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

---

## Course Details

| | | | |
|---|---|---|---|
| **Course Title:** | Power Electronics | **Module:** | 8th |
| **Instructor:** | **Engr. Shayan Tariq Jan** | **Total Marks:** | 50 |

---

## Student Details

| | | | |
|---|---|---|---|
| **Name:** | **FAWAD AHMAD** | **Student ID:** | **13204** |

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:<br>1. 1 – φ Uncontrolled Half Wave Rectifier and Full Wave Bridge Rectifier<br>2. 1 – φ Uncontrolled Rectifier and Controlled Rectifiers (Bridge Rectifier). | CLO 2<br>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.<br>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:<br>1. Vdc<br>2. Idc<br>3. Vrms<br>4. Irms<br>5. Which rectifier do you think is better and why. | CLO 2<br>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.<br>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<br>1. Vout<br>2. Iout<br>3. Iin<br>4. Inductor (L) | CLO 3<br>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.<br>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<br>1. Vout<br>2. Iout<br>3. Iin<br>4. Inductor (L) | CLO 3<br>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.<br>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<br>1. Duty Cycle (D)<br>2. Iout<br>3. Vin<br>4. Inductor (L) | CLO 3<br>Marks 10 |

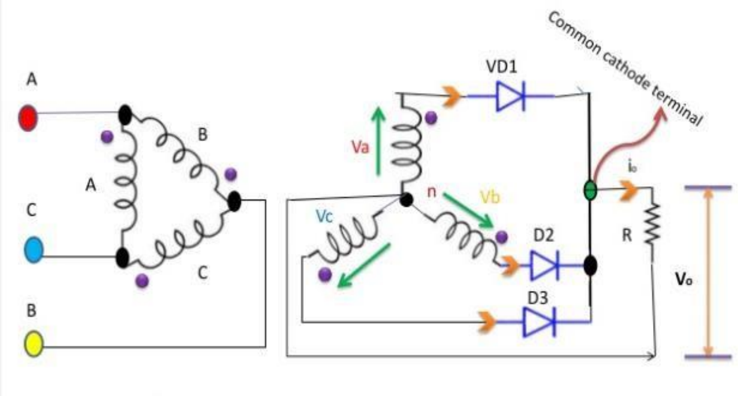
## Question 1:

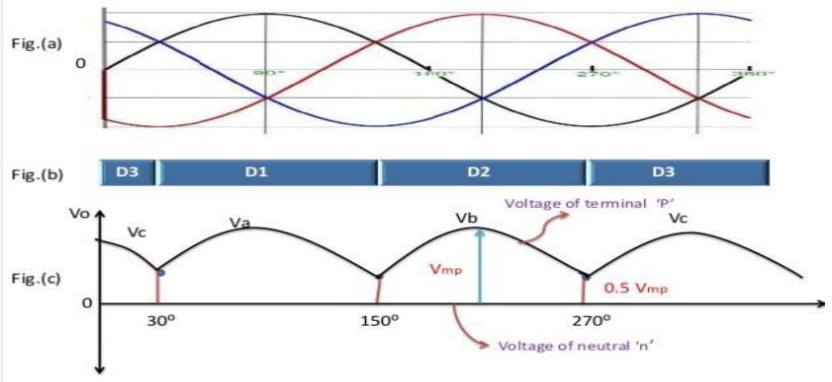
## ANSWER:

### φ Half – Wave uncontrolled 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.





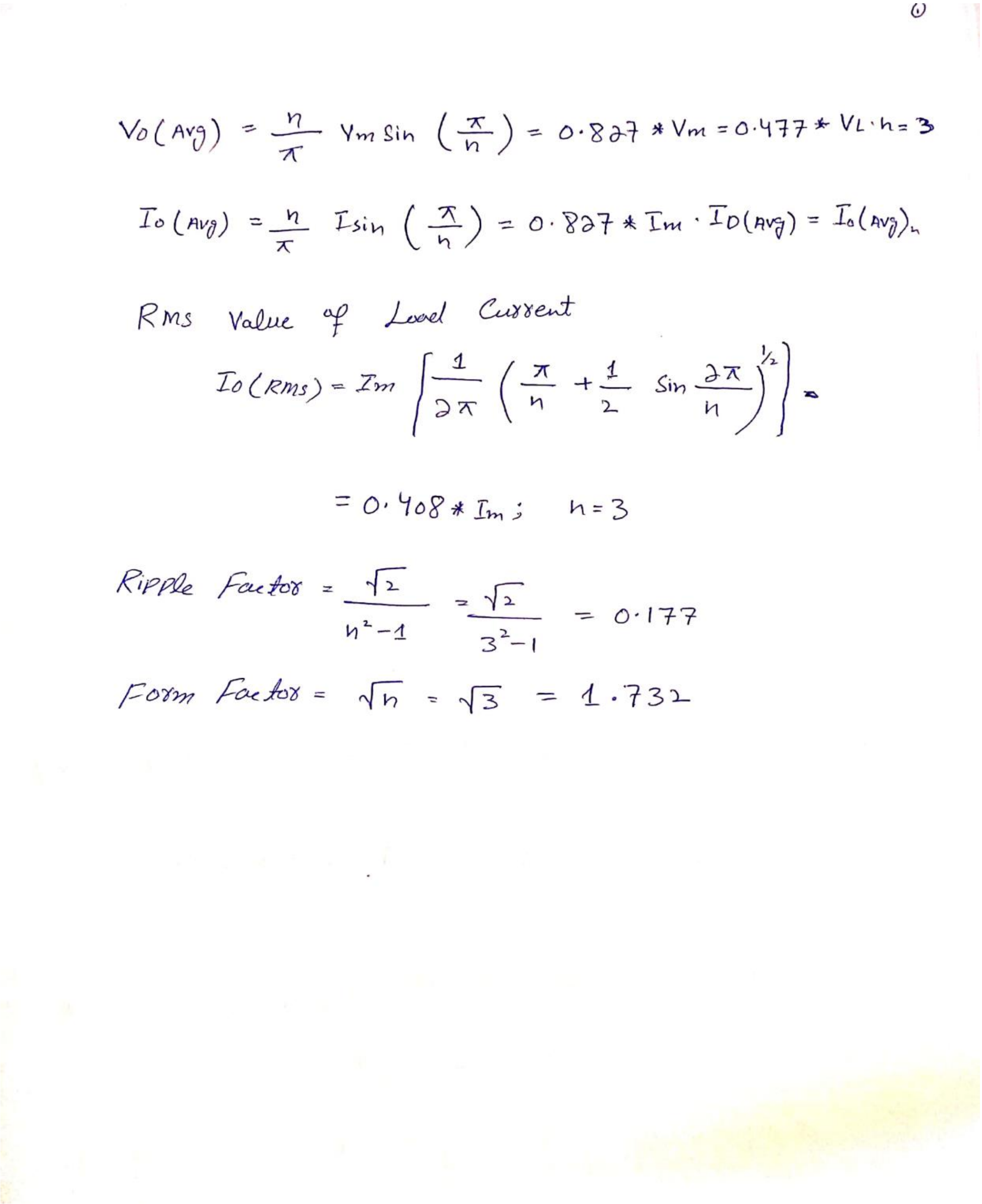
- The rectifier element connected to the line at the highest +ve instantaneous voltage can only conduct and pulsates between V max and 0.5 V max.
- It is called 3 – φ 3 pulse rectifier as the o/p is repeated thrice in every cycle of V s.
- The ripple frequency (f r) of the o/p voltage is

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

- 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.



