IQRA NATIONAL UNIVERSITY PESHAWAR

DEPTT. B.E. (ELECTRICAL)

8TH SEMESTER

SPRING 2020

MID TERM EXAMINATION

ENGINEERING MANAGEMENT AND ECONOMICS

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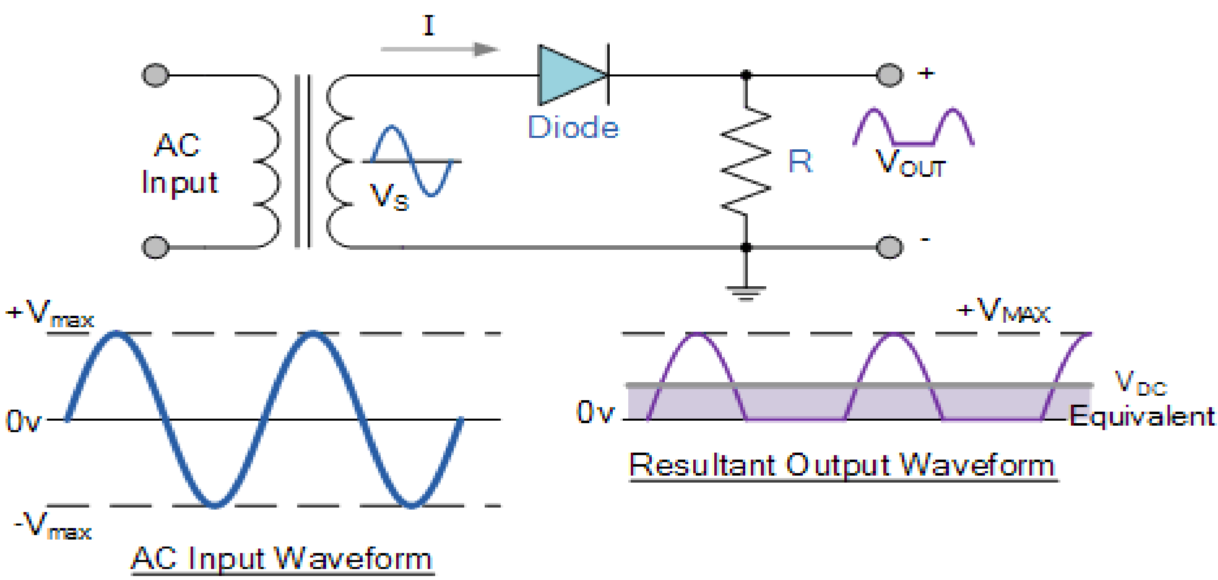
Q1: 10

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 – φ Uncontrolled Half Wave Rectifier and Full Wave Bridge Rectifier
2. 1 – φ Uncontrolled Rectifier and Controlled Rectifiers (Bridge Rectifier). **CLO2**

<u>1 – φ Uncontrolled Rectifier:</u>

- During each "positive" half cycle of the AC sine wave, the diode is forward biased as the anode is positive with respect to the cathode resulting in current flowing through the diode.
- Since the DC load is resistive (resistor, R), the current flowing in the load resistor is therefore proportional to the voltage (Ohm´s Law), and the voltage across the load resistor will therefore be the same as the supply voltage, V s (minus V f), that is the "DC" voltage across the load is sinusoidal for the first half cycle only so V out = V s.
- During each "negative" half cycle of the AC sinusoidal input waveform, the diode is reverse biased as the anode is negative with respect to the cathode.
- Therefore, NO current flows through the diode or circuit. Then in the negative half cycle of the supply, no current flows in the load resistor as no voltage appears across it so therefore, V out = 0



<u>Single Phase Half Wave Rectifier (R Load):</u>

$$Av.\ output\ Voltage\ V_o = \frac{1}{2\pi}\left[{}_0^{\pi} V \sin \omega\, t\ d(\omega t)\right] = \frac{V_m}{2\pi}\left| -\cos \omega t\ \right|_0^{\pi} = \frac{V}{\pi}$$

$RMS\ Output\ Voltage\ V_{rms} = [\frac{1}{2\pi}\int_0^{\pi} V_m{}^2 \sin \omega^2 t d(\omega t)]^{\frac{1}{2}} = \frac{V_m}{\sqrt{2\pi}}[\int_0^{\pi}\frac{1-cos2\omega t}{2} d(\omega t)]^{\frac{1}{2}} = \frac{V_m}{2}$

