FAAIQ SHAH

ID: 12930

Power Electronics

Submitted to: Sir Shayan

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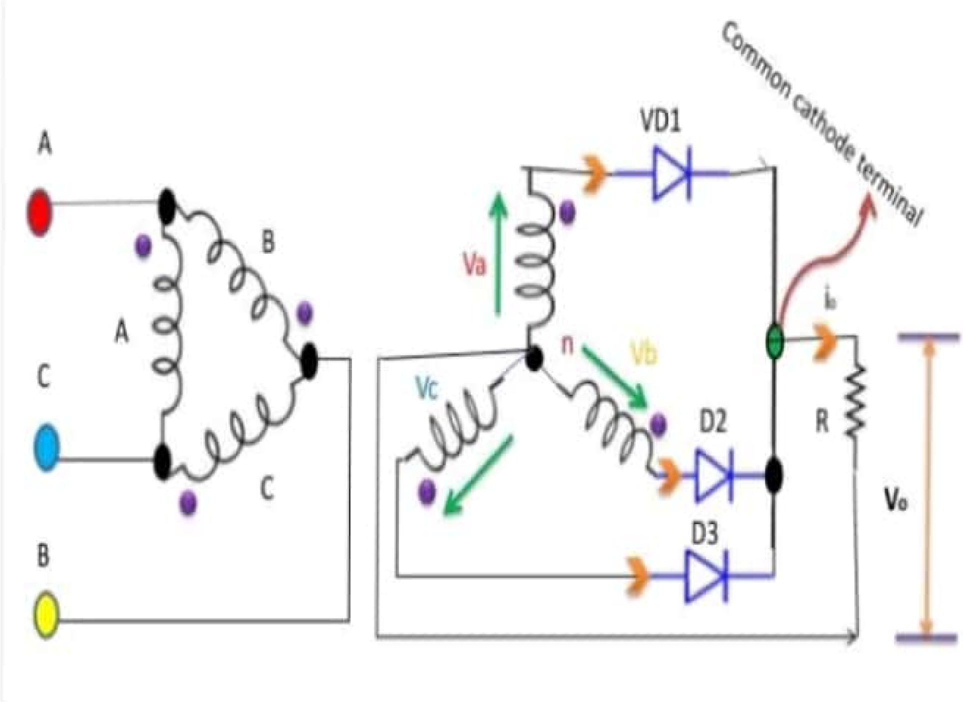
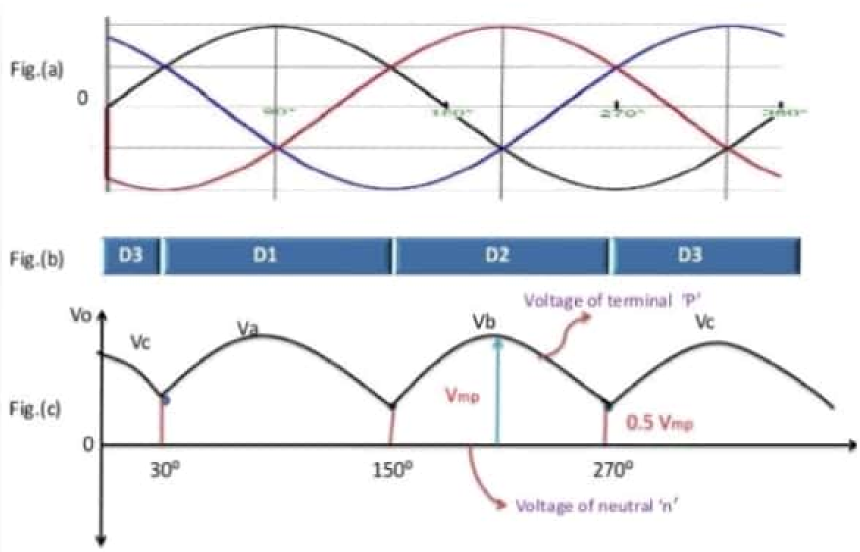
φ Half – Wave Rectifier:

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

[illegible]

- 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

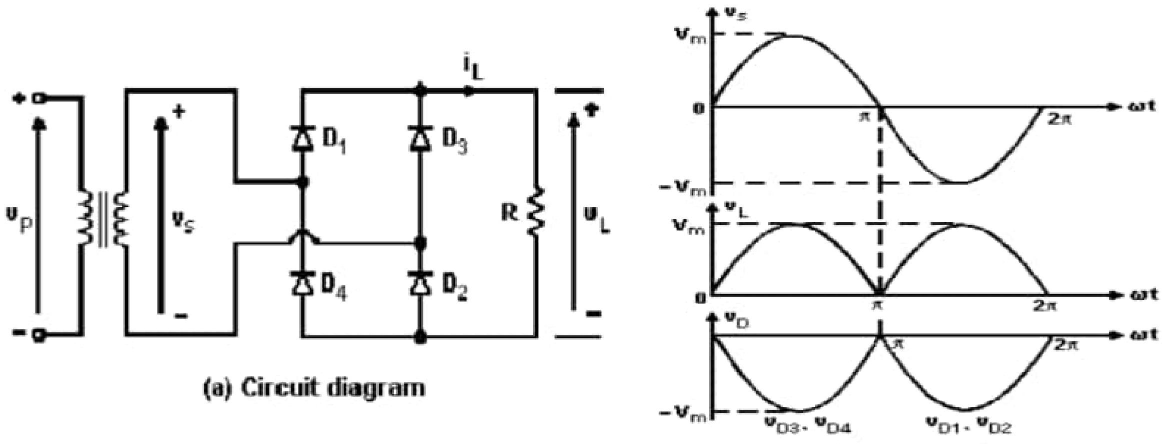
The average output voltage is the same as that for the centre - tapped transformer full- wave rectifier.

