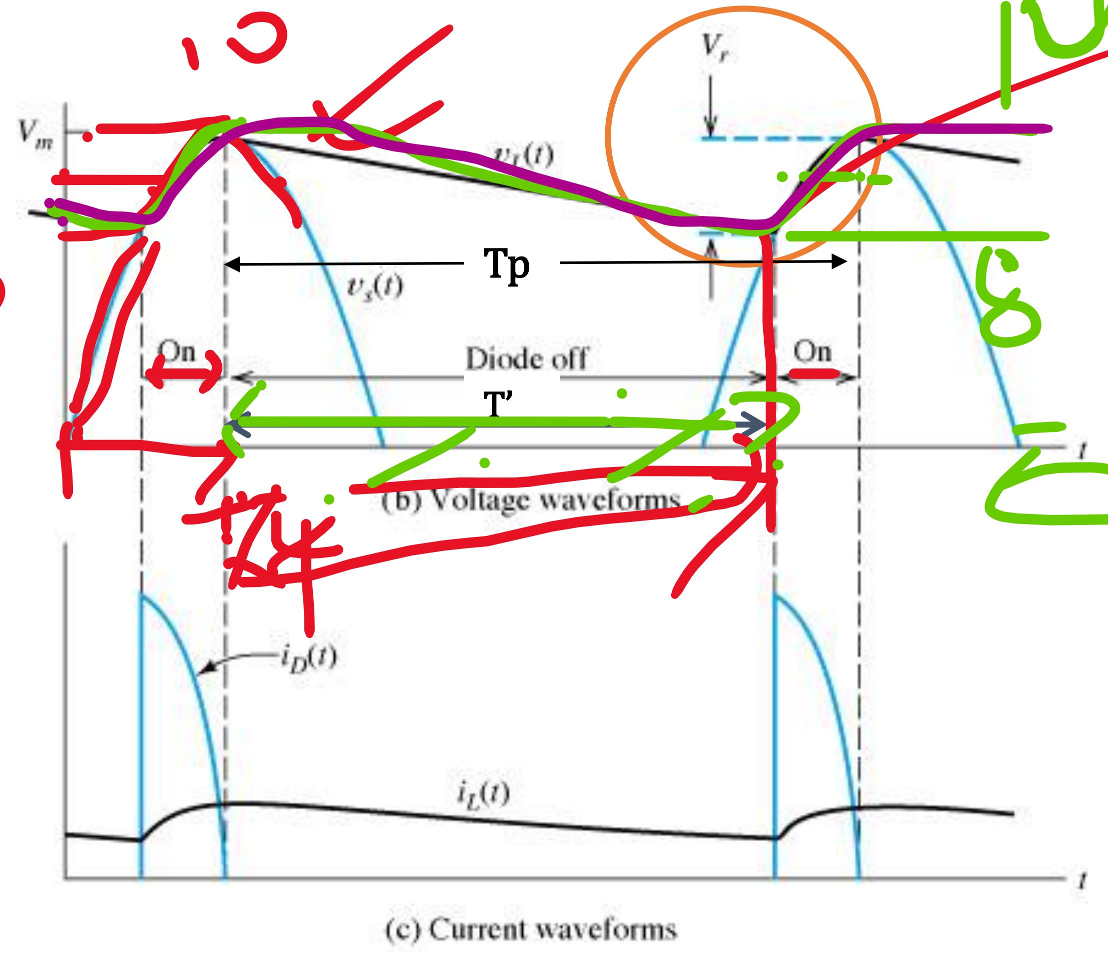


Figure: Half-wave rectifier with smoothing capacitor.

- V_r = ripple voltage
- $V_r = V_M - V_M e^{-T'/RC}$

where T' = time of the capacitor to discharge **to its lowest value**

$$\boxed{V_r = V_M \left(1 - e^{-T'/RC} \right)}$$

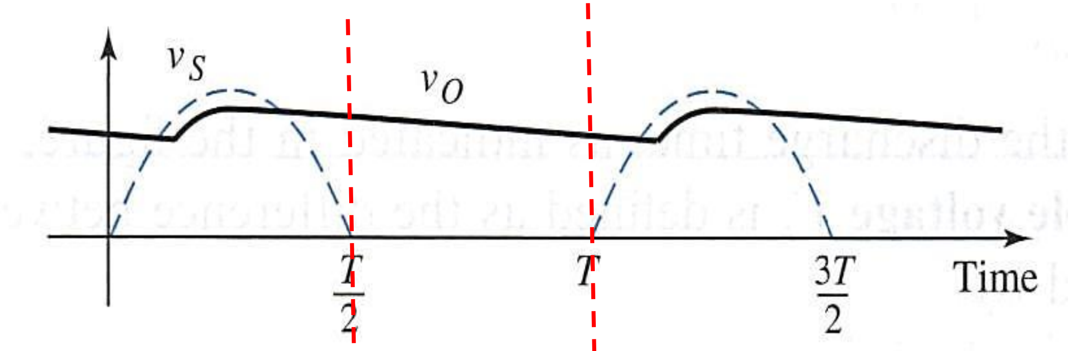
Expand the exponential in series,

$V_r = (V_M T') / RC$

- If the ripple is very small, we can approximate $T' = T_p$ which is the period of the input signal
- Hence for half wave rectifier