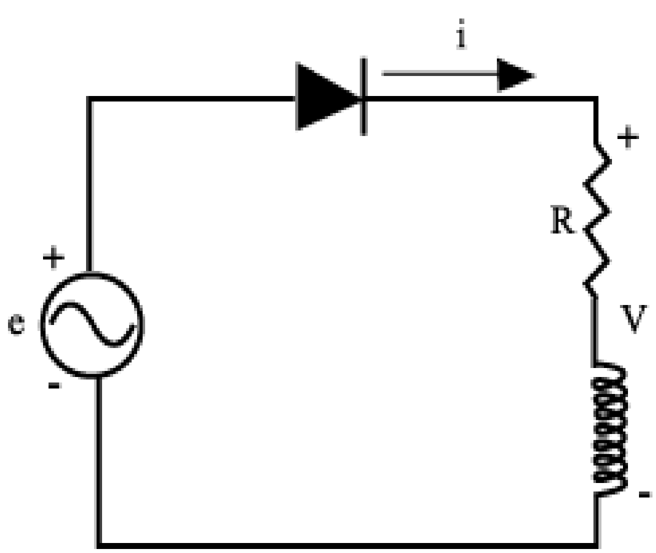
$Av.\ Load\ Current\ I_0 = \frac{V_0}{R} = \frac{V_m}{\pi R}$

$RMS\ Load\ Current\ I_{rms} = \frac{V_{rms}}{R} = \frac{V_m}{2R}$

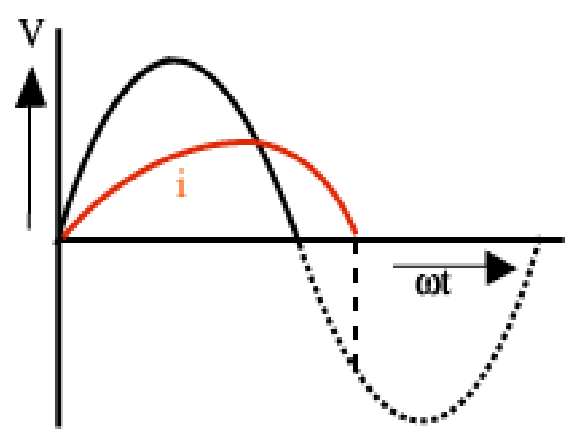
$Input\ Power\ Factor = \frac{V_{rms} * I_{rms}}{V_s * I_{rms}} = \frac{\sqrt{2}V_s}{2V_s} = 0.707\ lag$

Single Phase Half Wave Rectifier (RL Load):

- Current I_0 continues to flow even after source voltage V_S is negative because of the presence of inductance L in load.
- After + ve half cycle, diode remains ON, so – ve half cycle appears across load current until I_0 decays to zero at $\omega t = \beta$.
- When $I_0 = 0$ at $\omega t = \beta$; $V_L = 0$, $V_R = 0$ and V_S appears as reverse bias across diode D.
- At β, diode voltage V_D jumps from 0 to V M sin β where $\beta > \pi$.
- Here $\beta = \gamma$ is the conduction angle of the diode.
- $Av.\ output\ Voltage\ V_0 = \frac{1}{2\pi}\int_0^{\beta} V \sin \omega t d(\omega t) = \frac{V_m}{2\pi}(1 - cos\beta)$
- $Av.\ Output\ Currrent\ I_0 = \frac{V_0}{R} = \frac{V_m}{2\pi} = \frac{V_m}{2\pi}(1 - cos\beta)$



(a) Rectifier Circuit

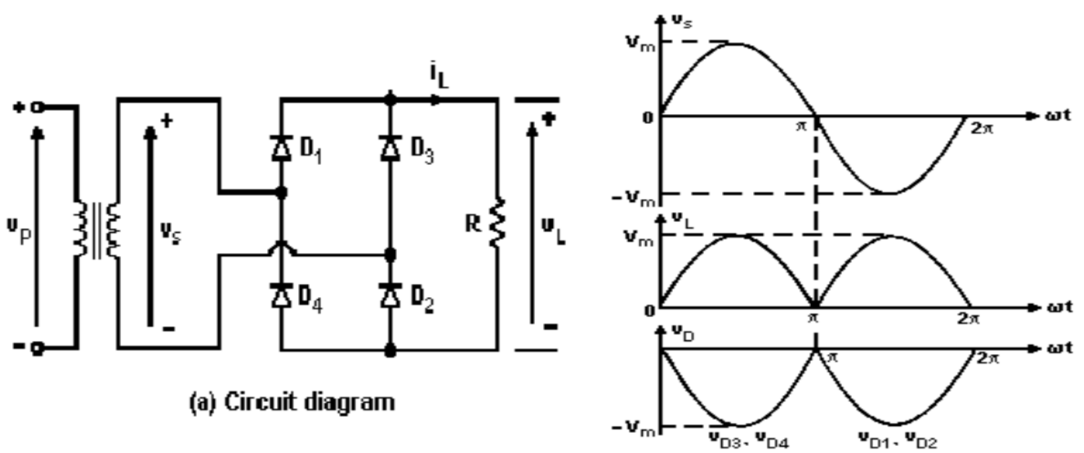


(b) Waveform

1 – φ Full Wave Bridge 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.
- $Peak\ Repetitive\ Diode\ Current\ I = \frac{V_m}{R}$
- $Av.\ Output\ Voltage\ V_0 = \frac{2V_m}{\pi};\ RMS\ Output\ Voltage\ V_{rms} = \sqrt{2}V_s$
- $Av.\ Diode\ Current\ I_D = \frac{1}{2\pi}\,{}_{0}^{\pi}I\ sin\omega t d(\omega t) = \frac{I_m}{n};$
- $RMS\ Output\ \ Voltage\ V_{rms} = \sqrt{2}V_s$
- $RMS\ Diode\ \ Current\ \ I_{Drms} = [\frac{1}{2\pi}\,{}_{0}^{\pi}I_m{}^2 sin^2\omega t d(\omega t)]^{\frac{1}{2}} = \frac{I_m}{2}$



