MUFFAKHAM JAH COLLEGE OF ENGINEERING & TECHNOLOGY

Banjara Hills Road No 3, Hyderabad 34
www.mjcollege.ac.in

DEPARTMENT OF ELECTRICAL ENGINEERING

LABORATORY MANUAL

POWER ELECTRONICS LAB

For

B.E. III/IV (II – SEM) EEE& EIE

2014-15

Prepared by: **Mrs.Mahmooda Mubeen**
(Asst.Prof EED)

MUFFAKHAM JAH COLLEGE OF ENGINEERING & TECHNOLOGY
ELECTRICAL ENGG. DEPARTMENT

LIST OF EXPERIMENT

Power Electronics Lab. (EE-382)

1. SCR, BJT, MOSFET AND IGBT Characteristics.
2. Gate triggering circuits for SCR Using R, RC, UJT.
3. Single Phase Step down Cycloconverter with R and RL loads.
4. A.C. voltage controllers with R and RL loads.
5. Study of forced commutation techniques.
6. Two Quadrant D.C. Drive.
7. 1-Φ Bridge rectifier-half control and full control with R and RL loads.
8. Buck and Boost choppers.
9. 3-Φ Bridge rectifier-half control with R and loads.
10. Simulation of Single Phase Full converter and Semi converter.
11. Simulation of Single Phase & Three Phase Inverter.
12. Simulation of Single Phase cycloconverter
13. Single Phase Inverter with R & RL Load.

ELECTRICAL ENGINEERING DEPARTMENT
POWER ELECTRONICS LAB

STATIC CHARACTERISTICS OF SCR

Experiment 1a

Aim: To Study the static characteristics of SCR

Apparatus: SCR characteristic trainer kit
0-25 Volts Dc voltmeter
0-100 mA DC ammeter
CRO
Patch chords

Theory: SCR works in three modes**:**
1) Forward blocking mode
2) Forward conducting mode
3) Reverse blocking mode

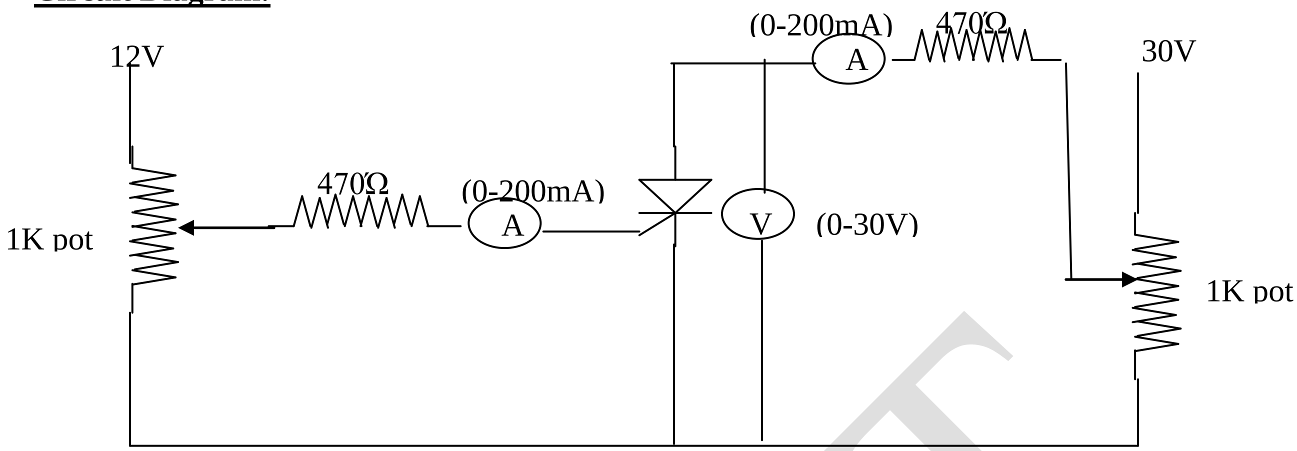
Forward blocking mode:
When anode is positive w.r.t cathode and the gate circuit is open the SCR is forward biased. A small forward leakage current flows. If the voltage is increased the break down occurs at a voltage called forward break-over voltage V_{BO}, SCR offers high input therefore it is treated as open, The SCR is in OFF state.

Forward conducting mode:
In this mode the conduction takes place from anode to cathode with the gate pulse is applied between gate and cathode, the SCR is turned ON. This is the ON state in which it behaves as a closed switch. The voltage drop across the device is due to resistive drop in the four layers.

Reverse blocking mode:

When cathode is positive with respect to anode with gate terminal open the device is in reverse blocking mode. This is the OFF state. If the reverse voltage is increased, the brake down occurs at V_{BR} (brake down voltage). The reverse current increases causing avalanche
The SCR is treated as open switch – OFF state

Circuit Diagram:



Observation Table: I_G = ----------- **mA**

Ig (mA)	Vak (V)

Procedure:

i) Static Characteristics without GATE pulse

a) Connect the circuit as shown, adjust Dc_1 to about 4V

b) Short the gate and the anode terminal.

c) Note down the anode voltage and current V_{AK} and I_{AK}

d) Open the gate terminal and note the holding current for applied DC_1 voltage and observe if the SCR is in the ON state.

e) Repeat the above procedure for different values of DC voltage. Until the SCR starts conducting.

f) Tabulate and plot V_{AK} Vs I_{AK}

ii) Static Characteristics with GATE pulse

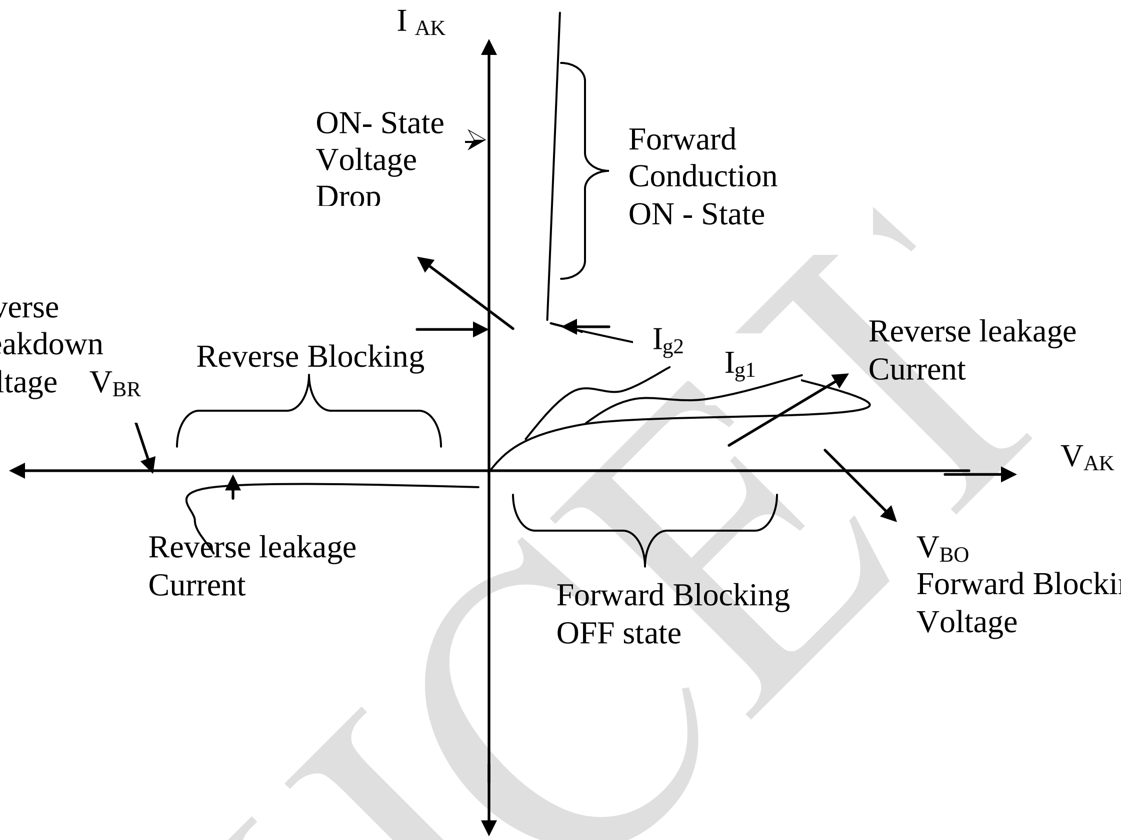
a) Connect as shown, adjust Dc_1 to its full value - 20V

b) Keep the gate voltage – DC_2 minimum such that the SCR is in the OFF state, minimum position in anti-clock wise direction

c) Vary the gate current by increasing DC_2 until the SCR fires (ON state) which is indicated by the current through SCR.

d) Tabulate and plot V_{AK} Vs I_{AK} for different values of gate current.

Expected Graphs:



Result: Thus the VI characteristics of SCR are drawn and the values from the graph sheet are noted down

Latching Current (I_L) = -------------
Holding current (I_H) = ----------------

Discussion of Result:

- Based on the theory discuss the difference between the values of latching and holding current.
- Check for V_{BO} for different gate current to understand the application of Gate current.

POWER ELECTRONICS LAB

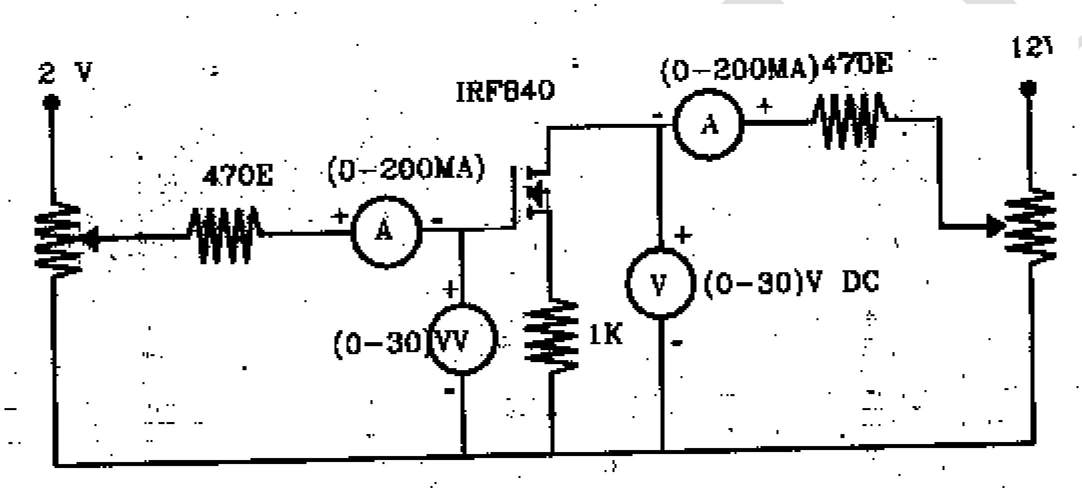
CHARACTERISTICS OF MOSFET

Experiment 1b

Aim: To study the output and transfer characteristics of MOSFET

Apparatus: Trainers Kit
Ammeter (0-200mA)
Voltmeter (0-20V)
Patch Chords

Circuit Diagram:



Procedure:

Output Characteristics

1) Connect the MOSFET drain – Source terminal to the MOSFET circuit terminal

2) Connect the ammeter in drain terminal, the voltmeter across the gate source terminal and another voltmeter across the drain – source terminal

3) Switch ON the supply

4) Fix the gate- source voltage using the pots

5) Smoothly vary the drain-Source terminal (V_{DS}) Voltage by varying the Pot_2 till the MOSFET turns ON. Note the Voltmeter and Ammeter readings.

6) Vary the V_{DS} and Note change in current I_D

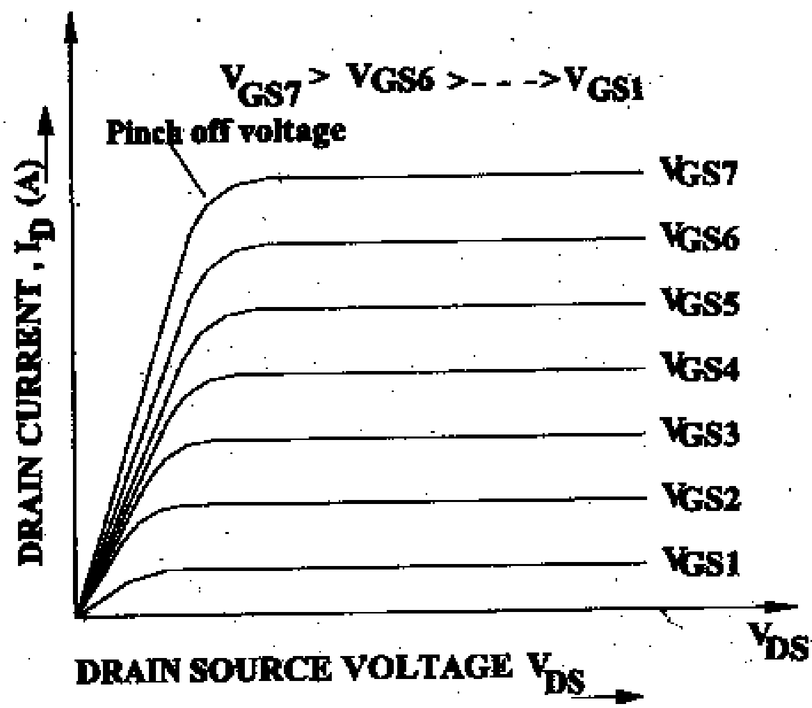
7) Note the value of pinch OFF Voltage for different values of V_{GS}

Observations:

a) Output Characteristics:

S.No.	$V_{GS (Constant)}$	
	V_{DS}	I_D

Expected Graphs:



Procedure:

Transfer characteristics

1) Switch ON the supply

2) Fix the drain- source voltage using the pots

3) Smoothly vary the Gate-Source terminal (V_{GS}) Voltage by varying the Pot_2 till the MOSFET turns ON. Note the Voltmeter and Ammeter readings

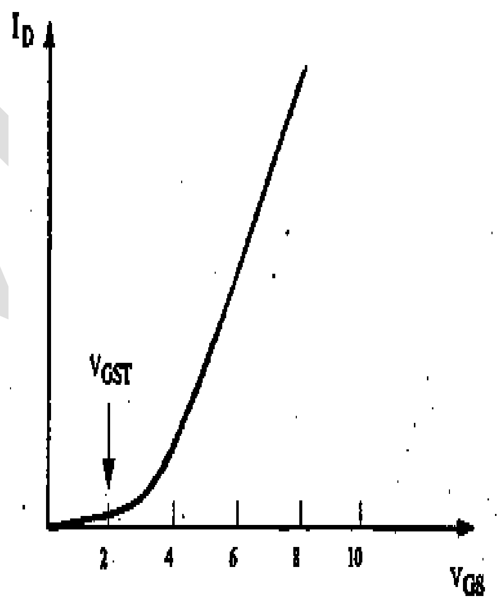
4) Vary the V_{GS} and Note change in current I_D

5) Note the value of Gate Threshould Voltage for different values of V_{DS}

b) **Transfer Characteristics**:

S.No.	$V_{DS(Constant)}$	
	V_{GS}	I_D

Expected Graphs:



Result: The output and transfer characteristics of the MOSFET are studied and graphs plotted. The pinch off Voltage is --------------------- for V_{GS} = ------------------ and gate threshold voltage for the transfer characteristics is -------------------------- for V_{DS} = ---------

Discussion of Result:

- Observe the Pinch of voltage obtained from output characteristics with different V_{GS} and comment on the result.
- Significance of Gate Threshold voltage in Transfer characteristics.
- Mention the device whether it is a voltage controlled or current controlled

ELECTRICAL ENGINEERING DEPARTMENT
POWER ELECTRONICS LAB

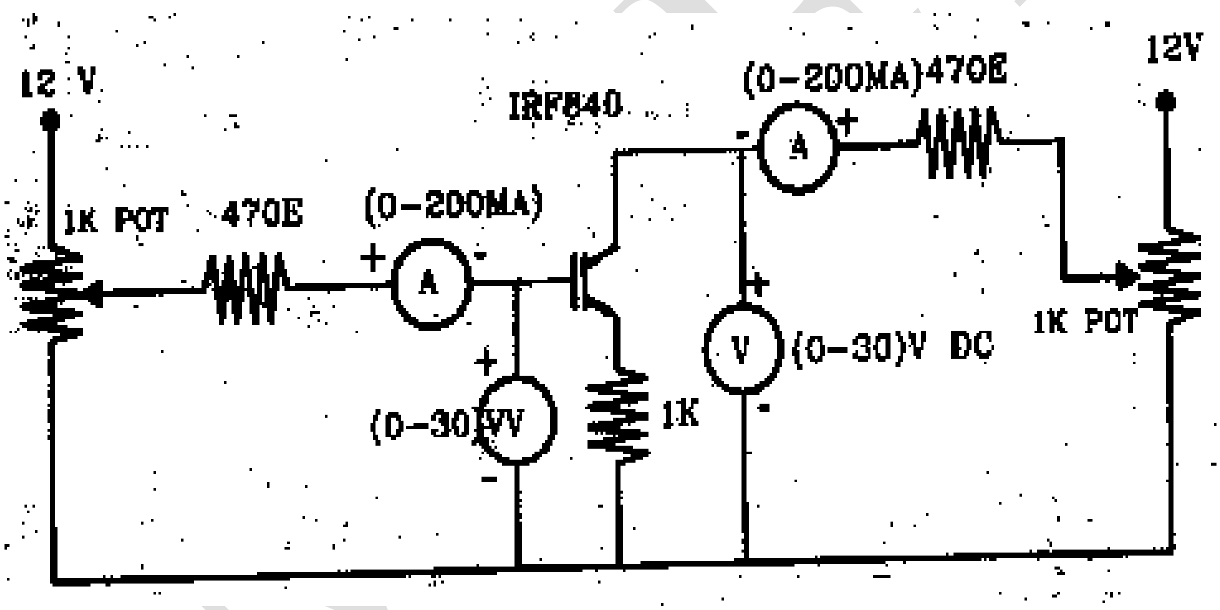
CHARACTERISTICS OF IGBT

Experiment 1c

Aim: To study the output and transfer characteristics of IGBT

Apparatus: Trainers Kit
Ammeter (0-200mA)
Voltmeter (0-20V)
Patch Chords

Circuit Diagram:



Procedure:

Out-Put Characteristics

6) Connect the collector, emitter and the gate terminals to the characteristics circuit

7) Connect the ammeter to measure the collector current

8) Connect a voltmeter across the gate -emitter and another voltmeter across the collector – emitter terminals

9) Switch ON the 230V AC supply

10) Fix the gate- emitter voltage (V GE) using the pot_1

11) Smoothly vary the Collector-Emitter (V_{CE}) Voltage by varying the Pot_2 till the IGBT turns ON. Note the Voltmeter and Ammeter (I_C) readings

12) Once turned ON, Increase the V_{CE} and Note change in current I_C

13) Repeat the steps 5 & 6 for different values of V_{GE}

14) Note the value of pinch OFF Voltage from the graph

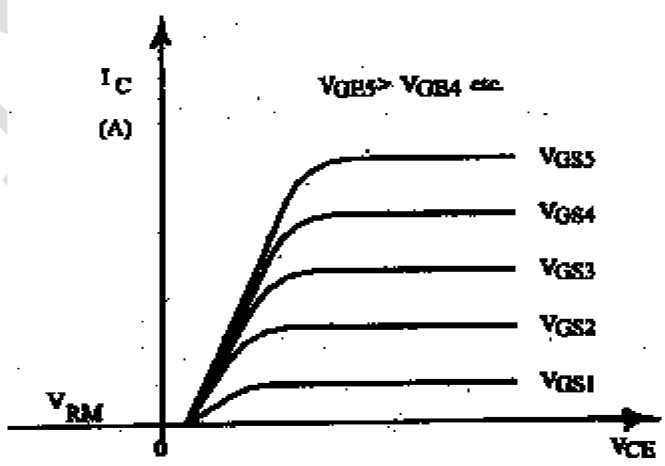
<u>Observations:</u>

a) Output Characteristics:

S.No.	V_{GE} (Constant)	
	V_{CE}	I_C

<u>Expected Graphs:</u>

<u>Output characteristics</u>



Transfer Characteristics:

15) Keep the V_{CE} constant using pot_2

16) Vary V_{GE} using pot_1 to trigger the IGBT, Note the values of V_{GE} and I_C

17) Smoothly increase the value of V_{GE} and not the values of voltage and current

18) Plot V_{GE} Vs I_C , Note the threshold value of voltage from the graph

19) Repeat for different values of V_{CE}

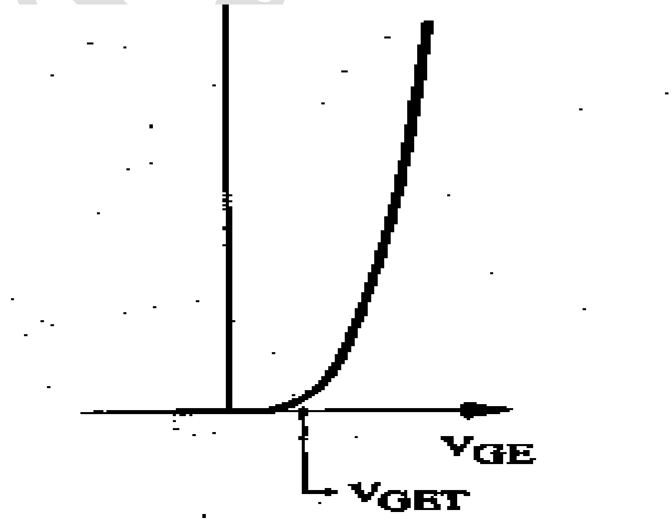
Observations:

b) Transfer Characteristics:

S.No.	$V_{CE(Constant)}$	
	V_{GE}	I_C

Expected Graphs:

Transfer Characteristics



Result: The output and transfer characteristics of the IGBT are studied and graphs plotted. The threshold Voltage is --------------------- fos V_{GE} = ------------------ and that for the transfer characteristics it s -------------------------- for V_{CE} = ----------.

Discussion of Result:

- Observe the Pinch of voltage obtained from output characteristics with different V_{GE} and comment on the result.
- Significance of Gate Threshold voltage in Transfer characteristics.
- Mention the device whether it is a voltage controlled or current controlled.

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT
POWER ELECTRONICS LAB

R, RC, UJT Firing of SCR

Experiment:2

Aim: To Study the operation of resistance firing circuit using R, RC & UJT firing module.

Apparatus: R, RC & UJT firing module.
CRO, 50V/4A Rheostat
Digital Multi-meter
Patch chords

Theory: **R-Firing**

The gate current is used for triggering instead of the gate pulse. In the circuit shown, when the gate current I_g is minimum, the SCR turns ON and the supply voltage V_s goes positive Swhile V_L goes negative such that V_s is almost equal to the load voltage V_L.

As V_s goes negative, SCR turns OFF and the load voltage V_L is Zero

The diode prevents the gate cathode current reverse bias during the negative half cycle.

Same sequence is repeated during the positive half cycle – V_S goes positive.

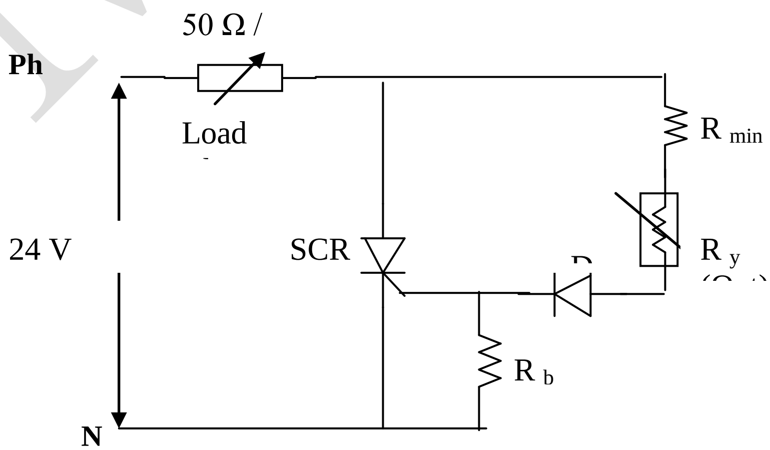
R is varied to vary the load voltage

RV will vary the firing angle

R_{min} limits the value of the gate current while varying R_V

R_b should be such that it causes minimum voltage drop across it so that it does not exceed maximum gate voltage.

Circuit Diagram: **R-Firing**



Procedure:

R-Firing

1. Connect the input supply to the trainer module
2. Connect P & N terminals to T_7 & T_9
3. Connect one end of the load rheostat to P terminal of 24V AC supply
4. Connect the other end of the load rheostat to N terminal of 24V AC supply
5. Connect the cathode (K) to the N terminal of SCR
6. Connect G & K terminals of firing circuit to G & K of SCR
7. Connect CRO ground to anode of SCR. Connect a Probe to T_7 and another probe to cathode of SCR
8. Switch ON the supply, Power ON/OFF switch, 24V ac Switch, Supply to CRO
9. Observe the waveform for input AC voltage & load voltage for different firing angles
10. Plot the waveforms
11. Measure the DC voltage across the load & rms value of the input voltage using a multi-meter.
12. Calculate the output voltage $V_{dc} = (\sqrt{2}V / 2\pi)(1+\cos\alpha)$
13. Compare the two values.