$V_r = (V_M T_p) / RC$

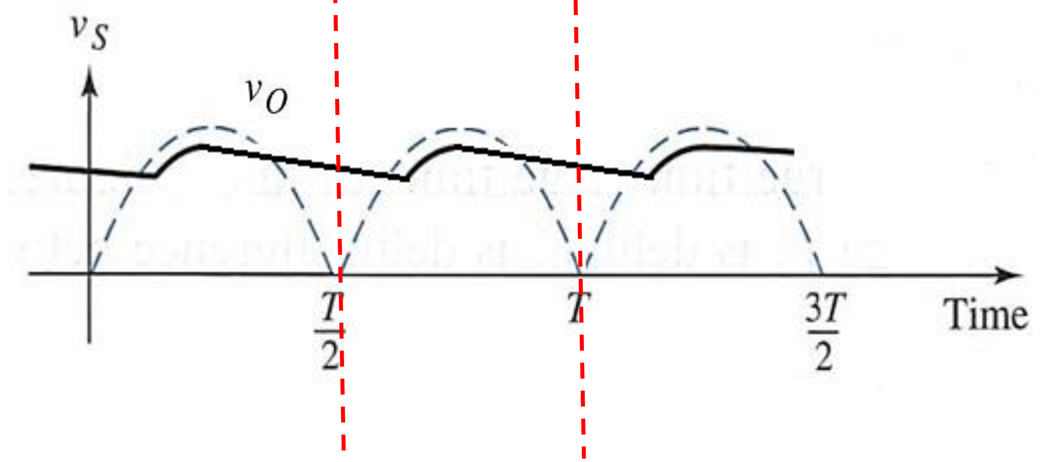
$$V_r = \frac{V_M}{fRC}$$

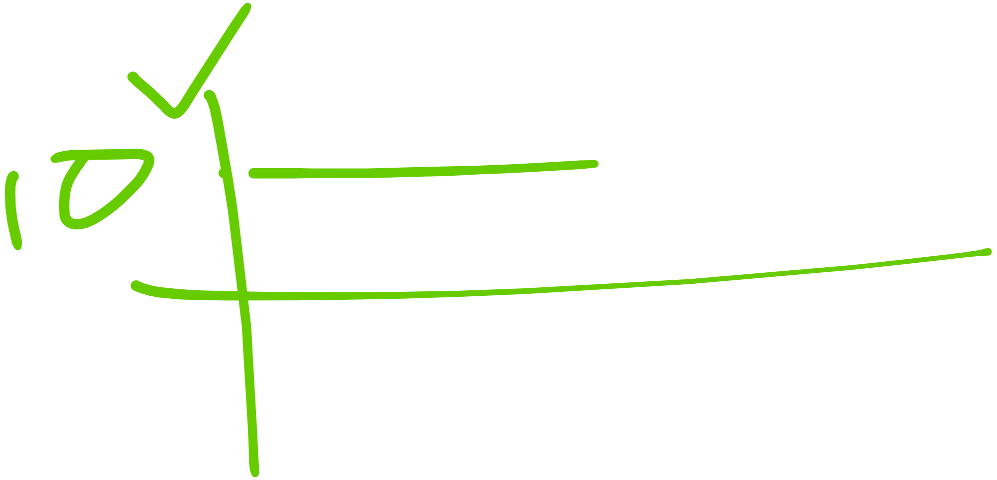


- For full wave rectifier

$V_r = (V_M 0.5T_p) / RC$

$$V_r = \frac{V_M}{2fRC}$$





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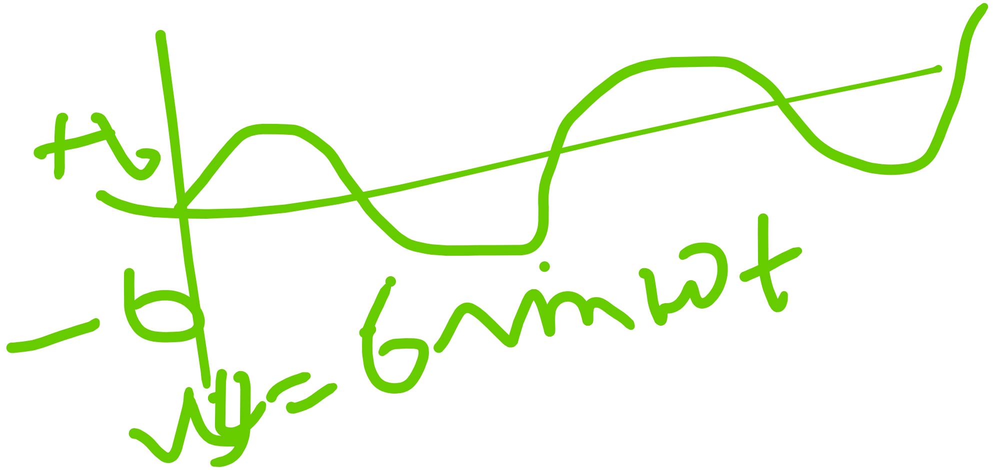