(a) Circuit diagram

(b) Waveforms

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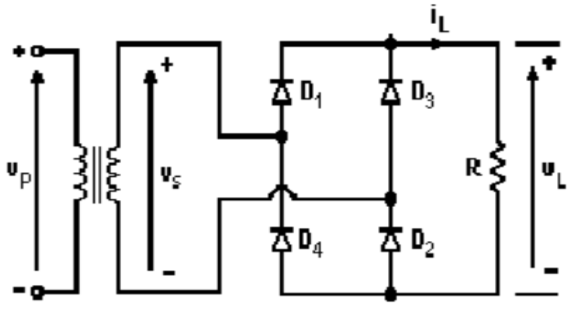
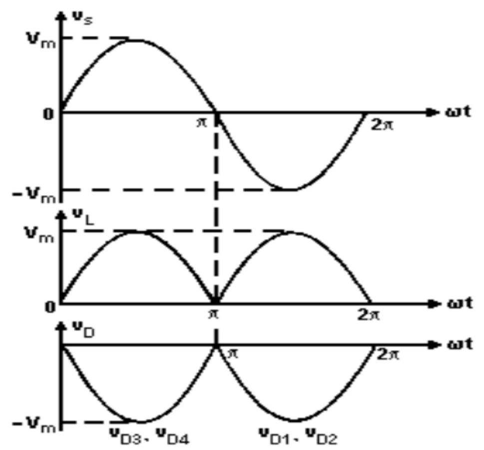
1 – φ Full Wave Uncontrolled Bridge Rectifier:

- 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.
- $Peak\ Repetitive\ Diode\ Current\ I = \frac{V_m}{R}$
- $Av.\ Output\ Voltage\ V_0 = \frac{2V_m}{\pi};\ RMS\ Output\ Voltage\ V_{rms} = \sqrt{2}V_s$
- $Av.\ Diode\ Current\ I_D = \frac{1}{2\pi}\,{}_{0}^{\pi}I\ sin\omega t d(\omega t) = \frac{I_m}{n};$
- $RMS\ Output\ \ Voltage\ V_{rms} = \sqrt{2}V_s$
- $RMS\ Diode\ \ Current\ \ I_{Drms} = [\frac{1}{2\pi}\,{}_{0}^{\pi}I_m{}^2 sin^2\omega t d(\omega t)]^{\frac{1}{2}} = \frac{I_m}{2}$