(i)

$$V_o(Avg) = \frac{n}{\pi} V_m \sin\left(\frac{\pi}{n}\right) = 0.827 * V_m = 0.477 * V_L \cdot n = 3$$

$$I_o(Avg) = \frac{n}{\pi} I\sin\left(\frac{\pi}{n}\right) = 0.827 * I_m \cdot I_D(Avg) = I_o(Avg)_n$$

Rms Value of Load Current

$$I_o(Rms) = I_m \left[\frac{1}{2\pi}\left(\frac{\pi}{n} + \frac{1}{2}\sin\frac{2\pi}{n}\right)\right]^{1/2} =$$

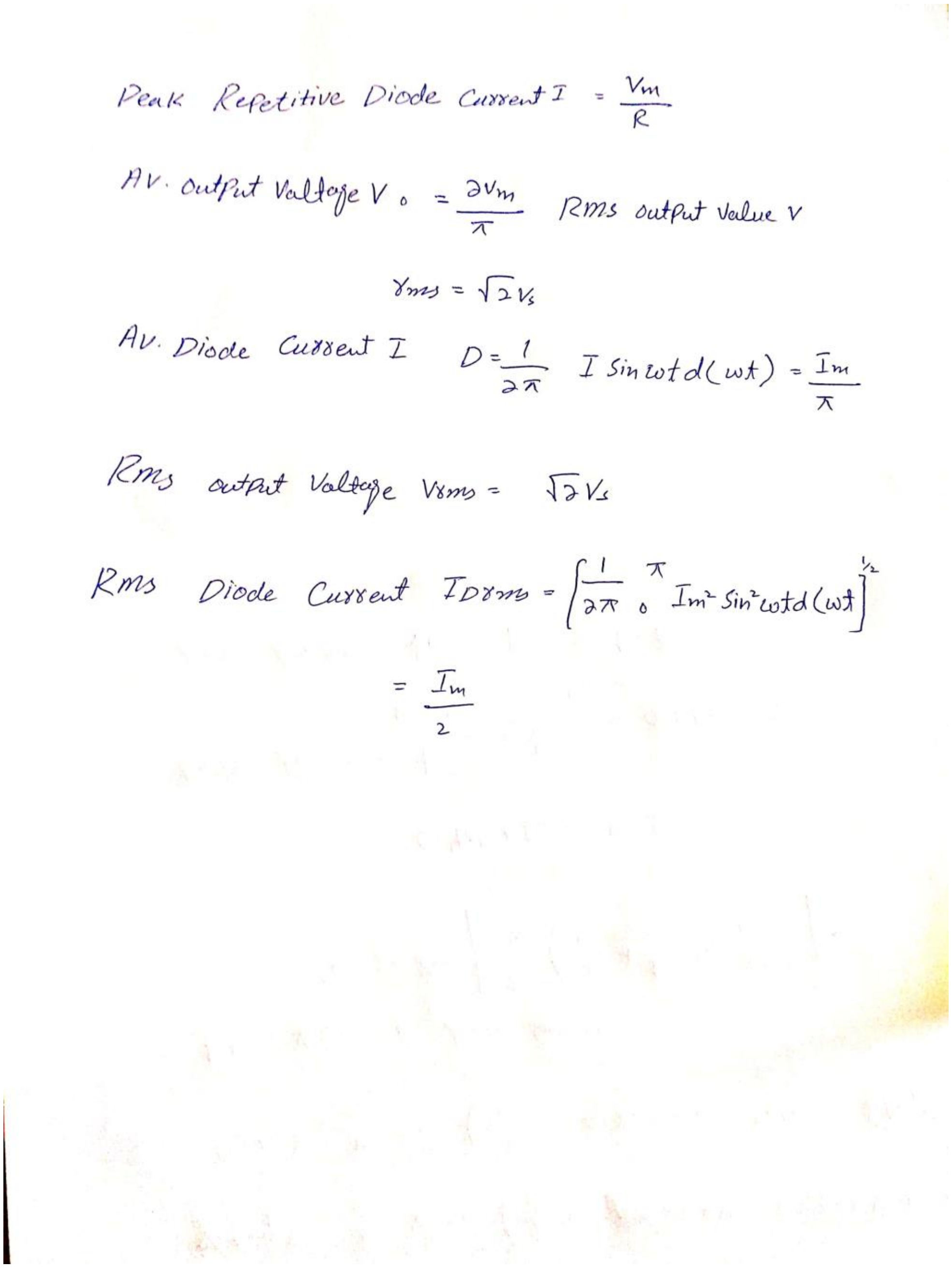
$$= 0.408 * I_m ; \quad n = 3$$

$$\text{Ripple Factor} = \frac{\sqrt{2}}{n^2-1} = \frac{\sqrt{2}}{3^2-1} = 0.177$$

$$\text{Form Factor} = \sqrt{n} = \sqrt{3} = 1.732$$

## **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 $V_o = \frac{2V_m}{\pi}$ Rms output Value V

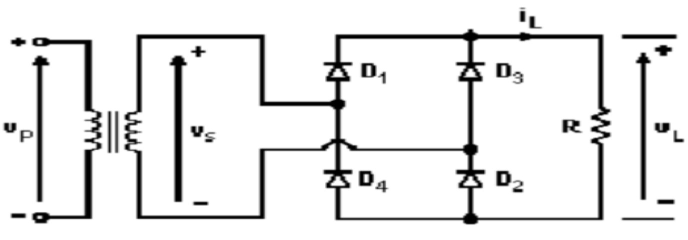
$V_{rms} = \sqrt{2}V_s$

Av. Diode Current $I_D = \frac{1}{2\pi} I \sin \omega t\, d(\omega t) = \frac{I_m}{\pi}$

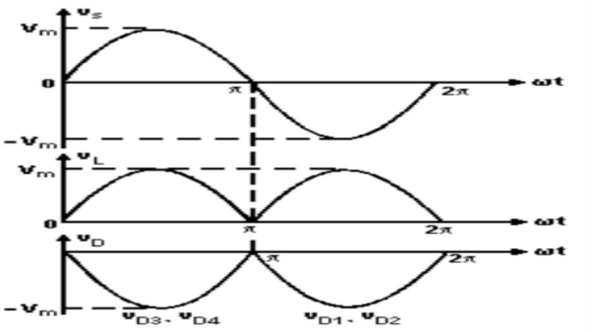
Rms output Voltage $V_{rms} = \sqrt{2}V_s$

Rms Diode Current $I_{Drms} = \left[\frac{1}{2\pi}\int_0^{\pi} I_m^2 \sin^2 \omega t\, d(\omega t)\right]^{1/2}$

$= \frac{I_m}{2}$



(a) Circuit diagram



(b) Waveforms

## PART (B):

### Phase Controlled Rectifiers:

- 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.