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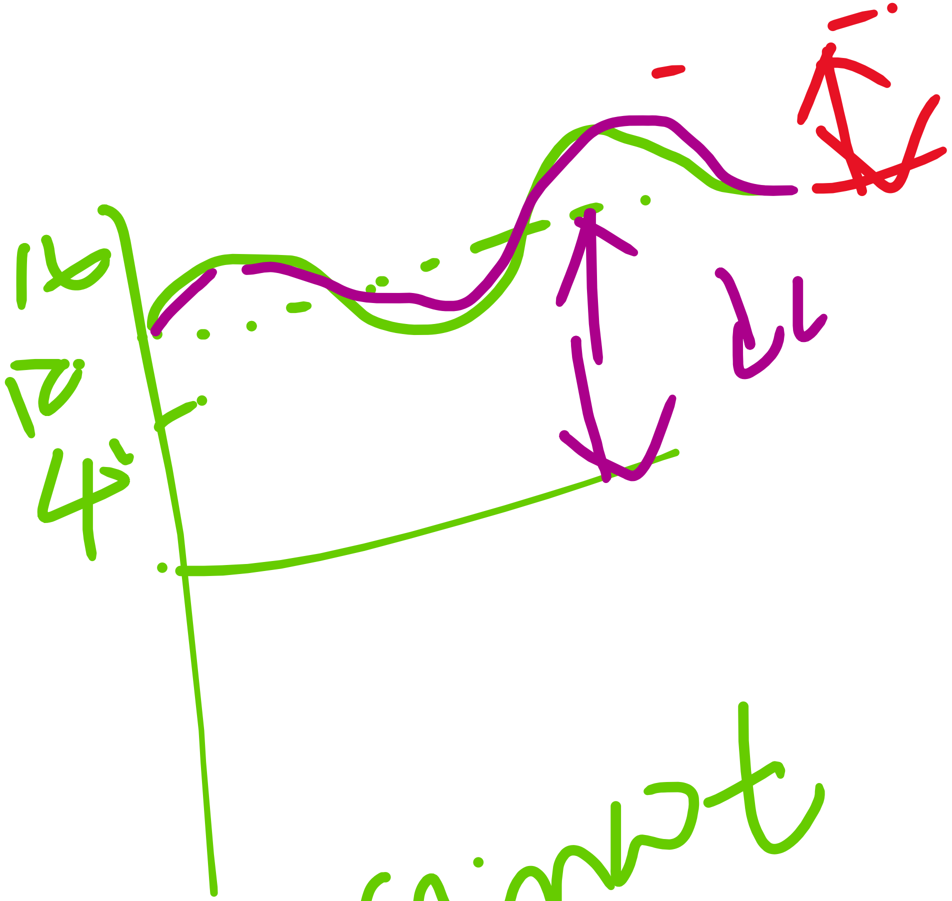