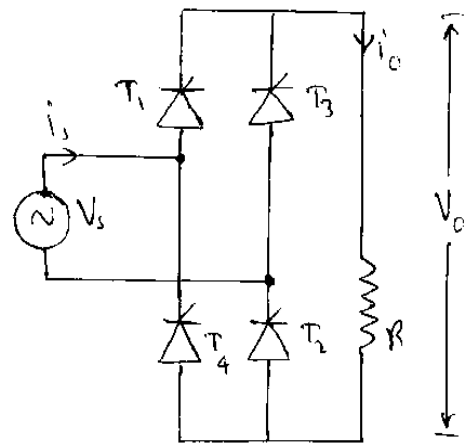
(a) Circuit diagram



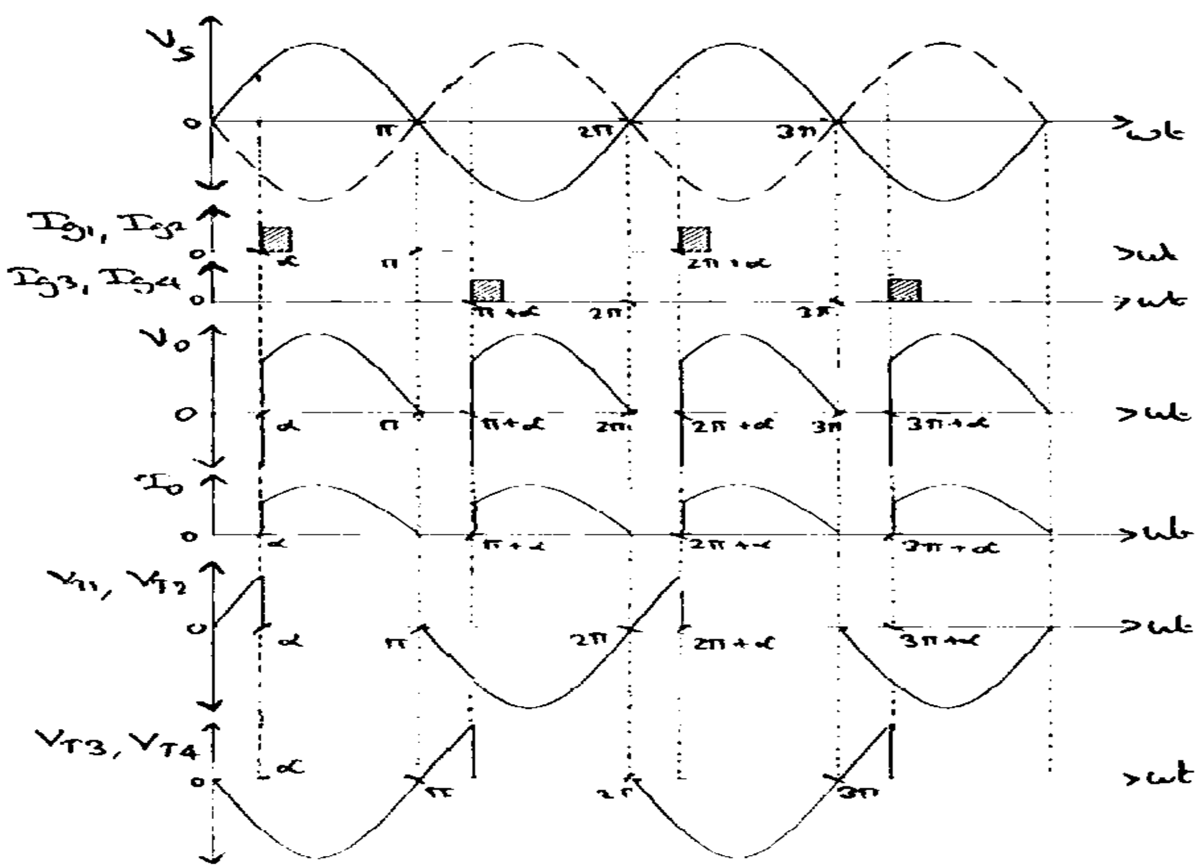
(b) Waveforms

1 – φ Full Wave Controlled Rectifier (R Load):

- The circuit consist of four thyristors T1, T2, T3 and T4, a voltage source Vs and a R Load.
- During the positive half cycle of the input voltage, the thyristors T1 & T2 is forward
- biased but it does not conduct until a gate signal is applied to it.
- When a gate pulse is given to the thyristors T1 & T2 at $\omega t = \alpha$, it gets turned ON and begins to conduct.
- When the T1 & T2 is ON, the input voltage is applied to the load through the path Vs-T1-
- Load-T2-Vs.
- During the negative half cycle, T3 & T4 is forward biased, the thyristor T1 & T2 gets
- reverse biased and turns OFF
- When a gate pulse is given to the thyristor T3 & T4 at $\omega t = \pi+\alpha$, it gets turned ON and begins to conduct.
- When T3 & T4 is ON, the input voltage is applied to the load Vs-T3-Load-T4-Vs.
- Here the load receives voltage during both the half cycles.
- The average value of output voltage can be varied by varying the firing angle α.
- The waveform shows the plot of input voltage, gate current, output voltage, output current and voltage across thyristor.



T1
T3
T4
T2
is
Vs
io
Vo
R



Vs
Ig1, Ig2
Ig3, Ig4
Vo
Io
VT1, VT2
VT3, VT4
ωt

Q2: 10

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. V_{dc}
2. I_{dc}
3. V_{rms}
4. I_{rms}

Which rectifier do you think is better and why. **CLO2**

Given Data:

Vm = 09 V

R = 13 Ω

To Find:

V_{dc}
I_{dc}
V_{rms}
I_{rms}

Solution:

Single Phase Half Wave Rectifier (R Load):

V_{dc}:

$$V_{dc} = \frac{V_m}{\pi}$$
$$V_{dc} = \frac{9}{3.14}$$
$$V_{dc} = 2.86V$$

I_{dc}:

$$I_{dc} = \frac{V_m}{\pi R}$$
$$I_{dc} = \frac{9}{(3.14)(13)}$$
$$I_{dc} = \frac{9}{40.82}$$
$$I_{dc} = 0.220A$$

V_{rms}:

$$V_{rms} = \frac{V_m}{2}$$
$$V_{rms} = \frac{9}{2}$$
$$V_{rms} = 4.5V$$

I_{rms}:

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

$I_{rms} = \frac{9}{2(13)}$

$I_{rms} = \frac{9}{26}$

$I_{rms} = 0.346A$

1 – φ Full Wave Uncontrolled Bridge Rectifier:

V_{dc}:

$V_0 = V_s = V_{dc} = \frac{2V_m}{\pi}$

$V_{dc} = \frac{2(9)}{3.14}$

$V_{dc} = \frac{18}{3.14}$

$V_{dc} = 5.729V$

I_{dc}:

$I_{dc} = \frac{V_m}{R}$

$I_{dc} = \frac{9}{13}$

$I_{dc} = 0.69A$

V_{rms}:

$V_{rms} = \sqrt{2}V_s$

$V_{rms} = \sqrt{2}(5.729)$

$V_{rms} = 8.10V$

I_{rms}:

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

$I_m = \frac{V_m}{R} = I_{dc}$

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

$I_{rms} = \frac{0.69}{2}$

$I_{rms} = 0.346A$

Full wave rectifier is better because the output voltage obtained by full wave rectifier is more than half wave rectifier.