□ = □ / R

□ □ . □ □ □ □ □ □ □ □ □ □ □ □ □ □ = 2□ □ / □

□ □ □ □ □ □ □ □ □ □ □ □ □ □ □ □ = 2Vs

□ □ . □ □ □ □ □ □ □ □ □ □ □ □ □ □ = 1/□ 2sin□ □ □ (□ □)= *Im/*□



(a) Circuit diagram

(b) Waveforms

(2)

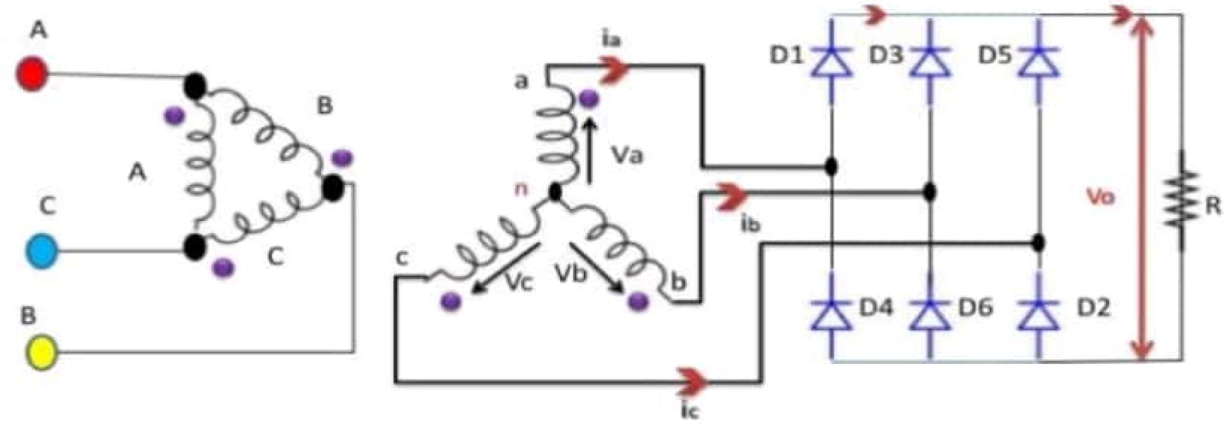
Uncontrolled bridge rectifiers:

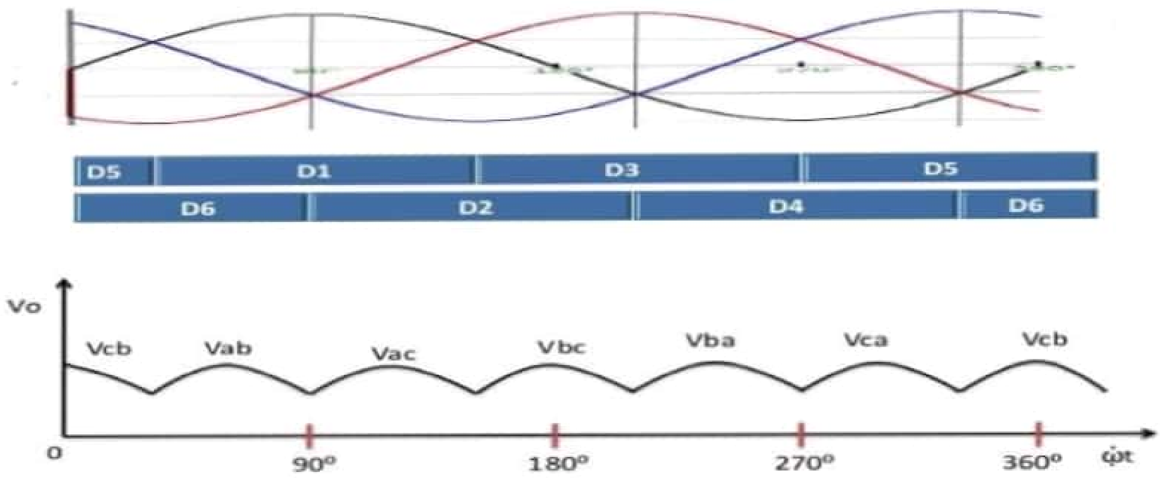
- Two series diodes are always conducting while four diodes are blocking.
- One of the conducting diodes is odd numbered while the other is even numbered.
- Each diode conducts for 120 °.
- Current flows out from the most +ve source terminal through an odd numbered diode through the load followed by 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 0° - 30°, the voltage at C is highest (arbitrarily). Hence D5 is conducting as it is the most +ve.
- Between 30° and 150°, A becomes the most +ve and hence conducting.
- During 150° - 270°, B being most +ve conducts.
- The cycle repeats itself.
- Each diode conducts for 120°.

