Department of Electrical Engineering
Assignment
Date: 27/06/2020

Course Details

Course Title: Power Electronics **Module:** 8th
Instructor: Sir Shayan Tariq **Total Marks:** 50

Student Details

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Note: Plagiarism of more than 20% will result in negative marking.
Similar answers of students will result in cancellation of the answer for all parties.

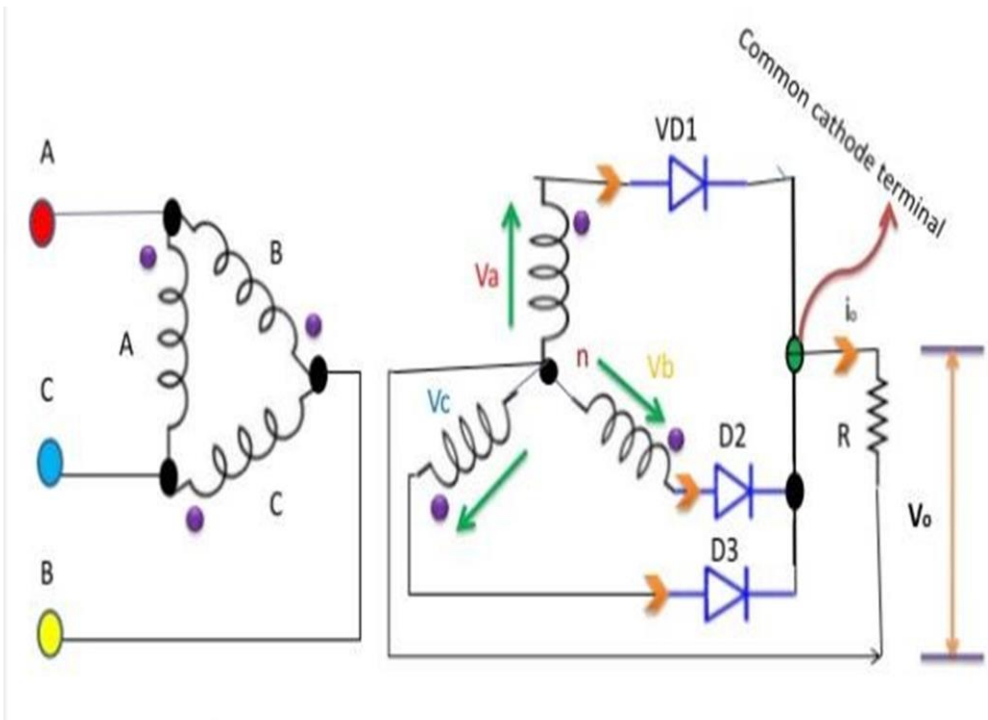
Q1.	Rectifiers are common circuits used in most electronic devices. There are multiple types of rectifiers used now a days. Explain in detail what are the similarities and differences between: 1. 1 – φUncontrolledHalf Wave Rectifier and Full Wave Bridge Rectifier 2. 1 – φ Uncontrolled Rectifier and Controlled Rectifiers (Bridge Rectifier).	CLO 2 Marks 10
Q2.	A AC voltage of Vm = (Last 2 digits of ID) V has to be delivered to a Resistive DC load of R = (First 2 digits of ID) ohms. The load and source are connected through 2 types of 1 – φ Uncontrolled rectifiers (Half Wave and Full Wave Bridge) and data is collected. Find the following for both rectifiers: 1. Vdc 2. Idc 3. Vrms 4. Irms 5. Which rectifier do you think is better and why.	CLO 2 Marks 10
Q3.	The Buck chopper is a type of DC-DC converter. Explain in detail the principals and working of Buck converter when the switch is open and closed. The buck converter is connected to a DC source voltage of Vin = 50V. The duty cycle is D = (Last 2 digits of ID) %,load of R = (First 2 digits of ID) ohms and switching frequency of 20kHz. What will be the 1. Vout 2. Iout 3. Iin 4. Inductor (L)	CLO 3 Marks 10

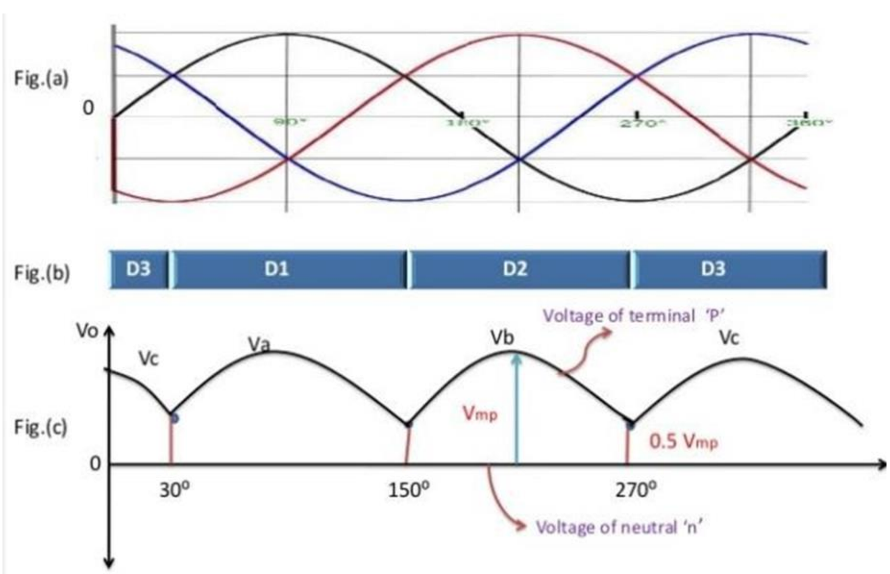
Q4	The Boost chopper is a type of DC-DC converter. Explain in detail the principals and working of Boost converter when the switch is open and closed. The boost converter is connected to a DC source voltage of Vin = 50V. The duty cycle is D = (Last 2 digits of ID) %, load of R = (First 2 digits of ID) ohms and switching frequency of 20kHz. What will be the 1. Vout 2. Iout 3. Iin 4. Inductor (L)	CLO 3 Marks 10
Q5	The Buck-Boost chopper is a type of DC-DC converter. Explain in detail the principals and working of Buck converter when the switch is open and closed. The Buck-Boost converter is connected to a DC source voltage of Vin = 50V. The Output voltage Vout = (Last 2 digits of ID) %, load of R = (First 2 digits of ID) ohms and switching frequency of 20kHz. What will be the 1. Duty Cycle (D) 2. Iout 3. Vin 4. Inductor (L)	CLO 3 Marks 10