Q3: 10

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.

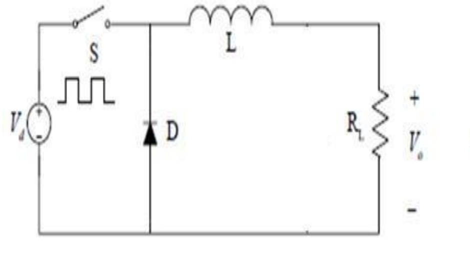
The buck converter is connected to a DC source voltage of Vin = 50V. The duty cycle is D = (Last 2 digits of ID) %, load of R = (First 2 digits of ID) ohms and switching frequency of 20kHz. What will be the

1. Vout
2. Iout
3. Iin
4. Inductor (L) **CLO3**

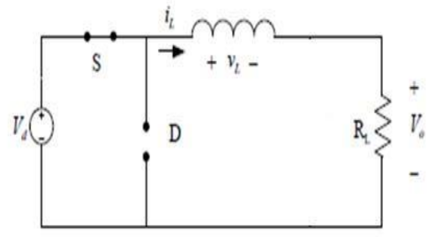
Step Down (Buck) Chopper:

- Output Voltage is less than input voltage.
- The thyristor in the circuit acts as a switch.
- When thyristor is ON, supply voltage appears across the load
- When thyristor is OFF, the voltage across the load will be zero.
- Practical arrangement includes an inductor (L) and a diode which are used to eliminate current pulsations providing a smooth DC current.
- With S closed, D is Off and it remains Off as long as S in On.
- The i/p current builds up exponentially and flows through L and load.
- V O equals V I.
- With S OFF or open, the current through L decays to zero.
- This causes an inductive voltage with opposite polarity across L.
- V L forward biases diode D.
- Current flows through L, Load and D.
- This arrangement permits the use of simple filter inductance L to provide a satisfactorily smooth DC load current.
- With higher switching frequency, smaller inductance is sufficient to get desired O/P.

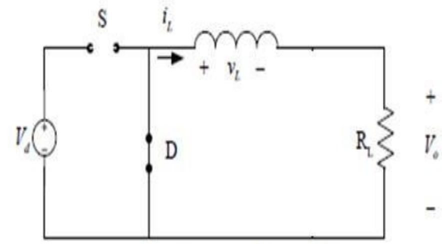
Circuit Diagrams:



CIRCUIT OF BUCK CONVERTER

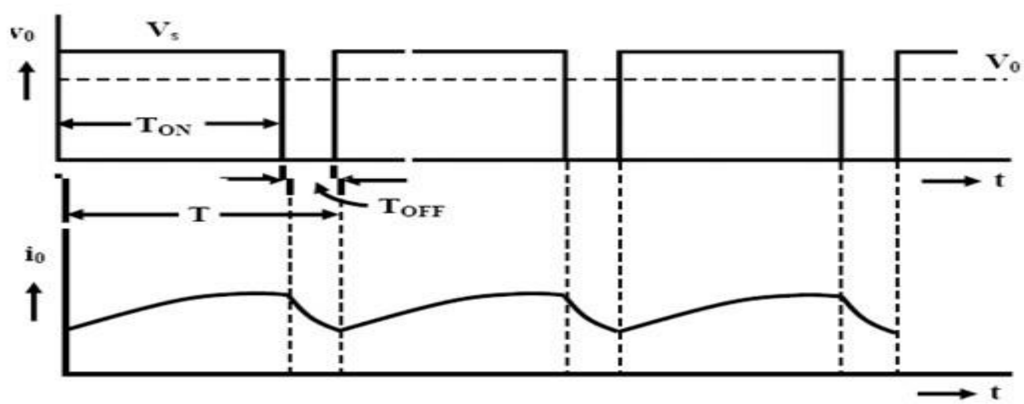


CIRCUIT WHEN SWITCH IS CLOSED



CIRCUIT WHEN SWITCH IS OPENED

- The o/p voltage is equal to the i/p voltage when the switch is ON and D is reverse biased.
- Diode current is same as the load current during T OFF.
- During T ON, I O is same as I I.



The average value of inductor current is:

$$I_L \frac{I_{max} + I_{min}}{2} = I_0 \frac{V_0}{R}$$

Again

$$V_L = V_0 = L \frac{d_{i0}}{dt} \rightarrow \frac{di_0}{dt} = \frac{V_0}{L} \rightarrow \Delta i_0 = \frac{V_0}{L} \Delta t$$

With Switch Open

$$\text{Peak to Peak Ripple Current Ip-p} = \Delta i_0 = I_{max} - I_{min} = \frac{V_0}{L} T_{OFF}$$