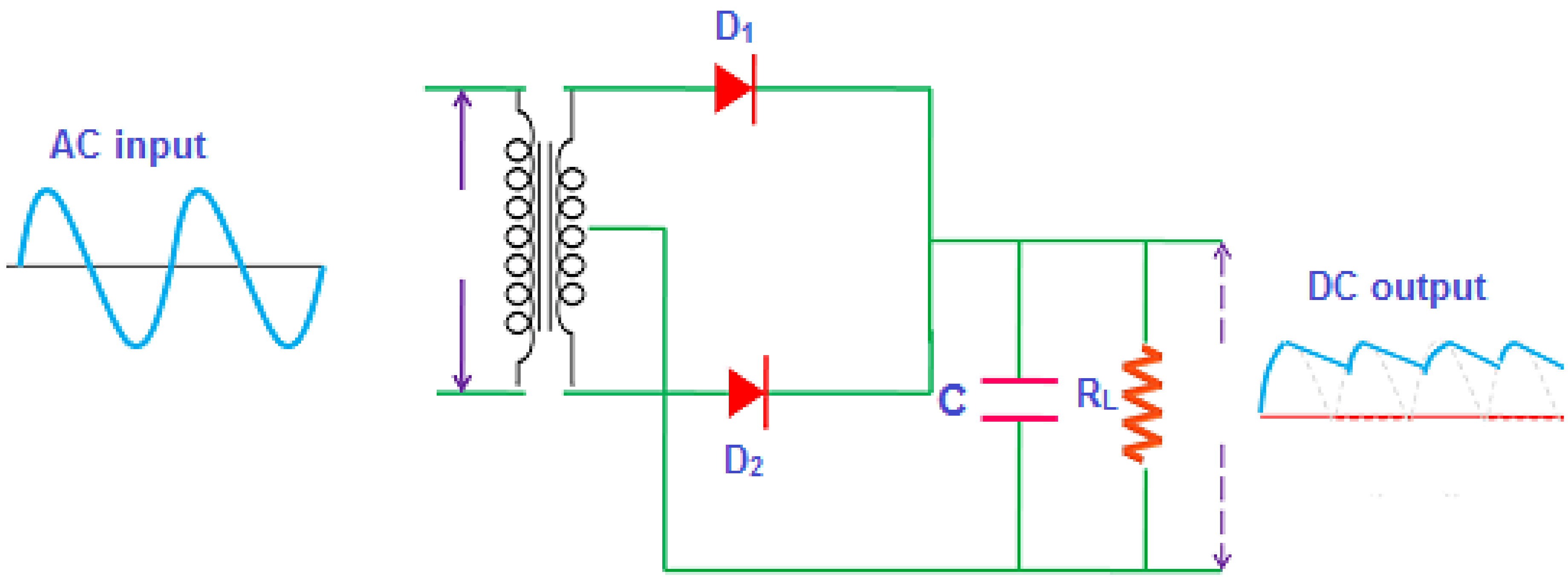
$= 10 + 6\sin\omega t$

DC   ac

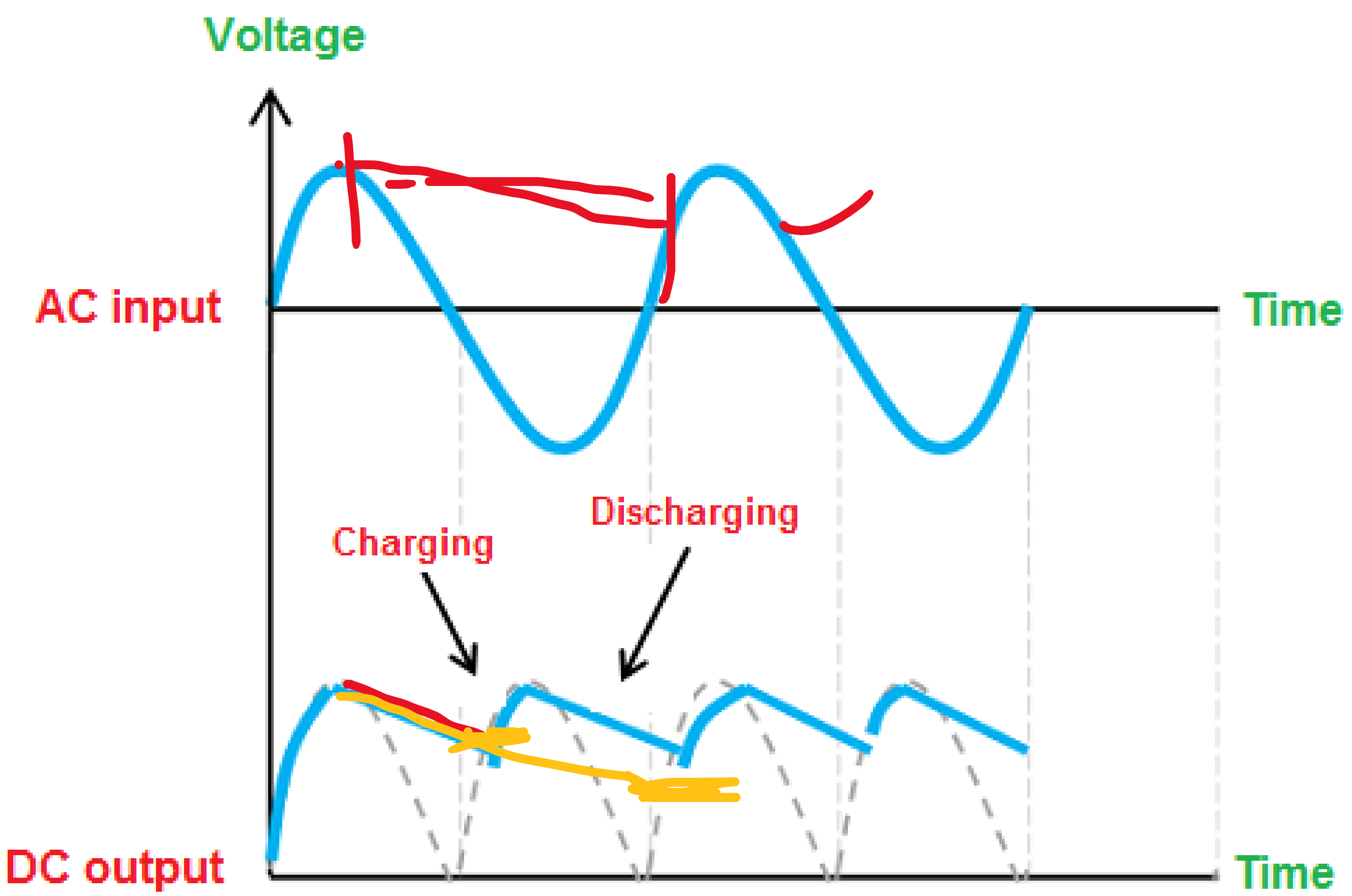
- When the capacitor is fully charged, it holds the charge until the input AC supply to the rectifier starts moving towards the negative half cycle.
- During the negative half cycle, diode D is reverse biased and it does not conduct.
- The input voltage to the filter is now less than the voltage to which the capacitor was charged.
- Capacitor discharges the stored charges through the load resistor R_L which prevents the output load voltage from falling to zero.
- The capacitor keeps discharging until the input supply voltage is more than the capacitor voltage.
- When the positive half cycle arrives, the diode D conducts and the capacitor starts charging again.
- As long as the input supply voltage is greater than the capacitor voltage, the capacitor keeps charging.

Center Tapped Full-wave Rectifier with Filter

- Half-wave rectifier:
  - ➢ Output contains large ripples.
  - ➢ DC signal obtained at the output after filtering is not a pure DC.
  - ➢ Power loss is high in half-wave rectifier.
- In the centre tapped rectifier Diode D_1 conducts for the positive half cycle while diode D_2 conducts for the negative half cycles of the input voltage.
- The output is a series of positive pulses.
- The output is still a pulsating DC though it is smoother than the output of the half-wave rectifier without a filter.



- The positive half cycles at the input of the filter charge the capacitor.
- Capacitor charges to the maximum value of the input supply voltage.
- The capacitor stores a maximum charge exactly at the quarter positive half cycle in the waveform.