Observation Table:

Vrms	T(msec)	t (msec)	α (degrees)	Vo(measured)	Vo(cal) $= \frac{Vm}{2\pi}(1+\cos\alpha)$ V
25.4	3.2	0	0°	11.18	11.43

Model Calculation:

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

$$\text{Vo (calculated)} = \frac{Vm}{2\pi}(1+\cos\alpha)\ V$$

$$= \frac{25.4 * \sqrt{2}}{2\pi}(1+\cos 0^\circ)$$

$$Vo = 11.43V$$

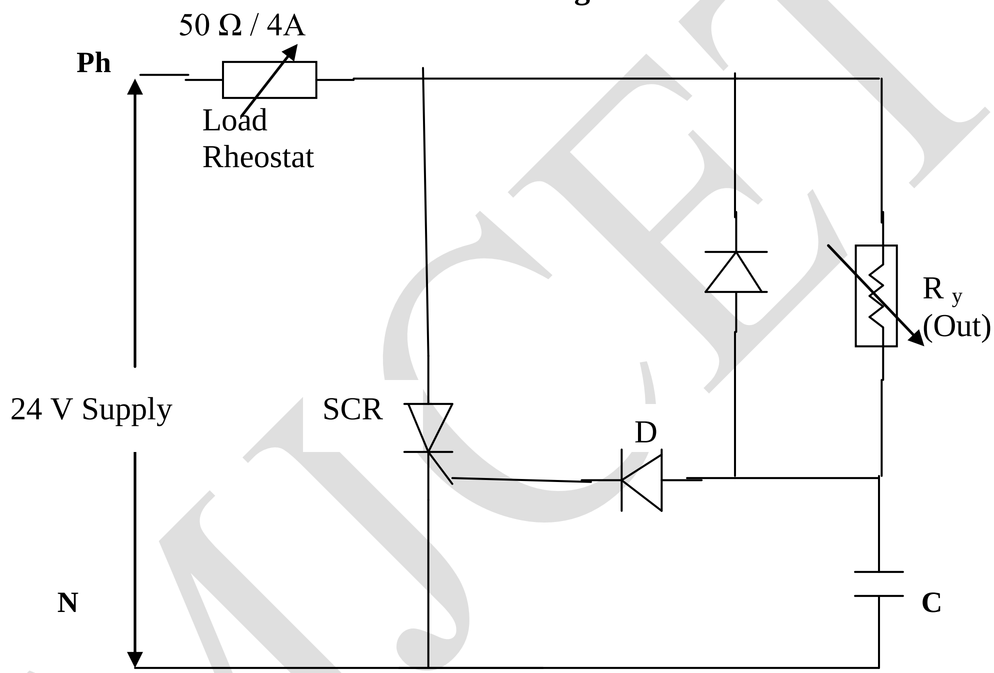
Theory:

RC- Firing

When V_S goes positive and the capacitor voltage V_C is equal to the gate triggering voltage V_{gt} where ($V_{gt} = V_{gmin} + V_{D1}$), the SCR will turn ON. The capacitor holds a small value of voltage. During positive half cycle the capacitor charges through D_2 .The diode D_1 prevents break down of the gate to cathode junction during negative half cycle.

Circuit Diagram:

RC-Firing



Procedure:

RC-Firing

1. Connect the input supply to the trainer module
2. Connect P & N terminals to T_{12} & T_{13}
3. Connect one end of the load rheostat to P terminal of 24V AC supply
4. Connect the other end of the load rheostat to N terminal of 24V AC supply
5. Connect the cathode (K) to the N terminal of SCR
6. Connect G & K terminals of firing circuit to G & K of SCR
7. Connect CRO ground to anode of SCR. Connect a Probe to T_7 and another probe to cathode of SCR.

8. Switch ON the supply, Power ON/OFF switch, 24V ac Switch, Supply to CRO
9. Observe the waveform for input AC voltage & load voltage for different firing angles
10. Plot the waveforms
11. Measure the DC voltage across the load & rms value of the input voltage using a multi-meter.
12. Calculate the output voltage $V_{dc} = (\sqrt{2}V / 2\pi)(1+\cos\alpha)$
13. Compare the two values.

Observation Table:

Vrms	T(msec)	t (msec)	α (degrees)	Vo(measured)	Vo(cal) = $\frac{Vm}{2\pi}(1+\cos\alpha)$ V
25.6	3.2	0.2	11.25°	11.11	11.41

Model Calculation:

$$Vm = Vrms*\sqrt{2}$$

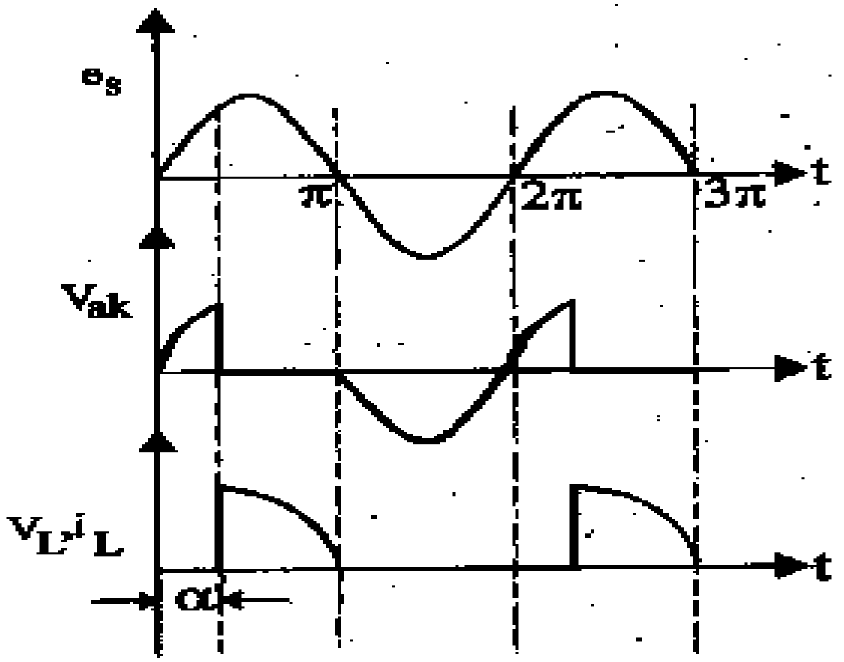
$$\text{Vo (calculated)} = \frac{Vm}{2\pi}(1+\cos\alpha)\ V$$

$$= \frac{25.6*\sqrt{2}}{2\pi}(1+\cos 11.25^{\circ})$$

$$Vo = 11.41V$$

EXPECTED GRAPH:

R, RC Firing Circuit



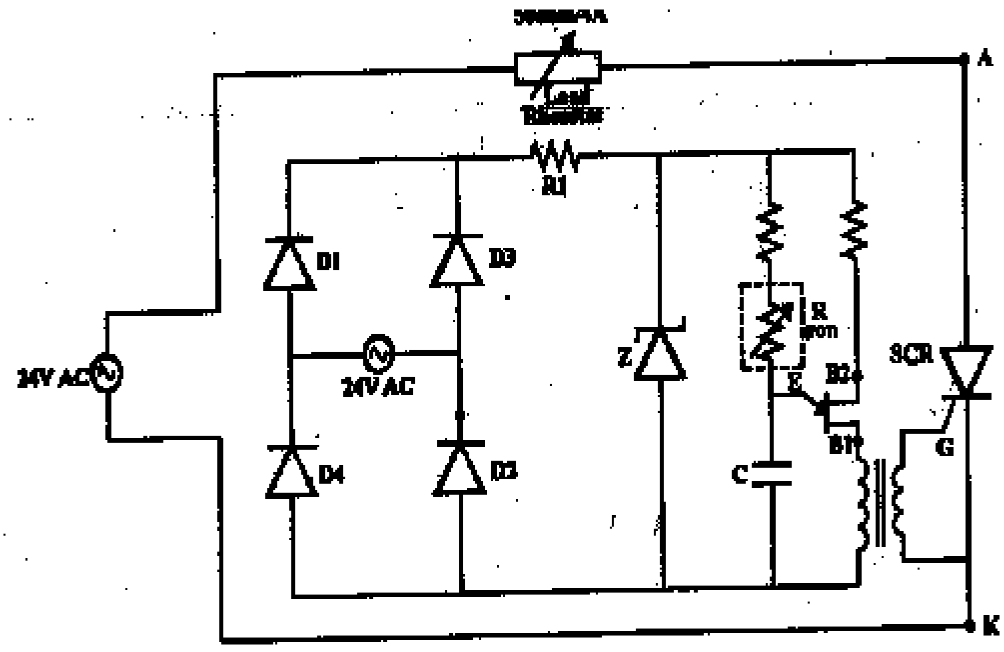
Theory:

UJT- Firing

Is also known as Ramp triggering. The diodes D_1 - D_4 rectifies the input AC to Dc. The Zener diode Z is used to clip the rectified voltage to a standard level V_Z which remains constant except when V_{dc} is zero.

The Zener voltage V_Z is applied to the charging circuit RC. The capacitor C charges by current i_1. When the capacitor voltage reaches the threshold voltage ηV_Z, the Emitter-base$_1$ junction breaks down and C charges through the primary of the pulse transformer sending current i_2.When i_2 is positive the SCR turns ON. The rate of rise of capacitor voltage can be varied using R. The firing angle can be controlled up to 150^0 .
It can be used in Single phase controller, single phase half wave controlled converter, single phase controlled bridge rectifier, etc

Circuit Diagram :



s

Procedure:

1. Connect the input supply to the trainer module
2. Connect one end of the load rheostat to A of the SCR
3. Connect the other end of the load rheostat to P terminal of 24V AC supply
4. Connect G_1 & K_1 terminals of UJT firing circuit to G & K of SCR
5. Switch ON the supply, Power ON/OFF switch, 24V ac Switch, Supply to CRO
6. Observe the waveform for input AC voltage & Pulsating DC voltage
7. Observe the Zener diode voltage(T_4) & capacitor voltage (T_5)
8. Plot the waveforms
9. Repeat the experiment for various firing angles

Observation Table:

Vrms	T(msec)	t (msec)	α (degrees)	Vo(measured)	Vo(cal) $=\frac{Vm}{2\pi}(1+\cos\alpha)$ V
25.8	3.2	0.4	10.78°	10.99	11.5

Model Calculation:

$$Vm = Vrms*\sqrt{2}$$

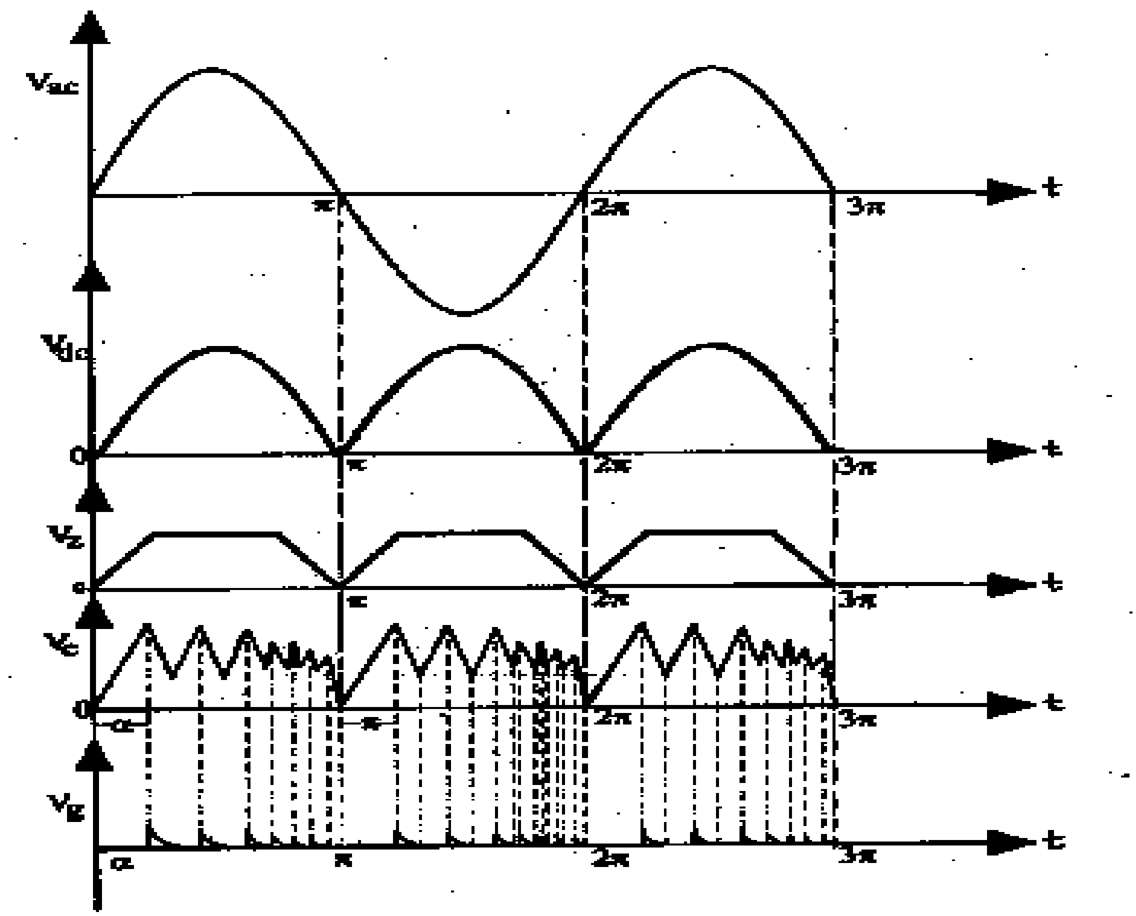
$$Vo\ (calculated) = \frac{Vm}{2\pi}(1+\cos\alpha)\ V$$

$$= \frac{25.8*\sqrt{2}}{2\pi}(1+\cos 10.78^{\circ})$$

$$= 11.5V$$

Expected graphs:

UJT Firing



Results: The wave forms for the R, RC, and UJT firing of the SCR are studied and plotted.

Discussion of Result:

- Analyze the output voltage waveform for different firing circuits and mention the limitation of each circuit.
- In all triggering circuits comment on firing angle vs output voltage.

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT
POWER ELECTRONICS LAB

SINGLE PHASE CYCLOCONVERTER

Experiment: 3

Aim: To Study the operation of cyclo-converter and observe the output waveforms.

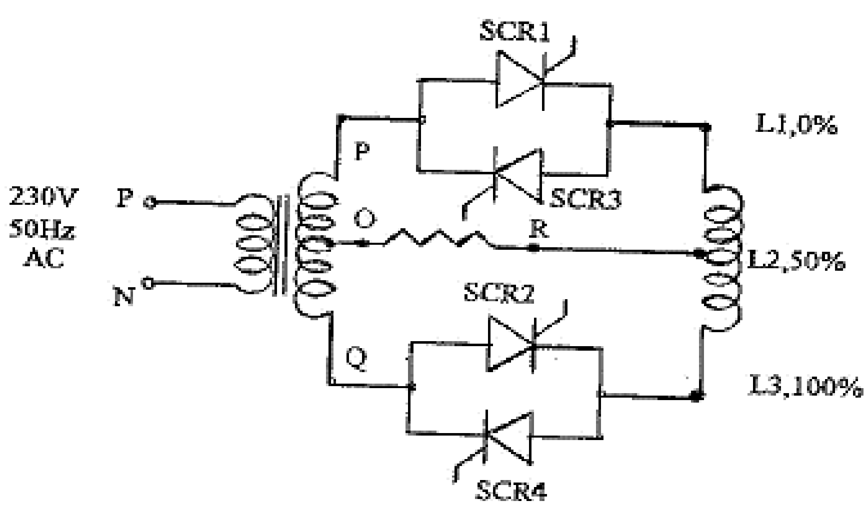
Apparatus Required: Cyclo-converter Kit, CRO & Patch cords.

Theory:

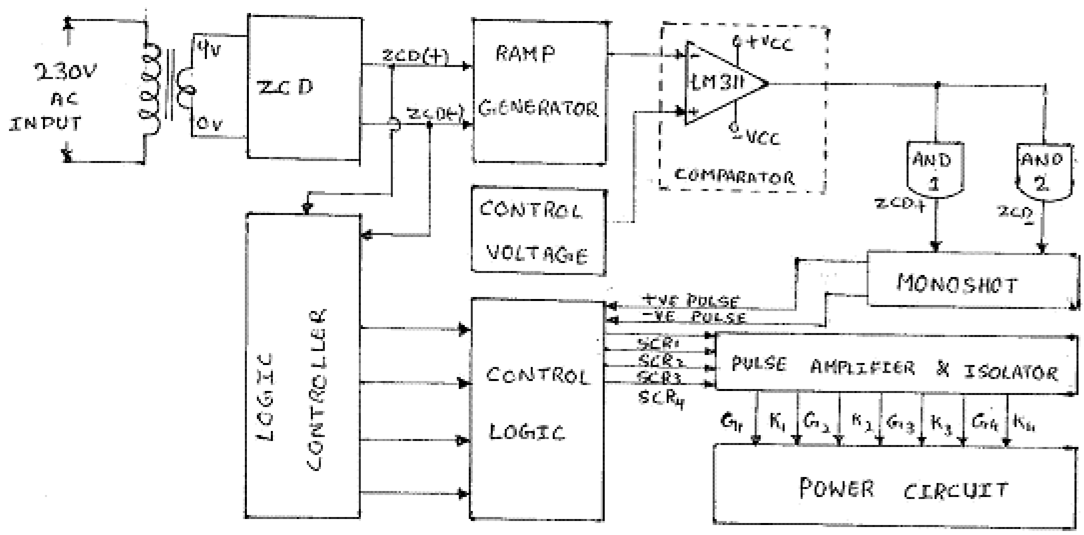
In the cycloconverter one group of thyristers produce positive polarity of the load voltage and the other group produces the other polarity. One group of SCRs are gated together. Depending on the polarity of the input only one of them will conduct. When P is positive w.r.t O then SCR1 will conduct otherwise SCR2 will conduct. Thus in both half cycles of the input the load voltage will be positive. The SCRs get turned OFF by natural commutation at the end of every half cycle.

Depending on the desired frequency, gating pulses to positive group of SCRs will be stopped and SCRs 3 & 4 will be gated SCR 3 conducts when p is +ve and SCR4 conducts when P is –ve.

Circuit Diagram:



Block Diagram:



Procedure:

1. Keep all the switches in the OFF position.
2. Connect the banana connector as given below

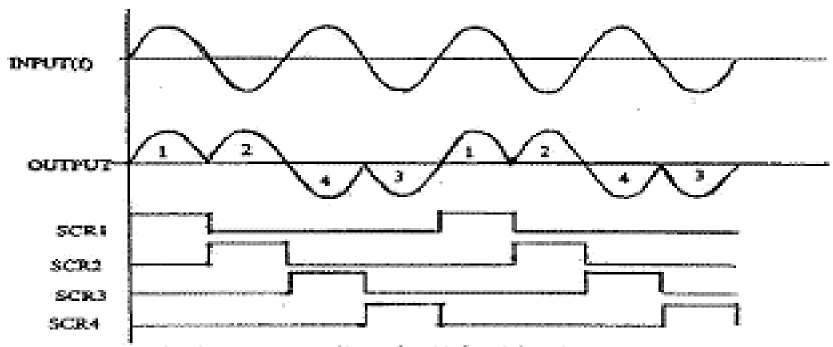
   A1 to K3& 24V AC output
   A2 to K4& 24V AC output
   A3 to K1 & L1
   A4 to K2& L3
   R2 to L2
   Out put of 0V to R1
   G1 to G1
   G2 to K2
   G3 to K3
   G4 to K4 and
   K1 to K1

3. Select the output frequency level from the table given below

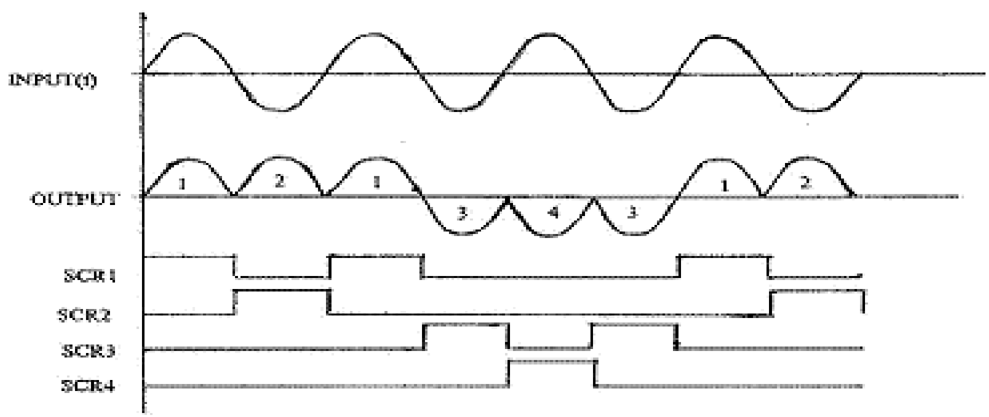
SA	SB	Frequency in Hz
0	1	12.5
1	1	16.67
1	0	25
0	0	50

4. Switch ON the trainer kit using Power ON/OFF switch
5. Switch ON the pulse release switch
6. Switch ON the 24V AC output
7. Vary the control voltage (V_c) to vary the firing angle, Observe the Waveforms.

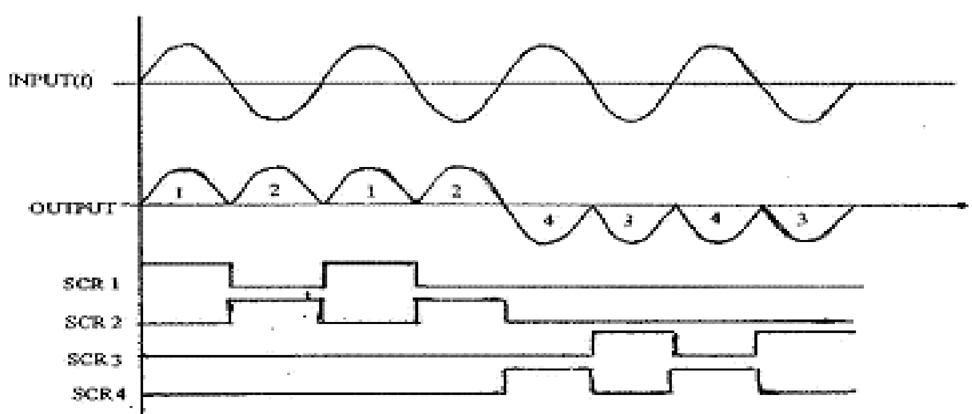
Expected Graphs:



Cycloconverter Waveforms for F/2 output frequency



Cycloconverter Waveforms for F/3 output frequency



Cycloconverter waveforms for f/4 output frequency

Output Waveforms

Results: The output of the cyclo converter for f, f/2 , f/3 and f/4 have been studied.

Discussion of Result:

- Comment on Time Period and frequency with reference to input frequency for different levels of output frequency.

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT
POWER ELECTRONICS LAB

SINGLE PHASE AC VOLTAGE CONTROLLER

Experiment : 4

Aim: To study the operation of an AC single phase voltage controller with R and RL load

Apparatus: Trainer Kit
CRO
Patch chords

Theory:

R- Load

An AC voltage regulator consists of two SCRs connected in anti parallel During positive half cycle, the SCR_2 is forward biased. The current flow is through terminal P – SCR_2 – the load and the terminal N.

During the negative half cycle the SCR_1 is forward biased. The current flow is through terminal N – SCR_2 – load –terminal P.

The firing angle of the SCRs is kept at 45^0 If tha delay angles of the two SCRs are equal, and the input voltage is V_m sinωt, the RMS output voltage will be given by formula stated in model calculation.

Thus by varying α from 0 to π, the RMS value of output voltage can be controlled from RMS input voltage to 0

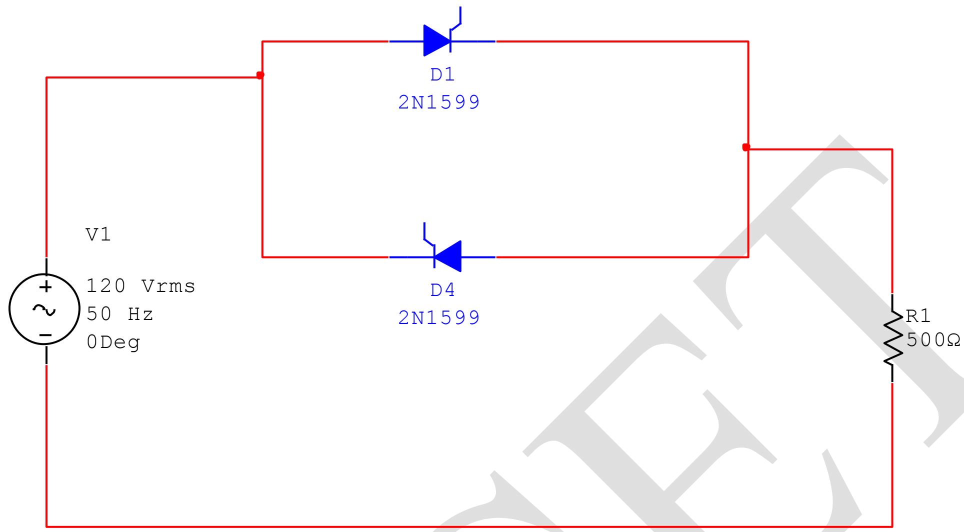
R- L Load

During the positive half cycle SCR_2 is triggered into a firing angle delay of α, the current rises slowly due to the inductor. The current continues to flow even after the supply voltage reverses, due to the energy stored in the inductor.