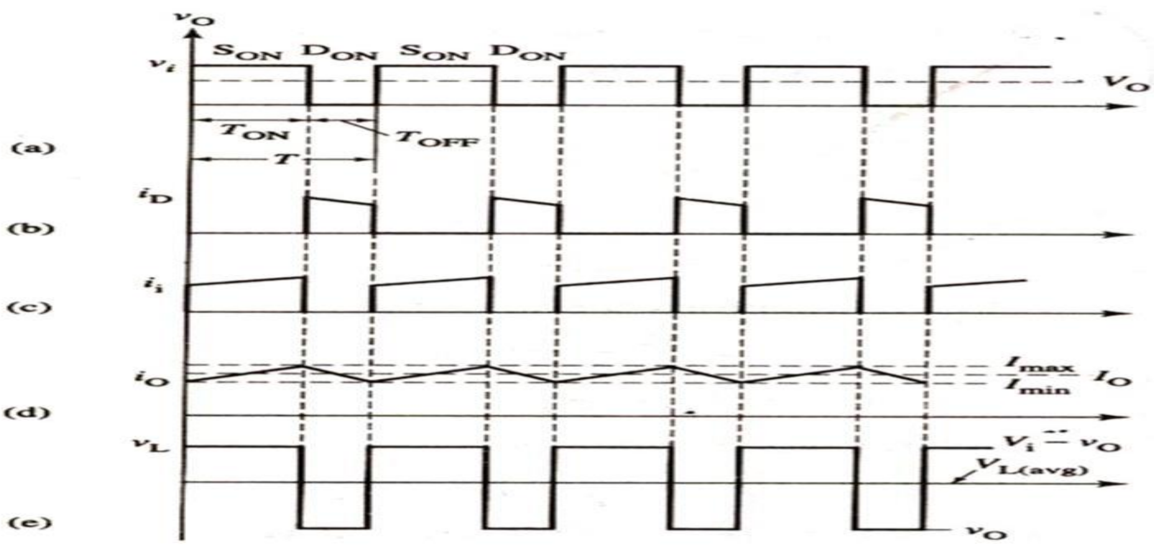
Hence,

$$I_{max} = \frac{V_0}{R} + \frac{V_0}{2L} T_{OFF}\ ;\ I_{min} = \frac{V_0}{R} - \frac{V_0}{2L} T_{OFF}$$

$$I_D \frac{I_{OFF}.T_0}{T};\ I_0 = \frac{I_i}{d}; d = duty\ cycle$$

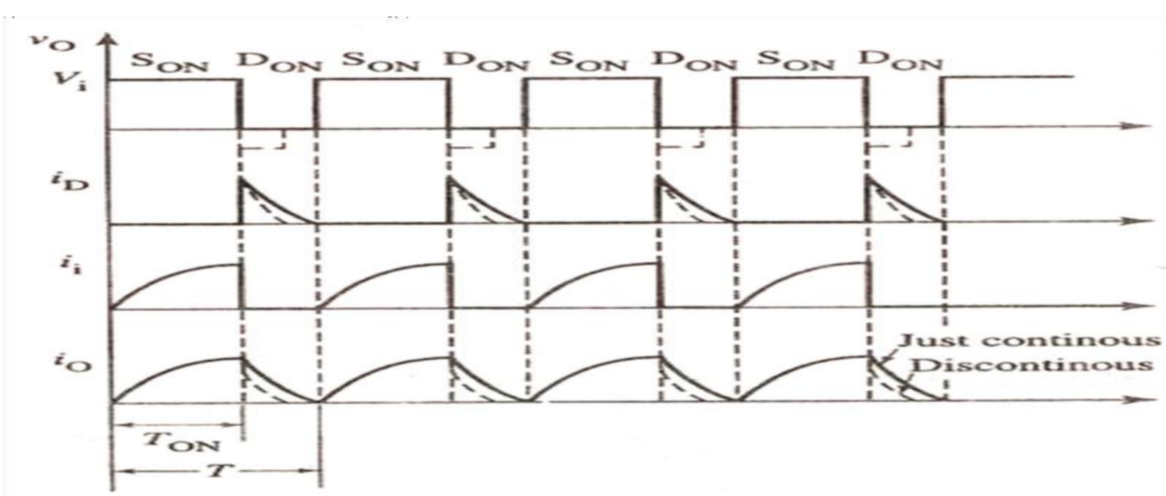
- As elements are ideal, DC power drawn from source must equal the DC power absorbed by load.

$$P_0 = P_i \rightarrow V_0 I_0 = V_i I_i$$



Step Down (Buck) Chopper – Discontinuous Current:

- For low value of "d" with low L, I L decreases and may fall to zero during T OFF.
- It again builds up with T ON, and hence it is called discontinuous current.



- This mode is undesirable and is avoided by proper selection of chopping frequency and L.
- The minimum value of L for continuous current mode is ensured by setting I min = 0.

$$I_{min} = 0 = \frac{V_0}{R} - \frac{V_0}{R} T_{OFF}$$

$$\frac{V_0}{R} = T_{OFF} . \frac{V_0}{2L}$$

$$2L = T_{OFF} R$$

$$L = \frac{T_{OFF}}{2} R$$

Numerical:

Given Data:

Vin = 50V

D = 9%

R = 13Ω

f = 20kHz

To Find:

Vout = ?