Question # 01

φ Half – Wave Rectifier:

It uses a 3 – φ transformer with primary in delta and secondary in star connection. D1, D2 and D3 have common connected cathode to common load R and all diodes are oriented in different phases and therefore called as Common – Cathode Circuit.





- The rectifier element connected to the line at the highest +ve instantaneous voltage can only conduct and pulsates between V max and 0.5 V max.
- It is called 3 – φ 3 pulse rectifier as the o/p is repeated thrice in every cycle of V s.
- The ripple frequency (f r) of the o/p voltage is

$$f_r = nf_s; \quad n = no.\ of\ diodes,\ f_s = AC\ supply\ freq.$$

- The ON diode connects its most +ve source terminal to the other two diode cathodes

keeping the other diodes OFF.

- The sudden switchover from one diode to another is called "commutation".
- Each diode conducts for 120 º intervals.
- Delta connection provides path for triplen (odd multiples of the 3rd harmonic) harmonic

currents stabilizing the voltage on star secondary.

Full wave uncontrolled Rectifier:

On the positive half cycle of transformer secondary supply voltage, diodes D1 and D2 conduct, supplying this voltage to the load.

On the negative half cycle of supply voltage, diodes D3 and D4 conduct supplying this voltage to the load.

It can be seen from the waveforms that the peak inverse voltage of the diodes is only V m

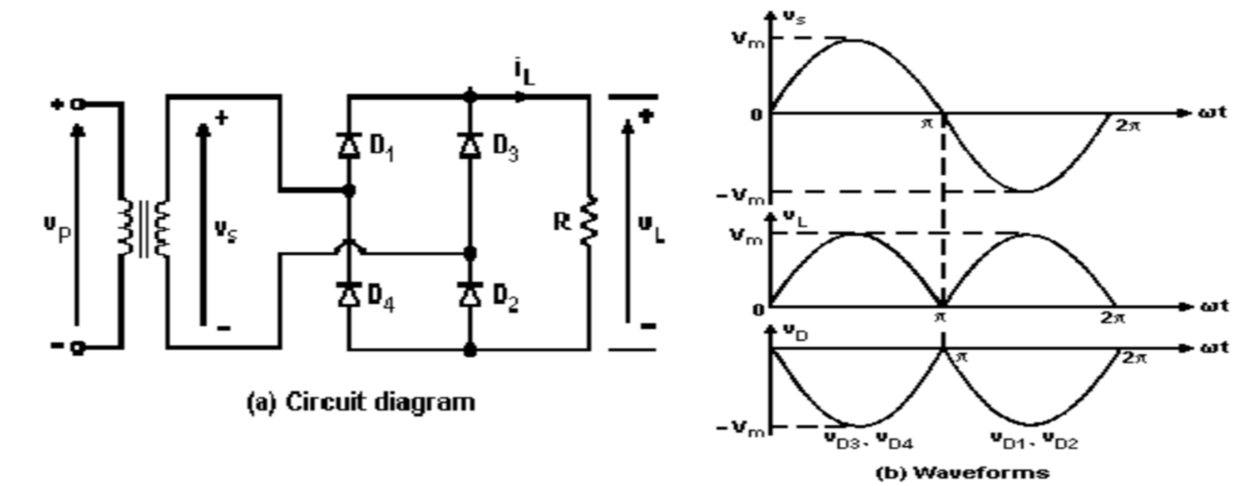
The average output voltage is the same as that for the centre - tapped transformer full- wave rectifier.