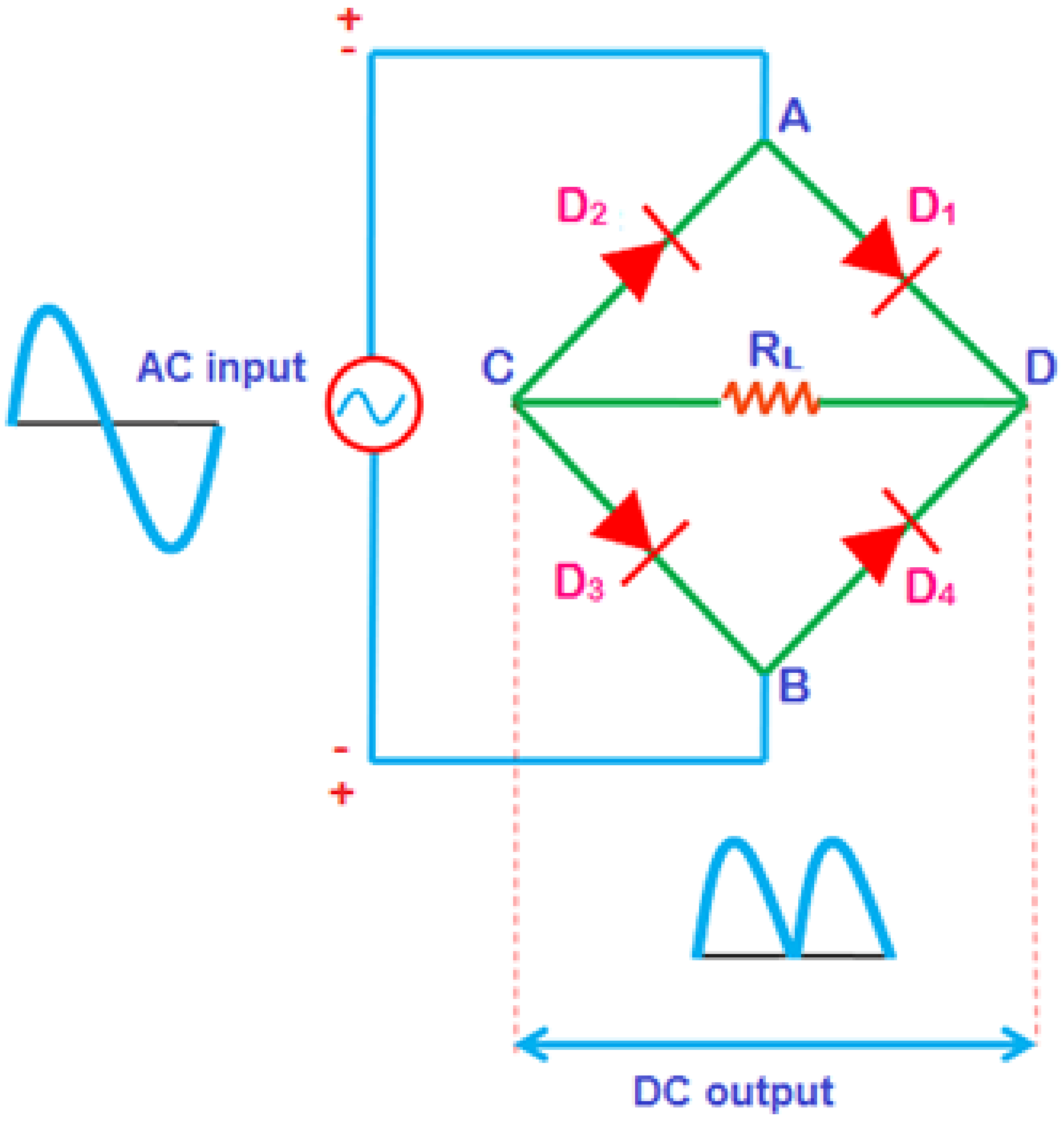

Voltage
AC input
Time
Charging
Discharging
DC output
Time

- When the AC voltage starts decreasing and becomes less than the capacitor voltage, then the capacitor starts slowly discharging.
- The discharging of the capacitor is very slow as compared to the charging of the capacitor so that the capacitor does not get enough time to completely discharged.
- Before the complete discharge of the capacitor happens, the charging again takes place. So only half or more than half of the capacitor charge get discharged.
- Charging of the capacitor happens only when the applied AC voltage is greater than the capacitor voltage i.e. when the supply voltage becomes greater than the capacitor voltage, the capacitor starts charging again.
- In both positive and negative half cycles, the current flows in the same direction across the load resistor R_L.
- Filter converts the pulsating DC voltage in a to pure DC voltage.

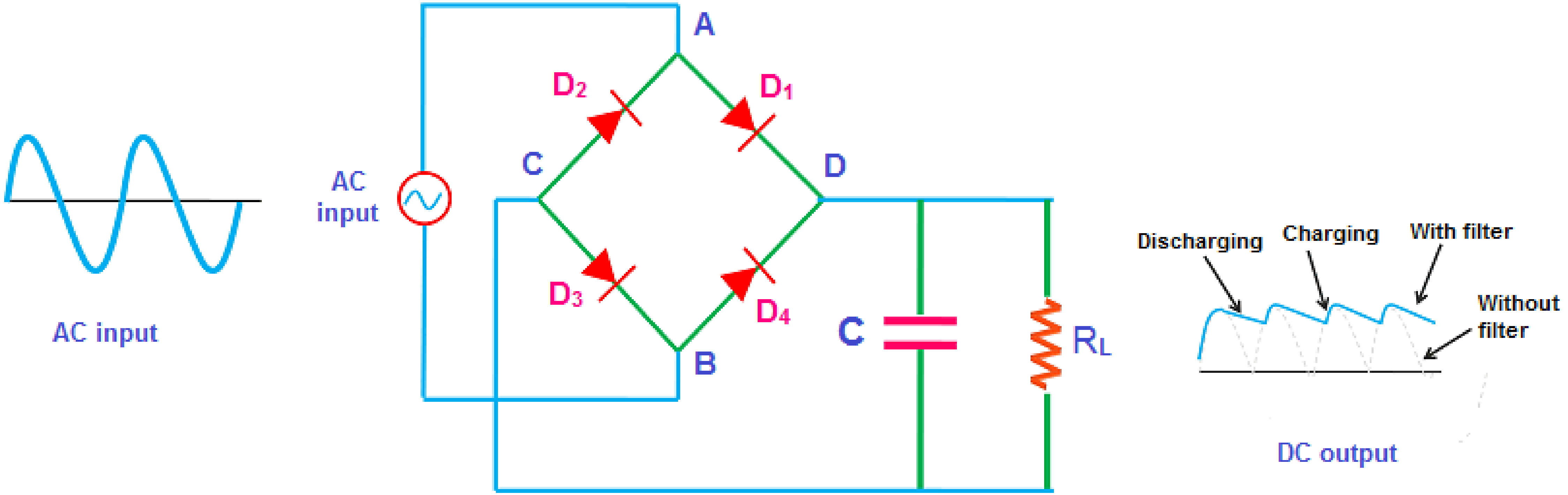
Bridge Rectifier with Filter

- In a center tapped full-wave rectifier, both positive and negative half cycles are rectified and as such no voltage is wasted at the output.
- The DC output produced by center tapped full wave rectifier is smoother compared to the half-wave rectifier output.
- However, the center tapped full-wave rectifier has one drawback – it needs a transformer which is very costly and it occupies a large space.
- The bridge rectifier is free from this drawback.
- The bridge rectifier does not need a transformer – it needs only two extra diodes.