Iout = ?

Iin = ?

Inductor (L) = ?

Solution:

I_{in}:

Vin = Iin × R

Iin = $\frac{50V}{13\Omega}$

Iin = 3.846A

I_{out}:

$$d = \frac{I_i}{I_o}$$

$$I_0 = \frac{I_i}{d}$$

$$I_0 = \frac{3.846}{0.09}$$

$$I_0 = 42.7\ A$$

V_{out}:

$$V_0 = I_0 R$$

$V_0 = 42.7 \times 13$

$V_0 = 555.13V$

Inductor (L):

$$L = \frac{T_{OFF}}{2} R$$

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

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

$$T = \frac{1}{20000}$$

T = 50µsec

$$L = \left(\frac{50}{2}\right) 13$$

L = 325µH

Q4: 10

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) **CLO3**

Step Up (Boost) Chopper:

- The output voltage is more than the input voltage by several times.
- L is used to provide a smooth i/p current.
- The SCR (S) acts as the switch which works in the PWM mode.
- With S On, the L is connected to the supply.
- Load voltage V L jumps instantaneously to V I, but current through L increases linearly & stores energy.
- When S is Open, the current collapses and energy stored in L is transferred to C through D.
- The induced voltage across the inductor reverses and adds to the source voltage increasing the O/P voltage.
- The current that was flowing through S now flows through L, D and C to the load.
- Energy stored in the inductor is released to the load.
- With S closed again, D becomes reverse biased, the capacitor energy supplies the load
- voltage and the cycle repeats.

$$V_O = V_i + V_L$$

- V O is always higher than V I as polarity of inductor voltage V L is same as V I.
- If inductor L is very large, source current I I is ripple free and is considered constant.

$$W_{ON} = V_i I_i T_{ON}$$

- Assuming C to be large enough to neglect the voltage ripples, V O is considered constant.

$$W_{OFF} = (V_o - V_i \quad * I_i * T_{OFF})$$

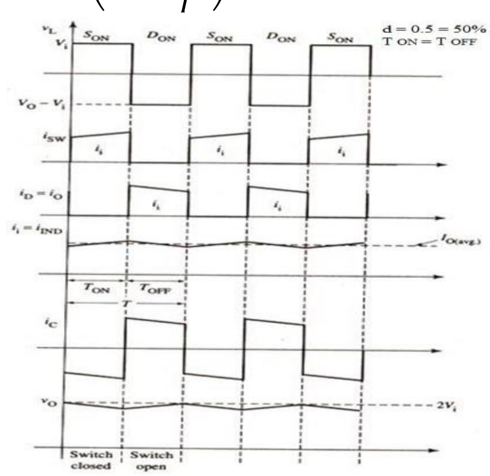
- Since losses are neglected, the energy transferred during T OFF by L mist be equal to energy gained during T ON.

$$W_{ON} = W_{OFF} = V_i I_i T_{ON} = (V_0 - V_i) * I_i * T_{OFF}$$

$$V_0 = V_1\left(1 + \frac{T_{ON}}{T_{OFF}}\right) = V_1\left(\frac{T}{T - T_{ON}}\right) = V_i\left(\frac{1}{1 - \frac{T_{ON}}{T}}\right) = V_1\left(\frac{1}{1-d}\right)$$

- Thus VO is always greater than VI.
- $P_1 = P_0 \rightarrow V_1 I_1 = \frac{V_0{}^2}{R} \rightarrow I_1 = \frac{V_0{}^2}{V_1} * \frac{1}{R}$
- $I_0 = I_1 * \frac{T_{OFF}}{T} => I_0 = I_1(1-d)$
- $P_0 = P_1 => V_1 I_1 = \frac{V_0{}^2}{R} = \frac{V_0{}^2}{(1-d)^2} * \frac{1}{R}$
- $I_1 = \frac{V_1}{(1-d)^2} * \frac{1}{R}$
- $I_L = \frac{I_{max} + I_{min}}{2} = I_1$

Where $I_{max} + I_{min} = 2 * I_1$



Voltage across L is

$V_L = V_1 = L * \frac{di_1}{dt}\ or\ \frac{di_1}{dt} = \frac{V_i}{L}$

$\Delta I_1 = \frac{V_1}{L} T_{ON}\ or\ I_{max} - I_{min} = \frac{V_1}{L} T_{ON}$

$Again$

$I_{max} + I_{min} = 2 * I_1$

Solving

$$I_{max} = V_1 \left[\frac{1}{R(1-d)^2} + \frac{T_{ON}}{2L}\right]$$

$$I_{min} = V_1 \left[\frac{1}{R(1-d)^2} - \frac{T_{ON}}{2L}\right]$$

$$I_{p-p} = I_{max} - I_{min} = \frac{V_1 T_{ON}}{L}$$

For continuous current mode:

$$I_{min} = 0 = V_1 \left[\frac{1}{R(1-d)^2} - \frac{T_{ON}}{2L}\right]$$

=> $\left[\frac{1}{R(1-d)^2} = \frac{T_{ON}}{2L}\right]$

=> L = $\frac{RT_{ON}}{2L}(1-d)^2$

Numerical:

Given Data:

Vin = 50V

D = 9%

R = 13Ω

f = 20kHz

To Find:

Vout = ?