□ □ □ □ □ □ □ □ □ □ □ □ □ = 1/□ 3 2□ /3 sin□ □ □ (□ □) 3Vm/ □ = 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

Solution:-

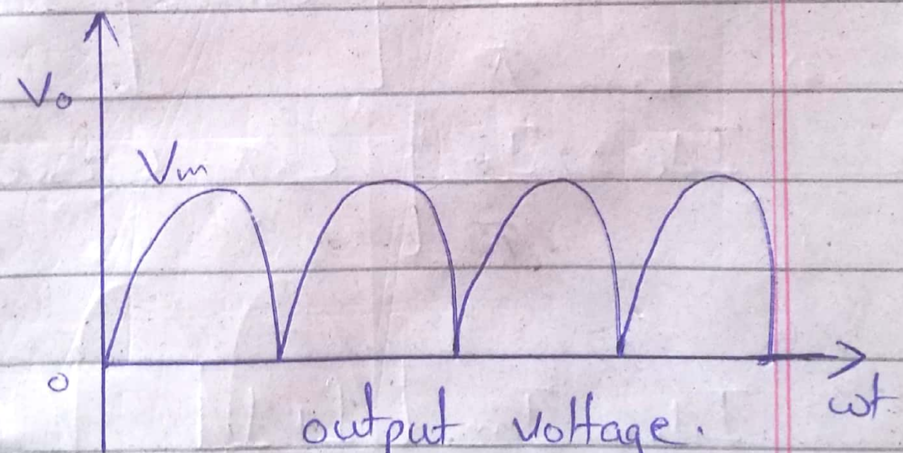
$V_m = 30\ V$

$R_L = 12\ \Omega$

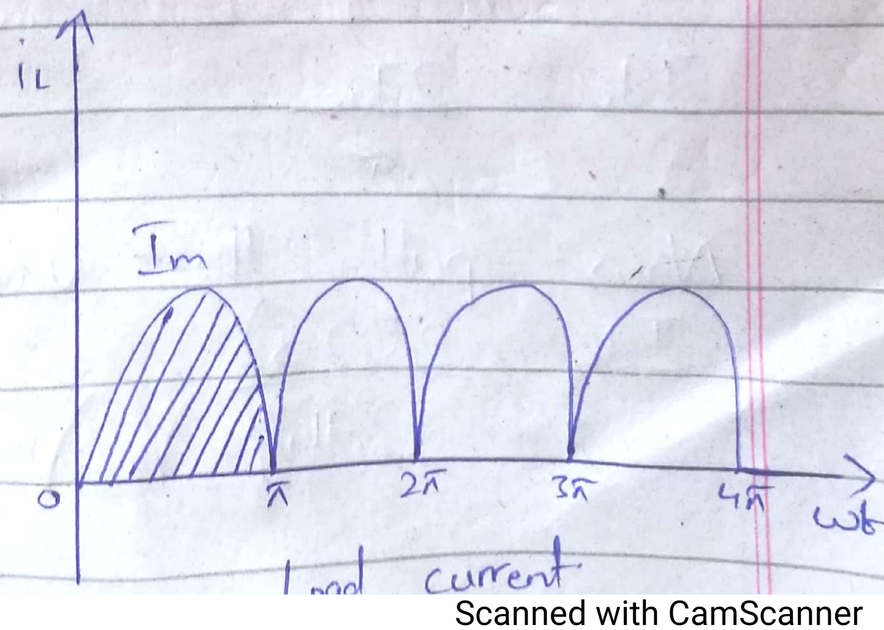
$I_m = V_m / R_L = 30/12 = I_m = 2.5\ A$

i) $I_{dc} = ?$

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



output voltage.



Load current

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

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

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

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

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

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

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

Now putt the values

$$I_{dc} = \frac{2(2.5)}{3.14}$$

$$I_{dc} = 1.59\ A$$

And

$V_{dc} = ?$

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

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

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

Putt the values

$$V_{dc} = \frac{2(30)}{3.14}$$

$$V_{dc} = 20\ V$$

In case of Half wave rectification.