Bridge Rectifier

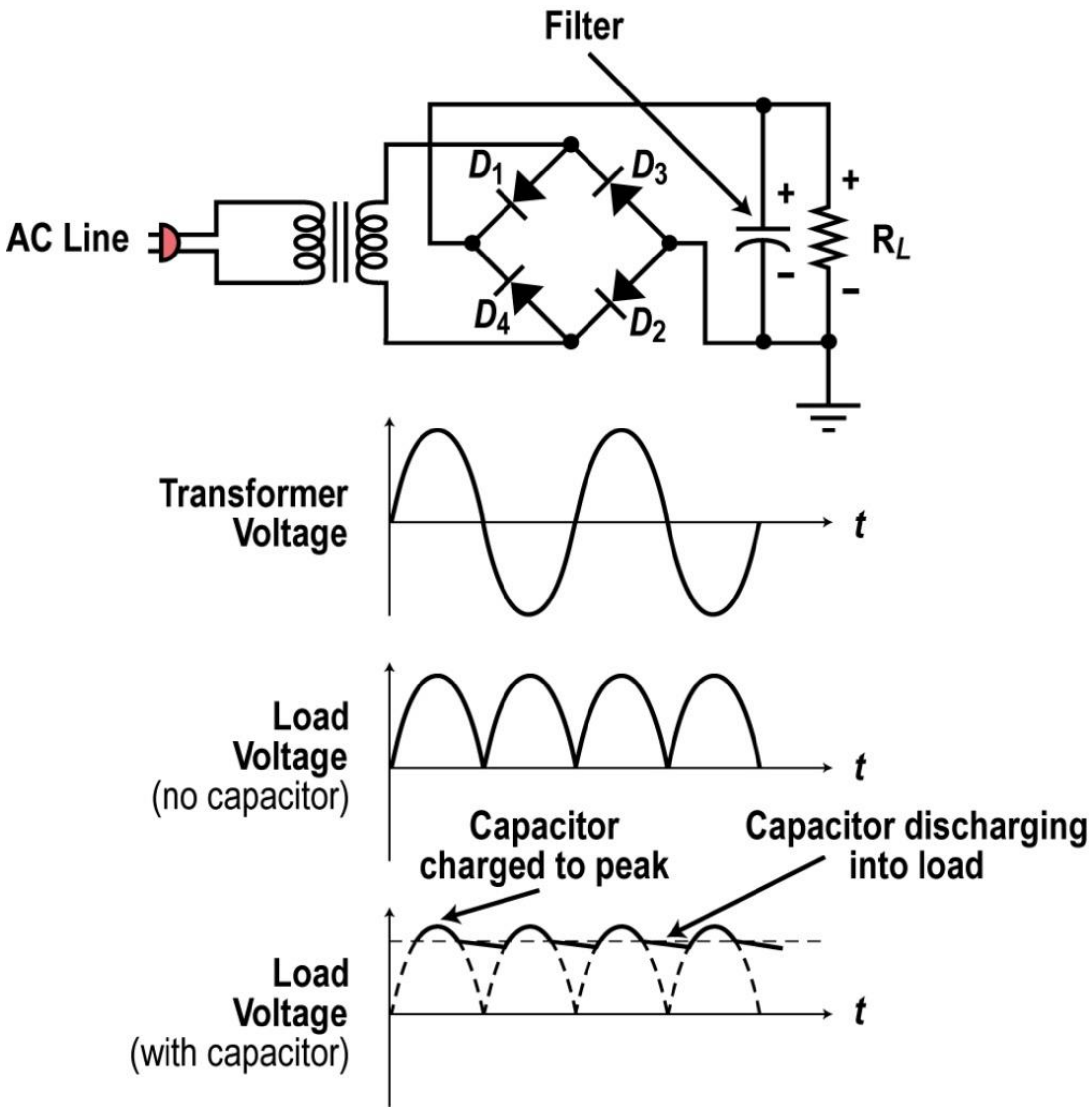


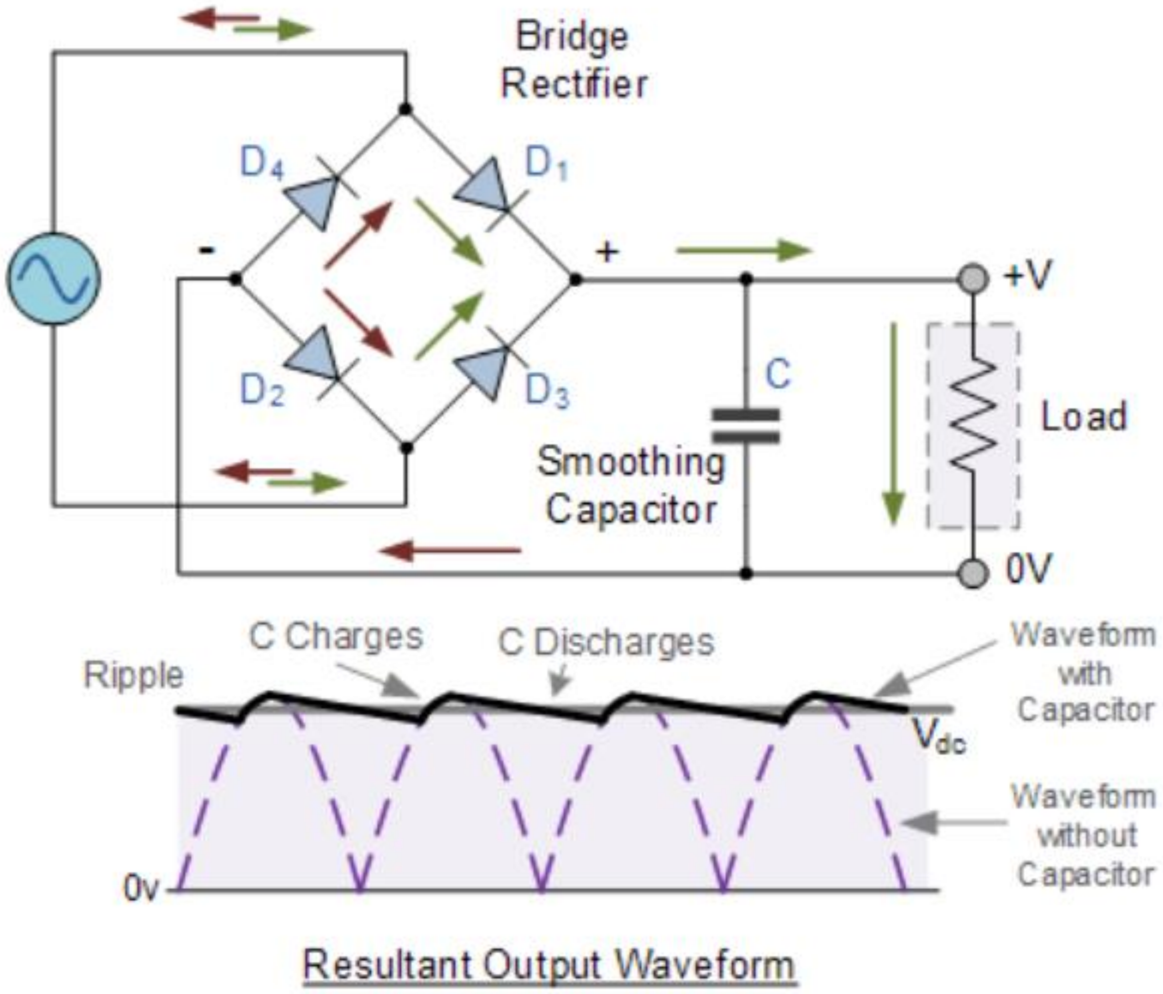
Bridge Rectifier with Filter



How the Filter Works

- A large capacitor is connected across the load resistor. This capacitor filters the pulses into a more constant DC.
- When the diode conducts, the capacitor charges up to the peak of the sine wave.
- Then when the sine voltage drops, the charge on the capacitor remains. Since the capacitor is large it forms a long time constant with the load resistor. The capacitor slowly discharges into the load maintaining a more constant output.
- The next positive pulse comes along recharging the capacitor and the process continues.