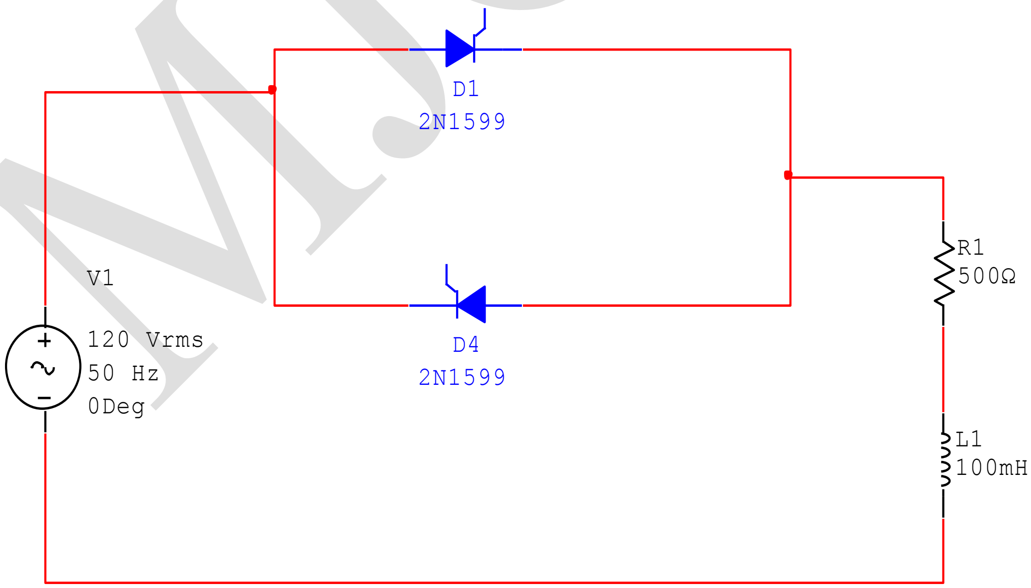
As long as the SCR_2 conducts, the conduction drop across it will reverse bias SCR_1 , hence it will not conduct even if gating signal is applied. It can be triggered into conduction during the negative half cycle after SCR_2 turns OFF. The wave forms are shown for both continuous and discontinuous current

Circuit Diagram:

R-Load



R-L Load



Procedure:

R –Load

1. Connect anode of SCR2 to the cathode of SCR_1
2. Connect the 24V AC positive terminal to anode of SCR_2
3. Connect R load terminal between cathode of SCR_1 and 24V AC output.
4. Connect the CRO across the load
5. Connect the voltmeter across the load terminals
6. Connect G_2 & K_2 of firing circuit to G_2 & K_2 of SCR_2
7. Switch ON the trainer kit
8. Place the switch S_2 in SCR mode
9. Switch ON the 24V AC supply
10. Switch ON the denounce switch.
11. Note down the peak value of voltage V_m , triggering angle α and conduction angle γ
12. By varying the firing angle the output can be varied
13. Plot the graph V_m versus α and γ

RL – Load

1. Connect R and L in series then connect the load terminals between cathode of SCR_1 and 24V ac input.
2. Repeat the above steps
3. Observe the waveforms

Observation Table:

R – Load

SNo	Input Voltage	Firing Angle α	Measured Output	Calculated Output
1.	22.98V	56.25°	19.2V	20.99V

Model Calculation:

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

$$Vo(cal) = \frac{Vm}{\sqrt{2}}\sqrt{\left[\left(\frac{\pi-\alpha}{\pi}\right)+\frac{\sin 2\alpha}{2\pi}\right]}$$

***Vo calculated is RMS voltage across output.**

$$Vo(cal) = \frac{22.98 * \sqrt{2}}{\sqrt{2}}\sqrt{\left[\left(\frac{\pi-0.981}{\pi}\right)+\frac{\sin 2(56.25)}{2\pi}\right]}$$

Vo = 20.99 (56.25°= 0.981radians)

RL – Load

SNo	Input Voltage	Firing Angle α	Extinction angle β	Measured Output	Calculated Output
1.	23.33	56.25°	196.81°	20.7V	21.36V

Model Calculation:

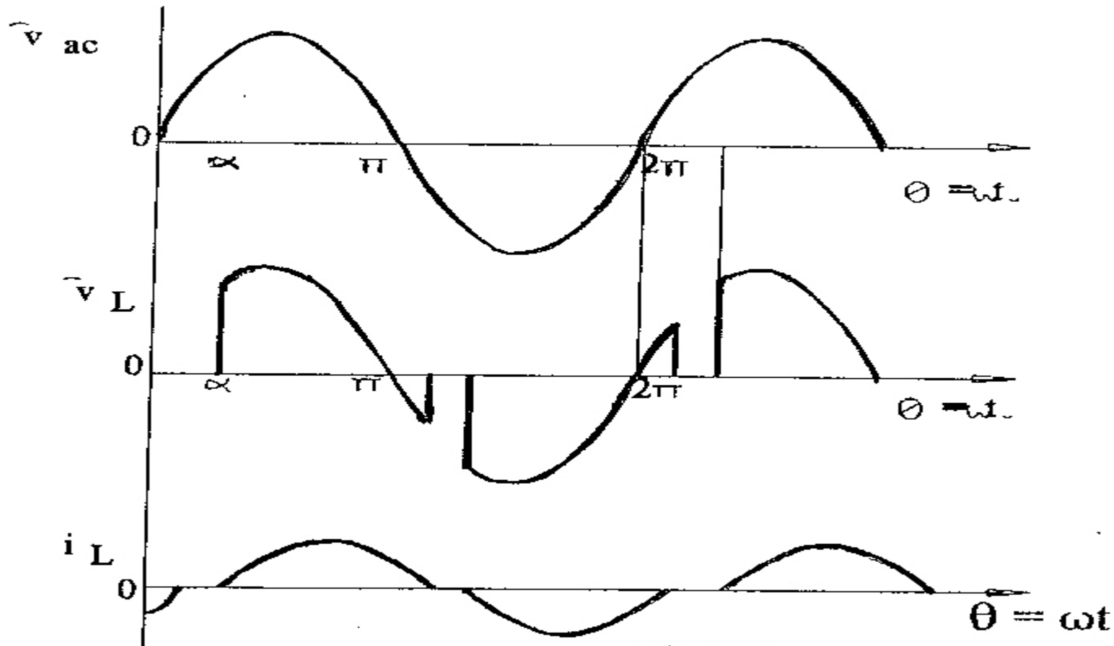
$$Vo(cal) = Vm\sqrt{\frac{1}{2\pi}\left[(\beta-\alpha)+\frac{\sin 2\alpha}{2}-\frac{\sin 2\beta}{2}\right]}$$

$$Vo(cal) = 23.33 * \sqrt{2}\sqrt{\frac{1}{2\pi}\left[(2.45)+\frac{\sin 2 * 56.25^\circ}{2}-\frac{\sin 2 * 196.81^\circ}{2}\right]}$$

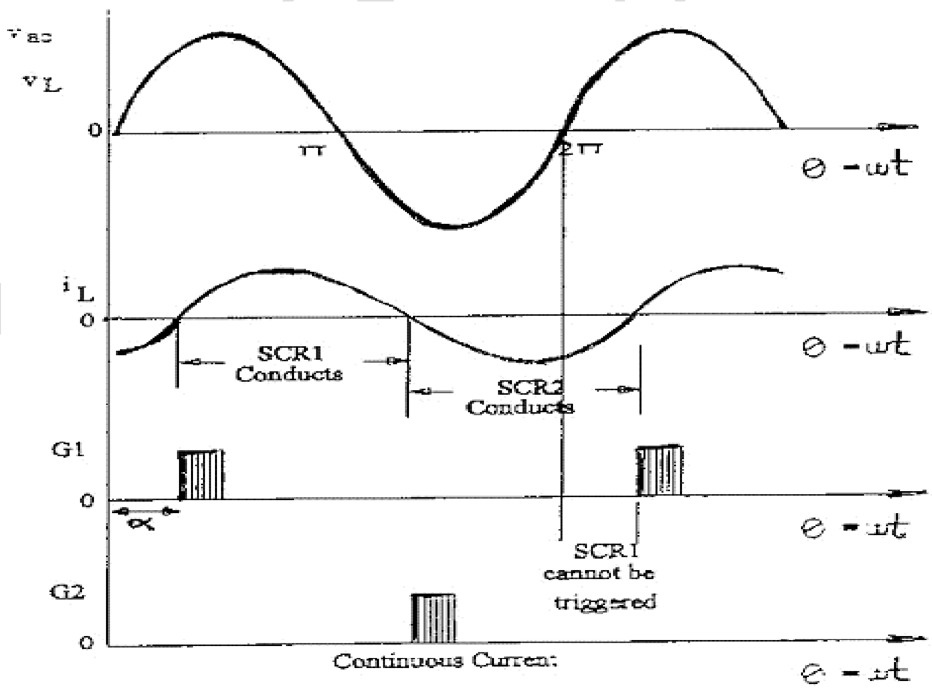
Vo = 21.36V

where : $(\beta-\alpha) = 196.81^\circ - 56.25^\circ = 140.55^\circ$
=2.45 radians

Expected graphs:

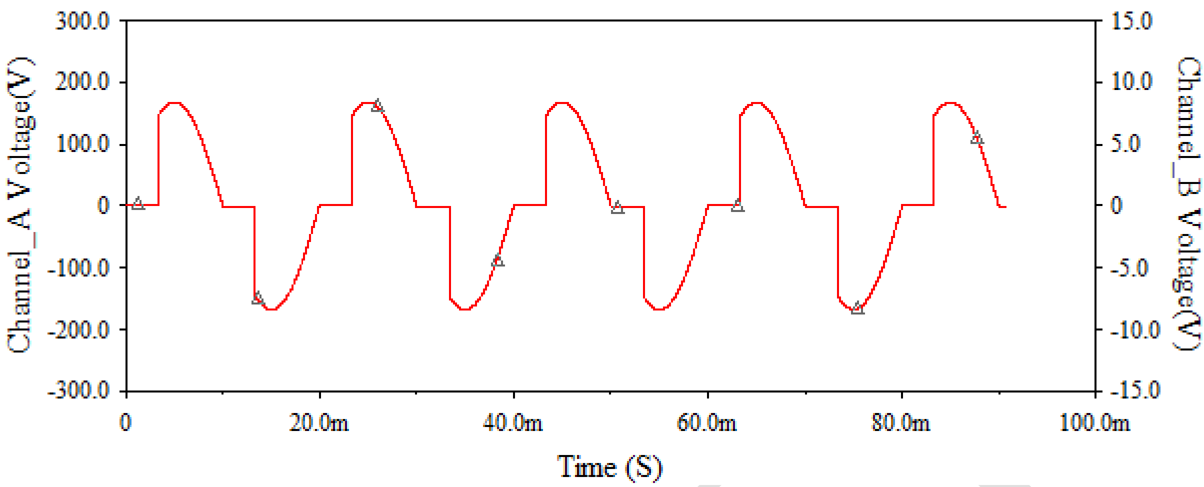


DisContinuous Current

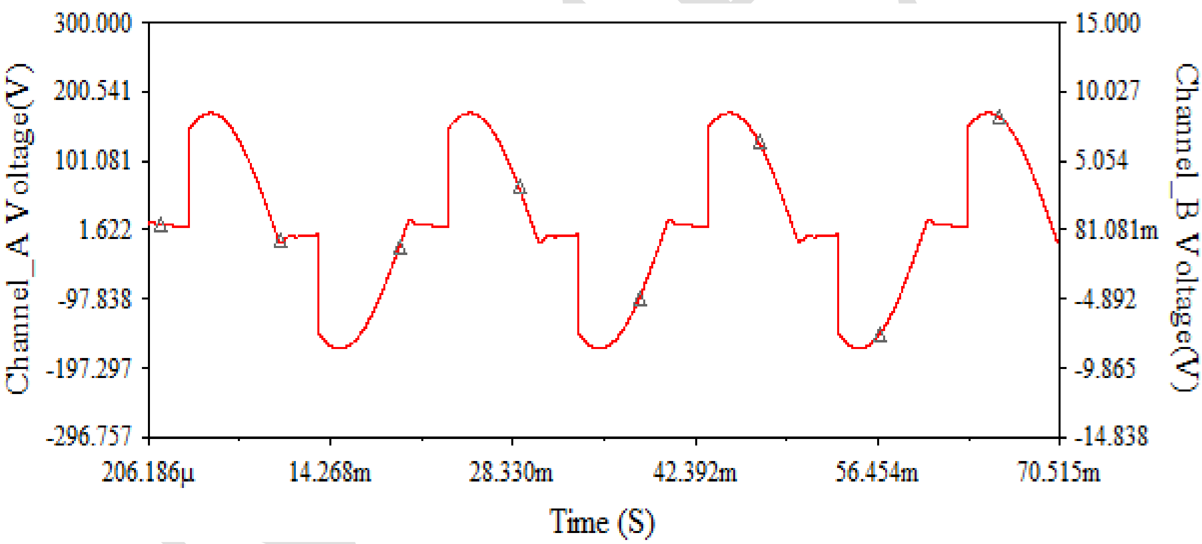


Continuous Current Mode

Simulation Results:



R-Load



RL-Load

Results: The SCR based single phase AC voltage controller or regulator with R & RL load is studied and the required graphs are plotted.

Discussion of Result:

- Mention the Purpose of Ac voltage controller.
- Analyze the effect of change in firing angle on output Voltage waveform.
- Compare the Theoretical values of Output voltage with Practical values with different firing angles.

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT
POWER ELECTRONICS LAB

STUDY OF COMMUTATION CIRCUITS

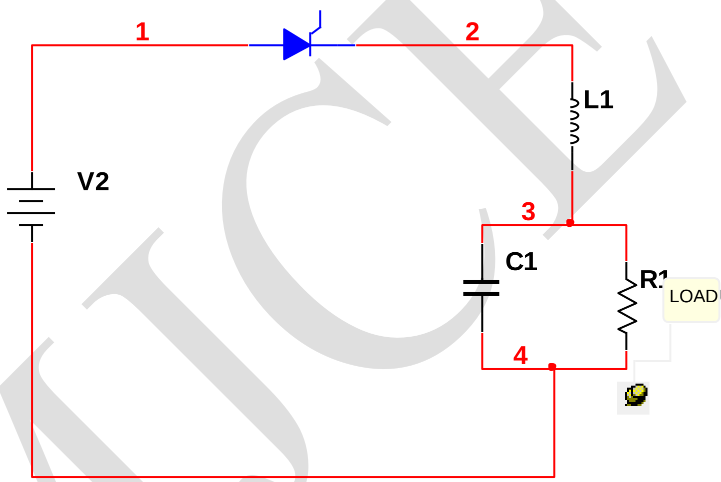
Experiment: 5

Aim: To Study the operation and the output waveforms of class A, B, C, D ,E and F commutation.

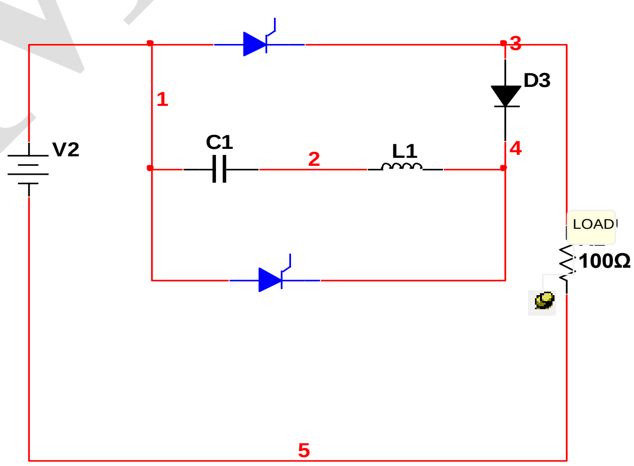
Apparatus Required: Thyristor forced commutation trainer, CRO & Patch chords

Circuit Diagram:

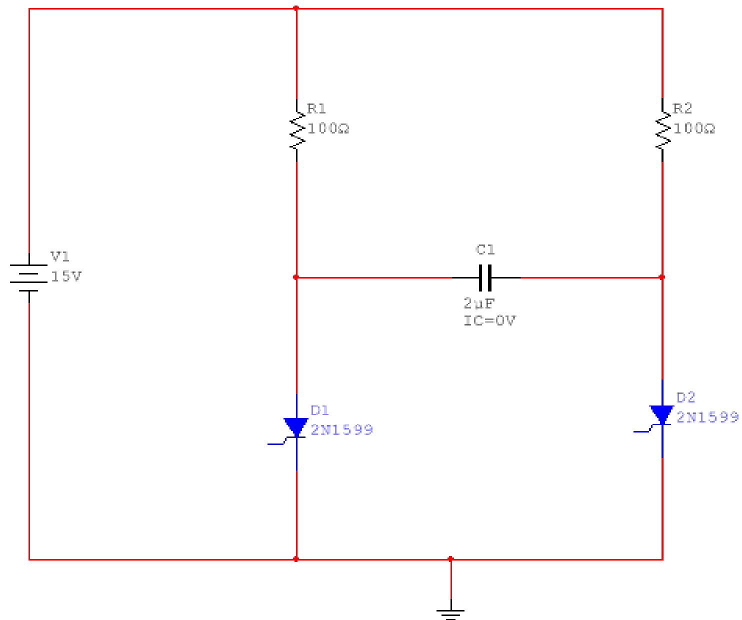
CLASS-A COMMUTATION



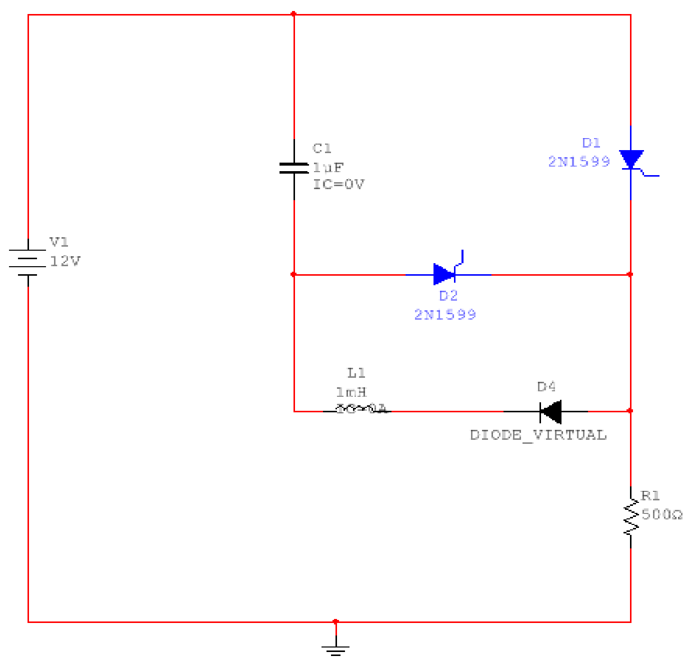
CLASS-B COMMUTATION



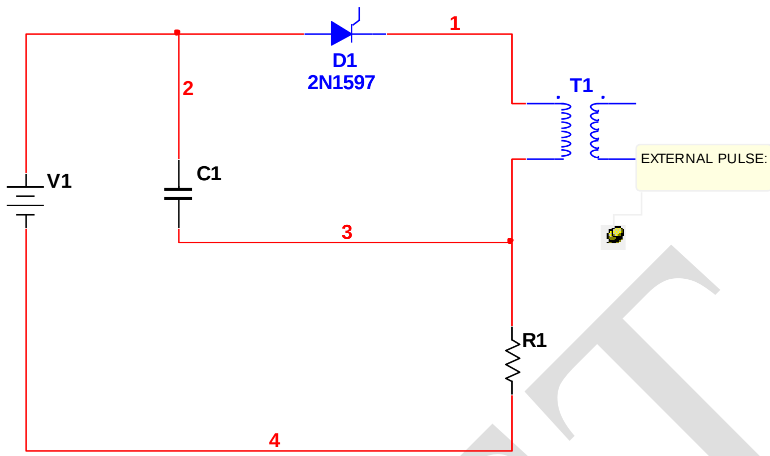
CLASS-C COMMUTATION



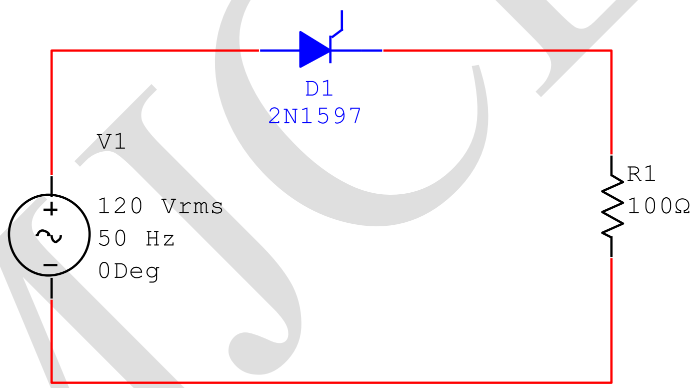
CLASS-D COMMUTATION



CLASS-E COMMUTATION



CLASS-F COMMUTATION



Procedure:

CLASS A: Connect G_1 of triggering circuit to G_1 of the power circuit
Connect K_1 of triggering circuit to K_1 of the power circuit
Connect +15V to A_1 terminal of SCR_1
Connect K_1 of SCR to inductor L_1
Connect another end of L_1 to C_2 and resistance R_{l2}
Connect other end of capacitor C_2 & Resistance R_{L2} to – 15 V DC
Connect CRO probe across the resistor R_{L2}.
Switch on the trainer kit ON/OFF switch, 15V Dc Supply, auxiliary switch of the SCR and the main SCR switch.
Slowly vary the frequency knob and observe the waveforms & Plot them

CLASS B: Connect G_1 of triggering circuit to G_1 of the power circuit
Connect K_1 of triggering circuit to K_1 of the power circuit
Connect G_2 of triggering circuit to G_2 of the power circuit
Connect K_2 of triggering circuit to K_2 of the power circuit
Connect +15V, A1of SCR1, A2 of SCR2, C_1 & C_2.
Connect the other end of C_1 to inductor L_1 through C_2
Connect another end of L_1 to anode of D_1
Connect the cathode of D_1 to cathode K1 of SCR1 through resistance R_{l2}
Connect other end of Resistance R_{L1} to – 15 V DC
Connect CRO probe across the resistor R_{L1}.
Switch on the trainer kit ON/OFF switch, 15V Dc Supply, auxiliary switch of the SCR and the main SCR switch.
Fix the frequency knob at certain value, vary the duty cycle knob step by step, and observe the waveforms & Plot them.
Connect G_2 of triggering circuit to G_2 of the power circuit
Connect K_2 of triggering circuit to K_2 of the power circuit

CLASS C: Connect G_1 of triggering circuit to G_1 of the power circuit
Connect K_1 of triggering circuit to K_1 of the power circuit
Connect G_2 of triggering circuit to G_2 of the power circuit
Connect K_2 of triggering circuit to K_2 of the power circuit
Connect the +15V to one end of RL_1& RL_2
Connect the capacitor C_1 to the other end of RL1& RL_2
Connect the anode of SCR_2 to RL_2
Connect the K_1 of SCR_1 to K_2 of SCR_2
Connect $K_1$of SCR_1 to +15V
Connect the CRO across RL_1
Switch on the trainer kit ON/OFF switch, 15V Dc Supply, auxiliary switch of the SCR and the main SCR switch.
Fix the frequency knob at certain value, vary the duty cycle knob step by step, and observe the waveforms & Plot them

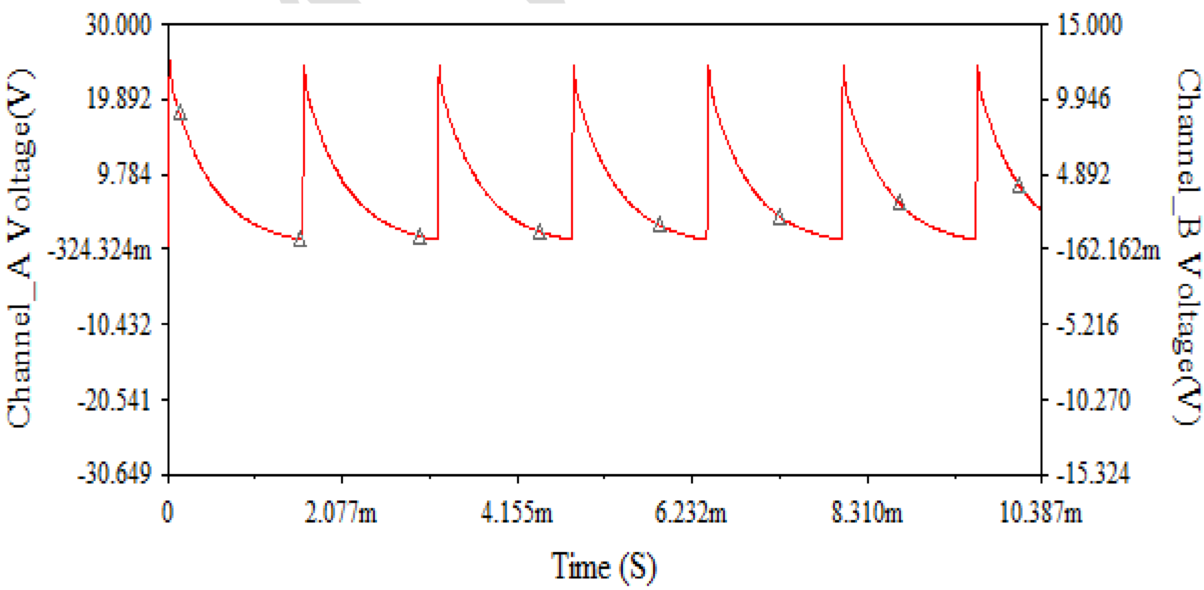
CLASS D: Connect G_1 of triggering circuit to G_1 of the power circuit
Connect K_1 of triggering circuit to K_1 of the power circuit
Connect G_2 of triggering circuit to G_2 of the power circuit
Connect K_2 of triggering circuit to K_2 of the power circuit
Connect +15V DC to $K_1$of SCR_1 and C_1
Connect other end of C1 to A2of SCR_2 and Anode of the diode D_1
Connect the cathode of D_1 to K_2 of SCR2 through the inductor L_1

Also connect the K_1 OF SCR_1 to load resistor RL_1
Connect $K_1$of SCR_1 to +15V and Connect the CRO across RL_1
Switch on the trainer kit ON/OFF switch, 15V Dc Supply, auxiliary switch of the SCR and the main SCR switch.
Fix the frequency knob at certain value, vary the duty cycle knob step by step, and observe the waveforms & Plot them.