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

$$I_{dc} = \frac{2.5}{3.14}$$

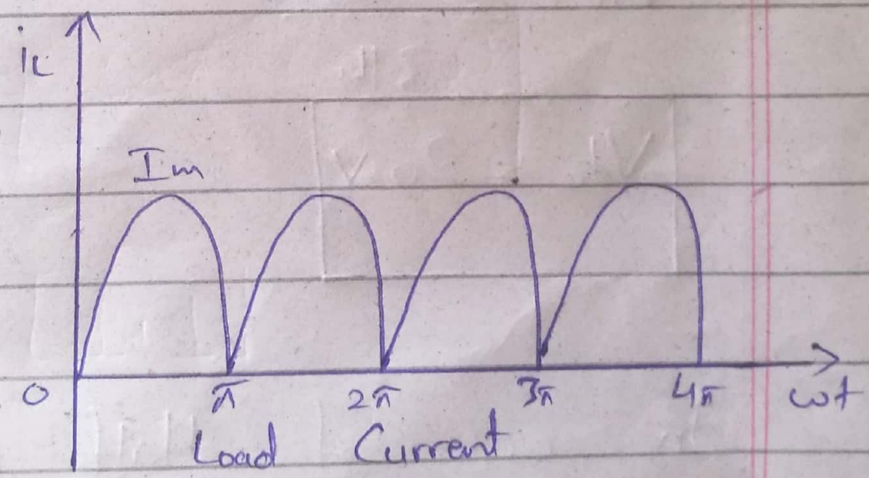
$I_{dc} = 0.79\ A$

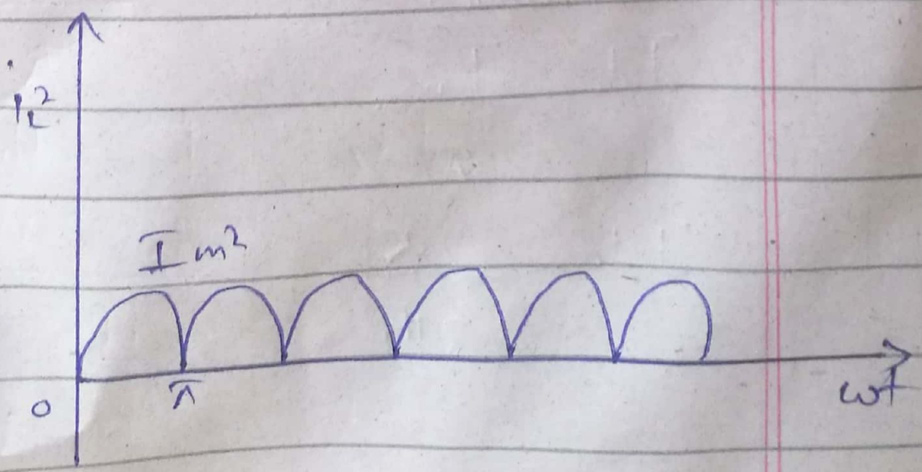
$$V_{dc} = \frac{V_m}{\pi}$$

$$V_{dc} = \frac{30}{3.14}$$

$V_{dc} = 10\ V$

3) $I_{rms} = ?$





$$I_{rms} = \sqrt{\frac{\text{area of the square of load current over full cycle}}{\text{period of the squared waveform}}}$$

$$I_{rms} = \sqrt{\frac{\int_0^{\pi} I_m^2 \sin^2 \omega t \, d(\omega t)}{\pi}}$$

$$I_{rms} = \sqrt{\frac{I_m^2}{2\pi} \int_0^{\pi} 2 \sin^2 \omega t \, d(\omega t)}$$

$$I_{rms} = \sqrt{\frac{I_m^2}{2\pi} \int_0^{\pi} (1 - \cos 2\omega t) \, d(\omega t)}$$

$$I_{rms} = \sqrt{\frac{I_m^2}{2\pi} \left[\omega t - \frac{\sin 2\omega t}{2} \right]_0^{\pi}}$$

$$I_{rms} = \frac{I_m^2}{2\pi} \left[\pi - \frac{\sin 2\pi}{2} - 0 + \frac{\sin 2(0)}{2} \right]^{1/2}$$

$$I_{rms} = \sqrt{\frac{I_m^2}{2\pi} \times \pi}$$

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

Putt the values.

$$I_{rms} = \frac{2.5}{\sqrt{2}}$$

$$\boxed{I_{rms} = 1.76\ A}$$

And

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

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

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

Putt the values.

$$V_{rms} = \frac{30}{\sqrt{2}}$$

$$\boxed{V_{rms} = 22\ V}$$

The value of I_{rms} and V_{rms} are same in case of half wave sectification.

5) I think the full wave uncontrolled rectifier will suit better for its efficiancy and its output.

Question # 03

Buck Converter:-

A buck converter 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 analogues to step down

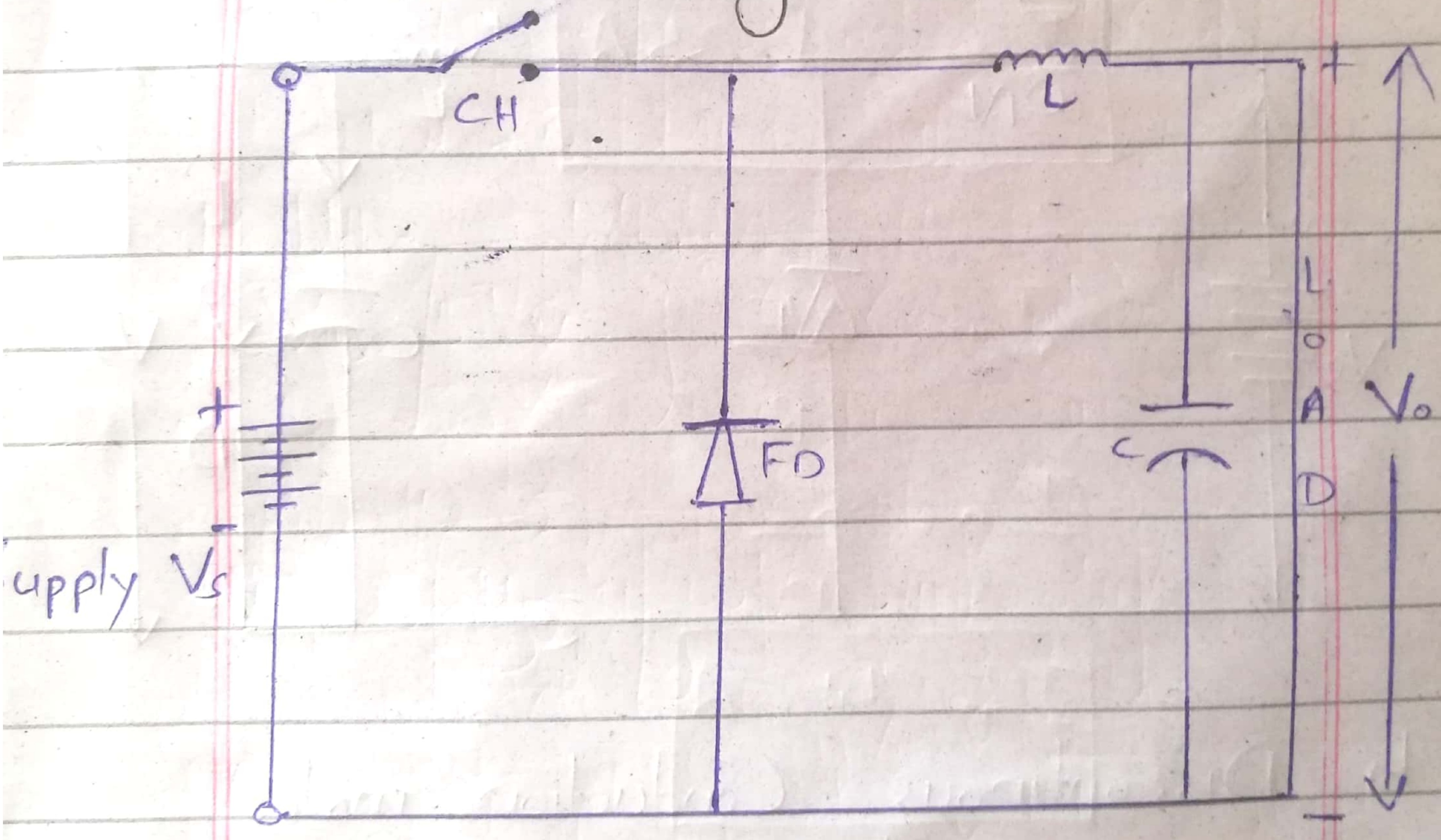
down transformer the input voltage is stepped down to a level less than the input voltage