### Phase Controlled Rectifiers – Applications

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

necessary.

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

### φ Uncontrolled Rectifier:

– φ Rectifier offers the following advantages:

1. Higher o/p voltage for a given i/p voltage.
2. Lower amplitude ripples i.e. output voltage is smoother.
3. Higher frequency ripples simplifying filtering.
4. Higher overall efficiency.

### φ Uncontrolled Rectifier: Classification:

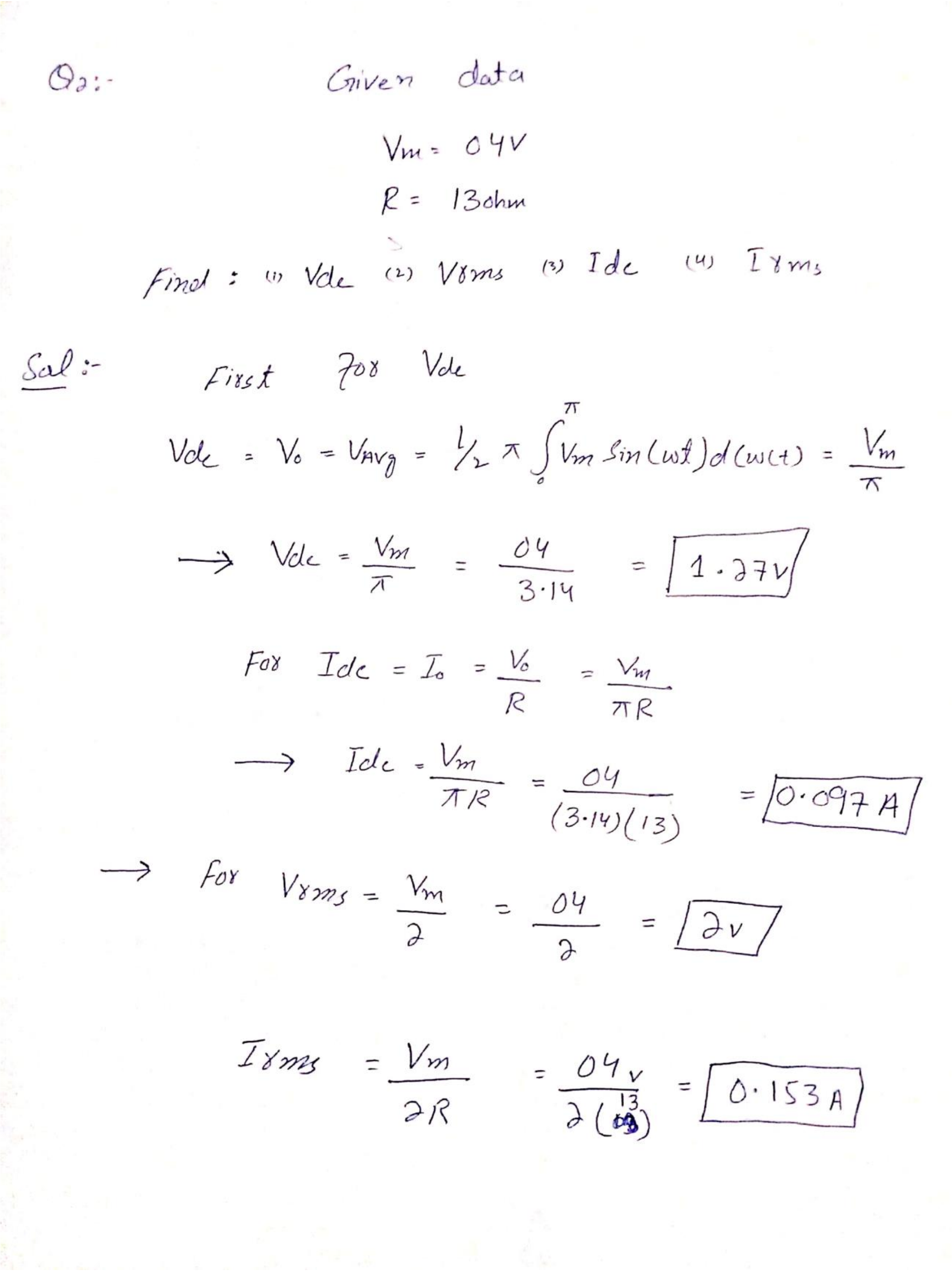
They are generally of four types.

1. 3 – φ Half – wave rectifier.
2. 3 – φ Mid – point 6 Pulse rectifier.
3. 3 – φ Bridge rectifier.

4 – φ 12 Pulse rectifier.

**QUESTION 2:**

**Solution:**



Q2:- Given data

$V_m = 04V$

$R = 13 ohm$

Find : (1) $V_{dc}$ (2) $V_{rms}$ (3) $I_{dc}$ (4) $I_{rms}$

Sol:- First for $V_{dc}$

$$V_{dc} = V_o = V_{Avg} = \frac{1}{2}\pi \int_0^{\pi} V_m \sin(\omega t)\, d(\omega t) = \frac{V_m}{\pi}$$

$$\rightarrow V_{dc} = \frac{V_m}{\pi} = \frac{04}{3.14} = \boxed{1.27V}$$

$$\text{For } I_{dc} = I_o = \frac{V_o}{R} = \frac{V_m}{\pi R}$$

$$\rightarrow I_{dc} = \frac{V_m}{\pi R} = \frac{04}{(3.14)(13)} = \boxed{0.097A}$$