$$Peak\ Repetitive\ Diode\ Current\ I = V_{m/R}$$

$$Av.\ Output\ Voltage\ V = 2V_{m/\pi}$$

$RMS\ Output\ Voltage =$ 2Vs

$Av.\ Diode\ Current\ I = 1/_\pi$ 2sin $\omega t\ d\ (\omega t) = Im/_\pi$



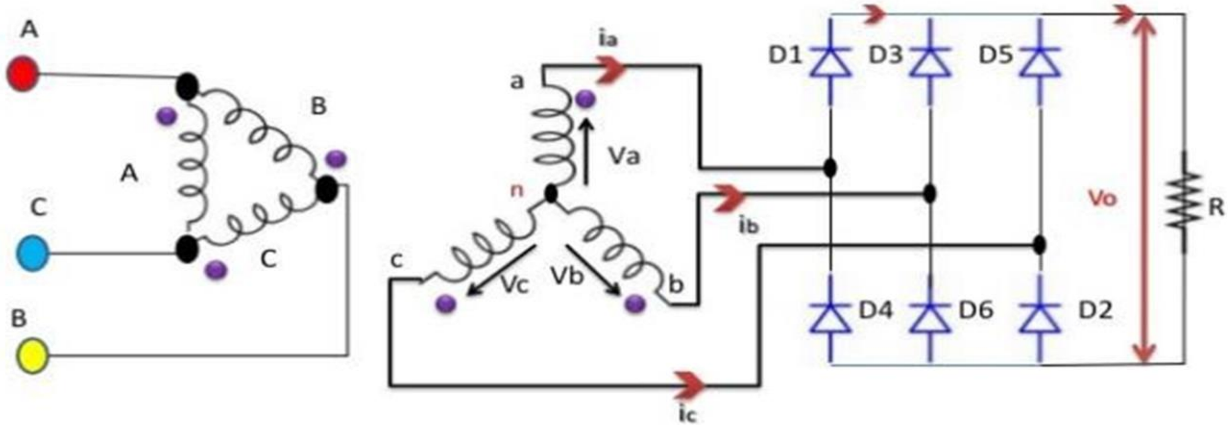
(2)

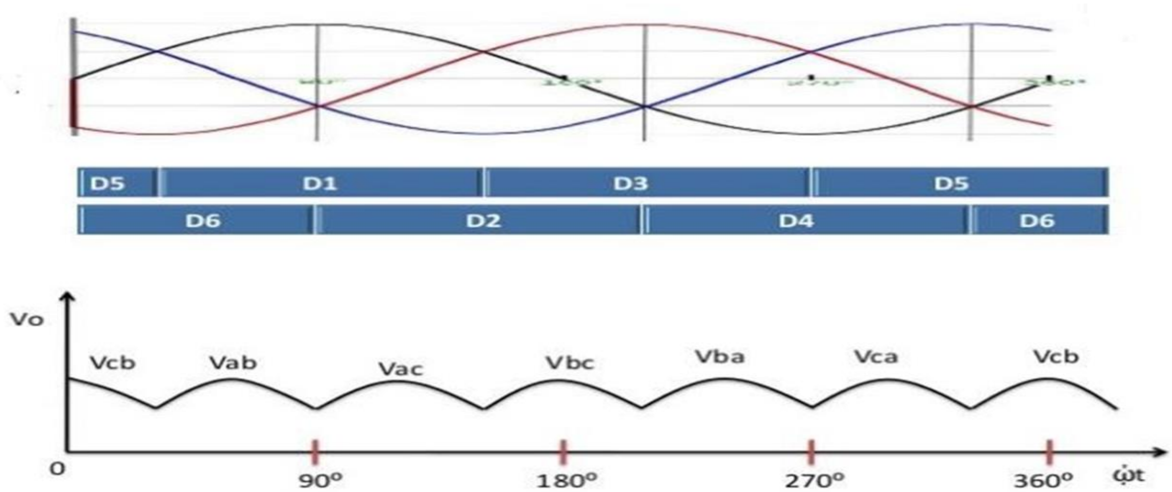
Uncontrolled bridge rectifiers:

- Two series diodes are always conducting while four diodes are blocking.
- One of the conducting diodes is odd numbered while the other is even numbered.
- Each diode conducts for 120 º.
- Current flows out from the most +ve source terminal through an odd numbered diode through the load followed by the even numbered diode and then back to the most –ve source terminal.
- Output has less ripples and the diodes are numbered in accordance to their conductance.
- The bridge uses both the +ve and –ve halves of the i/p voltage.
- Ripple frequency is 6*f.
- Upper set of diodes constitutes the +ve group while the lower set constitutes the –ve.
- Transformer Primary – Secondary is in Delta – Star configuration.
- The diode with the most +ve voltage will be conducting.
- B is chosen as reference.

- During 0º - 30º, the voltage at C is highest (arbitrarily). Hence D5 is conducting as it is the most +ve.
- Between 30º and 150º, A becomes the most +ve and hence conducting.
- During 150º - 270º, B being most +ve conducts.
- The cycle repeats itself.
- Each diode conducts for 120º.

$Output\ Voltage\ V= 1/\ \pi 3\ \ 2\pi/3\ \ \sin \omega td\ (\ \omega t)\ 3Vm/\ \pi = 0.955$





Controlled Rectifiers:

The converter circuit which converts AC to DC is called a Rectifier.

The rectifier circuit using diodes only is called an Uncontrolled rectifier circuit. All rectifiers are broadly categorized into three sections.

1. Controlled Rectifier - It has only thyristors. NO diodes
2. Half Controlled Rectifier - It has thyristor + diodes
3. Uncontrolled Rectifier - Only diodes

Control here means controlling when to start rectification and when to stop.

Unlike diode, an SCR does not become conducting immediately after its voltage has become positive.

It requires triggering by means of pulse at the gate.

So it is possible to make the thyristor conduct at any point on the half wave which applies positive voltage to its anode.

Thus the output voltage is controlled.

Steel rolling mills, paper mills, textile mills where controlling of DC motor speed is necessary.

- Electric traction.
- High voltage DC transmissions.
- Electromagnet power supplies.