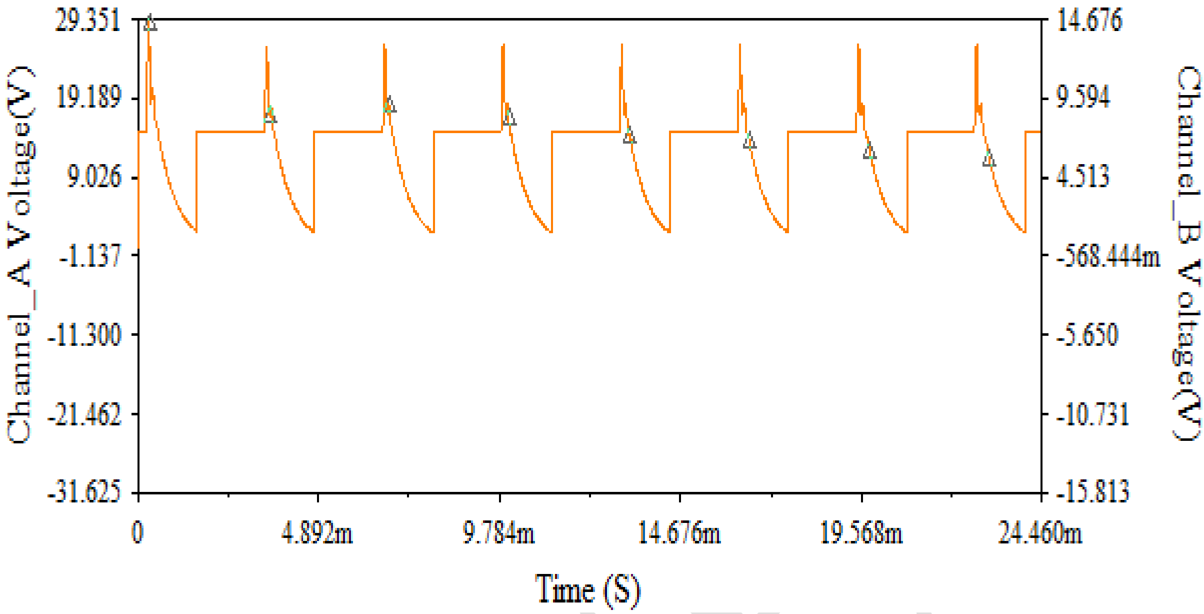
CLASS E: Connect G_1 of triggering circuit to G_1 of the power circuit
Connect K_1 of triggering circuit to K_1 of the power circuit
Connect +15V to A_1 terminal of SCR_1 and to capacitor C_1
Connect other terminal of C to Load and external pulse P_2.
Connect K_1 of SCR_1 to external pulse P_1.
Switch on the trainer kit ON/OFF switch, 15V Dc Supply, auxiliary switch of the SCR_1.
Fix the frequency knob at certain value, vary the duty cycle knob step by step, and observe the waveforms & Plot them

CLASS F: Connect G_1 of triggering circuit to G_1 of the power circuit
Connect K_1 of triggering circuit to K_1 of the power circuit
Connect 9V AC, $(A_{1})_{SCR1}$ and RL1 in series.
Connect CRO across RL_1
Switch ON the Kit, 9V AC and observe the waveforms

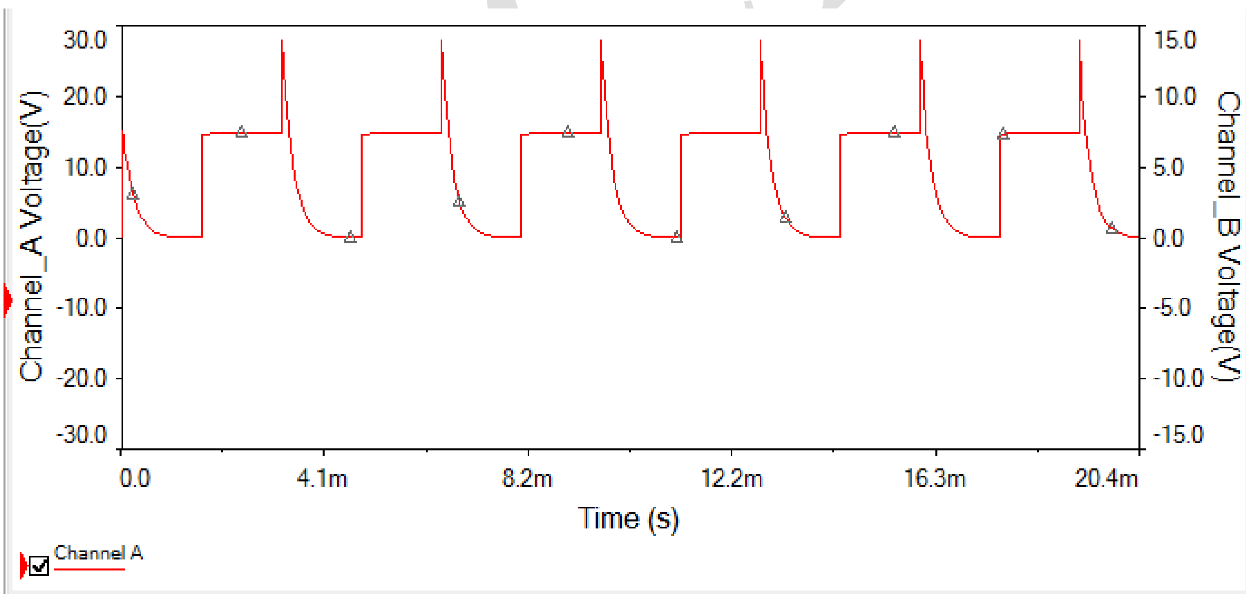
Expected Graphs:



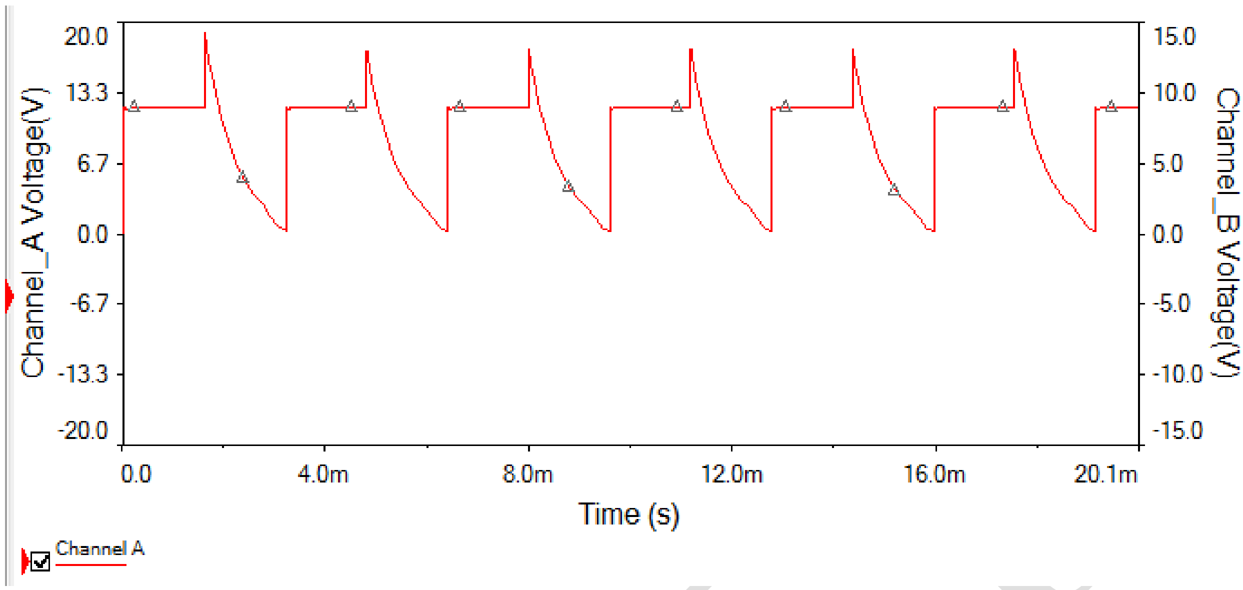
CLASS-A COMMUTATION



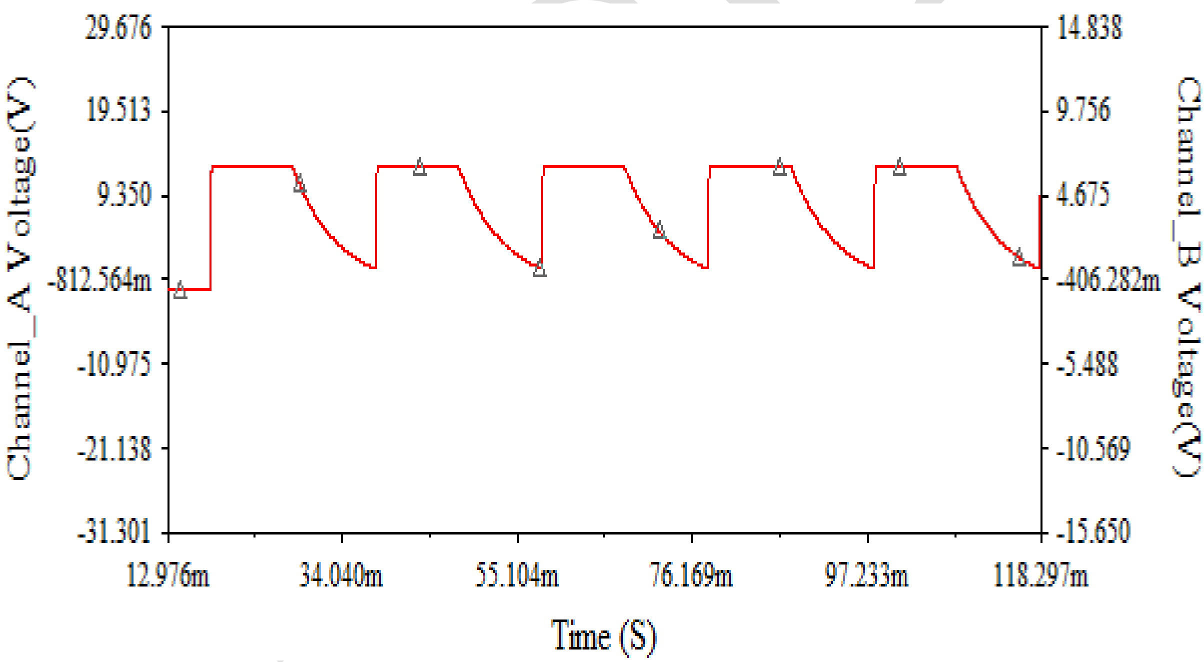
CLASS-B COMMUTATION



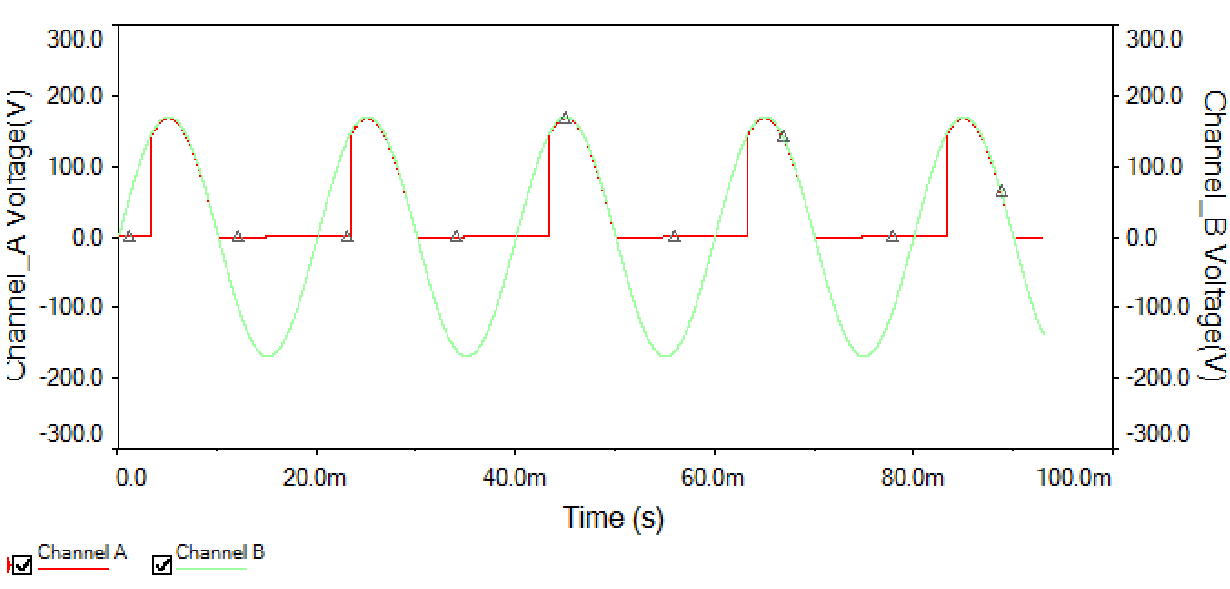
CLASS-C COMMUTATION



CLASS-D COMMUTATION



CLASS-E COMMUTATION



CLASS-F COMMUTATION

Results: The output waveforms of the forced commutation and natural commutation are observed.

Discussion of Result:

- Differentiate between forced commutation and natural commutation
- Analyze the output voltage waveform for different commutation Techniques
- Specify in what category each class(A, B, C, D, E, F) lies.

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT
POWER ELECTRONICS LAB

STUDY OF AN IGBT BASED TWO QUADRANT DC DRIVE

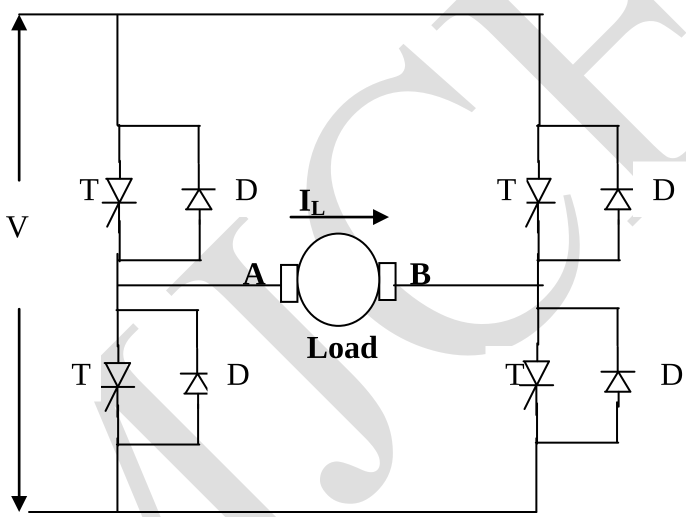
Experiment :6

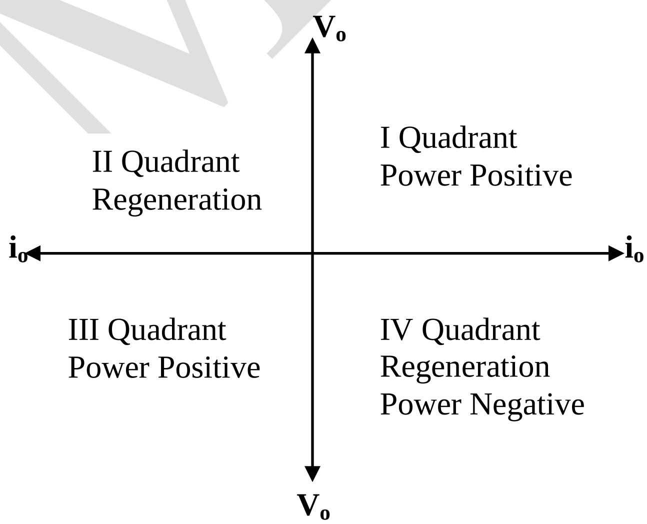
Aim: To study the IGBT based four quadrant chopper DC drive.

.

Apparatus: IGBT based four quadrant chopper DC drive trainer set
Probe Patch Chord
DC Motor
CRO

Circuit Diagram:





Theory: The chopper controlled circuit can operate in four quadrants of the V-I plane. The out put voltage and current can be controlled in both magnitude and direction. In the first quadrant the power flows from source to load and is positive. In the second quadrant the voltage is positive but the current is negative. Thus the power flows from load to source, in case of inductive loads. In third quadrant both voltage and current are negative hence the power flows from source to load. In the fourth quadrant, the current is positive and the voltage is negative thus the power is negative.

When the diodes are connected in anti-parallel with the thyristers it is called the full-bridge converter topology. The input voltage is constant; the output can be a variable DC voltage. Thus it is also called a DC-DC converter. When a gating signal is applied to the SCR, either the SCR or the diode will conduct depending on the direction of the output current.

Procedure:

- Connect the power module and the controller module to the AC supply.
- Connect the pwm output of the controller module to the pwm input of the power module using a pulse cable
- Connect the field terminal of the DC motor to the F + and F- and the armature terminals to A+ and A – terminals of the power module.
- Switch ON the power supply in both IGBT power module and the controller module.
    - Select S_2 at SCM(speed control mode) and S_1 at open loop
    - Keep the armature pot at minimum and S_3 at ON position.
    - Keep the field pot maximum.

      Reset the controller module using S_4

SCM Mode: The LCD will display the following one by one with a delay of few seconds.

Speed control Mode (SCM)

I.	Forward
II.	Reverse

Select the forward option with I quadrant switch, The display will show

D.C Drive (CW) D.CY.Field = 80% D.CY. Armature = 50% Actual speed = 0

Vary the armature duty cycle pot such that the motor runs in the selected direction and at a speed corresponding to the duty cycle.

D.C Drive (CW)
D.CY.Field = 80%
D.CY. Armature = 56%
Actual speed = 2

Select the reverse option using II quadrant switch, now the display will be

D.C Drive (CW)
D.CY.Field = 80%
D.CY. Armature = 56%
Actual speed = 2

FCM mode: Keep the switch S_1 in FCM mode (Four quadrant chopper control mode)

Keep armature pot at min, and field pot at maximum.

I quadrant
III quadrant

Select I Quadrant

I. Forward Running
II. Forward Braking

Reset the controller using S_4, Select forward running.
Vary the armature pot to vary the speed of the motor
Apply forward braking using II quadrant key.

Reset the controller with S_4
Select III quadrant

III. Reverse Running
IV. Reverse Braking

Vary the speed of the motor using the armature pot
Apply Reverse braking using IV quadrant key

Results: The four quadrant operation of the DC motor is studied.

Discussion of Result:

- Comment on Forward Running, Forward Braking, Reverse Running, Reverse Braking.

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT
POWER ELECTRONICS LAB

SINGLE PHASE BRIDGE RECTIFIER

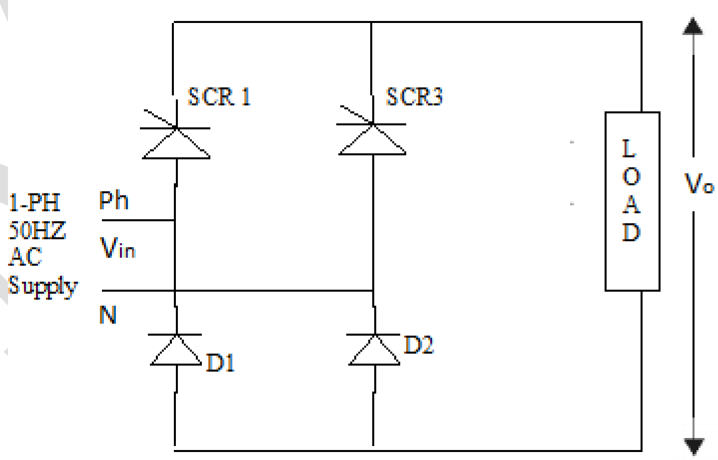
Experiment: 7

Aim: To Study the Single phase full wave bridge rectifier (Half and Full Controlled) with R load

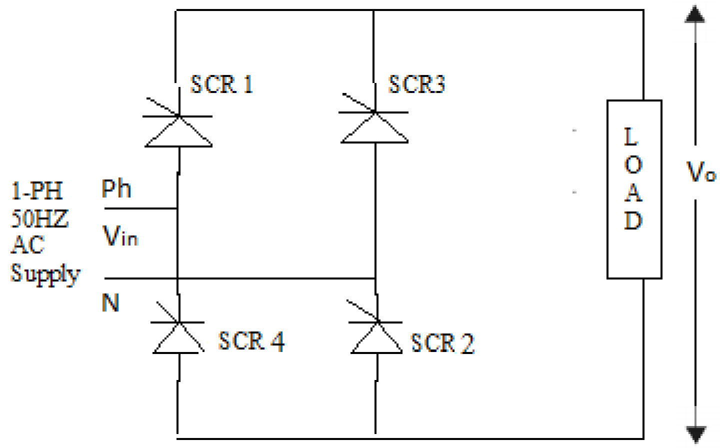
Apparatus:
Single Phase bridge rectifier Module
Single Phase Triggering Module
Multimeter, Rheostat (220Ω)
CRO, DC motor, Tachometer, Isolation Transformer & Auto-transformer
Patch chords

Theory: Phase control thyristors can control the output voltage of a rectifier, by varying the firing angle or delay angle α of the thyristor. In phase control thyristor commutation or turning OFF takes place by line or natural commutation. It has applications in industrial variable speed drives from very low to very high power levels as high as few Mega watts. The output is fed to DC motor to control the speed by varying the voltage.

Circuit Diagram:



Half Controlled Bridge Rectifier



Full Controlled Bridge Rectifier

Procedure:

a) Make the connection as per the circuit diagram

b) Keep control voltage potentiometer at minimum position and set all the switches in OFF position

c) Connect the supply across the line and neutral terminal of the device module

d) Connect the firing pulse from the single phase firing circuit into single phase triggering module in a sequence G-G and K-K

e) Connect the cathode terminal K_1 –K_3 of SCR $_1$ and SCR_3

f) Connect the anode terminals A_2-A_4 of SCR $_2$ and SCR_4

g) Connect the resistance terminal to A_2-and K_3

h) Connect the voltmeter across the motor (load)terminals

i) Switch ON the single Phase triggering module

j) Switch ON the MCB

k) Switch ON the De-bounce logic switch

l) Adjust the control voltage by using potentiometer

m) Tabulate the speed and motor voltage and plot the graph for R and RL(motor)

Observations: **Full & Half Controlled Bridge Rectifier**

Vrms	**T(msec)**	**t (msec)**	**α (degrees)**	**Vo(measured)**	**Vo(cal) $= \frac{Vm}{\pi}(1+\cos\alpha)$ V**
28.9	**5.1**	**1**	**35.29°**	**22.2**	**23.62**

Model Calculation:

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

$$\text{Vo (calculated)} = \frac{Vm}{\pi}(1+\cos\alpha)\ V$$

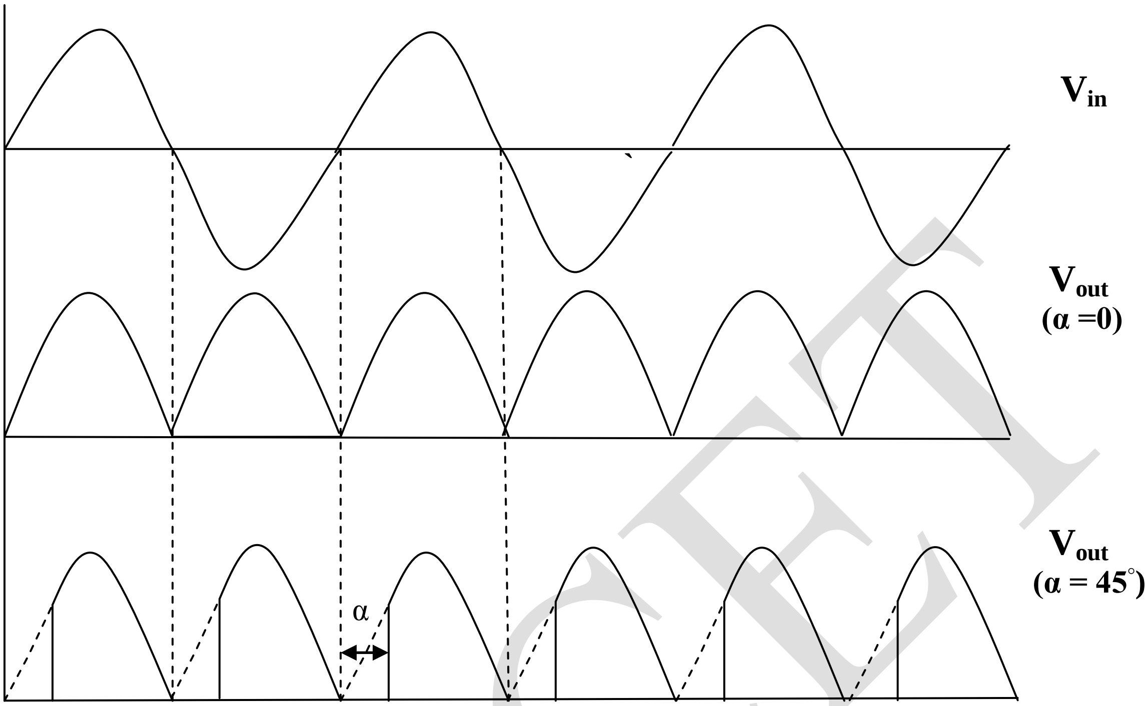
$$= \frac{28.9 * \sqrt{2}}{\pi}(1+\cos 35.29)$$

$$Vo = 23.62V$$

Precautions:

1) Set all the switches to the OFF positions
2) To switch ON and OFF the supply voltage correct sequence
3) Perform the experiment with supply voltage less than 55V AC for resistive loads
4) Use isolation Transformer

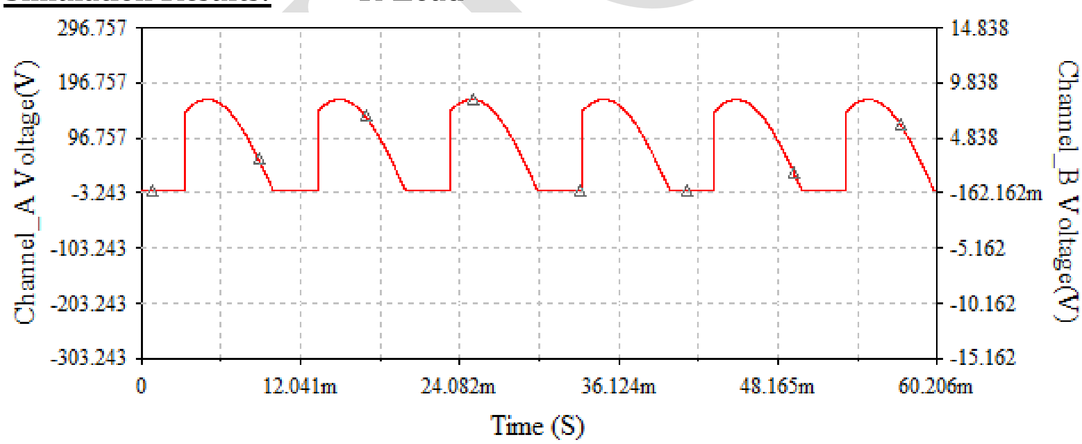
Expected graphs:



Half & Full Controlled Bridge Rectifier.

Results: The output waveforms of the across the load and the SCR are observed and plotted.

Simulation Results: **R-Load**



Discussion of Result:

- Mention the Purpose of Rectifier
- Analyze the effect of change in firing angle on output Voltage waveform.
- Compare the Theoretical values of Output voltage with Practical values with different firing angles.

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT
POWER ELECTRONICS LAB

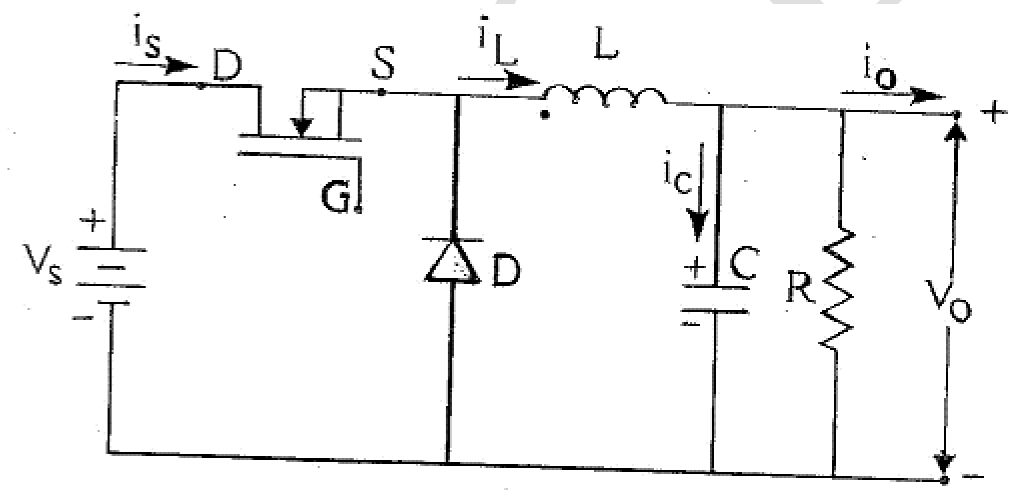
DC-DC BUCK-BOOST CONVERTER

Experiment: 8a

Aim: To study the open loop response of a buck – boost converter with line and load regulation.