Iout = ?

Iin = ?

Inductor (L) = ?

Solution:

I_{in}:

$$Ii = \frac{V_i}{(1-d)^2} \times \frac{1}{R}$$

$$= \frac{50}{(1-0.09)^2} \times \frac{1}{13}$$

$$= \frac{50}{(0.91)^2} \times \frac{1}{13}$$

$$= 60.38 \times \frac{1}{13}$$

= 4.644

I_{out}:

I out = I1 (1-d)

Io = 4.644 (1 – 0.09)

Io = 4.22604 A

V_{out}:

$$V_0 = (0.09)(50)$$

V_0 = 4.5V

Inductor (L):

$$L = \frac{RT_{ON}}{2}(1-d)^2$$

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

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

T = 0.00005sec

T_{ON} = 0.09 x 0.00005

T_{ON} = 4.5µsec

$$L = \frac{(13)(4.5)}{2}(1-0.09)^2$$

$L = (29.25 \times 10^{-6})\ (0.8281)$

$L = 24.22\mu H$

Q5: 10

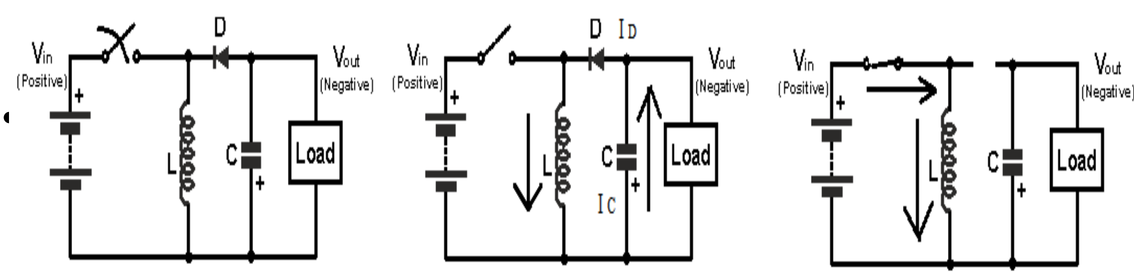
The Buck-Boost chopper is a type of DC-DC converter. Explain in detail the principals and working of Buck converter when the switch is open and closed.

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) **CLO3**

Buck – Boost Chopper:

- It combines the concept of both the step – up and step – down choppers.
- The output voltage is either higher or lower than the input voltage.
- The output voltage polarity can also be reversed.
- The switch is either an SCR or GTO or IGBT.
- When S in ON, D is reverse biased & I D is zero.
- The voltage across L is equal to the i/p voltage.
- The capacitor supplies energy to the output load
- The current through the inductor increases linearly with time.
- With S OFF, the source is disconnected.
- The current through inductor does not change instantaneously and it forward biases the diode, providing a path for the load current.
- O/P voltage becomes equal to the inductor voltage.
- With S = ON (T ON); W ON = VI*II*TON
- With S = OFF (T OFF); W ON = VI*II*TOFF



$$I_1 = \bar{I}_L d = \left(\frac{I_{max} + I_{min}}{2}\right) d$$

The average O/P power is given as

$$P_1 = V_1 I_1 = \left(\frac{I_{max} + I_{min}}{2}\right) dV_1 = P_0 = \frac{{V_0}^2}{R}$$

$$I_{max} + I_{min} = \frac{2dV_1}{R(1-d)^2}$$

$$I_{max} - I_{min} = \frac{V_1}{L} dT$$

$$I_{max} = V_1 \left[\frac{1}{R(1-d)^2} + \frac{T}{2L}\right] d$$

$$I_{min} = V_1 \left[\frac{1}{R(1-d)^2} - \frac{T}{2L}\right] d$$

$$I_{p-p} = \frac{V_1 T_d}{L}$$

For continuous current condition:

$$I_{min} = 0 = V_1 \left[\frac{1}{R(1-d)^2} - \frac{T}{2L}\right] d$$

=> L = $\frac{RTd}{2}(1-d)^2$

Numerical:

Given Data:

Vin = 50V

D = 9%

R = 13Ω

f = 20kHz

To Find:

Vout = ?

Iout = ?

Iin = ?

Inductor (L) = ?

Solution:

d:

$d = \frac{I_i}{I_0}$

Iin = $\frac{50V}{13\Omega}$

Iin = 3.846A

I_{out}:

$d = \frac{I_i}{I_o}$

$I_0 = \frac{I_i}{d}$

$I_0 = \frac{3.846}{0.09}$

$I_0 = 42.7\ A$

V_{out}:

$V_0 = I_0 R$

$V_0 = 42.7 \times 13$

$V_0 = 555.13V$

Inductor (L):

$L = \frac{T_{OFF}}{2} R$

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

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

$T = \frac{1}{20000}$

T = 50µsec

$L = \left(\frac{50}{2}\right) 13$

L = 325µH