Question # 02

Question # 02

⇒ Solutions:-

$V_m = 32V$

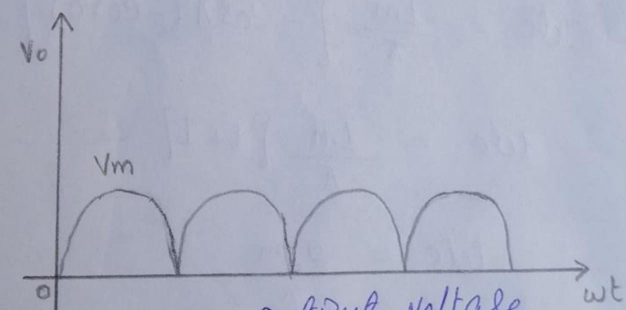
$R_L = 13\,\Omega$

$I_m = V_m / R_L = 32/13$

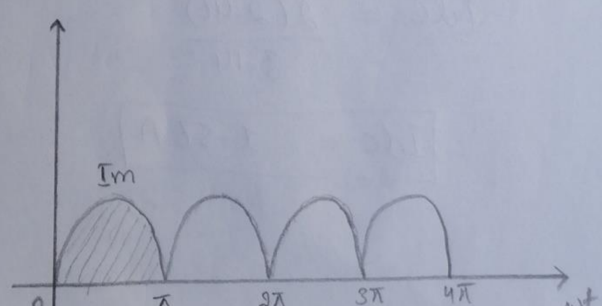
$I_m = 2.46A$

(1) $I_{dc} = ?$

First we will find I_{dc} in full-wave rectification



Output voltage



Load current

$$I_{dc} = \frac{\text{Area under the load current over full cycle}}{\text{period of the cycle}}$$

$$I_{dc} = \int_0^{\pi} \frac{I_m \sin \omega t \, d(\omega t)}{\pi}$$

$$I_{dc} = \frac{I_m}{\pi} \int_0^{\pi} \sin \omega t \, d(\omega t)$$

$$I_{dc} = \frac{I_m}{\pi} \left[-\cos \omega t \right]_0^{\pi}$$

$$I_{dc} = \frac{I_m}{\pi} \left[-\cos \pi \left(-\cos 0 \right) \right]$$

$$I_{dc} = \frac{I_m}{\pi} \left[1 + 1 \right]$$

$$I_{dc} = \frac{2 I_m}{\pi}$$

Putting values :-

$$I_{dc} = \frac{2(2.46)}{3.14}$$

$$\boxed{I_{dc} = 1.56 A}$$

(2) Vdc = ?

$$V_{dc} = I_{dc} \times R_L$$

$$\frac{2I_m}{\pi} \times R_L$$

$$V_{dc} = \frac{2V_m}{\pi}$$

Putting values

$$V_{dc} = \frac{2(32)}{3.14}$$

$$\boxed{V_{dc} = 20.38V}$$

⇒ In case of half wave Rectification

$$I_{dc} = \frac{I_m}{\pi}$$

$$I_{dc} = \frac{2.46}{3.14}$$

$$\boxed{I_{dc} = 0.78A}$$

$$V_{dc} = \frac{V_m}{\pi} \Rightarrow \frac{32}{3.14}$$

$$\boxed{V_{dc} = 10.19V}$$

(3) $I_{rms} = ?$

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

Putting values

$$I_{rms} = \frac{2.46}{\sqrt{2}}$$

$$\boxed{I_{rms} = 1.73}$$

(4) $V_{rms} = ?$

$$V_{rms} = I_{rms} \times R_L$$

$$= \frac{I_m}{\sqrt{2}} \times R_L$$

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

Putting values

$$V_{rms} = \frac{80}{\sqrt{2}}$$

$$\boxed{V_{rms} = 22.6\ A}$$

(4) Full wave uncontrolled rectifier is better for its efficiency & Rectification.

Question # 03

Buck Chopper:

A Buck chopper is a switch mode DC to DC electronic converter in which the output voltage will be transformed to level less than the input voltage. It is also called as step down converter. The name step down converter comes from the fact that analogous to step down transformer the input voltage is stepped down to a level less than the input voltage. By law of conservation of energy the input power has to be equal to output power (assuming no losses in the circuit).

Input power (P_{in}) = output power (P_{out})

Since $V_{in} > V_{out}$ in a buck converter, it follows then that the output current will be greater than the input current. Therefore in buck converter

$V_{in} > V_{out}$ and $I_{in} < I_{out}$

Principle:

The DC to DC converters will circuit will change the voltage source. To higher or lower or something else. By purpose of the designer or our circuit ideas.

When we see a basic buck converter circuit as **Figure 1**. It is easy to understand with:

- Uin is an input voltage as popular of a European country. And “Vin” of the United States.
- Uout is an output voltage of European countries. And “Vout” on the United States.

In this circuit, it consists of 3 main components only.

- S is a switch, in the real circuit, we use a transistor.
- D is a diode.
- L is a coil or indictor.
- C is a Capacitor.

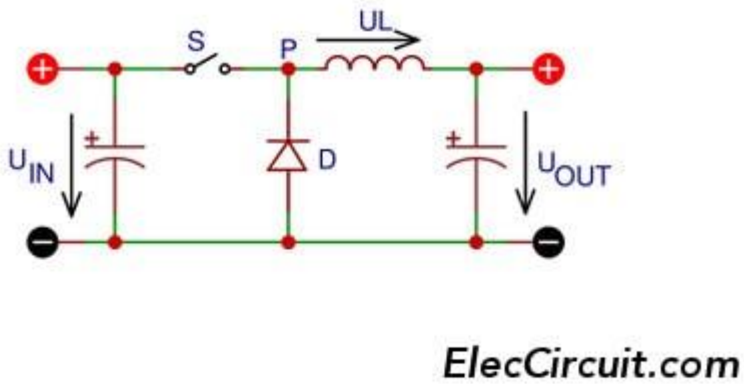


Figure 1 Buck converter working principle
Figure 1 is basic buck converter circuit. It powers a certain output voltage. Other converter systems may call that a step down.