$$\rightarrow \text{For } V_{rms} = \frac{V_m}{2} = \frac{04}{2} = \boxed{2V}$$

$$I_{rms} = \frac{V_m}{2R} = \frac{04v}{2(13)} = \boxed{0.153A}$$

# 1-Ø Full wave Bridge Rectifier (uncontrolled)

→ $V_s = V_m = V_{dc} = \dfrac{2(04)}{3.14} = \boxed{2.54V}$

→ $I_{dc} = \dfrac{V_m}{R} = \dfrac{04}{13} = \boxed{\cancel{2.69A}}$

$I_{dc} = \dfrac{04}{13} = \boxed{0.30A}$

→ $V_{rms} = \sqrt{2}\,V_s = \sqrt{2}\,(2.54) =$

$\boxed{V_{rms} = 3.59V}$

→ $I_{rms} = \dfrac{I_{dc}}{2} = \dfrac{0.30A}{2}\ \boxed{= 0.15A}$

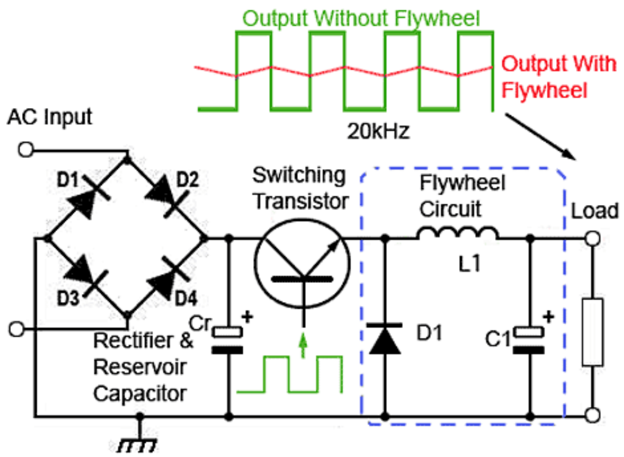
**QUESTION 3:**

**ANSWER:**

## The Buck Converter:

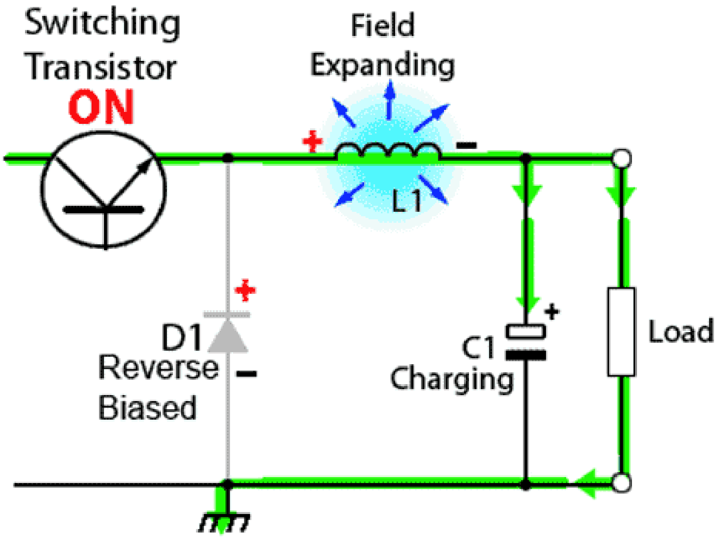
The Buck Converter is used in SMPS circuits where the DC output voltage needs to be lower than the DC input voltage. The DC input can be derived from rectified AC or from any DC supply. It is useful where electrical isolation is not needed between the switching circuit and the output, but where the input is from a rectified AC source, isolation between the AC source and the rectifier could be provided by a mains isolating transformer.

The switching transistor between the input and output of the Buck Converter continually switches on and off at high frequency. To maintain a continuous output, the circuit uses the energy stored in the **inductor** L, during the on periods of the switching transistor, to continue supplying the load during the off periods. The circuit operation depends on what is sometimes also called a Flywheel Circuit. This is because the circuit acts rather like a mechanical flywheel that, given regularly spaced pulses of energy keeps spinning smoothly (outputting energy) at a steady rate.



## Transistor Switch ‘on’ Period:

In Fig. 3.1.2 therefore, when the switching transistor is switched on, it is supplying the load with current. Initially current flow to the load is restricted as energy is also being stored in L1, therefore the current in the load and the charge on C1 builds up gradually during the ‘on’ period. Notice that throughout the on period, there will be a large positive voltage on D1 cathode and so the diode will be reverse biased and therefore play no part in the action.



## Transistor Switch 'off' Period:

When the transistor switches off as shown in Fig 3.1.3 the energy stored in the magnetic field around L1 is released back into the circuit. The voltage across the inductor (the back e.m.f.) is now in reverse polarity to the voltage across L1 during the 'on' period, and sufficient stored energy is available in the collapsing magnetic field to keep current flowing for at least part of the time the transistor switch is open.

The back e.m.f. from L1 now causes current to flow around the circuit via the load and D1, which is now forward biased. Once the inductor has returned a large part of its stored energy to the circuit and the load voltage begins to fall, the charge stored in C1 becomes the main source of current, keeping current flowing through the load until the next 'on' period begins.

The overall effect of this is that, instead of a large square wave appearing across the load, there remains only a ripple waveform, i.e. a small amplitude, high frequency triangular wave with a DC level of:

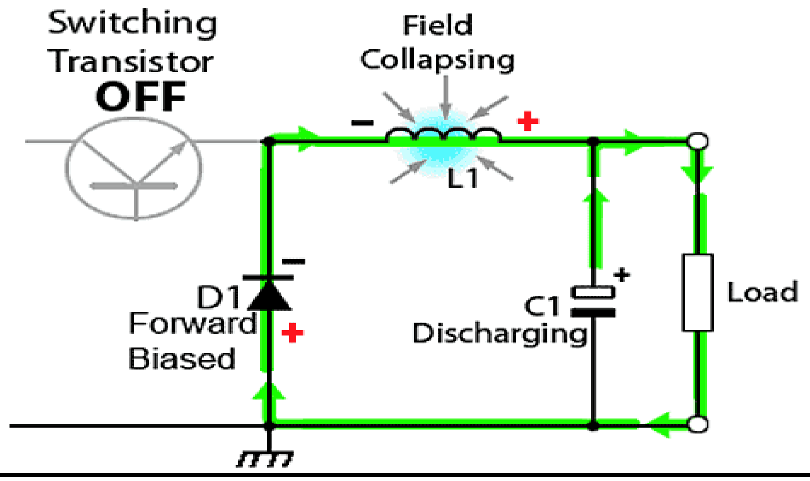
$V_{OUT}$ = $V_{IN}$ x (On time of switching waveform ($t_{ON}$) / periodic time of switching waveform( T))

or:

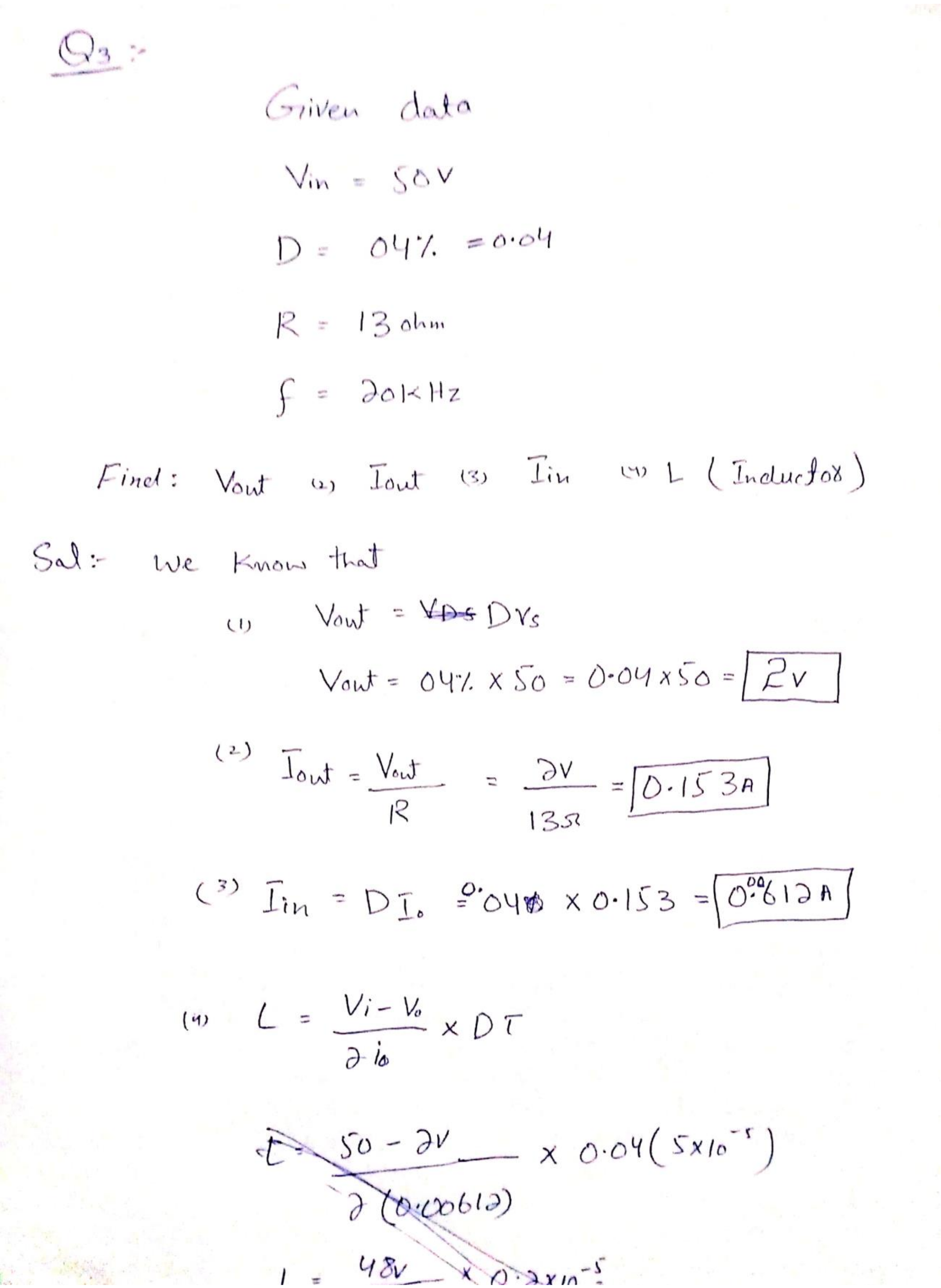
$$V_{OUT} = V_{IN} \frac{t_{ON}}{T}$$

Fig. 3.1.4 Buck Converter Operation

Therefore if the switching waveform has a mark to space ratio of 1:1, the output $V_{OUT}$ from the buck Converter circuit will be $V_{IN}$ x(0.5/1) or half of $V_{IN}$. However if the mark to space ratio of the switching waveform is varied, any output voltage between approximately 0V and $V_{IN}$ is possible.


Switching Transistor
OFF
Field Collapsing
−
+
L1
D1
Forward Biased
−
+
+
C1
Discharging
Load

**PART (B):**



Q3 :-

Given data

$V_{in} = 50V$

$D = 04\% = 0.04$

$R = 13\ ohm$

$f = 20KHz$

Find : Vout (2) Iout (3) Iin (4) L ( Inductor )

Sol :- we know that

(1) $V_{out} = \cancel{VDs}\ DV_s$

$V_{out} = 04\% \times 50 = 0.04 \times 50 = \boxed{2V}$

(2) $I_{out} = \frac{V_{out}}{R} = \frac{2V}{13\Omega} = \boxed{0.153A}$

(3) $I_{in} = D I_o = 0.04 \times 0.153 = \boxed{0.00612A}$

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

$$\cancel{L = \frac{50 - 2V}{2(0.00612)} \times 0.04(5\times10^{-5})}$$

$L = \frac{48V}{} \times 0.2\times10^{-5}$

**QUESTION 4:**

**ANSWER:**

## Boost Converter:

Switched mode supplies can be used for many purposes including DC to DC converters. Often, although a DC supply, such as a battery may be available, its available voltage is not suitable for the system being supplied. For example, the motors used in driving electric automobiles require much higher voltages, in the region of 500V, than could be supplied by a battery alone. Even if banks of batteries were used, the extra weight and space taken up would be too great to be practical. The answer to this problem is to use fewer batteries and to boost the available DC voltage to the required level by using a boost converter. Another problem with batteries, large or small, is that their output voltage varies as the available charge is used up, and at some point the battery voltage becomes too low to power the circuit being supplied. However, if this low output level can be boosted back up to a useful level again, by using a boost converter, the life of the battery can be extended.

The DC input to a boost converter can be from many sources as well as batteries, such as rectified AC from the mains supply, or DC from solar panels, fuel cells, dynamos and DC generators. The boost converter is different to the Buck Converter in that it’s output voltage is equal to, or greater than its input voltage. However it is important to remember that, as power (P) = voltage (V) x current (I), if the output voltage is increased, the available output current must decrease.

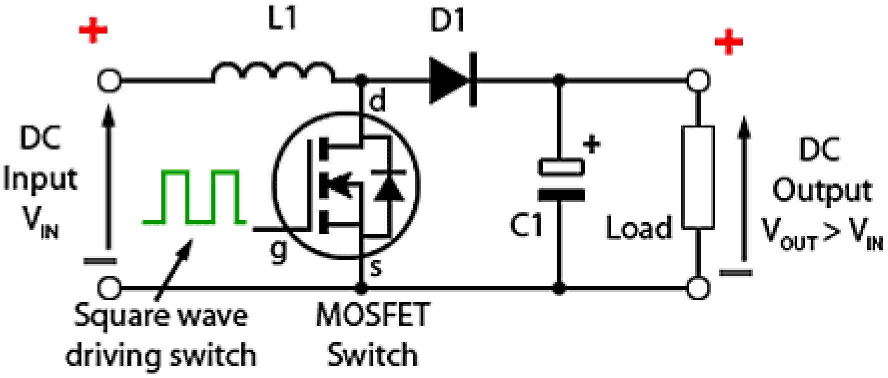


Fig. 3.2.1 Basic Boost Converter Circuit

Fig. 3.2.1 illustrates the basic circuit of a Boost converter. However, in this example the switching transistor is a power MOSFET, both Bipolar power transistors and MOSFETs are used in power switching, the choice being determined by the current, voltage, switching speed and cost considerations. The rest of the components are the same as those used in the buck converter illustrated in Fig. 3.1.2, except that their positions have been rearranged.