Apparatus: DC-DC Converter trainer Kit
Pulse Patch Chord
Rheostat
CRO
Multimeter

Circuit Diagram:



Buck Converter

Procedure-A : **Line Regulation (OPEN LOOP)**

Buck operation (Set pulse voltage to 50% ie 2.7V) & for Boost operation (Set pulse voltage max-100% ie. 4.6V)

1. Connect the P8 of PWM generator to the PWM input of Buck-Boost Converter Circuit

2. Connect the feedback voltage of buck-boost converter circuit to feed back volt input PWM generator
3. Connect the CRO at T3
4. Connect the 0-30V DC RPS across P1 & P2 Switch ON the AC power supply
5. Switch on the power ON/OFF switch
6. View the carrier signal in the CRO, at T3.
7. Set the switch SW1 in downward position, SW2 in upward direction and view the PWM signal at T1 as in fig 2. The duty cycle may be changed by changing the SET VOLTAGE.
8. Switch ON the DC 15V supply
9. View the following wave forms
   a. Device Current I_Q across I1 & I2
   b. Diode current I_D across I3 & I4
   c. Inductor Current I_L across I3 & I7
   d. Device Voltage V_Q across I2 & I3
   e. Rectified Voltage across I5 & I8
   f. Inductor voltage V_L across I7 & I8
   g. The feed back signal at T6
10. Connect the CRO across P5 & P6 to view the output voltage.

Observation Table:

Line Regulation

Vary input voltage below and above 15V

Set voltage: **2.7V** *(Buck operation*)

S.no	Input Voltage Vin	T_{ON}	T_{OFF}	D= T_{ON}/T	Output Voltage Measured(Vo)	Output calculated Vo= [D/(1-D)]*Vs
1	3V	22μs	33 μs	0.4	1.66V	1.98V

Model Calculation:

$$\mathbf{T = T_{ON} + T_{OFF}}$$
$$= 22\mu s + 33\ \mu s = 55\ \mu s$$

$$\mathbf{D = T_{ON} / T}$$
$$\mathbf{= 22/55 = 0.4}$$

Vo (calculated) = [D/(1-D)]*Vs

= 0.4/(1-0.4)]*3

Vo =1.98V

Set voltage: **4.6V** (Boost operation)

S.no	Input Voltage Vin	T_{ON}	T_{OFF}	D= T_{ON}/T	Output Voltage Measured(Vo)	Output calculated Vo= [D/(1-D)]*Vs
1	3V	41μs	10 μs	0.8	9.72V	12V

Model Calculation:

$$\mathbf{T = T_{ON} + T_{OFF}}$$
$$= 41\mu s + 10\ \mu s = 51\ \mu s$$

$$\mathbf{D = T_{ON} / T}$$
$$\mathbf{= 41/51 = 0.4}$$

Vo (calculated) = [D/(1-D)]*Vs

= 0.8/(1-0.8)]*3

Vo =12V

Procedure-B:

Load Regulation

1. Connect the rheostat bet P5 and P6
2. Connect an ammeter in series with the rheostat
3. For 0 external resistance the output is 5V, ($I_{L=}$.3-.7Amp)
4. vary the resistance till the load current is 0.7Amp
5. Tabulate the measured readings

Observation Table :

Load Regulation

SET Input voltage = 15V

Vary the rheostat for (I_L = 0.3 to 0.7)

Measure and tabulate the following readings.

Set pulse voltage: **2.7V** *(Buck operation)*

Input Voltage Vin	T_{ON}	T_{OFF}	**D= T_{ON}/T** (T= T_{ON}+ T_{OFF})	Load Resistor (R Ω)	I_L(mamps)	Output Voltage Measured(Vo)	Output calculated Vo= I*R(volts)
15	24μs	38 μs	0.38	59.2	156	9.21	9.23

Model Calculation:

$$T = T_{ON} + T_{OFF}$$
$$= 24\mu s + 38\ \mu s = 62\ \mu s$$

$$D = T_{ON} / T$$
$$= 24/62 = 0.38$$

Vo (calculated)= I*R(volts)

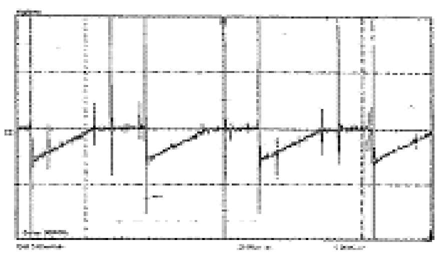
$$= 156*10^{-3}*59.2\ V$$
$$Vo = 9.23V$$

Set pulse voltage: **4.7V** *(Boost operation)*

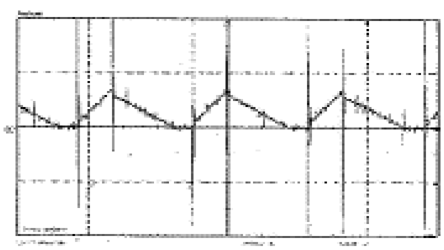
Input Voltage Vin	T_{ON}	T_{OFF}	**D= T_{ON}/T** (T= T_{ON}+ T_{OFF})	Load Resistor (R Ω)	I_L(amps)	Output Voltage Measured(Vo)	Output calculated Vo= I*R(volts)
15							

Expected Waveforms For Line And Load Regulation:

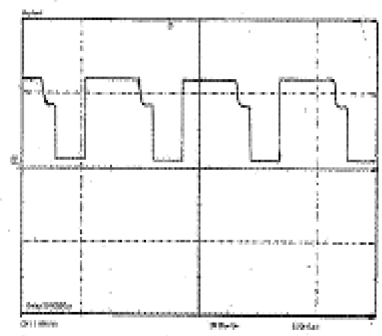
View the diode D current across I3 and I4.



View the inductor current IL across I3 and I7.



View device voltage across I2 and I3.



Results:

a- Line Regulation

The open loop response for buck & boost operation for line regulation has been examined

The output Voltage is maintained at __________ Volts with an input voltage from ....Volt to .... Volts

b- Load Regulation

The open loop response for buck & boost operation for load regulation has been examined.

Discussion of Result:

- Compare the theoretical results with practical results.
- Effect of change in duty cycle on output voltage for line & load regulation.

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT
POWER ELECTRONICS LAB

DC-DC BOOST CONVERTER

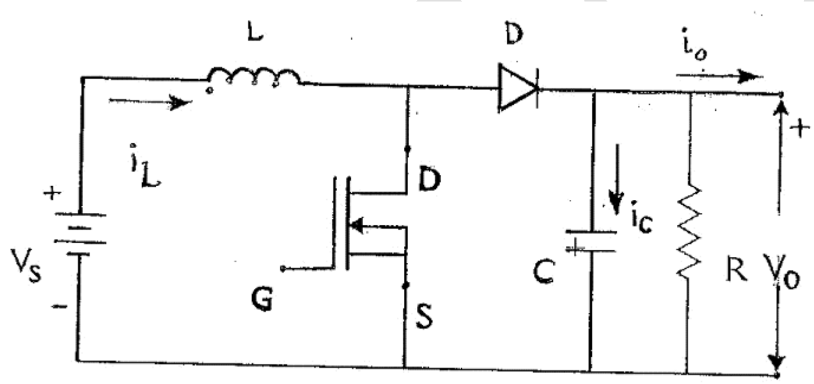
Experiment: 8b

Aim: To study the closed loop response of a boost converter with line and load regulation.

Apparatus:

DC-DC Converter trainer Kit
Pulse Patch Chord
0-30V DC supply
CRO

Circuit Diagram:



Boost Converter

Procedure-A :

Line Regulation

Switch the circuit to boost operation mode:

1. Connect the P8 of PWM generator to the PWM input of Buck-Boost Converter Circuit
2. Connect the feedback voltage of buck-boost converter circuit to feed back volt input PWM generator
3. Connect the CRO at T3
4. Connect the 0-30V DC RPS across P1 & P2 Switch ON the AC power supply
5. Switch on the power ON/OFF switch
6. View the carrier signal in the CRO, at T3 as in fig 1.
7. Set the switch SW1 and SW2 in downward direction and view the PWM signal at T1 as in fig 2. The duty cycle may be changed by changing the SET VOLTAGE.
8. Switch ON the DC 15V supply

9. View the following wave forms
   a. Device Current I_Q across I1 & I2 (fig 3)
   b. Diode current I_D across I3 & I4 (fig4)
   c. Inductor Current I_L across I3 & I7 (fig5)
   d. Device Voltage V_Q across I2 & I3 (fig 6)
   e. Rectified Voltage across I5 & I8 (fig7)
   f. Inductor voltage V_L across I7 & I8 (fig 8)
   g. The feed back signal at T6
10 Connect the CRO across P5 & P6 to view the output voltage.

Procedure-B :

Load Regulation

1. Connect the rheostat bet P5 and P6
2. Connect an ammeter in series with the rheostat
3. For 0 external resistance the output is 5V, ($I_{L=}$.3-.7Amp)
4. vary the resistance till the load current is 0.7Amp
5. Tabulate the measured readings

Observations:

A- Line Regulation

Measure and tabulate the following readings.

Note: Boost operation not possible for minimum set voltage of the pulsesie.1.2 V

Set voltage: **2.7V**

S.no	Input Voltage Vin	T_{ON}	T_{OFF}	D= T_{ON}/T	Output Voltage Measured(Vo)	Output calculated Vo= [D/(1-D)]*Vs

Set voltage: **4.6V**

S.no	Input Voltage Vin	T_{ON}	T_{OFF}	D= T_{ON}/T	Output Voltage Measured(Vo)	Output calculated Vo= [D/(1-D)]*Vs

Vary input voltage below and above 15V

B- Load Regulation

Measure and tabulate the following readings.

SET Input voltage = 15V

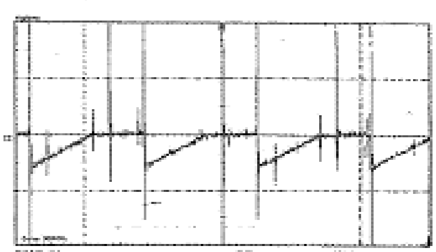
Set voltage: **4.7V** *(Boost operation*)

Input Voltage Vin	T_{ON}	T_{OFF}	**D= T_{ON}/T** ($T= T_{ON}+T_{OFF}$)	Load Resistor (R Ω)	I_L(amps)	Output Voltage Measured(Vo)	Output calculated Vo= I*R(volts)
15V							

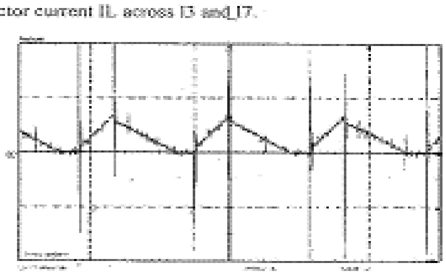
Vary the rheostat for (I_l = 0.3 to 0.7)

<u>Expected Waveforms For Line And Load Regulation:</u>

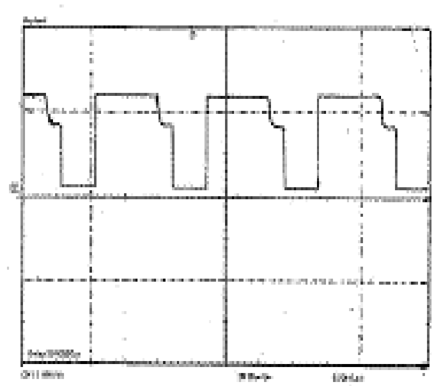
View the diode D current across I3 and I4.

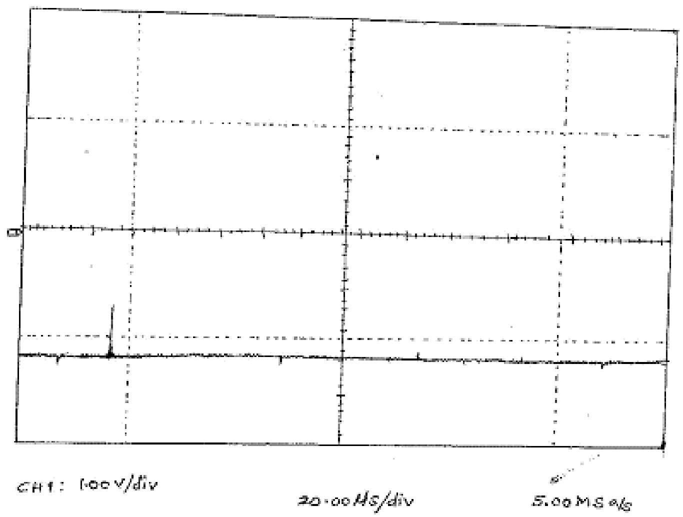


.View the inductor current IL across I3 and I7.



.View device voltage across I2 and I3.





Results:

14. Line Regulation

The closed loop response for BOOST operation for line regulation has been examined

The output Voltage is maintained at __________ Volts with an input voltage from ....Volt to .... Volts

B- Load Regulation

The closed loop response for BOOST operation for load regulation has been examined.

Discussion of Result:

- Compare the theoretical results with practical results.
- Effect of change in duty cycle on output voltage for line & load regulation.

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT
POWER ELECTRONICS LAB

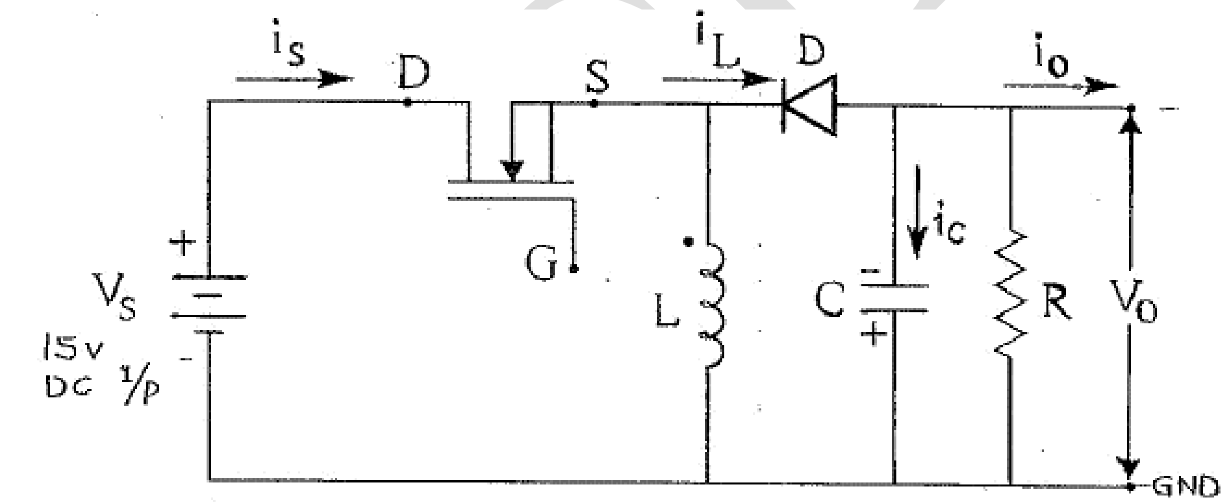
DC-DC BUCK CONVERTER

Experiment : 8c

Aim: To study the close loop response of a buck converter with line and load regulation.

Apparatus: DC-DC Converter trainer Kit
Pulse Patch Chord
0-30V DC supply
CRO

Circuit Diagram:



Procedure-A :

Line Regulation

1. Connect the P8 of PWM generator to the PWM input of Buck-Boost Converter Circuit
2. Connect the feedback voltage of buck-boost converter circuit to feed back volt input PWM generator
3. Connect the CRO at T3
4. Connect the 0-30V DC RPS across P1 & P2 Switch ON the AC power supply
5. Switch on the power ON/OFF switch
6. View the carrier signal in the CRO, at T3 as in fig.

7. Set the switch SW1 in upward position, SW2 in downward direction and view the PWM signal at T1 as in fig. The duty cycle may be changed by changing the SET VOLTAGE.
8. Note down T_{on} and T_{off} values to calculate the duty cycle ($D = T_{on}/T$) .

9. Switch ON the DC 15V supply
10. View the following wave forms
    a. Device Current I_Q across I1 & I2
    b. Diode current I_D across I3 & I4
    c. Inductor Current I_L across I3 & I7
    d. Device Voltage V_Q across I2 & I3
    e. Rectified Voltage across I5 & I8
    f. Inductor voltage V_L across I7 & I8
    g. The feed back signal at T6
11. Connect the CRO across P5 & P6 to view the output voltage and calculate the output voltage using the formula $V_0 = [D] * V_s$
12. Vary the input voltage from 0 to 15V.

Observations:

Line Regulation

Measure and tabulate the following readings.

SET voltage = below 15 V

Note: Buck operation not possible for maximum set voltage of the pulses ie.4.7 V

Set pulse voltage: minimum **(1.2)V**

S.no	Input Voltage Vin	T_{ON}	T_{OFF}	$D= T_{ON}/T$	Output Voltage Measured(Vo)	Output calculated Vo= [D]*Vs

Set voltage: **2.7V** (50% 0f pulse voltage)

S.no	Input Voltage Vin	T_{ON}	T_{OFF}	$D= T_{ON}/T$	Output Voltage Measured(Vo)	Output calculated Vo= [D]*Vs

Procedure-B :
Load Regulation

1. Connect the rheostat bet P5 and P6
2. Connect an ammeter in series with the rheostat
3. For 0 external resistance the output is 5V, ($I_{L=}$.3-.7Amp)
4. vary the resistance till the load current is 0.7Amp
5. Tabulate the measured readings

Observations:

Load Regulation

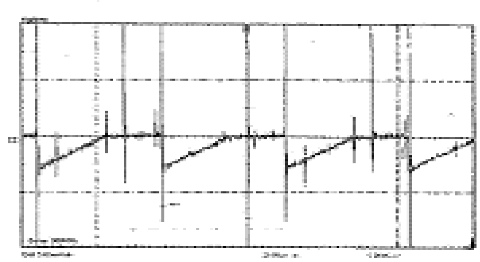
Measure and tabulate the following readings.
Vary the rheostat for (I_L = 0.3 to 0.7Amps)
SET Input voltage = 15V

Set pulse voltage: minimum (1.2V) (Buck operation)

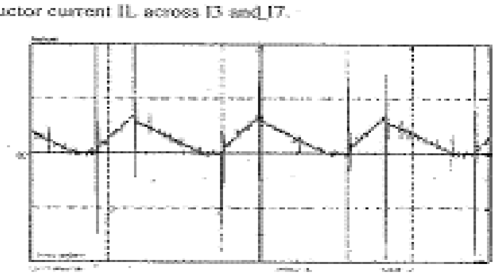
Input Voltage Vin	T_{ON}	T_{OFF}	**D= T_{ON}/T** ($T = T_{ON} + T_{OFF}$)	Load Resistor (R Ω)	I_L(amps)	Output Voltage Measured(Vo)	Output calculated Vo= I*R(volts)
15V							

Expected Waveforms For Line And Load Regulation:

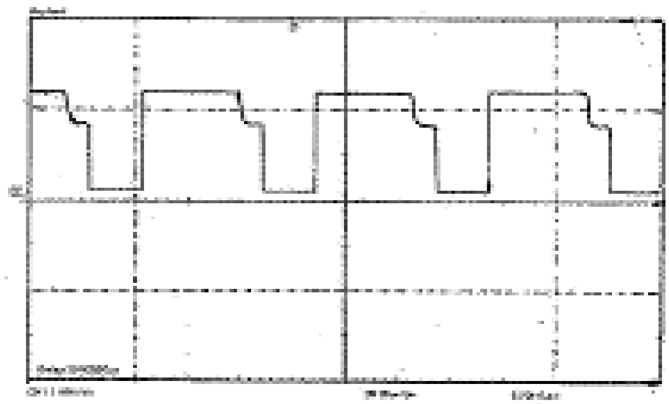
View the diode D current across I3 and I4.



View the inductor current IL across I3 and I7.



.View device voltage across I2 and I3.



Results:

Line Regulation

The close loop response for buck converter for line regulation has been examined

The output Voltage is maintained at __________ Volts with an input voltage from ....Volt to .... Volt

Load Regulation

The close loop response of buck converter with load regulation has been examined.

Discussion of Result:

- Compare the theoretical results with practical results.
- Effect of change in duty cycle on output voltage for line & load regulation.

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT
POWER ELECTRONICS LAB

THREE PHASE BRIDGE RECTIFIERS

Experiment: 9

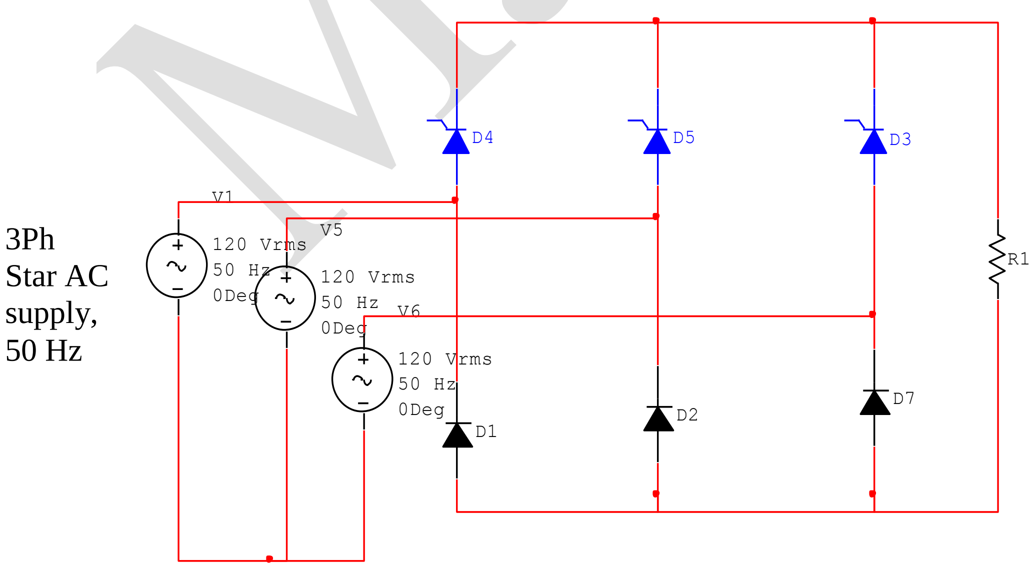
Aim: To verify and measure output voltage of half control and full control of a three phase bridge rectifiers

Apparatus: Three Phase bridge rectifier trainer Kit
CRO, DC Voltmeter
Patch chords

Theory: Phase control thyristors can control the output voltage of a rectifier, by varying the firing angle or delay angle α of the thyristor. In phase control thyristor commutation or turning OFF takes place by line or natural commutation. It has applications in industrial variable speed drives from very low to very high power levels as high as few Mega watts.

Circuit Diagram:

Half controlled Rectifier



Procedure:

Full wave Half controlled rectifier

1. Connect RL1 from load panel across load
2. Connect R-R1 , Y-Y1 & B-B1 and also R-R3 , Y-Y3 & B-B3
3. Connect load between Positive terminal of DC supply and negative terminal of DC supply
4. Connect the oscilloscope through attenuator across the load and switch on the power.
5. Observe the Load voltage and Phase diode voltage waveforms
6. Turn the phase control clockwise ie. Firing angle"α"and calculate load voltage V_L
7. Repeat for various loads and observe the change in the waveforms

Observation Table:

Vrms (line)	Vm (line)	T(msec)	t (msec)	α (degrees)	Vo(measured)	Vo(calculated)
48.1	68.01	3.4	0.4	14.11°	62.2	63.97

Model Calculation:

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

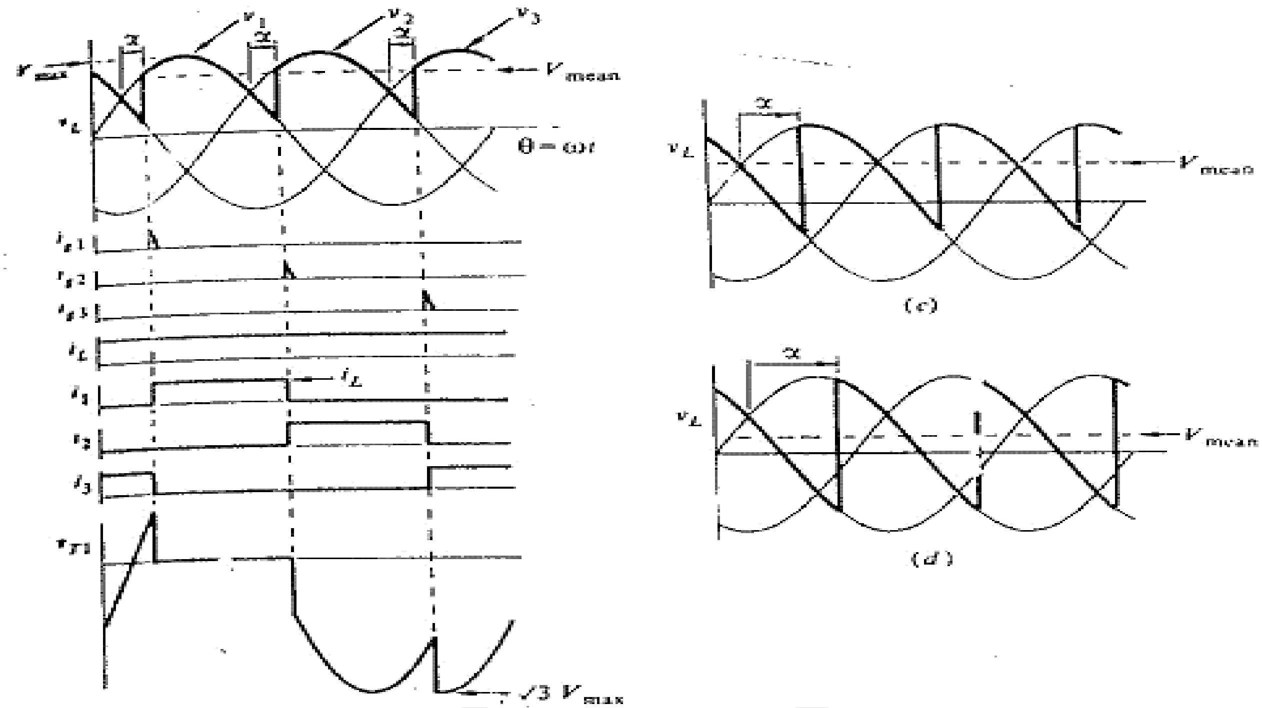
$$\alpha = (t/T)*120$$
$$= (0.4/3.4)*120$$
$$= 14.11^\circ$$

$$\text{Vo (calculated)} = \frac{3Vm\text{ (line)}}{2\pi}(1+\cos\alpha)\text{ V}$$