First, the Uin charges into capacitor until full. The its voltage is same as the **power supply** input.

Next, switch closed into the circuit. Therefore the **positive voltage** to drop across the coil L.
The current flow through **coil** to increase up in linear rate. While there is energy stored in the coil.
Then, the S open up. So, the current of L flow to the output capacitor.

And it flows through **Diode** (D). It makes the voltage drop across the coil L in backward (negative).
And, the current through the coil reduces in linear. The energy stored at the output capacitor.

When the switch (S) connected to the circuit again. The system started working the new one. To be able to supply the load continuously.

In Practice, It is difficult **to control** the switch(S). Which It will make the energy to the output.

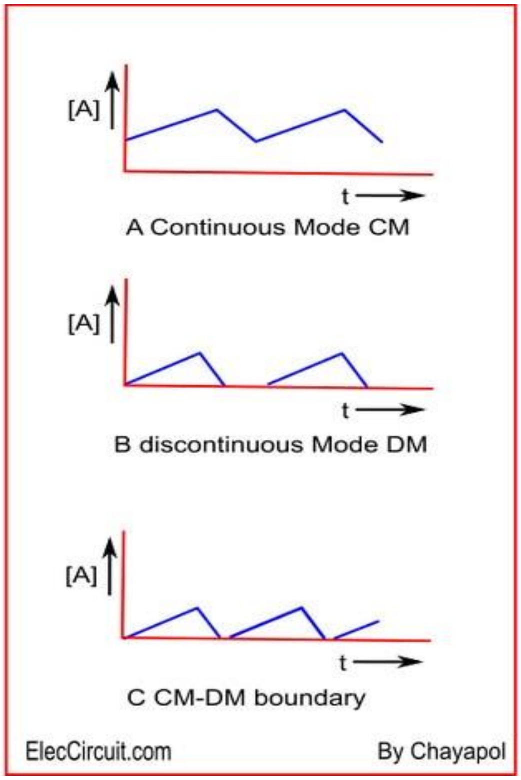


Figure 2 Three types of current mode

In normal principle, the electricity flows in 3 modes. As shown in Figure 2.

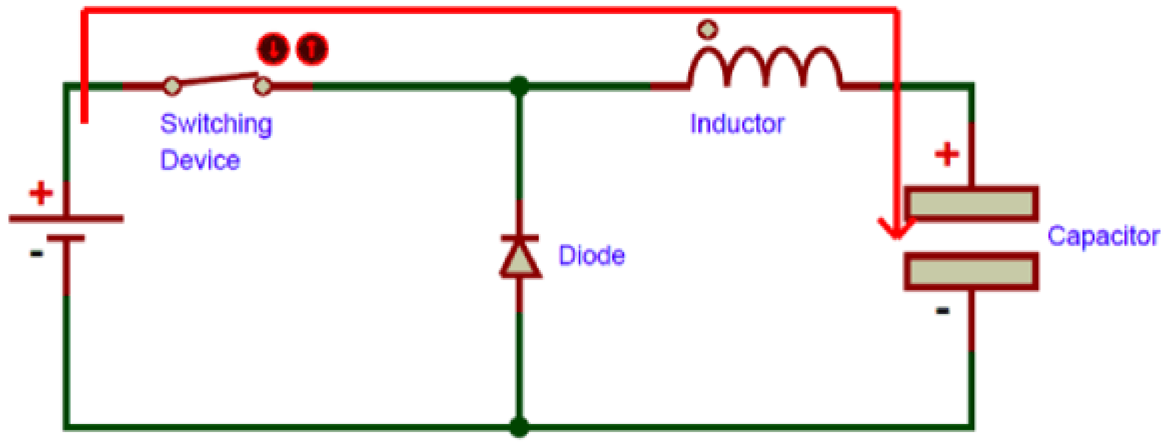
- Continuous mode (CM): When switch is closed. Then, **the current** is continuously flowing in coil. See Figure 2A
- Discontinuous mode (DM): But if we control times to **switch on-off** .
- CM/DM boundary: This mode, the switch turn-on immediately, if current of coil drop to zero.

Working:

The working of a buck converter can be broken down into a few steps.

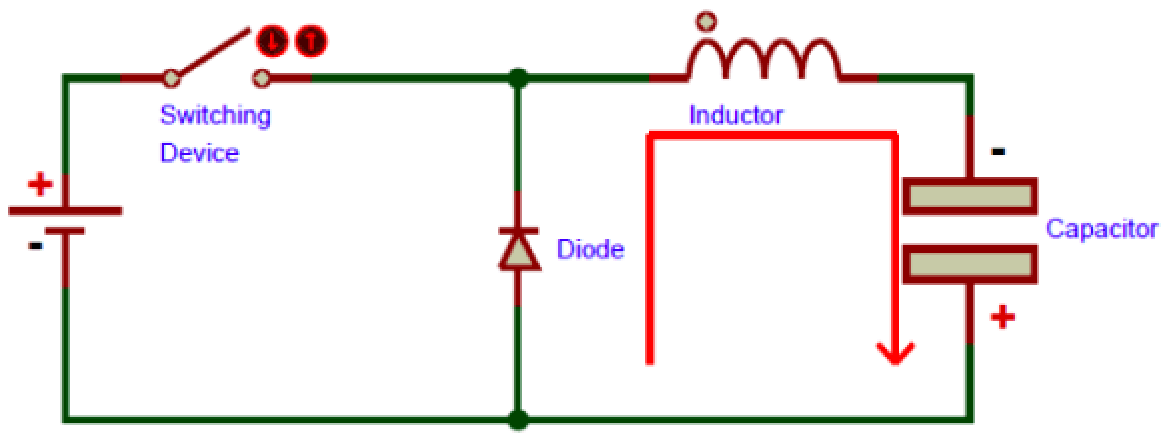
STEP – 1:

The switch turns on and lets current flow to the output capacitor, charging it up. Since the voltage across the capacitor cannot rise instantly, and since the inductor limits the charging current, the voltage across the cap during the switching cycle is not the full voltage of the power source.



STEP – 2:

The switch now turns off. Since the current in an inductor cannot change suddenly, the inductor creates a voltage across it. This voltage is allowed to charge the capacitor and power the load through the diode when the switch is turned off, maintaining current output current throughout the switching cycle.



These two steps keep repeating many thousands of times a second, resulting in continuous output.

Question #03 ①

Part (b)

Data :-

$V_{in} = 50V$

$D = 32\%$ (13032)

$R = 13\Omega$ (13032)

$f = 20KHz$

(i) $V_{out} = ?$

$V_o = d(V_i)$

$= (0.32)(50)$

$V_o = 16V$

(ii) $I_{out} = ?$

$I_{out} = \frac{V_o}{R}$

$I_{out} = \frac{16V}{13}$

$I_{out} = 1.23A$

(iii) $I_{in} = ?$

$$I_{in} = \frac{V_i}{R}$$

$$I_{in} = \frac{50}{13}$$

$$\boxed{I_{in} = 3.84}$$

(iv) Inductor = ?

$$L = \frac{T_{OFF}}{2} \quad \text{— (i)}$$

As we know that

$$V_o = dV_i$$

$$d = V_o / V_i = \frac{16}{50}$$

$$d = 0.32$$

(*) $\frac{T_{ON}}{T} = 0.32$ $\quad \because d = \frac{T_{ON}}{T}$

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

$$T_{ON} = 0.32 \times T$$

$$T_{ON} = \frac{0.32}{f}$$

$$T_{ON} = \frac{0.32}{20(10^3)Hz} = 16\ \mu s$$

from equation (*) we have

$$\frac{T_{ON}}{T} = 0.32$$

$$\frac{T_{ON}}{0.32} = T \Rightarrow \frac{16\mu s}{0.32} = 50\ \mu s$$

③

Now

$$T = T_{ON} + T_{OFF}$$

$$T_{OFF} = T - T_{ON}$$

$$T_{OFF} = 50\,\mu s - 16\,\mu s$$

$$\boxed{T_{OFF} = 34\,\mu s}$$

Putting these values in eq ① we get

$$L = \frac{34\,\mu s}{2} \times 13$$

$$\boxed{L = 221\,\mu H}$$

Question # 04

boost chopper:

A boost converter is one of the simplest types of switch mode converter. As the name suggests, it takes an input voltage and boosts or increases it. All it consists of is an inductor, a semiconductor switch, a diode and a capacitor. Also needed is a source of a periodic square wave.

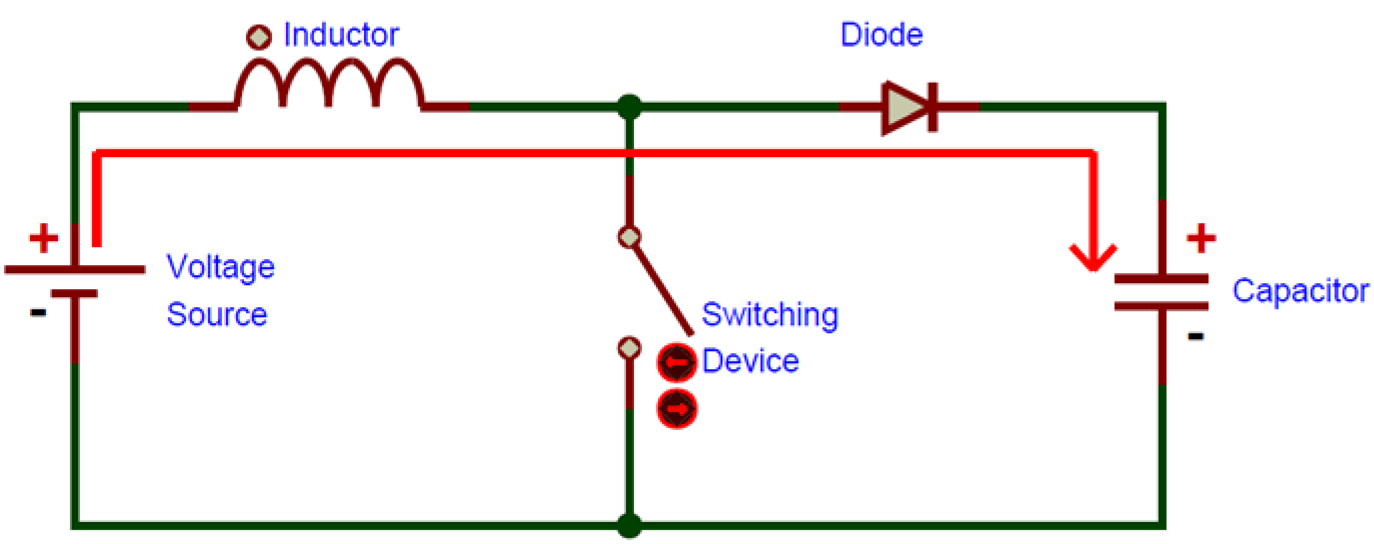
Principle:

The main working principle of boost converter is that the inductor in the input circuit resists sudden variations in input current. When switch is OFF the inductor stores energy in the form of magnetic energy and discharges it when switch is closed. The capacitor in the output circuit is assumed large enough that the time constant of RC circuit in the output stage is high. The large time constant compared to switching period ensures a constant output voltage $V_o(t) = V_o$(constant)

Working:

STEP – 1

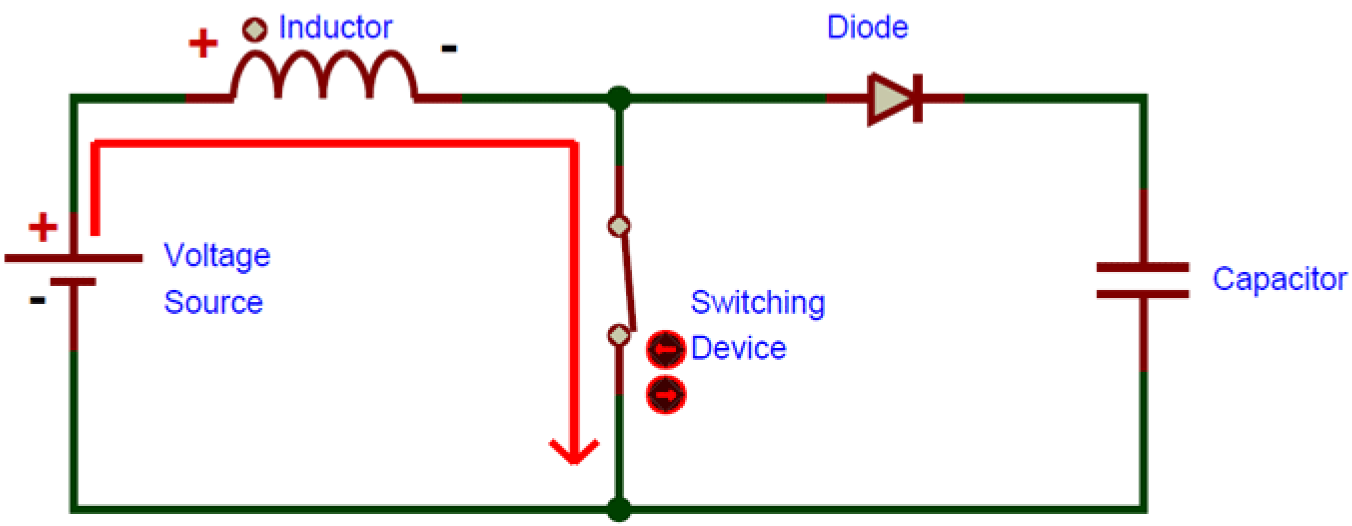
The output capacitor is charged to the input voltage minus one diode drop.



STEP – 2

Now, it's time to turn the switch on. Our signal source goes high, turning on the MOSFET. All the current is diverted through to the MOSFET through the inductor. Note that the output capacitor stays charged since it can't discharge through the now back-biased diode.

The power source isn't immediately short circuited, of course, since the inductor makes the current ramp up relatively slowly. Also, a magnetic field builds up around the inductor. Note the polarity of the voltage applied across the inductor.



STEP – 3

The MOSFET is turned off and the current to the inductor is stopped abruptly.

The very nature of an inductor is to maintain smooth current flow; it doesn't like sudden changes in current. So it does not like the sudden turning off of the current. It responds to this by generating a large voltage with the opposite polarity of the voltage originally supplied to it using the energy stored in the magnetic field to maintain that current flow.

Question # 04
Numerical Part

=> Given data :-

$V_{in} = 50V$

$D = 32\% = 0.32\%$

$R = 13\,\Omega$

$f = 20Hz$

find :-

(i) $V_{out} = ?$

$$V_{out} = \frac{V_S}{1-D} \Rightarrow \frac{50}{1-0.32}$$

$$\boxed{V_{out} = 73.5V}$$

(ii) $I_{out} = ?$

$$I_{out} = \frac{V_{out}}{R} \Rightarrow \frac{73.5}{13}$$

$$\boxed{I_{out} = 5.65A}$$

(iii) $I_{in} = ?$

$$I_{in} = \frac{I_{out}}{1-D} \Rightarrow \frac{5.65}{1-0.32}$$

$$\boxed{I_{in} = 8.30}$$

Question # 05

Buck boost chopper:

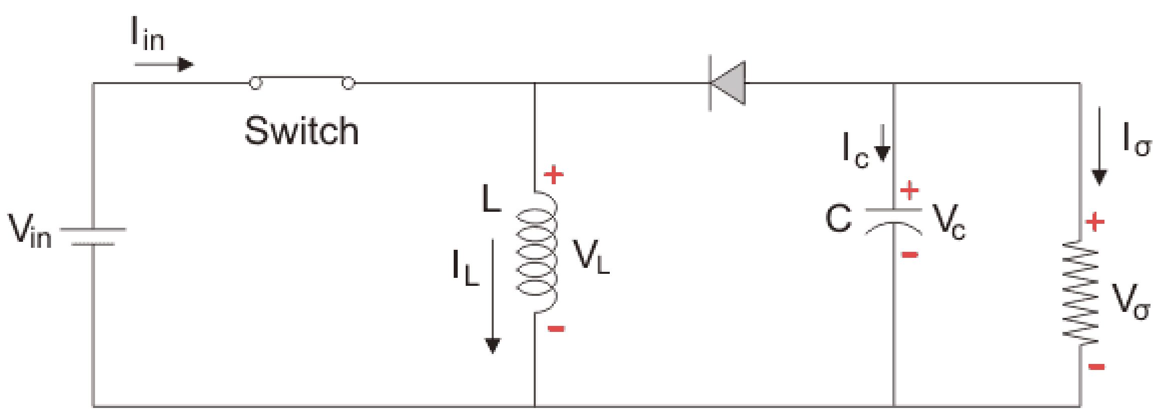
The buck boost chopper is a DC to DC converter. The output voltage of the DC to DC converter is less than or greater than the input voltage. The output voltage of the magnitude depends on the duty cycle. These converters are also known as the step up and step down transformers and these names are coming from the analogous step up and step down transformer.

Principle:

The main working principle of Buck Boost converter is that the inductor in the input circuit resists sudden variations in input current. When switch is ON the inductor stores energy from the input in the form of magnetic energy and discharges it when switch is closed. The capacitor in the output circuit is assumed large enough that the time constant of RC circuit in the output stage is high. The large time constant compared to switching period ensures that in steady state a constant output voltage $V_o(t) = V_o$(constant) exists across load terminals.

Working:

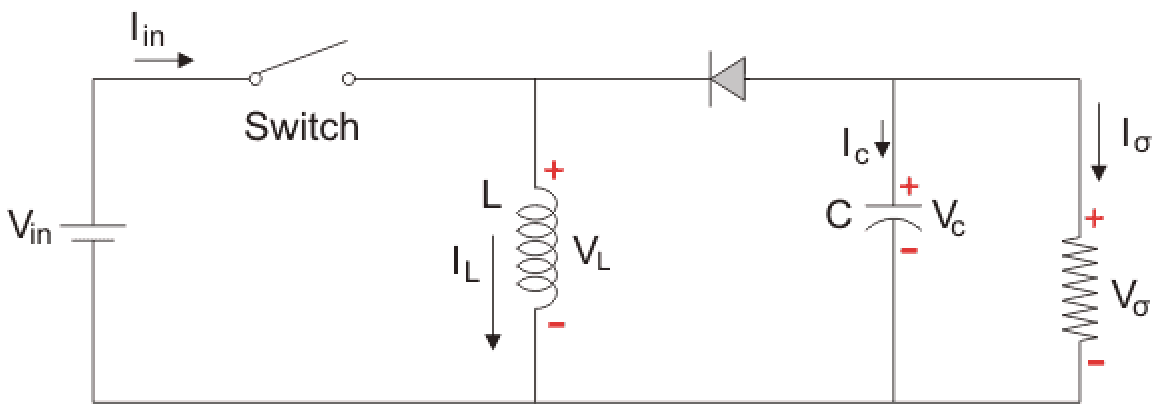
Step I : Switch is ON, Diode is OFF



The Switch is ON and therefore represents a short circuit ideally offering zero resistance to the flow of current so when the switch is ON all the current will flow through the switch and the inductor and back to the DC input source. The inductor stores charge during the time the switch is ON and when the solid state switch is

OFF the polarity of the Inductor reverses so that current flows through the load and through the diode and back to the inductor. So the direction of current through the inductor remains the same.

Step II : Switch is OFF, Diode is ON



In this mode the polarity of the inductor is reversed and the energy stored in the inductor is released and is ultimately dissipated in the load resistance and this helps to maintain the flow of current in the same direction through the load and also step-up the output voltage as the inductor is now also acting as a source in conjunction with the input source. But for analysis we keep the original conventions to analyse the circuit using KVL.

Question # 05

Numerical part

Given data :

$V_{in} = 50V$

$V_{out} = 32V$

$R = 13\Omega$

① $1 - D = \dfrac{-V_{in}}{V_o - V_{in}}$

$-D = \dfrac{-V_{in} - 1}{V_o - V_{in}}$

$D = \dfrac{V_{in} + 1}{V_o + V_{in}}$

$D = \dfrac{50V + 1}{0.32 + 50}$

$\boxed{D = 1.013}$

② $I_{out} = \dfrac{V_o}{R} =$

$I_{out} = \dfrac{0.32}{13}$

$\boxed{I_{out} = 0.0246A}$

(3) $I_{in} = \frac{I_o D}{1-D} \Rightarrow \frac{0.0246 \times 1.013}{1 - 1.013}$

$$\boxed{I_{in} = 1.916}$$

(4) Inductor (L) = ?

$$L = \frac{V_{in} \times D}{f \times \Delta I}$$

$\therefore \Delta I = V_{out} - V_{in}$

$= 0.32 - 50$

$\Delta I = 49.68$

$$L = \frac{50 \times 1.013}{20000 \times 49.68}$$

$$L = \frac{50.65}{993600}$$

$$\boxed{L = 5.09 \times 10^{-5} \mu H}$$