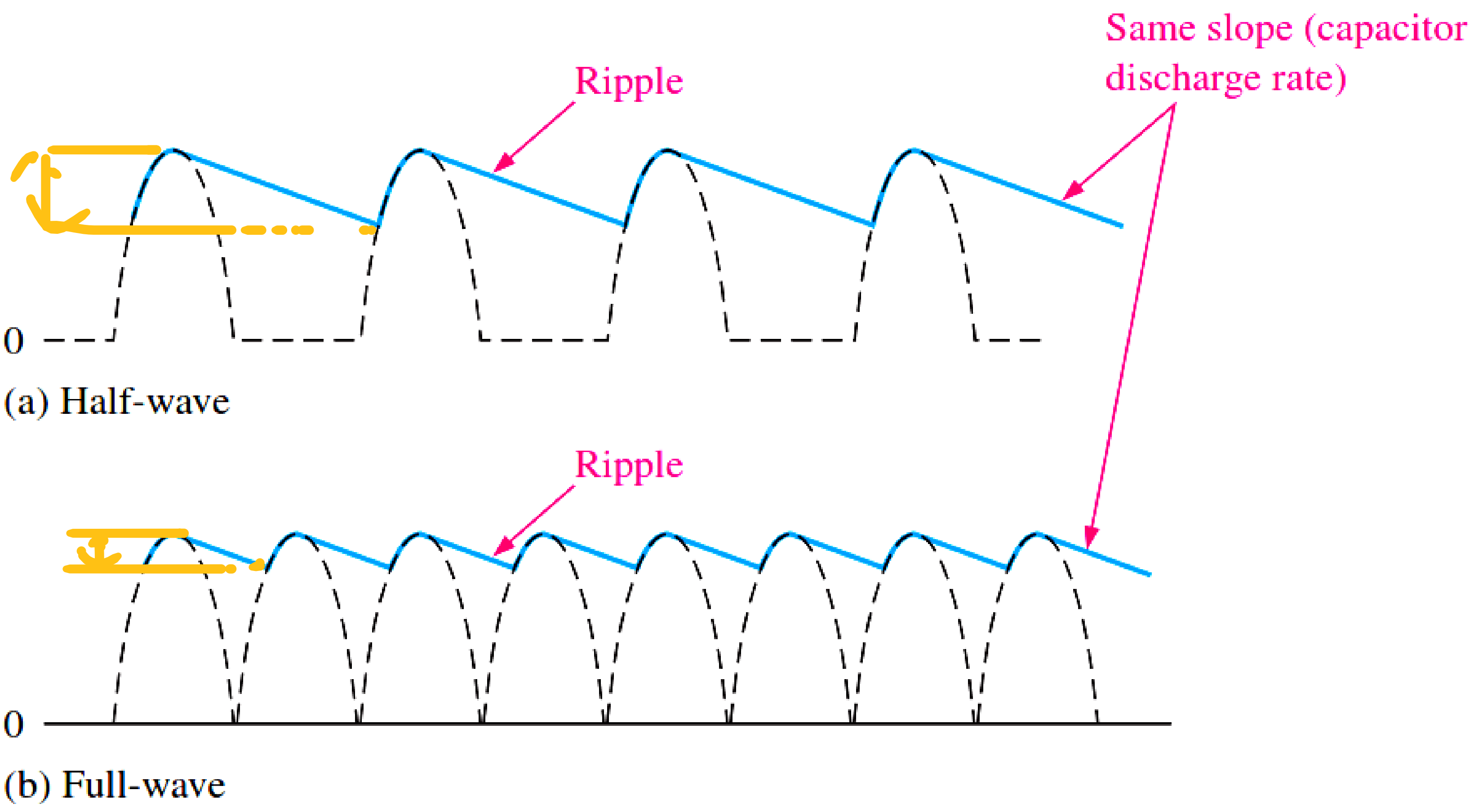



Bridge Rectifier
D4
D1
D2
D3
-
+
+V
0V
C
Smoothing Capacitor
Load
C Charges
C Discharges
Ripple
Waveform with Capacitor
Vdc
Waveform without Capacitor
0v
Resultant Output Waveform

Ripple

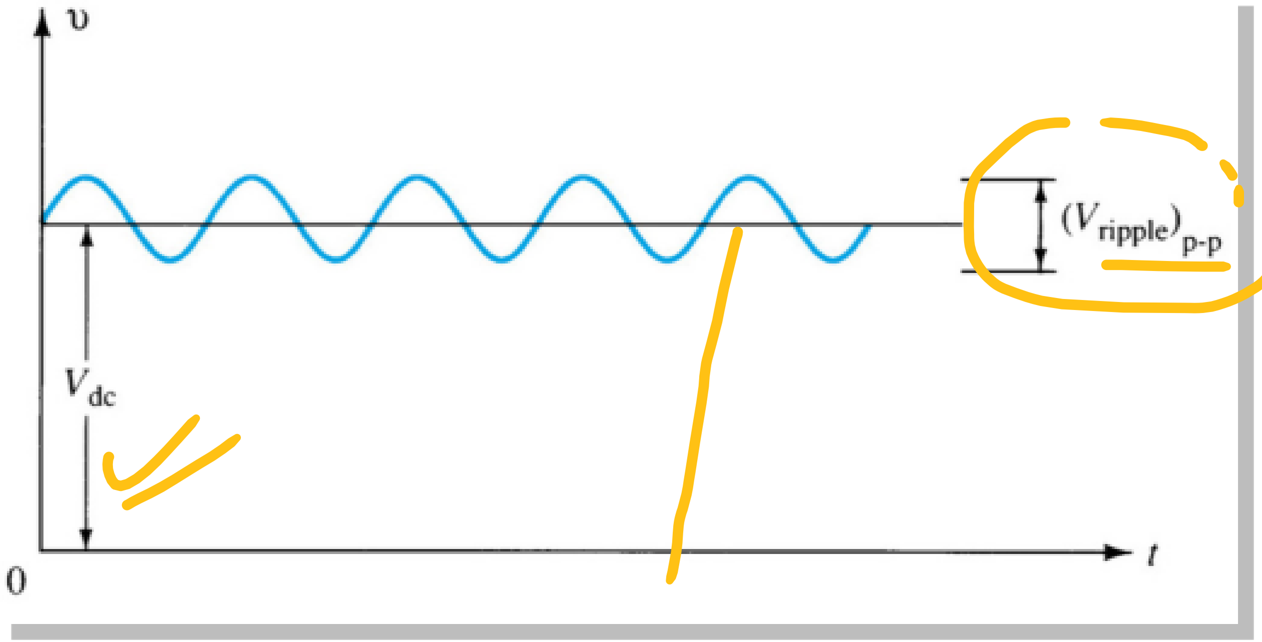
- The bridge rectifier allows both positive and negative half cycles of the input AC signal.
- The DC output produced by the bridge rectifier is not a pure DC but a pulsating DC. This pulsating DC contains both AC and DC components.
- The capacitor does a good job of smoothing the pulses from the rectifier into a more constant DC.
- A small variation occurs in the DC because the capacitor discharges a small amount between the positive and negative pulses. Then it recharges. This variation is called ripple.
- The ripple appears to be a sawtooth shaped AC variation riding on the DC output. It can be reduced further by making the capacitor larger.
- A small amount of ripple can be tolerated in some circuits but the lower the better overall.

Comparison of ripple voltages for half-wave and full-wave rectified voltages with the same filter capacitor and load and derived from the same sinusoidal input voltage.



Ripple Factor

After the filter circuit a small amount of AC is still remaining. The amount of ripple voltage can be rated in terms of ripple factor (r).



$$\%r = \frac{\text{ripple voltage (rms)}}{\text{dc voltage}} = \frac{V_{r(rms)}}{V_{dc}} \times 100$$

Rectifier Ripple Factor

Half-Wave

DC output:

$$V_{dc} = 0.318V_m$$

AC ripple output:

$$V_{r(rms)} = 0.385V_m$$

Ripple factor:

$$\%r = \frac{V_{r(rms)}}{V_{dc}} \times 100$$

$$= \frac{0.385V_m}{0.318V_m} \times 100 = 121\%$$

Full-Wave

DC output:

$$V_{dc} = 0.636V_m$$

AC ripple output:

$$V_{r(rms)} = 0.308V_m$$

Ripple factor:

$$\%r = \frac{V_{r(rms)}}{V_{dc}} \times 100$$

$$= \frac{0.308_{Vm}}{0.636_{Vm}} \times 100 = 48\%$$

References:

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