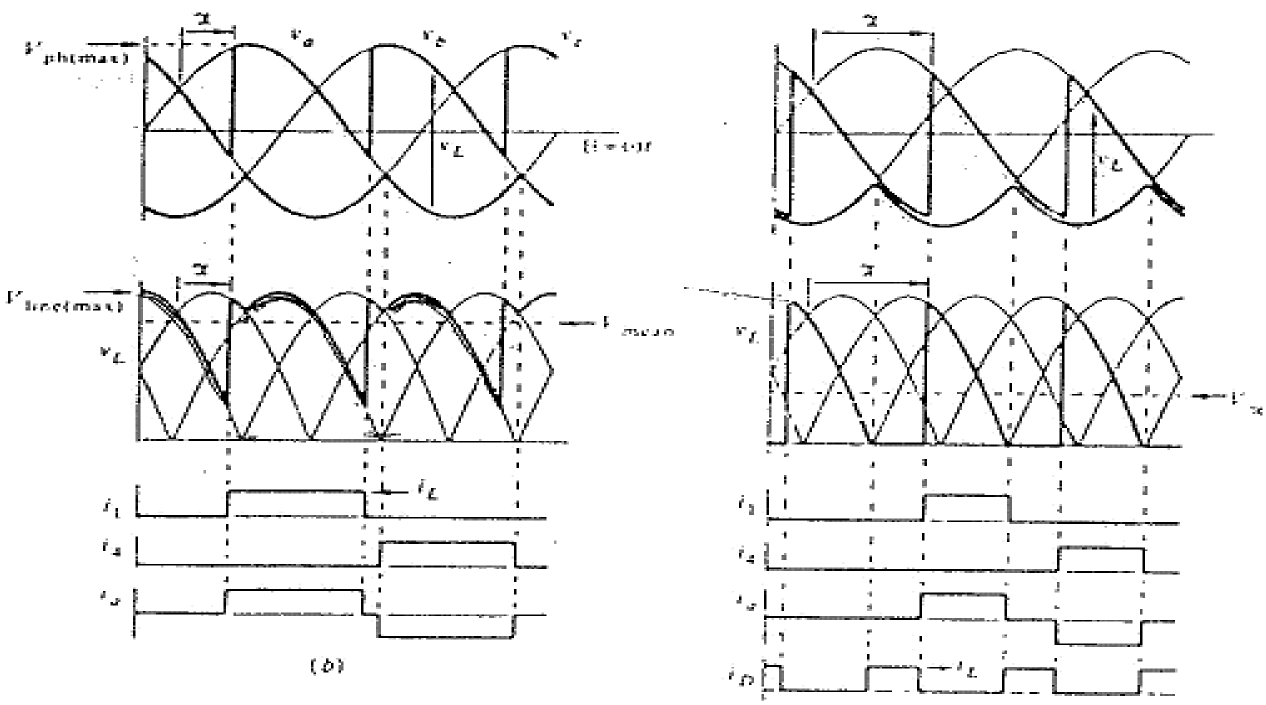
$$= \frac{3*48.1*\sqrt{2}}{2\pi}(1+\cos 14.11^\circ)$$

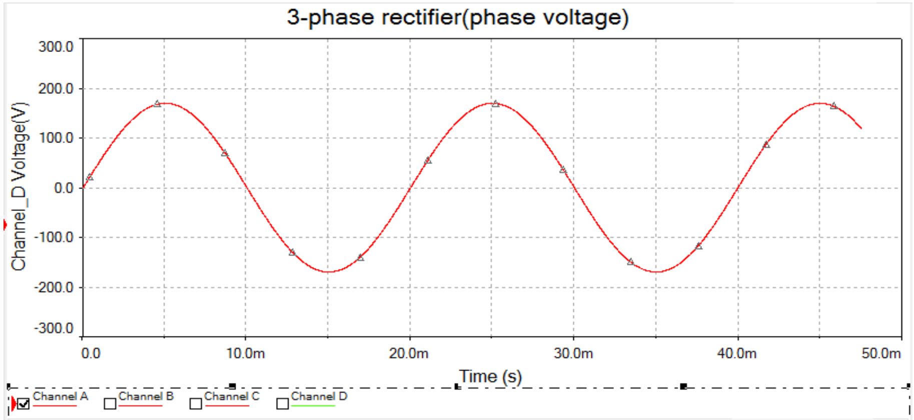
$$Vo = 63.97V$$

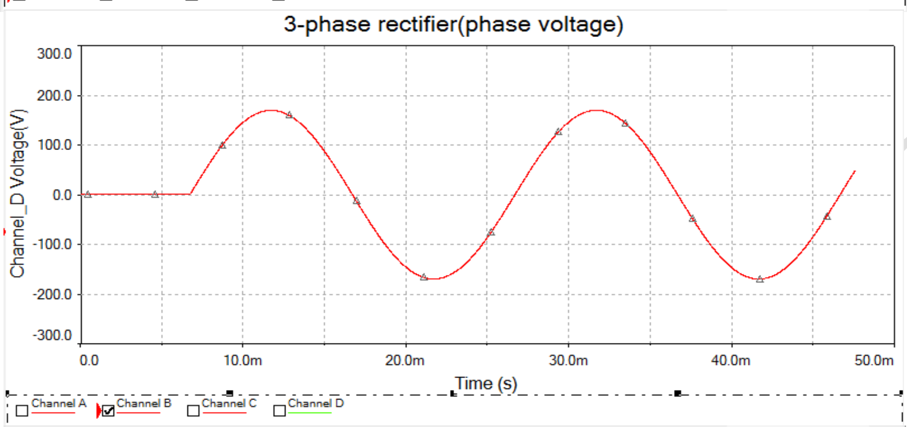
Expected graphs:

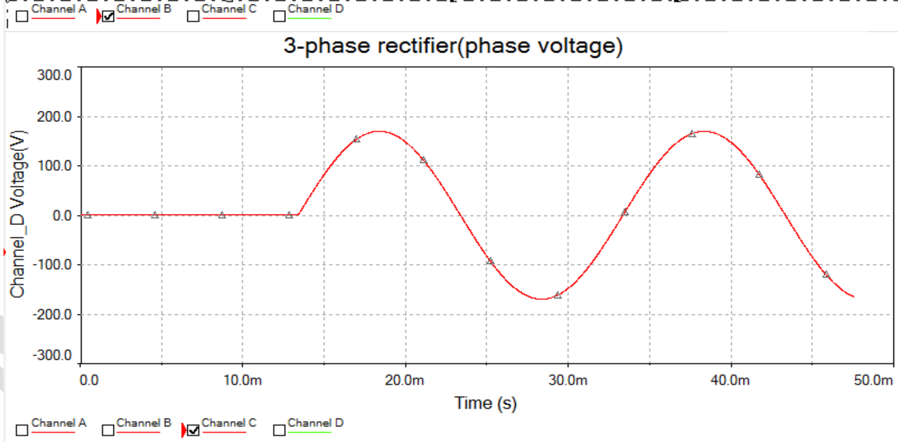


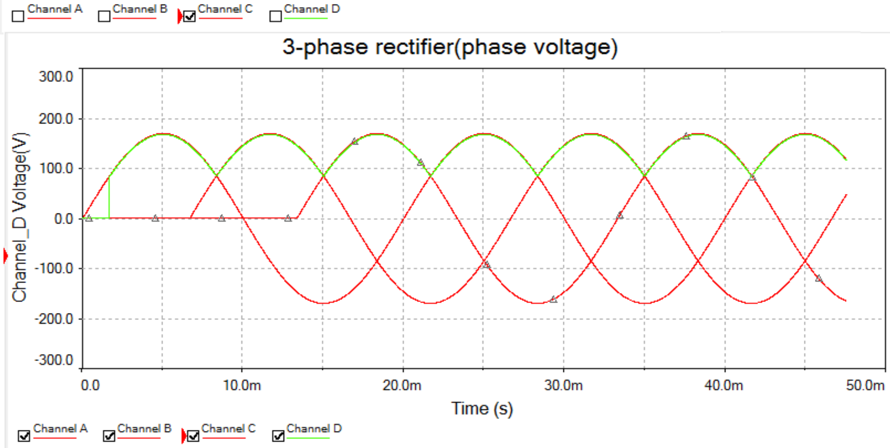
Half controlled

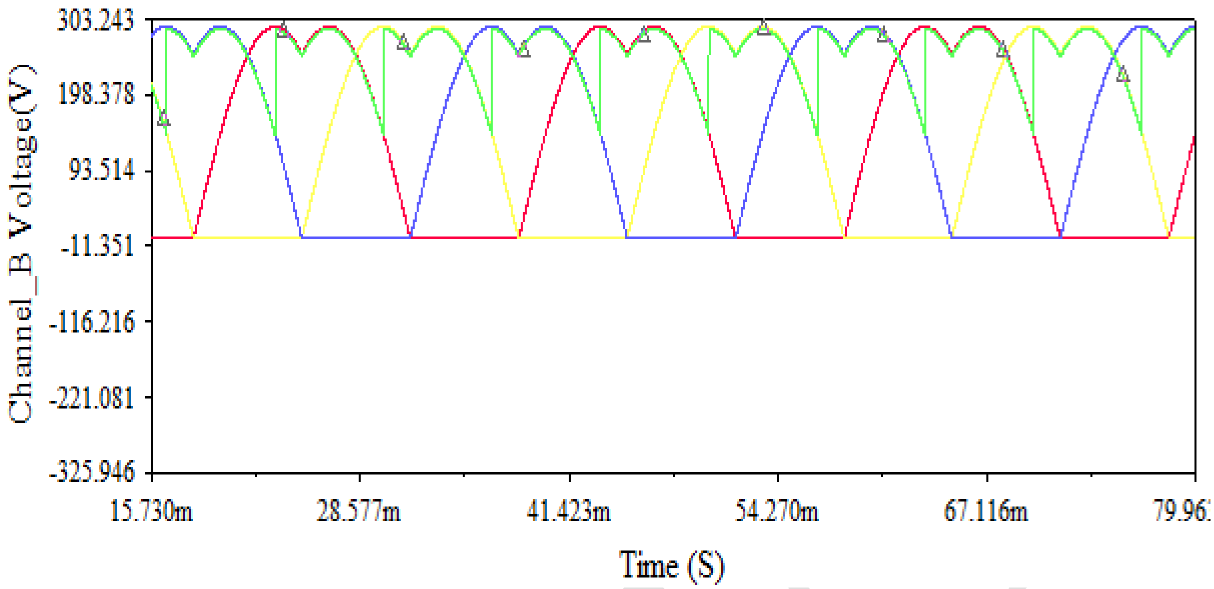



3-phase rectifier(phase voltage)
Channel_D Voltage(V)
300.0
200.0
100.0
0.0
-100.0
-200.0
-300.0
0.0
10.0m
20.0m
30.0m
40.0m
50.0m
Time (s)
Channel A
Channel B
Channel C
Channel D


3-phase rectifier(phase voltage)
Channel_D Voltage(V)
300.0
200.0
100.0
0.0
-100.0
-200.0
-300.0
0.0
10.0m
20.0m
30.0m
40.0m
50.0m
Time (s)
Channel A
Channel B
Channel C
Channel D


3-phase rectifier(phase voltage)
Channel_D Voltage(V)
300.0
200.0
100.0
0.0
-100.0
-200.0
-300.0
0.0
10.0m
20.0m
30.0m
40.0m
50.0m
Time (s)
Channel A
Channel B
Channel C
Channel D


3-phase rectifier(phase voltage)
Channel_D Voltage(V)
300.0
200.0
100.0
0.0
-100.0
-200.0
-300.0
0.0
10.0m
20.0m
30.0m
40.0m
50.0m
Time (s)
Channel A
Channel B
Channel C
Channel D



Results: The output waveforms across the load have been observed for half controlled 3 phase rectifier

Discussion of Result:

- Compare the theoretical and practical values of output voltage and analyse the output voltage waveform for different firing angles.
- Comment on conduction period of each thyristor .

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT
POWER ELECTRONICS LAB

SINGLE PHASE SEMI CONVERTER (FULL CONTROLLED)

Experiment: 10a

Aim: To Study the single phase half wave rectifier (full controlled) with R RL and RLE loads using Multisim Simulation Software

Apparatus: Multisim simulation software

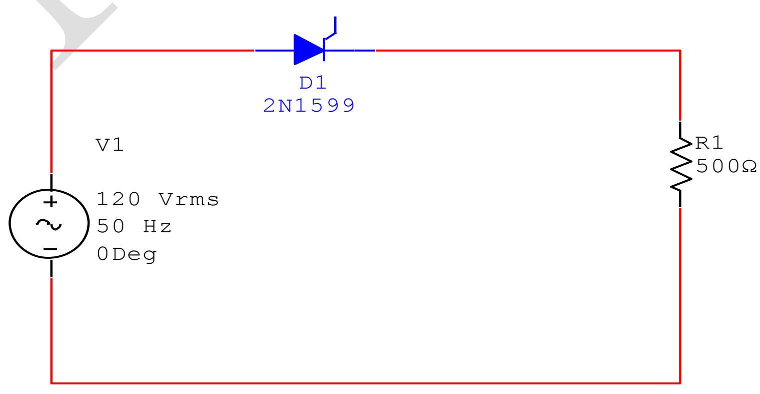
Theory: A single phase half wave circuit is one which produces only one pulse of load current during one cycle of source voltage. A simple controlled rectifier circuit consists of a thyristor connected to a source and a load. The SCR conducts only when the anode current is more positive than the cathode and a gating signal is applied. It blocks the current until it is triggered. It turns OFF by reversal of voltage at ωt = π.3π, 5π etc. since it reverse biases the device.

Firing angle is defined as the angle between the instant the thyristor conducts if it were a diode and the instant it is triggered.

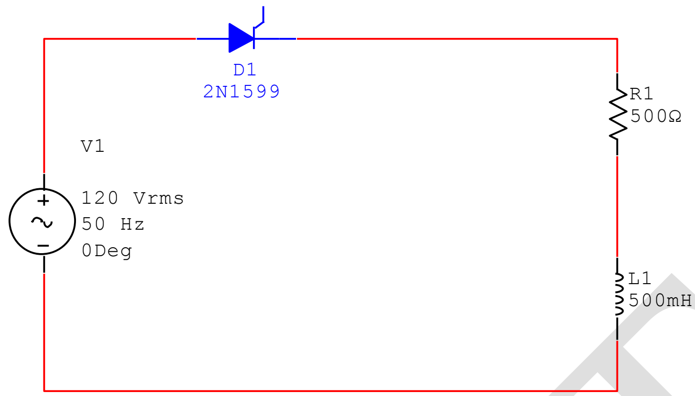
Procedure: Switch ON the computer double click on the multisim icon. You get the drawing window. Pick the components from the virtual component library.ON the grid. Rig the circuit for the R, RL and RLE loads .Pick the CRO from the instrument bar and connect it across the load also pick and drop the multimeter across the load. Connect a square wave source between the gate and the anode of the SCR as firing pulse and Observe the wave forms.

Circuit Diagram:

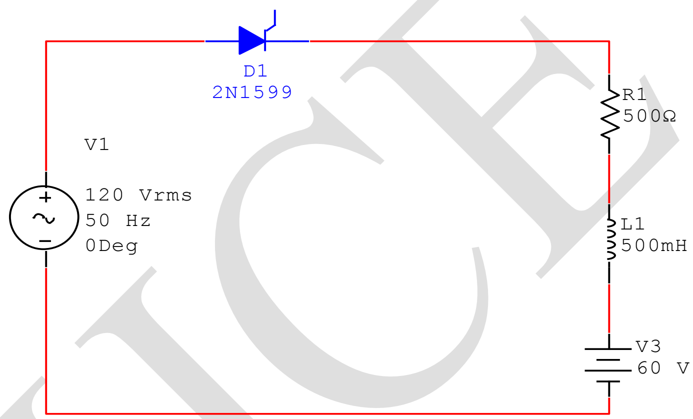
R-Load



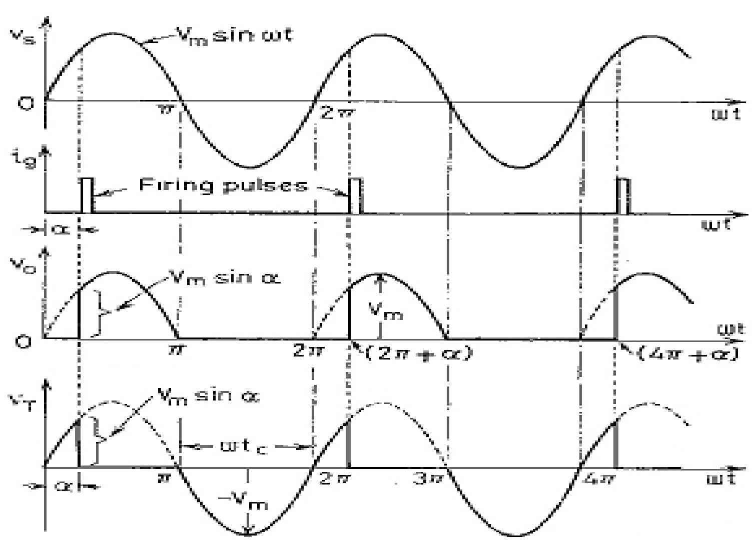
RL-Load



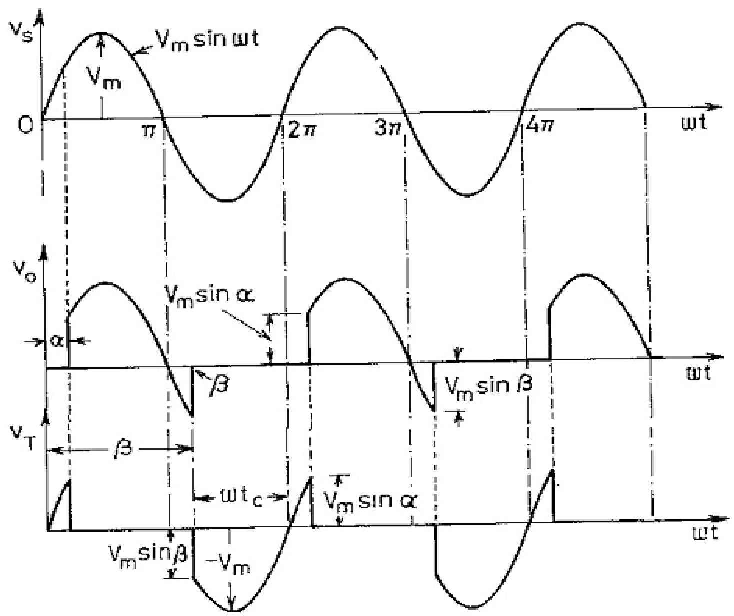
RLE- Load



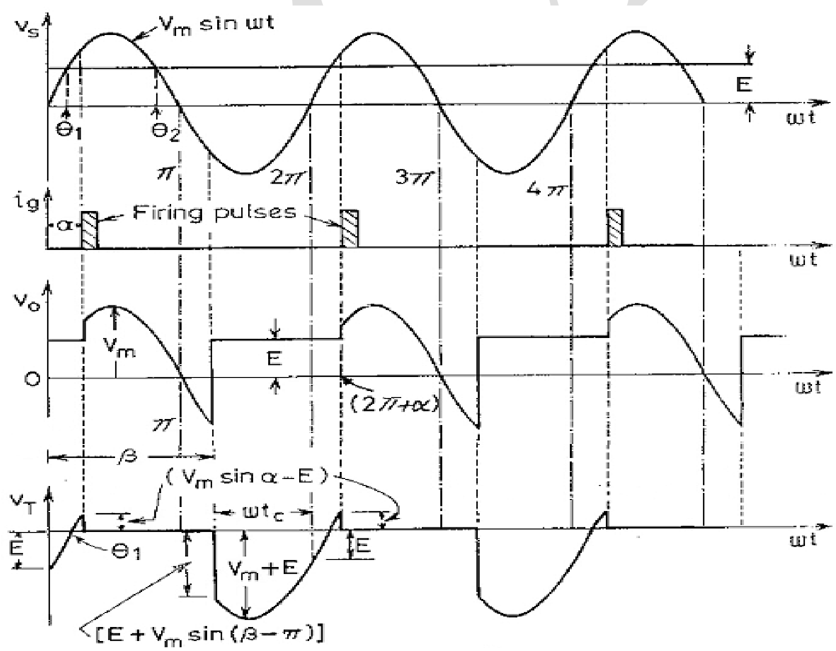
Expected Waveforms:



R-LOAD

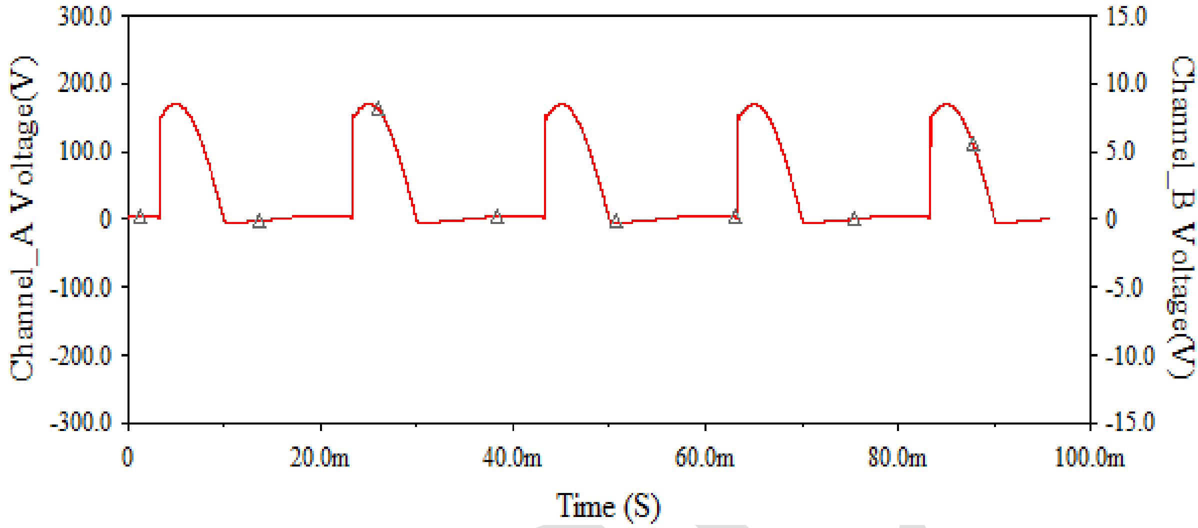


RL LOAD

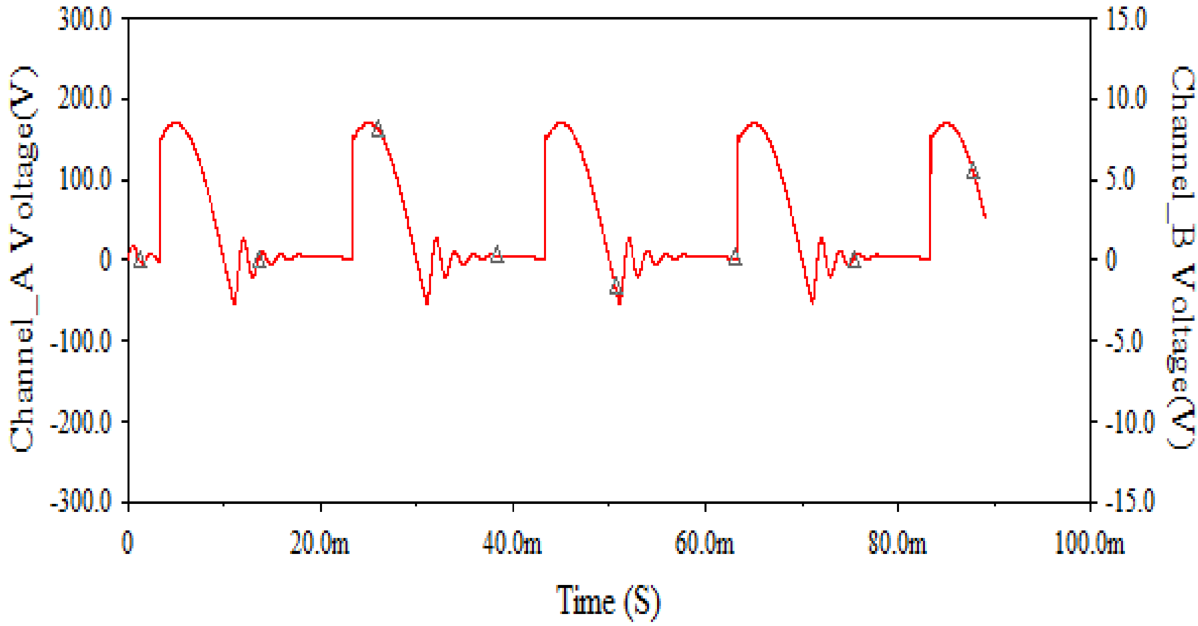


RLE LOAD

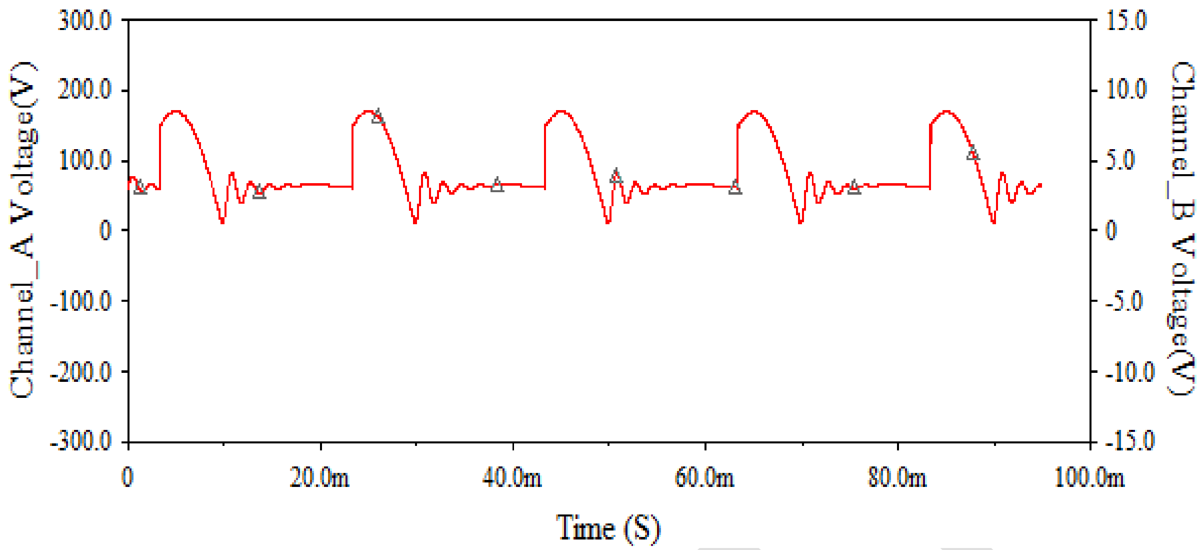
Simulation Results Of Output Voltage:



Semi Converter with R-Load



Semi Converter with RL-Load



Semi Converter with RLE-Load

Results: The multisim software is learnt. The wave forms for single, phase half wave R Rl and RLE loads have been observed.