Principle of Operation:-

The main working principle of buck converter is that the inductor in the input circuit resists sudden variation in the input current. When the switch is ON the inductor stores energy in the form of magnetic energy and discharges it when the 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)

Circuit Diagrame:-

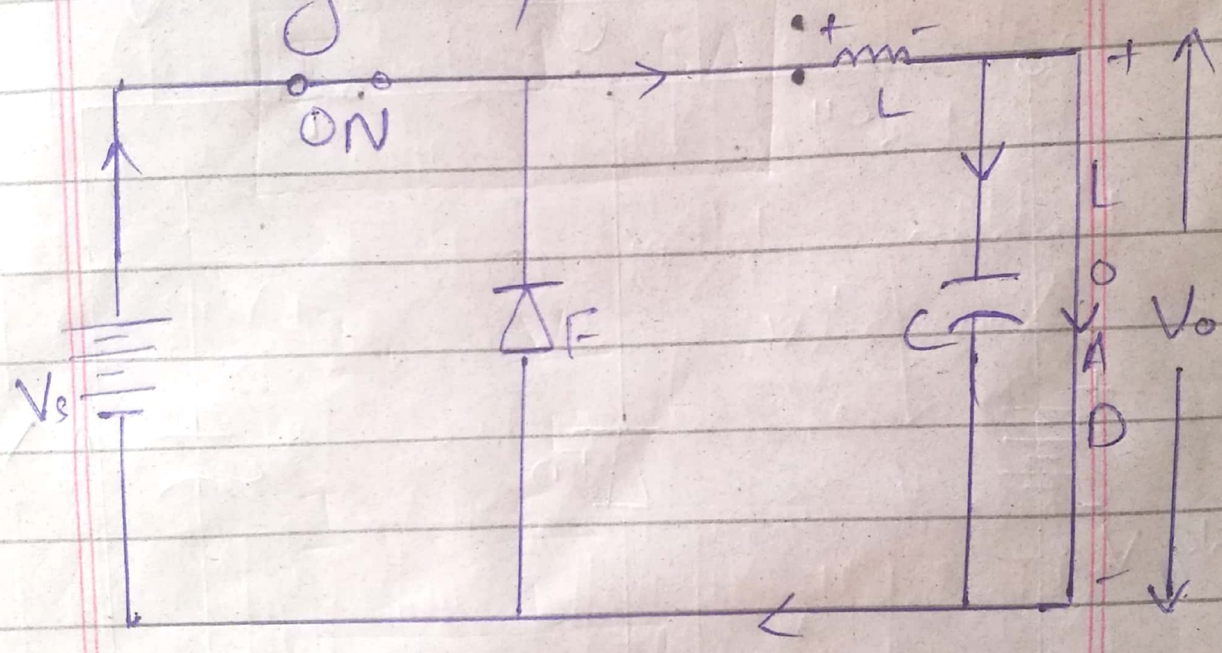


Modes of operation of Buck converter:-

The buck converter can be operated in two modes.

a) Continous conduction mode:

In this mode the current through inductor never goes to zero i-e inductor partially discharges before the start of the switching cycle.



b) Discontinous Conduction mode:

In the mode the current through inductor goes to zero i-e inductor is completely discharged at the end of switching cycle.