## Boost converter Operation:

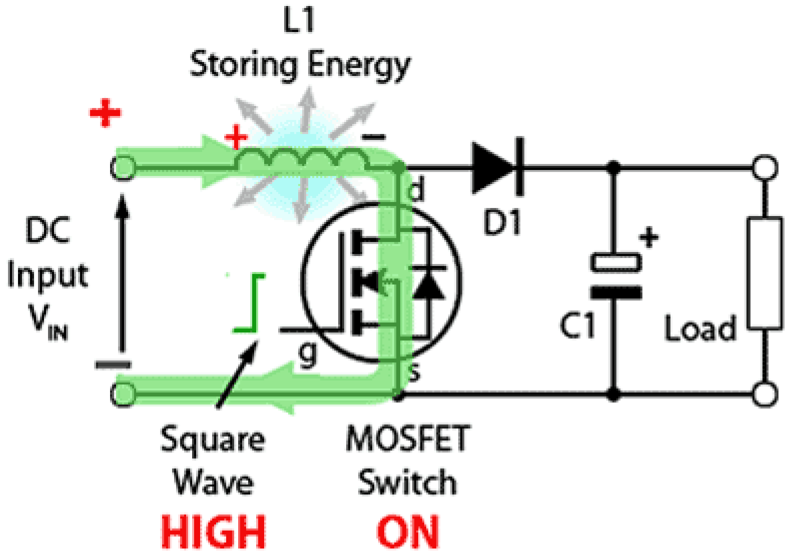


Fig. 3.2.2 Boost Converter Operation at Switch On

Fig 3.2.2 illustrates the circuit action during the initial high period of the high frequency square wave applied to the MOSFET gate at start up. During this time MOSFET conducts, placing a short circuit from the right hand side of L1 to the negative input supply terminal. Therefore a current flows between the positive and negative supply terminals through L1, which stores energy in its magnetic field. There is virtually no current flowing in the remainder of the circuit as the combination of D1, C1 and the load represent a much higher impedance than the path directly through the heavily conducting MOSFET.

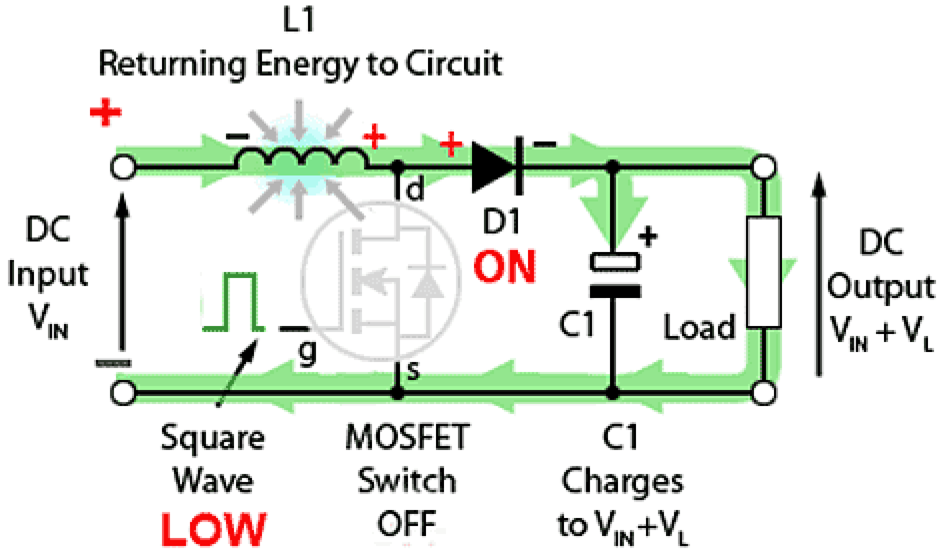


Fig. 3.2.3 Current Path with MOSFET Off

Fig. 3.2.3 shows the current path during the low period of the switching square wave cycle. As the MOSFET is rapidly turned off the sudden drop in current causes L1 to produce a back e.m.f. in the opposite polarity to the voltage across L1 during the on period, to keep current flowing. This results in two voltages, the supply voltage $V_{IN}$ and the back e.m.f.($V_L$) across L1 in series with each other.

This higher voltage ($V_{IN}$ +$V_L$), now that there is no current path through the MOSFET, forward biases D1. The resulting current through D1 charges up C1 to $V_{IN}$ +$V_L$ minus the small forward voltage drop across D1, and also supplies the load.

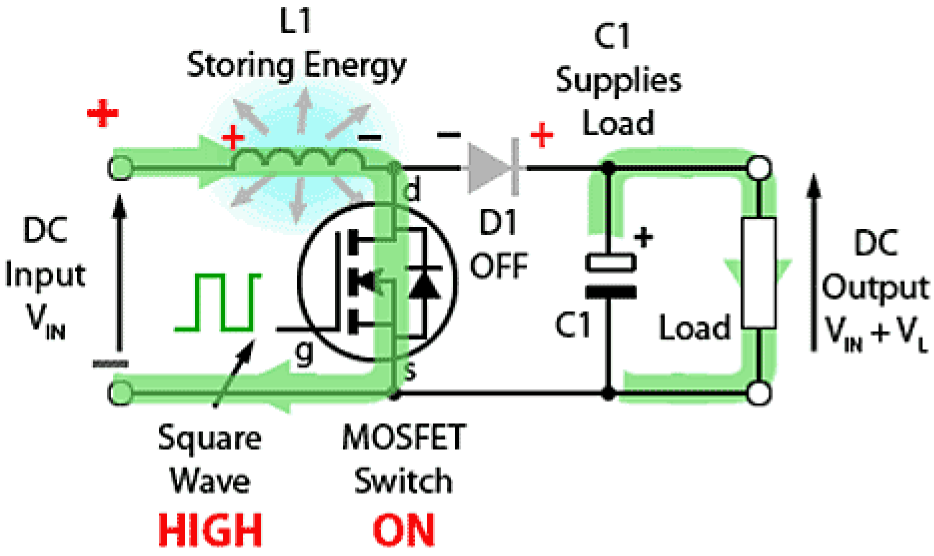
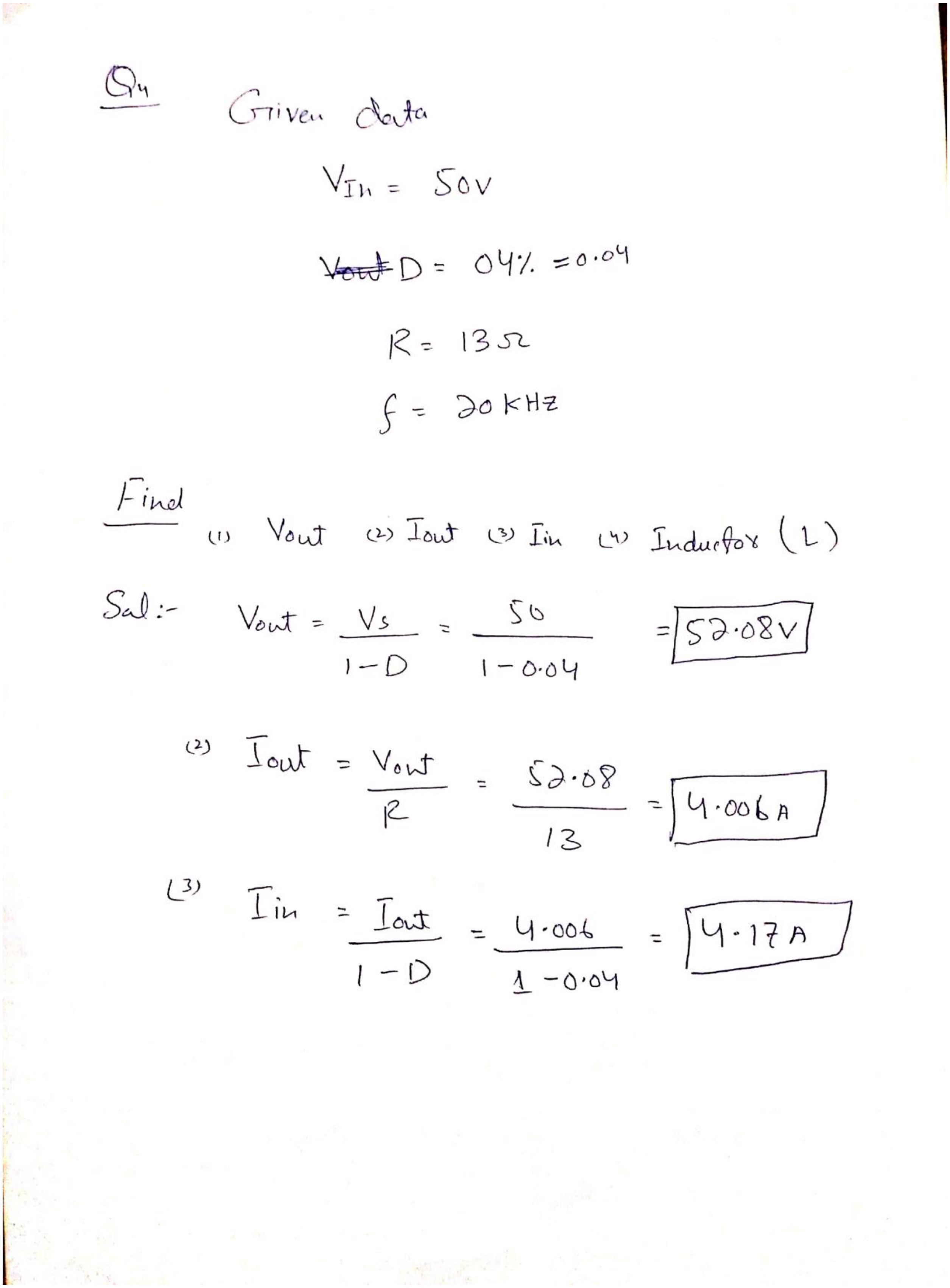