Discussion of Result:

- Comment on changes in output voltage waveform with change in firing angle.
- Comment on changes in output voltage waveform with change in load.

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT
POWER ELECTRONICS LAB

SINGLE PHASE FULL CONVERTER (FULL CONTROLLED)

Experiment:10b

Aim: To Study the single phase full wave rectifier (full controlled) with R RL and RLE loads using Multisim Simulation Software

Apparatus: Multisim simulation software

Theory: A single phase half wave circuit is one which produces only one pulse of load current during positive half cycle of source voltage and another pulse of load current in negative half cycle of source voltage, both in same direction. Hence producing DC voltage for an applied Ac voltage. A Full bridge half controlled rectifier circuit consists of a 2-thyristors and two diodes connected to a source and a load whereas a Full bridge full controlled rectifier circuit consists of a 4-thyristors connected to a source and a load. The SCR conducts only when the anode current is more positive than the cathode and a gating signal is applied. It blocks the current until it is triggered. It turns OFF by reversal of voltage at $\omega t = \pi$. 3π, 5π etc. since it reverse biases the device.

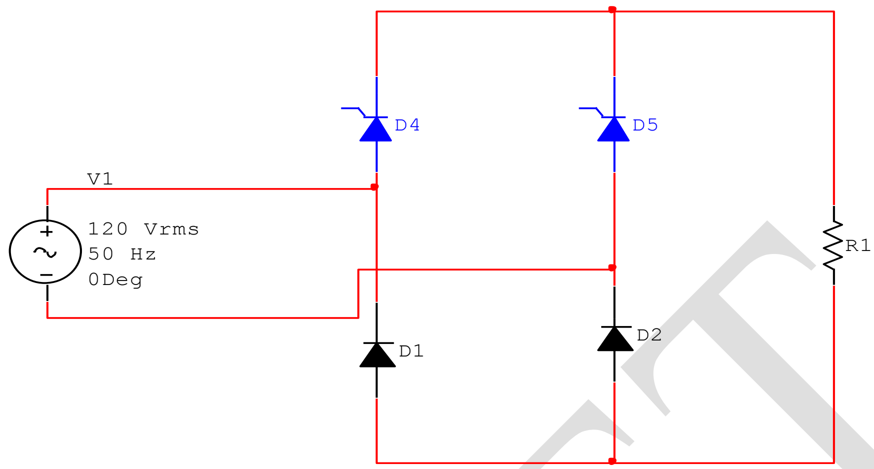
Firing angle is defined as the angle between the instant the thyristor conducts if it were a diode and the instant it is triggered.

Procedure:

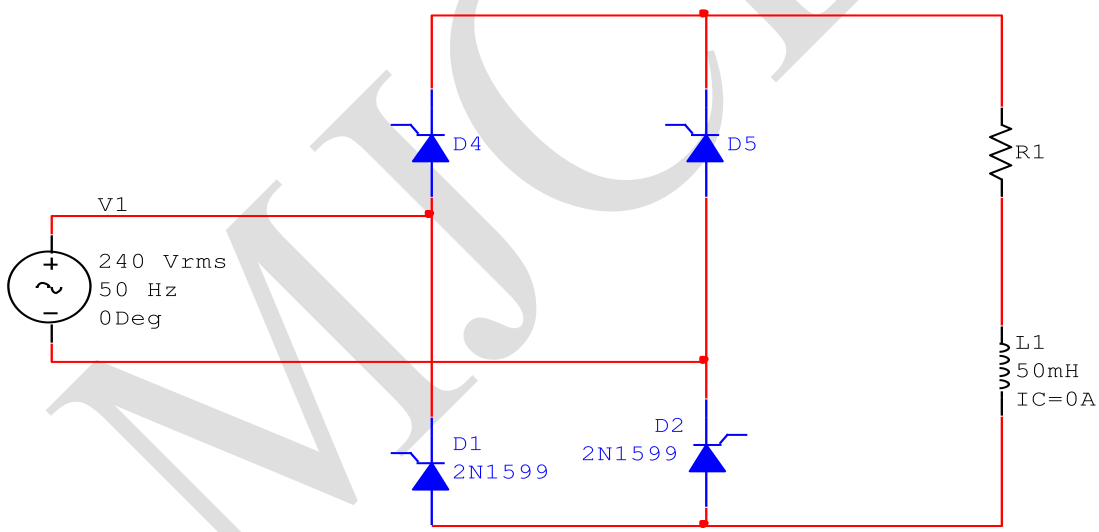
Switch ON the computer double click on the multisim icon. You get the drawing window. Pick the components from the virtual component library.ON the grid. Rig the circuit for the R, RL, RL with Freewheeling Diode and RLE loads .Pick the CRO from the instrument bar and connect it across the load also pick and drop the multimeter across the load. Connect a square wave source between the gate and the anode as firing pulse of the SCR and Observe the wave forms.

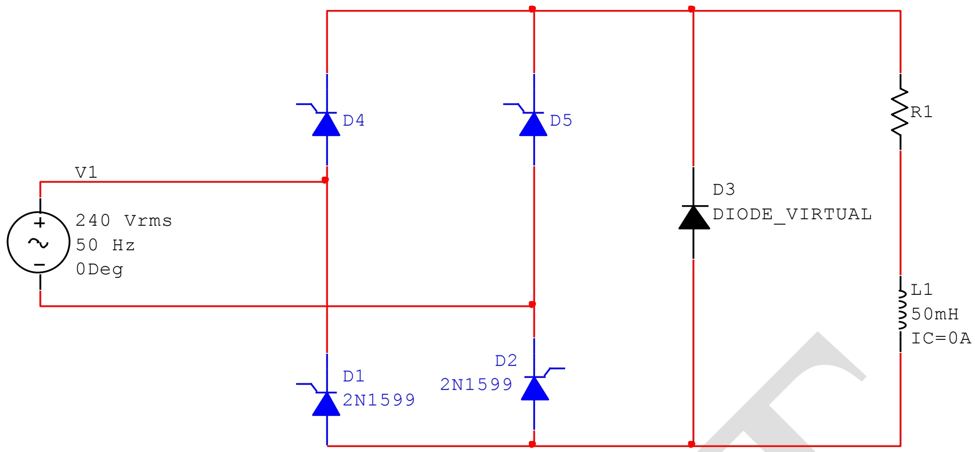
Circuit Diagram :

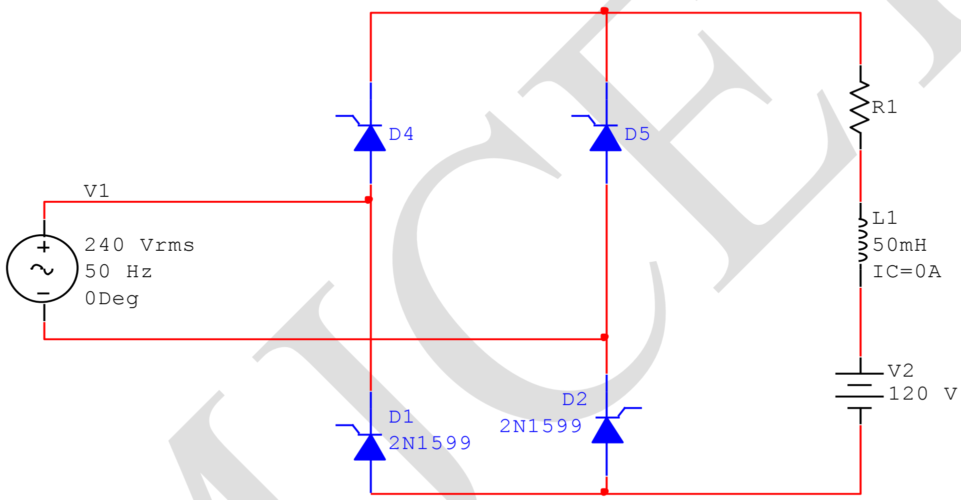
Full Converter half controlled with R-Load:



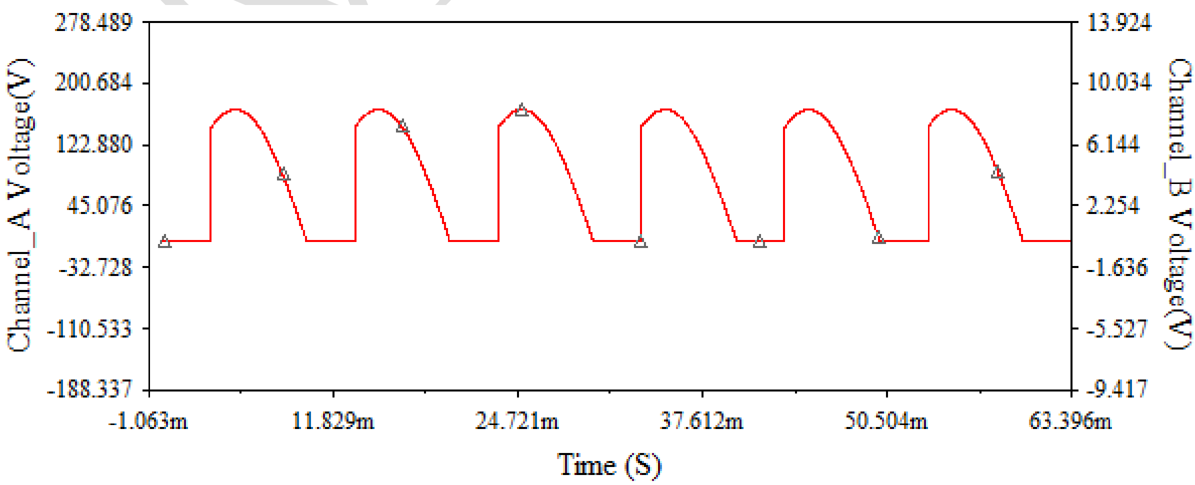
Full Converter half controlled with RL-Load:



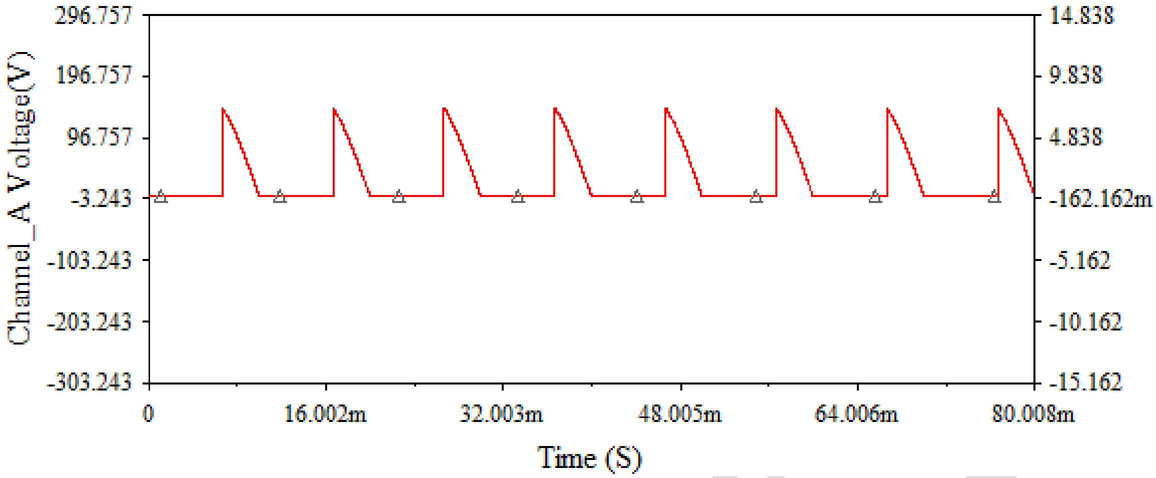




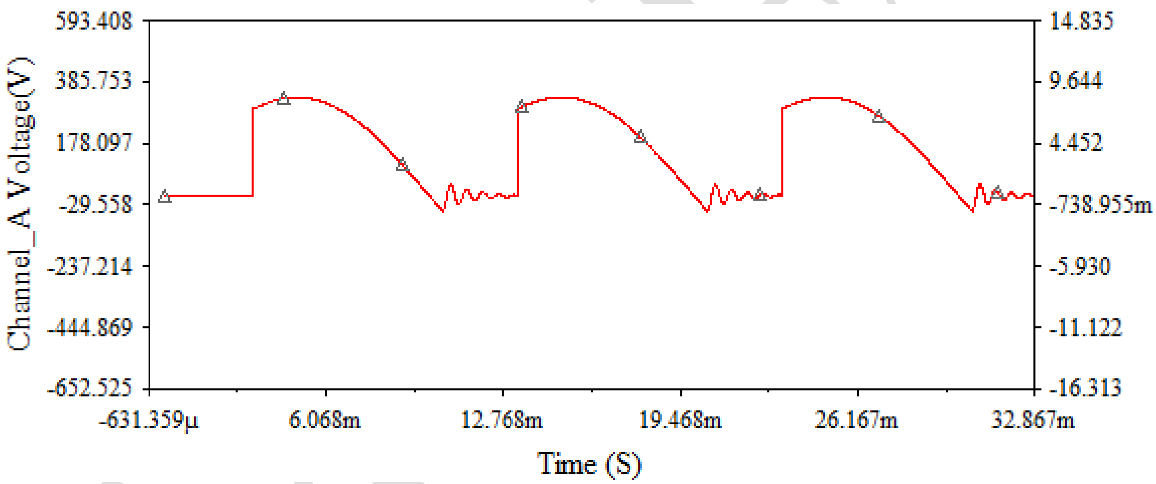
Expected Waveform of Output Voltage:



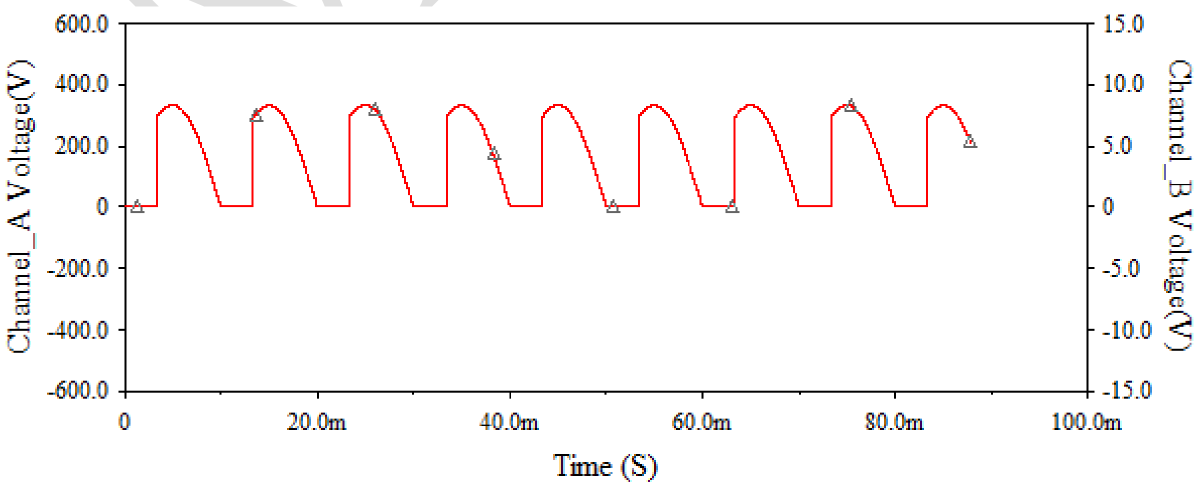
For Full & half controlled Converter with R-Load (α = 30°)



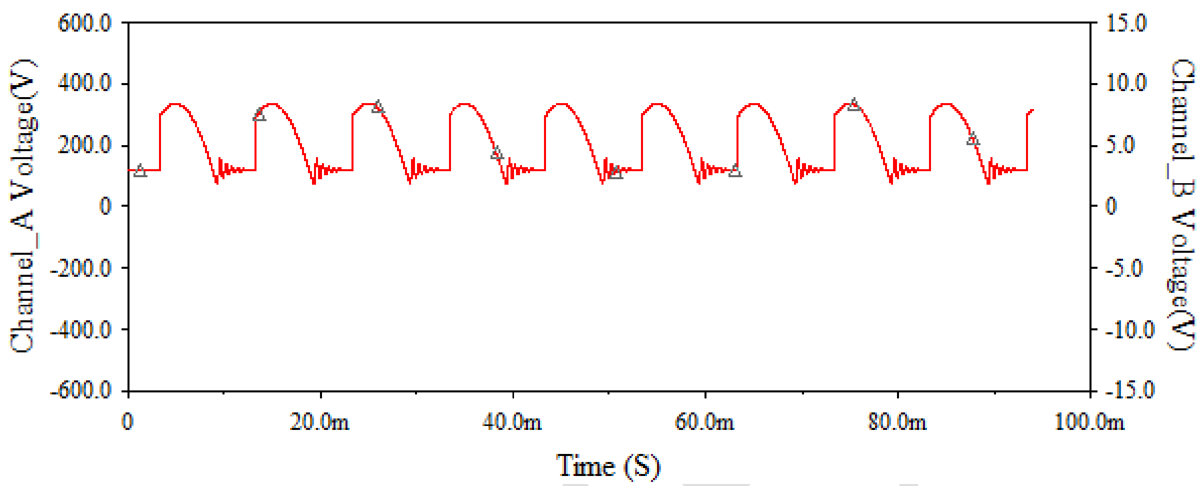
Full & half controlled Converter with R-Load (α = 60°)



Full & half controlled Converter with RL-Load



Full controlled Converter with RL-Load & Freewheeling Diode



Full controlled Converter with RLE-Load

Results: The multisim software is learnt. The wave forms for single phase half wave with R RL and RLE loads have been observed.

Discussion of Result:

- Comment on changes in output voltage waveform with change in firing angle.
- Comment on changes in output voltage waveform with change in load.

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT
POWER ELECTRONICS LAB

THREE PHASE INVERTER

Experiment: 11

Aim: To Study the operation of 3- phase inverter **180° & 120°** mode of operation and observe the output waveforms using Multisim software.

Apparatus: Multisim software.

Theory:

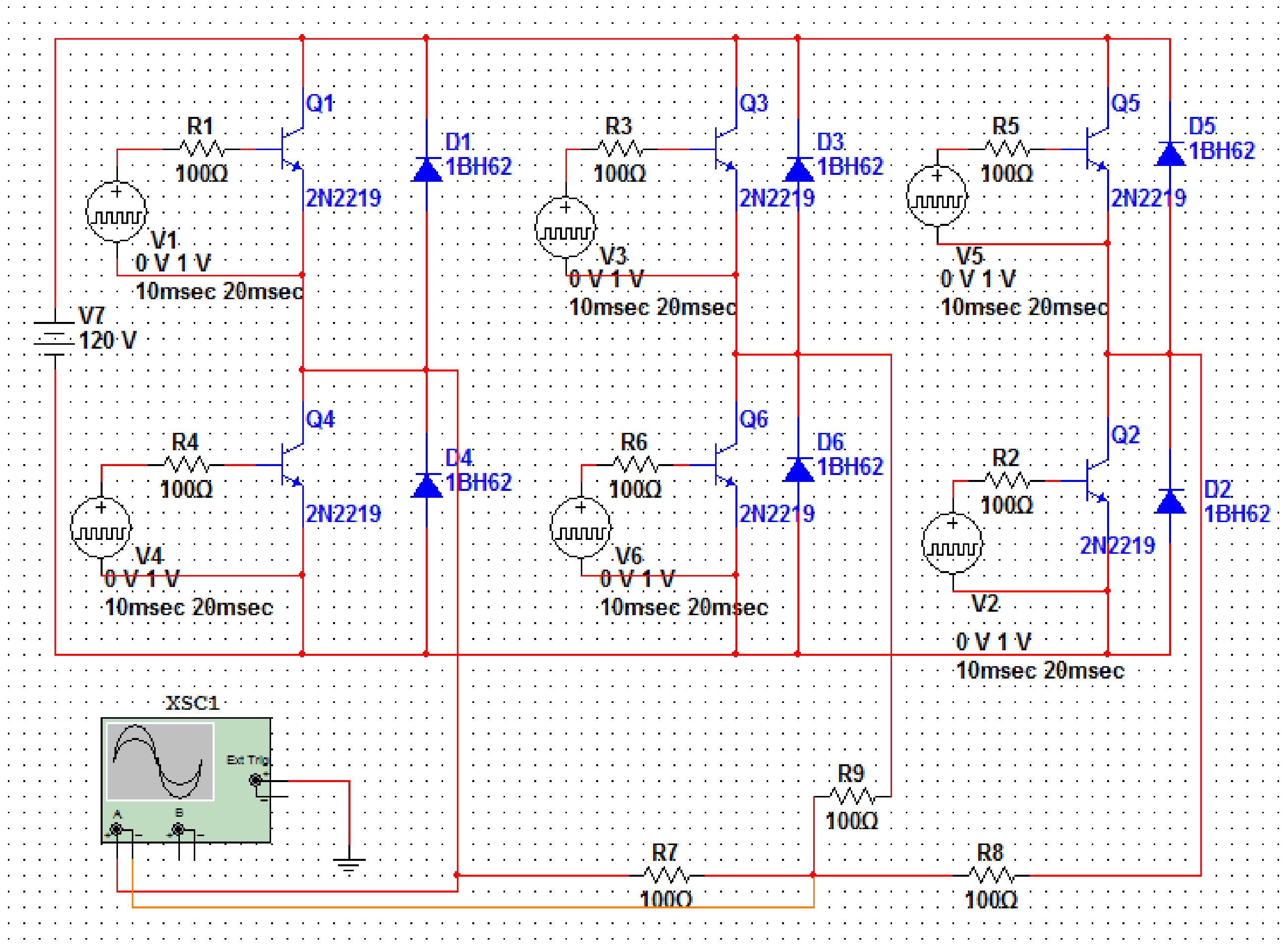
Inverter basically converts DC to AC. In three phase inverter the output is three phase ac. It works in two modes depending upon the conduction period of each transistor in the circuit ie.**180°& 120°**.In both the modes each transistor is triggered in the same sequence as they are numbered with an interval of 60°.In complete one cycle of output there exists six steps of operation each of duration 60°.In every step of 60° duration in **180°** mode of operation, three switches are conducting two from upper group and one from lower group & in **120°** mode of operation, one switch from upper group and one from lower group conducts.

Procedure:

Switch ON the computer, double click on the multisim icon. You get the drawing window. Pick the components from the virtual component library. ON the grid, rig the circuit for the 3-phase inverter circuit with R-load. Connect a square wave source between the gate and the anode of all six transistors. Pick the CRO from the instrument bar and connect it across the load Observe the output wave forms for 180°& 120° (line & phase voltages) modes of operation. Instead of thyristors, transistors are used as switches in order to avoid the complexity of the circuit as use of thyristors will add the commutation circuit input being DC

<u>Circuit diagram</u>:

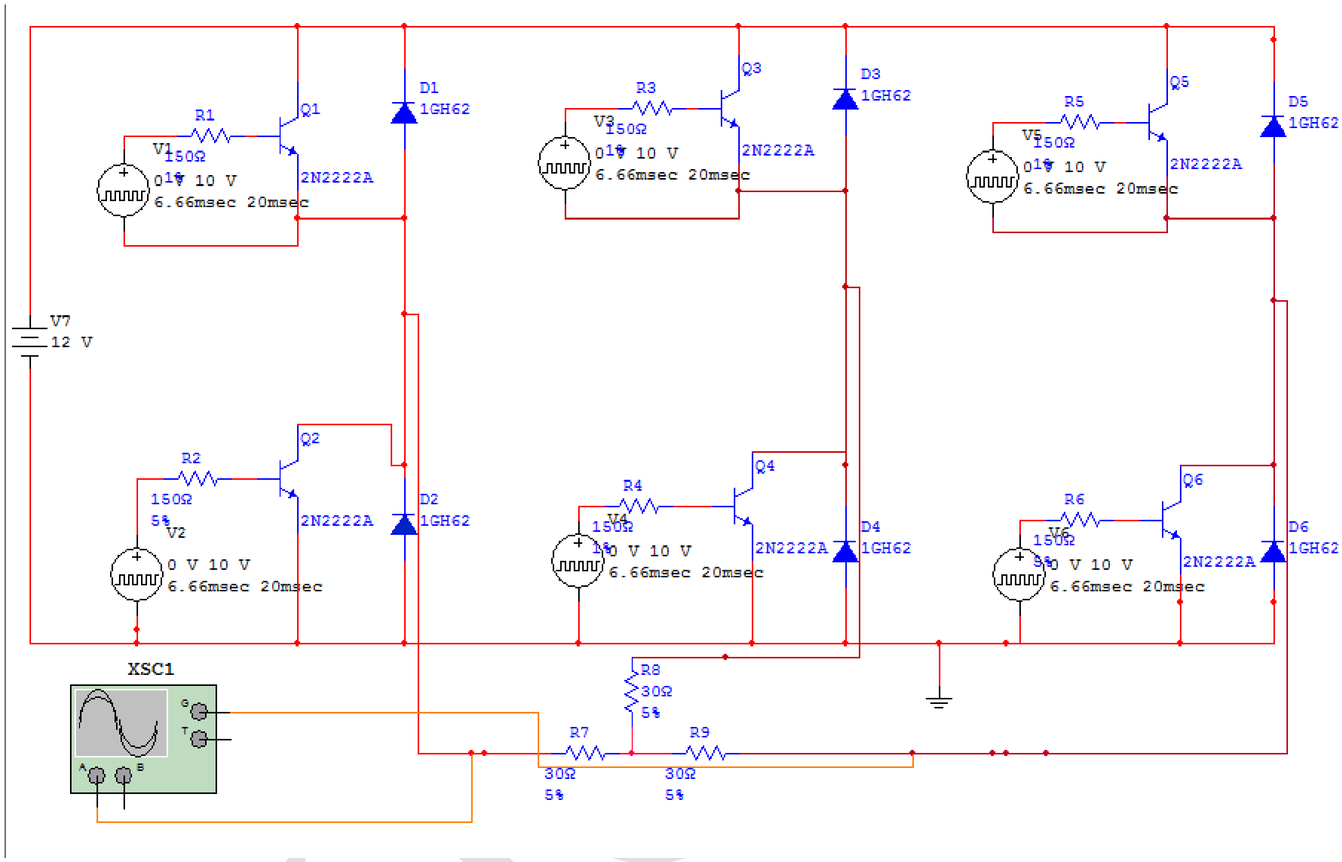
(a) Inverter with 180° mode of operation



TRIGGERING PULSES FOR ALL SIX TRANSISTOR (<u>180° MODE</u>)

Transistor No. →	T_1	T_2	T_3	T_4	T_5	T_6
Initial Value	0	0	0	0	0	0
Final Value	10	10	10	10	10	10
Delay Time	0 (m sec)	3.33(m sec)	6.66(m sec)	10(m sec)	13.33(m sec)	16.66(m sec)
Rise Time	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)
Fall Time	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)
Pulse width	10 (m sec)	10 (m sec)	10 (m sec)	10 (m sec)	10 (m sec)	10 (m sec)
Time Period	20 (m sec)	20 (m sec)	20 (m sec)	20 (m sec)	20 (m sec)	20 (m sec)