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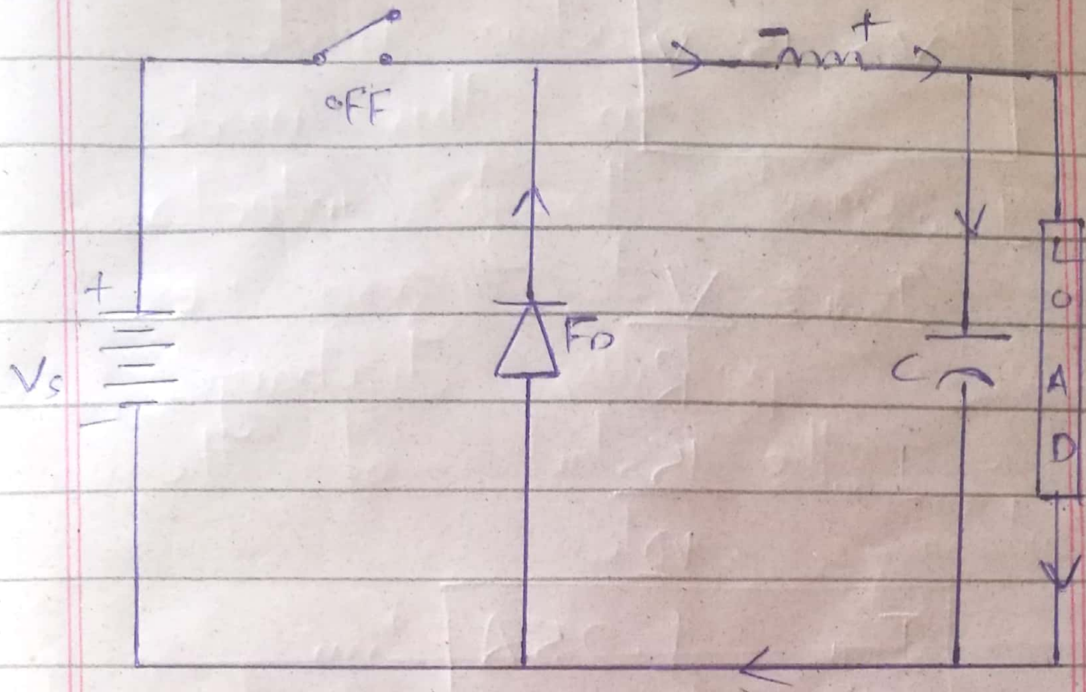

Problem solution:-

$V_{in} = 50\,V$

$D = 30\,\%$

$R_L = 12\,\Omega$

$F = 20\,kHz$

$V_{out} = ?$

As we know that the expression is.

$\langle V_o \rangle = DV_i$

Simply put the values.

$\langle V_o \rangle = 0.3 \times 50$

$$\langle V_o \rangle = 15\ V$$

ii) $I_{out} = ?$

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

$$I_{out} = \frac{15}{12}$$

$$I_{out} = 1.25A$$

iii) $I_{in} = ?$

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

$$I_{in} = \frac{50}{12}$$

$$I_{in} = 4.16\ A$$

iv) Inductance L.

As we know that

$$\frac{T_{ON}}{T} = 0.3 \qquad \therefore d = \frac{T_{ON}}{T}$$

$$T_{ON} = 0.3 \times T.$$

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As $T = 1/f$

$$T_{ON} = \frac{0.31}{f}$$

$$T_{ON} = \frac{0.31}{20,000} = 1.5 \times 10^{-5}\ \mu s$$

Also

$$\frac{T_{ON}}{T} = 0.3$$

$$\frac{T_{ON}}{0.3} = T$$

Putt the values.

$$T = \frac{1.5 \times 10^{-5}}{0.3}$$

$$T = 5 \times 10^{-5}\ \mu s$$

And

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

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

$$T_{OFF} = 5 \times 10^{-5} - 1.5 \times 10^{-5}$$

$$T_{OFF} = 3.5 \times 10^{-5}$$

Now we will find

L

$$L = \frac{V_i - V_o}{2 i_o} \times DT$$

Putt the values.

$$L = \frac{50 - 15}{2(1.25)} \times (0.3)(5 \times 10^{-5})$$

$$L = \frac{35}{2.5} \times 1.5 \times 10^{-5}$$

$$\boxed{L = 0.00021 \mu H}$$

Question #04

Boost Converter:-

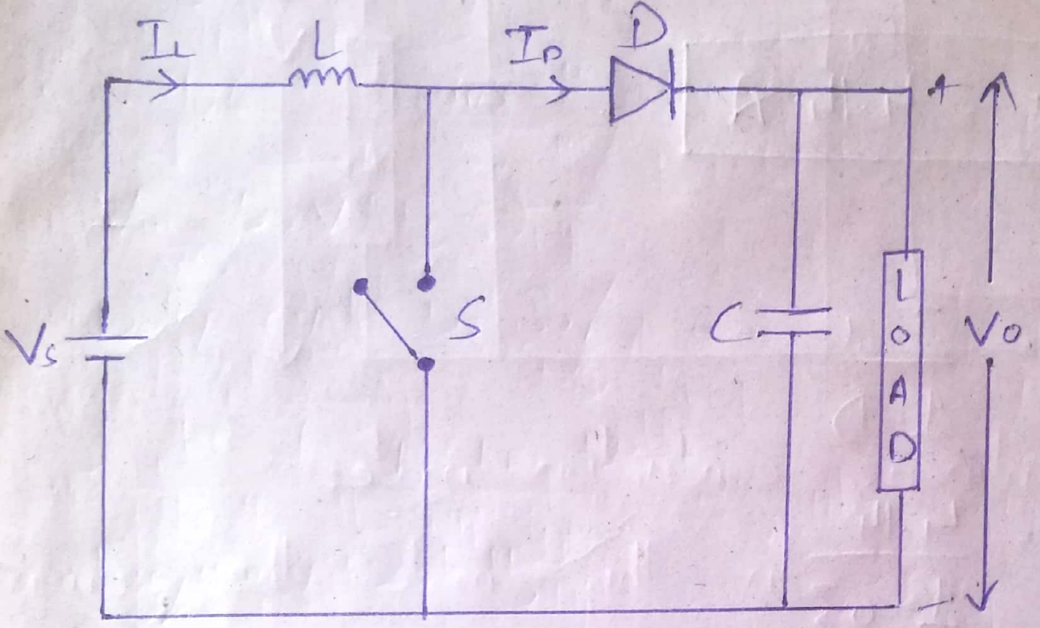
A boost converter is a switch mode DC to DC converter in which the output voltage is greater than the input voltage. It is also called as step up converter. The name step up converter comes from the fact that analogues to step up transformer the input voltage is stepped up to a level greater than the input voltage.