Fig. 3.2.4 Current Path with MOSFET On

Fig.3.2.4 shows the circuit action during MOSFET on periods after the initial start up. Each time the MOSFET conducts, the cathode of D1 is more positive than its anode, due to the charge on C1. D1 is therefore turned off so the output of the circuit is isolated from the input, however the load continues to be supplied with $V_{IN}$ +$V_L$ from the charge on C1. Although the charge C1 drains away through the load during this period, C1 is recharged each time the MOSFET switches off, so maintaining an almost steady output voltage across the load.

The theoretical DC output voltage is determined by the input voltage ($V_{IN}$) divided by 1 minus the duty cycle (D) of the switching waveform, which will be some figure between 0 and 1 (corresponding to 0 to 100%) and therefore can be determined using the following formula:

## PART (B):



Q4

Given data

$V_{In} = 50V$

~~Vout~~ $D = 04\% = 0.04$

$R = 13\Omega$

$f = 20 KHZ$

Find

(1) Vout (2) Iout (3) Iin (4) Inductor (L)

Sol:-

$$V_{out} = \frac{V_s}{1-D} = \frac{50}{1-0.04} = \boxed{52.08V}$$

(2) $$I_{out} = \frac{V_{out}}{R} = \frac{52.08}{13} = \boxed{4.006A}$$

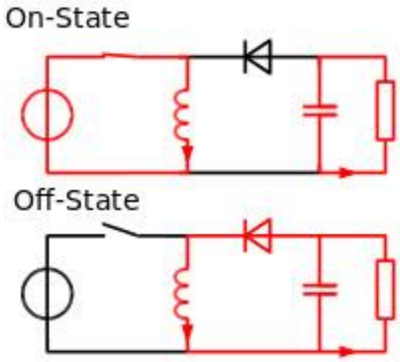
(3) $$I_{in} = \frac{I_{out}}{1-D} = \frac{4.006}{1-0.04} = \boxed{4.17A}$$

**QUESTION 5:**

**ANSWER:**

## Buck Boost Converter

It is a type of DC to DC converter and it has a magnitude of output voltage. It may be more or less than equal to the input voltage magnitude. The buck boost converter is equal to the fly back circuit and single inductor is used in the place of the transformer. There are two types of converters in the buck boost converter that are buck converter and the other one is boost converter. These converters can produce the range of output voltage than the input voltage. The following diagram shows the basic buck boost converter.



**Buck Boost Converter**

### Working principle of Buck-Boost Converter:

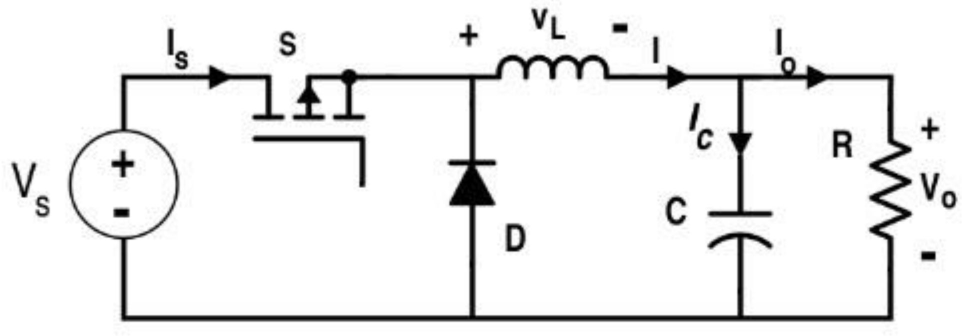
The working operation of the DC to DC converter is the inductor in the input resistance has the unexpected variation in the input current. If the switch is ON then the inductor feed the energy from the input and it stores the energy of magnetic energy. If the switch is closed it discharges the energy. The output circuit of the capacitor is assumed as high sufficient than the time constant of an RC circuit is high on the output stage. The huge time constant is compared with the switching period and make sure that the steady state is a constant output voltage Vo(t) = Vo(constant) and present at the load terminal.

There are two different types of working principles in the buck boost converter.

- Buck converter.
- Boost converter.

### Buck Converter Working

The following diagram shows the working operation of the buck converter. In the buck converter first transistor is turned ON and second transistor is switched OFF due to high square wave frequency. If the gate terminal of the first transistor is more than the current pass through the magnetic field, charging C, and it supplies the load. The D1 is the Schottky diode and it is turned OFF due to the positive voltage to the cathode.



Buck Converter Working

The inductor L is the initial source of current. If the first transistor is OFF by using the control unit then the current flow in the buck operation. The magnetic field of the inductor is collapsed and the back e.m.f is generated collapsing field turn around the polarity of the voltage across the inductor. The current flows in the diode D2, the load and the D1 diode will be turned ON.

The discharge of the inductor L decreases with the help of the current. During the first transistor is in one state the charge of the accumulator in the capacitor. The current flows through the load and during the off period keeping Vout reasonably. Hence it keeps the minimum ripple amplitude and Vout closes to the value of Vs

## Boost Converter Working

In this converter the first transistor is switched ON continually and for the second transistor the square wave of high frequency is applied to the gate terminal. The second transistor is in conducting when the on state and the input current flow from the inductor L through the second transistor. The negative terminal charging up the magnetic field around the inductor. The D2 diode cannot conduct because the anode is on the potential ground by highly conducting the second transistor.

By charging the capacitor C the load is applied to the entire circuit in the ON State and it can construct earlier oscillator cycles. During the ON period the capacitor C can discharge regularly and the amount of high ripple frequency on the output voltage. The approximate potential difference is given by the equation below.

**VS + VL**

During the OFF period of second transistor the inductor L is charged and the capacitor C is discharged. The inductor L can produce the back e.m.f and the values are depending up on the rate of change of current of the second transistor switch. The amount of inductance the coil can occupy. Hence the back e.m.f can produce any different voltage through a wide range and determined by the design of the circuit. Hence the polarity of voltage across the inductor L has reversed now.

The input voltage gives the output voltage and atleast equal to or higher than the input voltage. The diode D2 is in forward biased and the current applied to the load current and it recharges the capacitors to VS + VL and it is ready for the second transistor.

## Modes Of Buck Boost Converters

There are two different types of modes in the buck boost converter. The following are the two different types of buck boost converters.

- Continuous conduction mode.
- Discontinuous conduction mode.

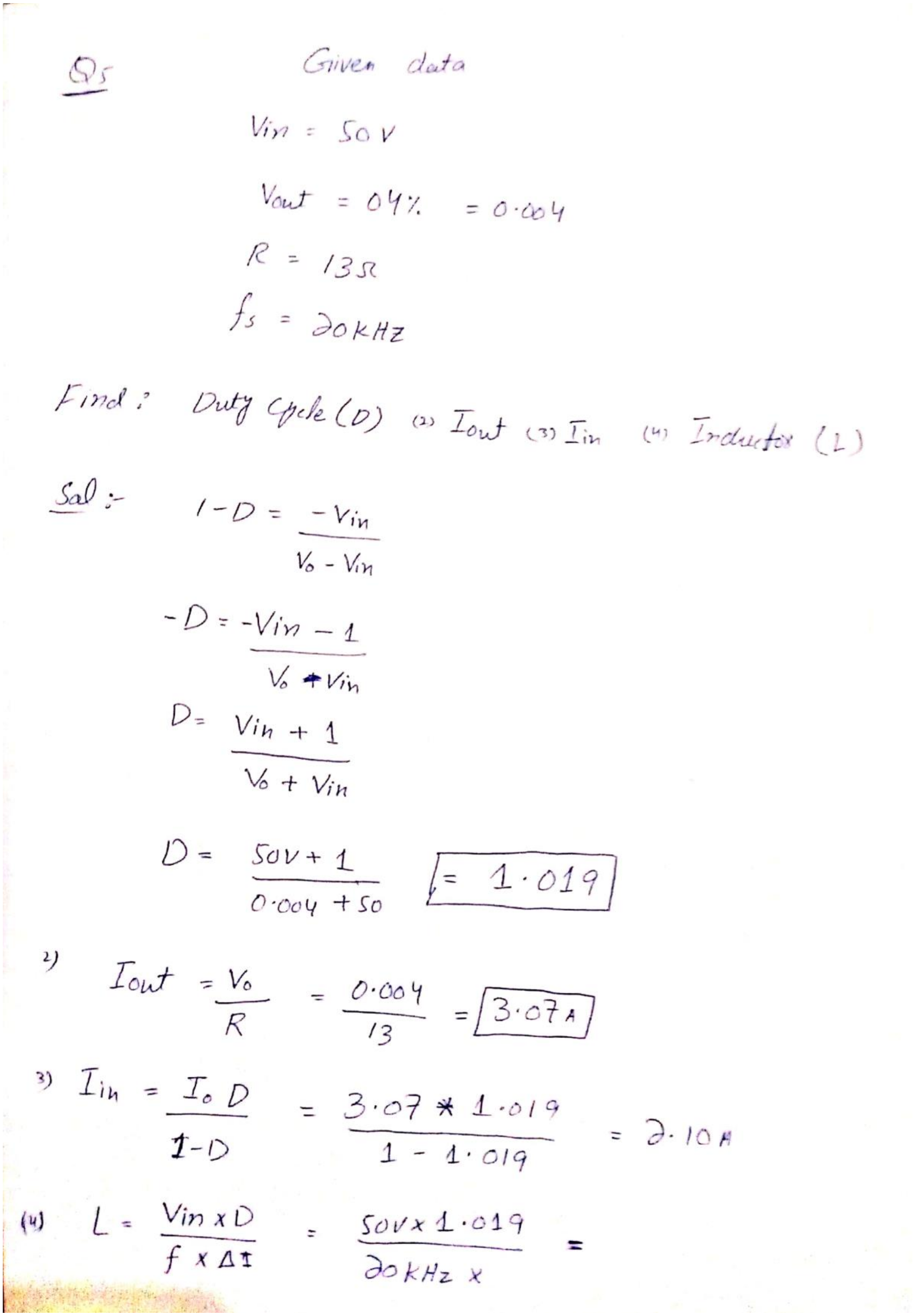
### *Continuous Conduction Mode*

In the continuous conduction mode the current from end to end of inductor never goes to zero. Hence the inductor partially discharges earlier than the switching cycle.

### *Discontinuous Conduction Mode*

In this mode the current through the inductor goes to zero. Hence the inductor will totally discharge at the end of switching cycles.

**PART B:**



Q5 Given data

$V_{in} = 50\,V$

$V_{out} = 04\% = 0.004$

$R = 13\Omega$

$f_s = 20\,kHz$

Find: Duty Cycle (D) (2) $I_{out}$ (3) $I_{in}$ (4) Inductor (L)

Sol :-

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

$$-D = \frac{-V_{in} - 1}{V_o + V_{in}}$$

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

$$D = \frac{50V + 1}{0.004 + 50} \boxed{= 1.019}$$

2)

$$I_{out} = \frac{V_o}{R} = \frac{0.004}{13} = \boxed{3.07A}$$

3)

$$I_{in} = \frac{I_o D}{1 - D} = \frac{3.07 * 1.019}{1 - 1.019} = 2.10A$$

(4)

$$L = \frac{V_{in} \times D}{f \times \Delta I} = \frac{50V \times 1.019}{20kHz \times} =$$