Principle of operation of Boost converter:-

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 is 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)

Circuit Diagram:-

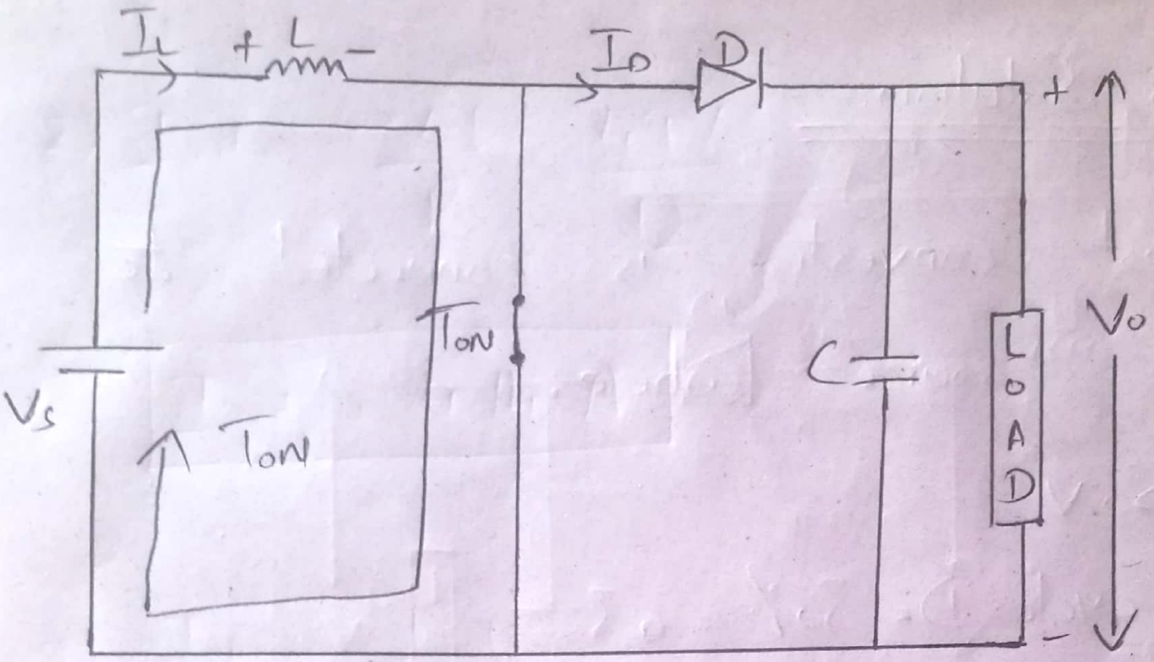


Modes of operation of Boost Converter:-

The boost converter can be operated in two modes.

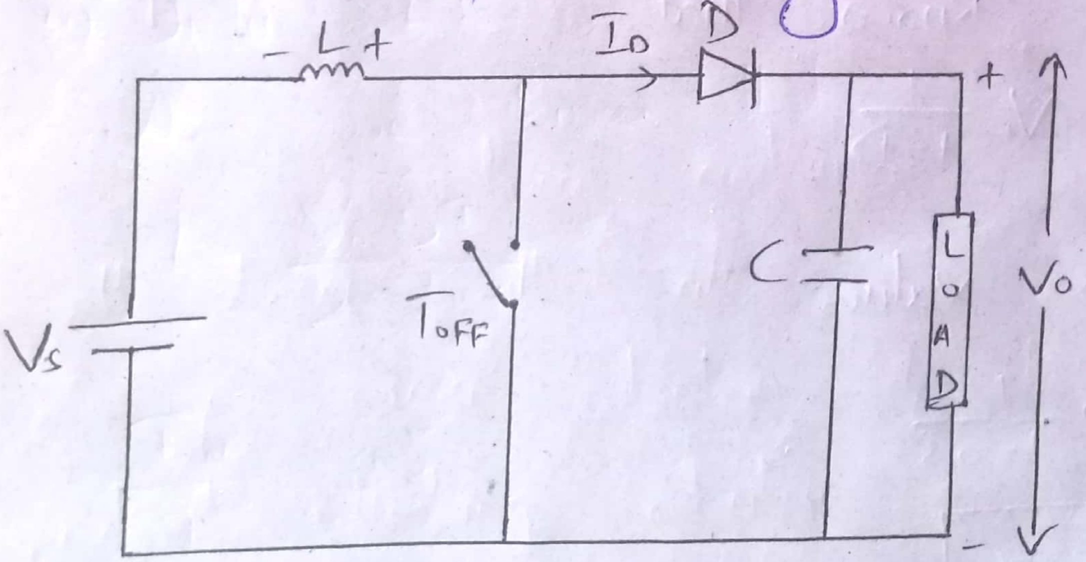
a) Continuous Conduction mode:

In this mode the current through inductor never goes to zero i.e inductor partially discharges before the start of the switching cycle.



2) Discontinous conduction mode:

In this mode the current through inductor goes to zero i-e inductor is completely discharged at the the end of switching cycle.



Problem Solution:-

A Boost converter is connected to a DC source where:

$V_{in} = 50V$

Duty cycle $D = 30\% = 0.3$

load of $R = R_L = 12\,\Omega$

Frequency $= 20KHz$

Find:-

① $V_{out} = ?$

As we know that

$$\langle V_o \rangle = V_i \frac{1}{1-D}$$

Putting the values

$$V_o = 50 \frac{1}{1-0.3}$$

~~[illegible]~~

$$\boxed{V_o = 49.7V}$$

2) $I_{out} = \frac{V_{out}}{R} = \frac{49.7}{12}$

$$\boxed{I_{out} = 4.14\ A}$$

3) $I_{in} = \frac{I_{out}}{1-D}$

$I_{in} = \frac{4.14}{1-0.3}$

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

4) Inductor L:-

As we know that

$L = \frac{V_i\, DT}{2 \langle I_{in} \rangle}$

$\frac{T_{ON}}{T} = 0.3$

$T_{ON} = 0.3 \times T$

As $T = 1/f$

$T_{ON} = \frac{0.3}{f}$

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$T_{on} = \frac{0.3}{20,000} = 1.5 \times 10^{-5}$

Also

$\frac{T_{ON}}{T} = 0.3$

$\frac{T_{ON}}{0.3} = T$

$T = \frac{1.5 \times 10^{-5}}{0.3}$

$T = 5 \times 10^{-5}$

And

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

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

$T_{OFF} = 5 \times 10^{-5} - 1.5 \times 10^{-5}$

$T_{OFF} = 3.5 \times 10^{-5}$

Now Put the values.

$L = \frac{V_i D T}{2 \langle I_{in} \rangle}$

$L = \frac{50 \times 0.3 \times 5 \times 10^{-5}}{2 \times 3.84}$

$L = \frac{0.00075}{7.68}$

$L = 0.00009765 \text{ H}$

Question # 05

Answer:-

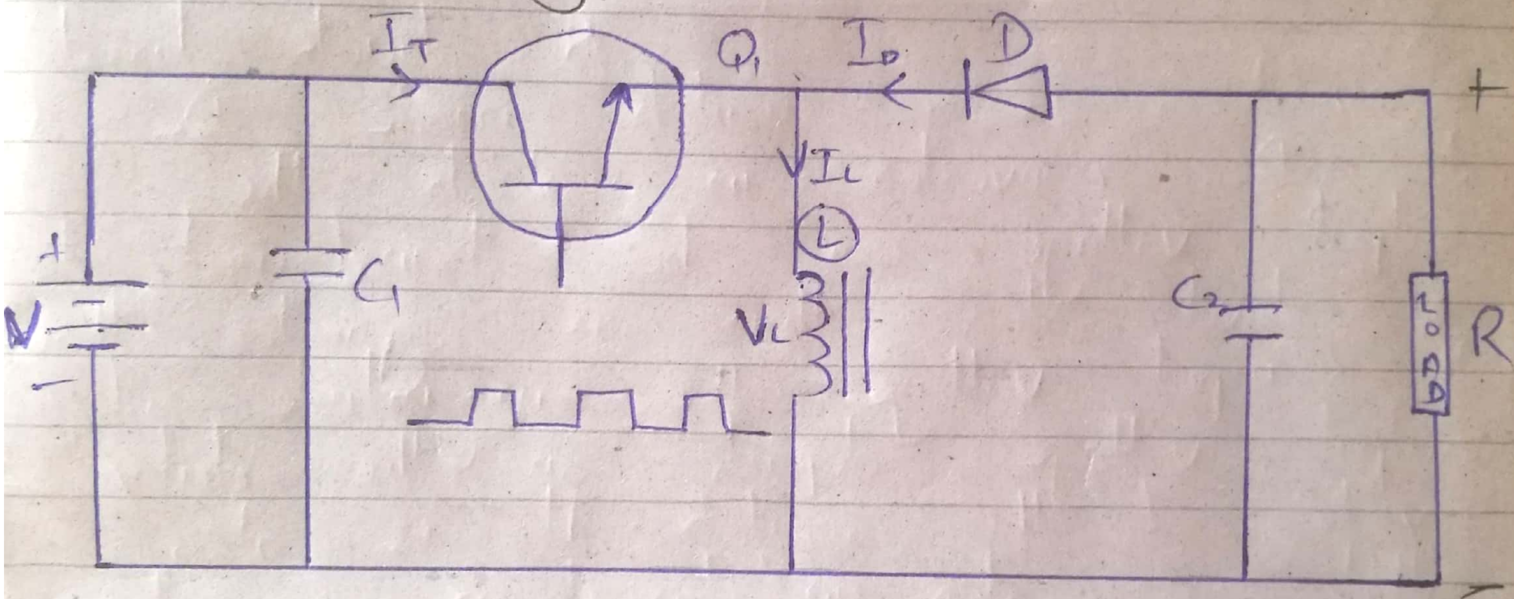
Buck Boost Converter:-

A buck boost converter is a switch mode DC to DC converter in which the output voltage can be transformed to a level less than or greater than the input voltage. The magnitude of output voltage depends on the duty cycle of the switch. It is also called as step up / step down converter. The name stepup/stepdown converter comes from the fact that analogues to step up/ step down transformer the input voltage can be stepped ~~down~~ up/ down to a level greater than /less than the input voltage.

Principle of Operation:-

The main working principle of buck boost converter is that the inductor in the input circuit resists sudden variations in input current. When the switch is ON the inductores stores energy from the input in the form of magnetic energy and discharges it when the switch is closed.

Circuit Diagrame.



Problem Solution:-

A buck boost converter