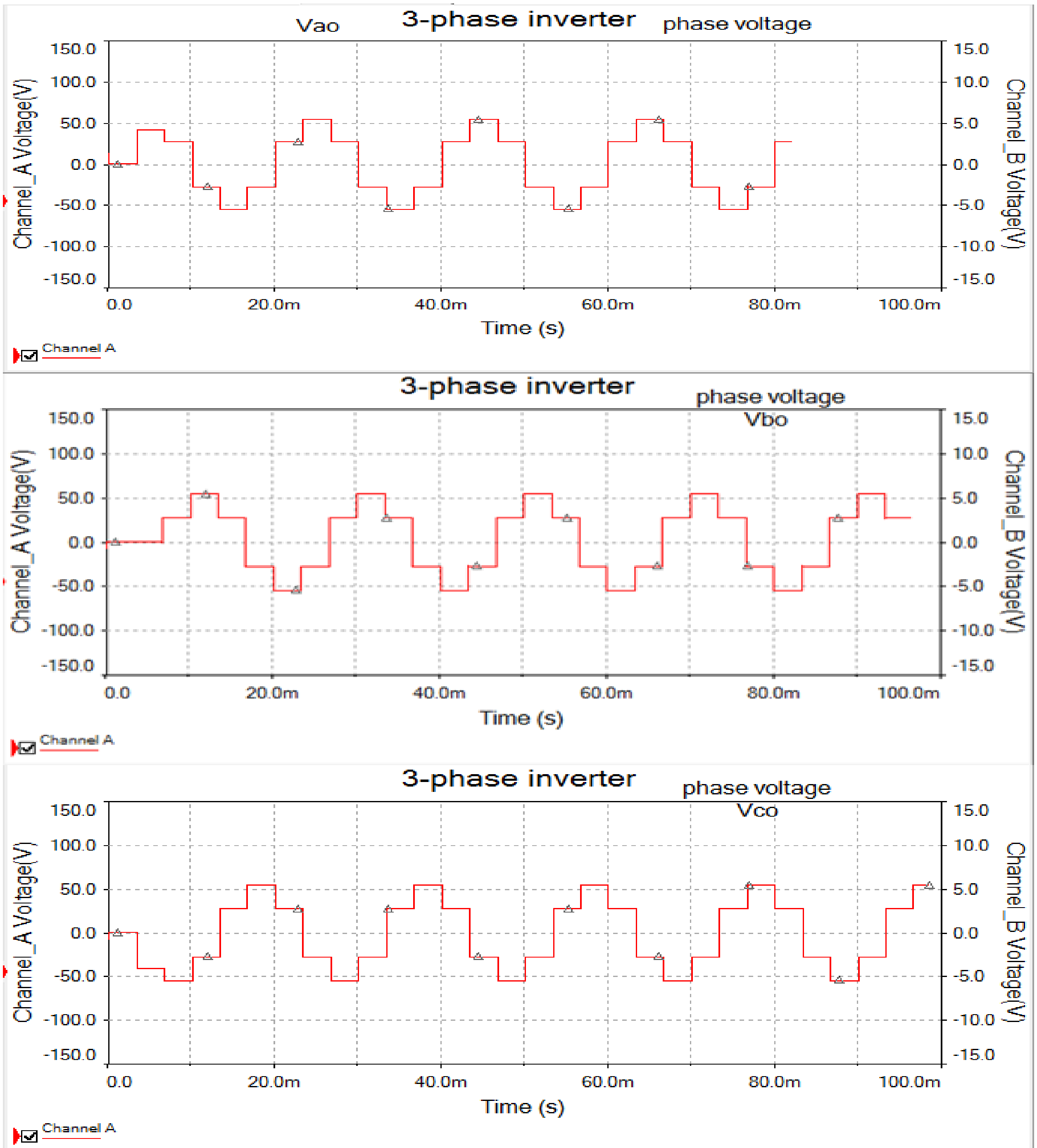
Circuit diagram: **(b) Inverter with 120° mode of operation**



TRIGGERING PULSES FOR ALL SIX sTRANSISTORS (120° MODE)

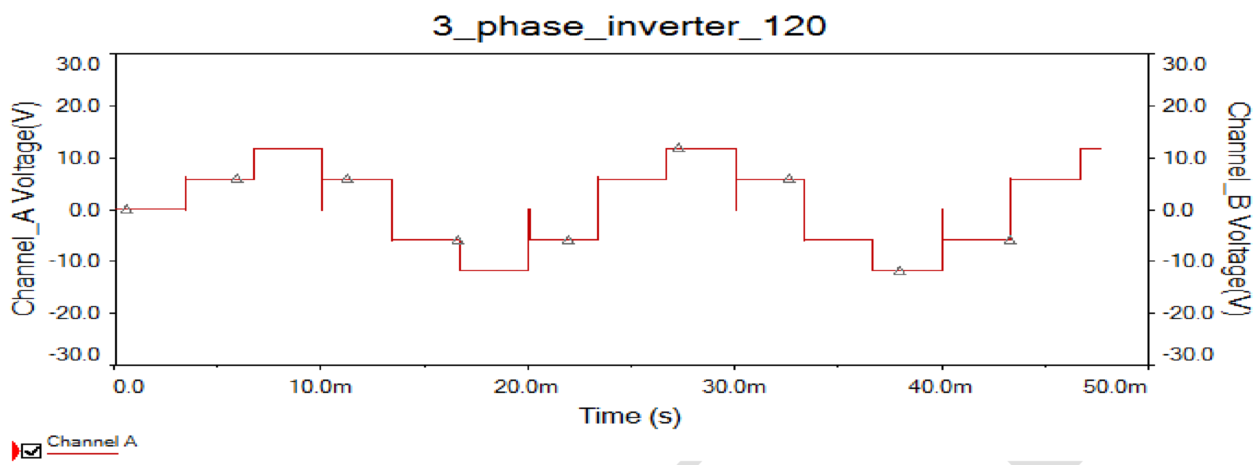
Transistor No. →	T_1	T_2	T_3	T_4	T_5	T_6
Initial Value	0	0	0	0	0	0
Final Value	10	10	10	10	10	10
Delay Time	0 (m sec)	3.33(m sec)	6.66(m sec)	10(m sec)	13.33(m sec)	16.66(m sec)
Rise Time	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)
Fall Time	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)
Pulse width	6.66(m sec)	6.66(m sec)	6.66(m sec)	6.66(m sec)	6.66(m sec)	6.66(m sec)
Time Period	20 (m sec)	20 (m sec)	20 (m sec)	20 (m sec)	20 (m sec)	20 (m sec)

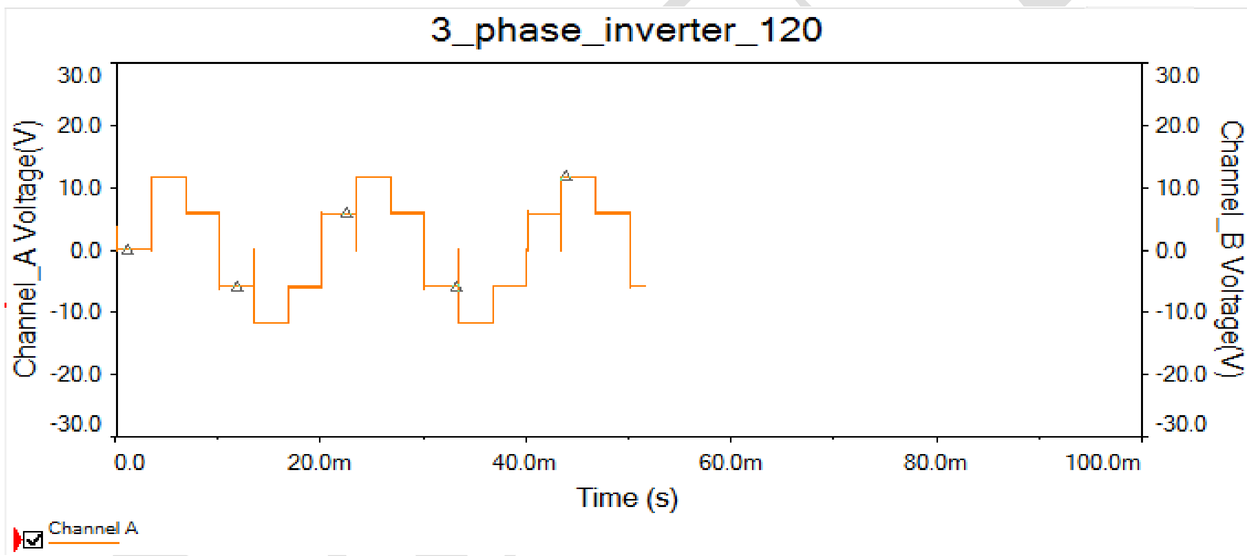
<u>Expected Graphs</u>: **(a) Inverter with 180° mode of operation**

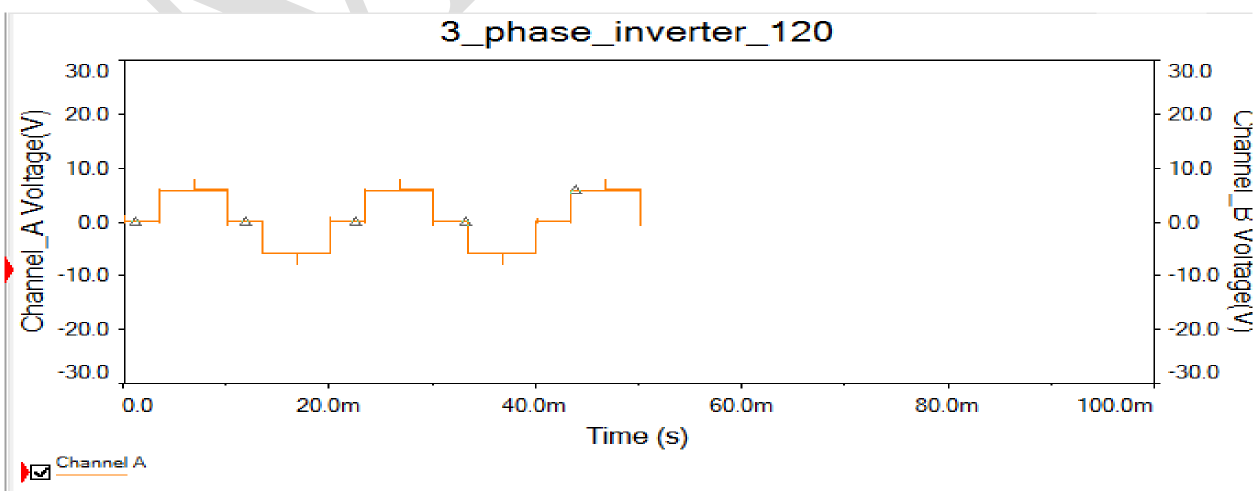


Expected Graphs:

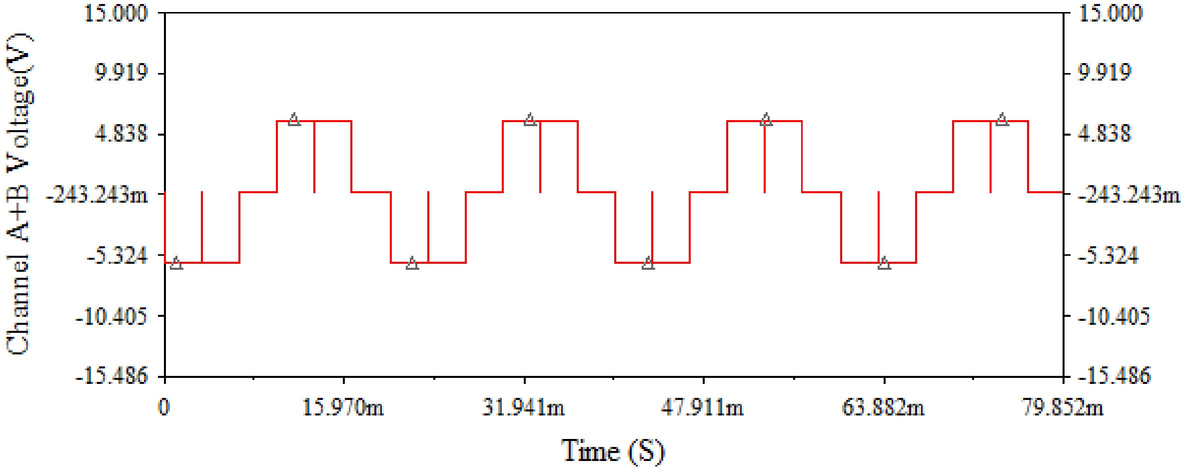
(b) Inverter with 120° mode of operation

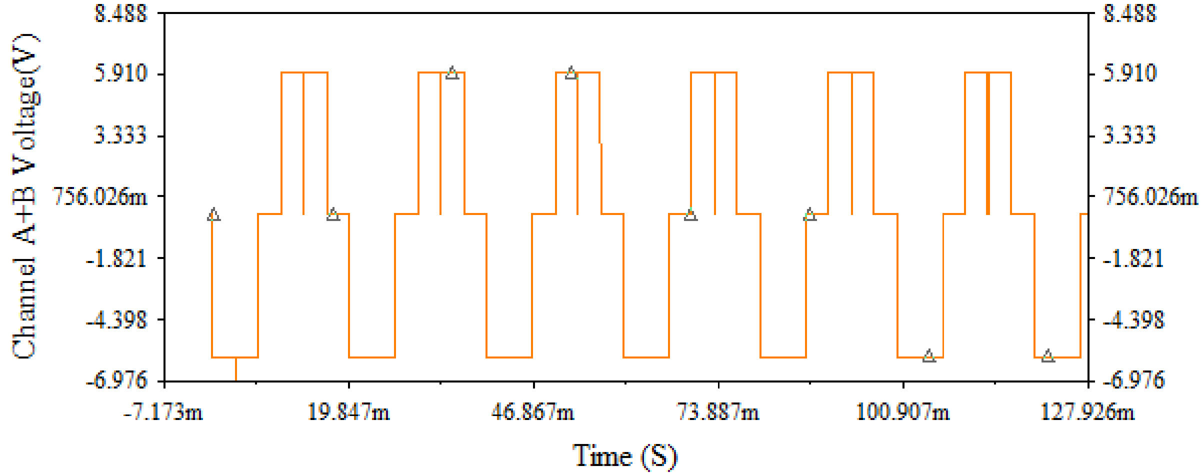


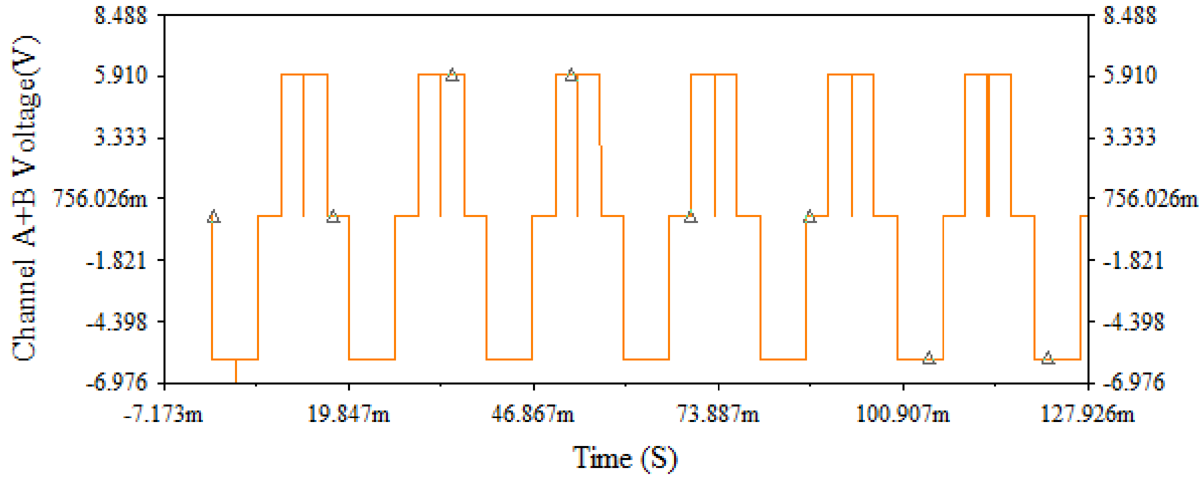




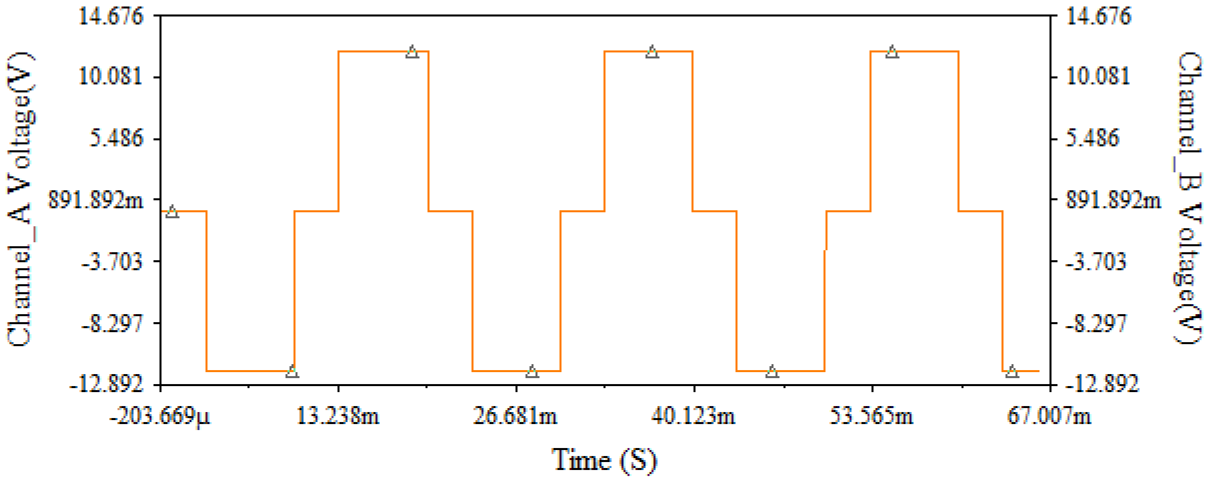
Waveforms of 3-Φ Line voltages for 120° mode of operation:

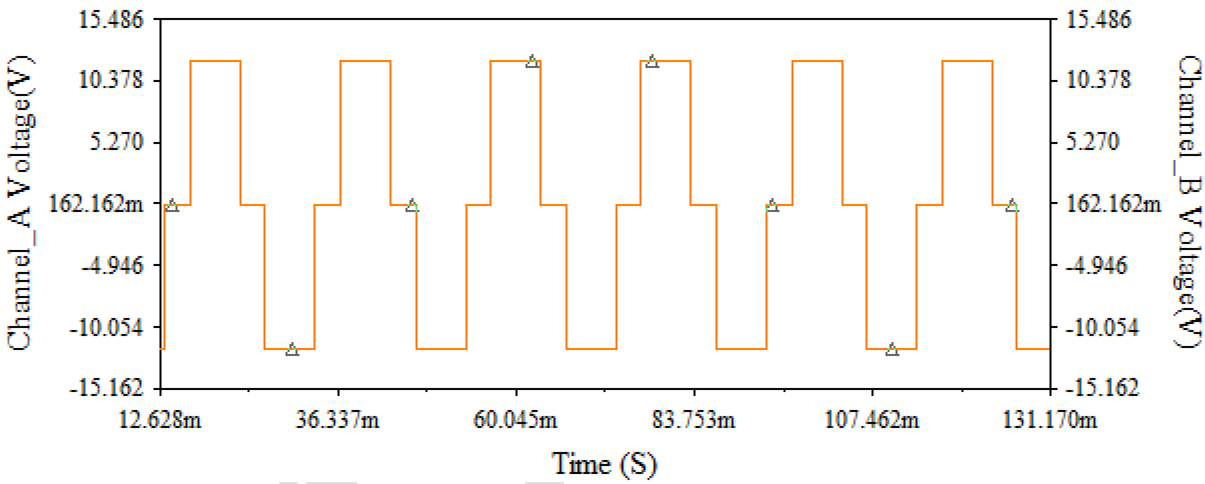


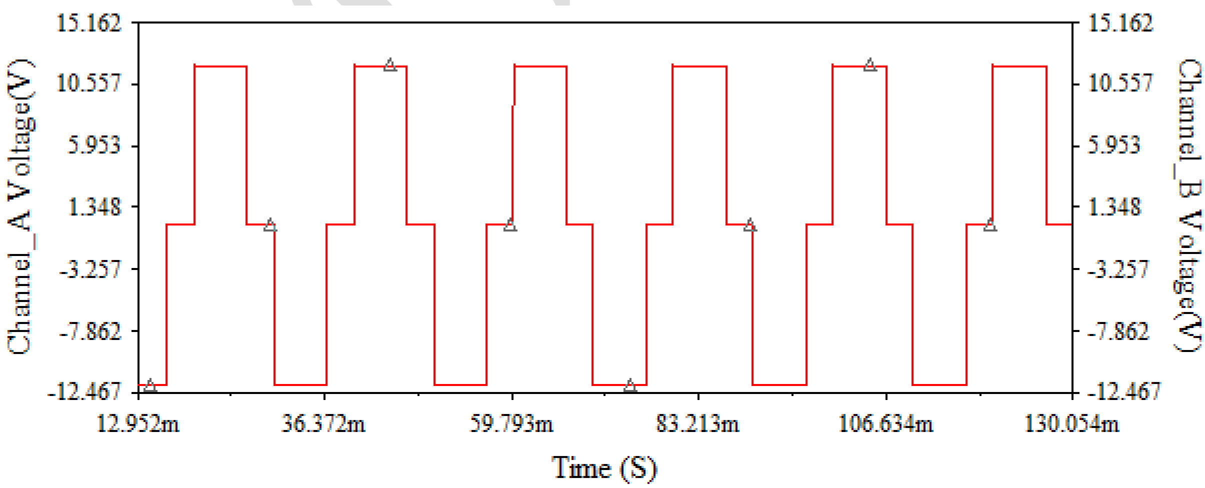




Waveforms of 3-Φ Line voltages for 180° mode of operation:







Result: The multisim software is learnt and the waveforms of three phase inverter with R-Load (phase & line voltages) are observed for both**180**$^{\circ}$ **& 120**$^{\circ}$ modes of operation.

Discussion of Result:

- Analyze the output voltage (line & phase) waveforms for both**180**$^{\circ}$ **& 120**$^{\circ}$ modes of operation and comment on the result.

MUFFAKHAM JAH COLLEGE OF ENGINEERING AND TECHNOLOGY
ELECTRICAL ENGINEERING DEPARTMENT
POWER ELECTRONICS LAB

SIMULATION OF SINGLE PHASE CYCLOCONVERTER

Experiment: 12

Aim: To Study the operation of Cycloconverter and observe the output waveforms using Multisim software.

Apparatus: Multisim software

Theory:

In cycloconverter one group of thyristors produce positive polarity of the load voltage and other group produces the negative polarity of the load voltage. Only one of them will conduct at a time. When 'P' is positive with respect to 'O', then SCR1 will conduct otherwise SCR2 will conduct. Thus in both the half cycles of the input, the load voltage will be positive. The SCR's get turned off by natural commutation at the end of every half cycle. Depending on the desired frequency gating pulses to positive group of SCR's (T1, T2) & negative group of SCR's (T3, T4) are given.

Procedure:

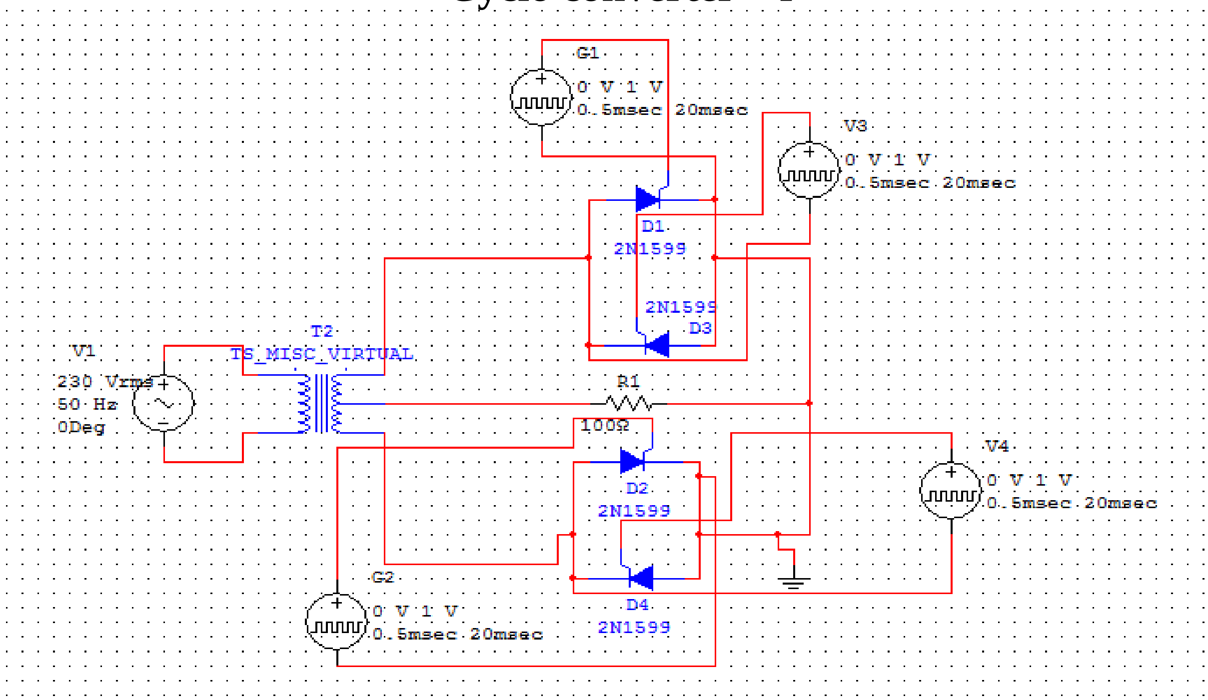
Switch ON the computer, double click on the multisim icon. You get the drawing window. Pick the components from the virtual component library. ON the grid, rig the circuit for the cycloconverter circuit with R-load. Connect a pulse voltage by selecting a signal voltage source from the virtual component between the gate and the cathode of all thyristors. Pick the CRO from the instrument bar and connect it across the load. Observe the output wave forms for f, f/2, f/3, f/4 modes of operation as per their respective circuits and triggering pulse sequences..

TRIGGERING PULSES FOR "F "MODE OF OPERATION

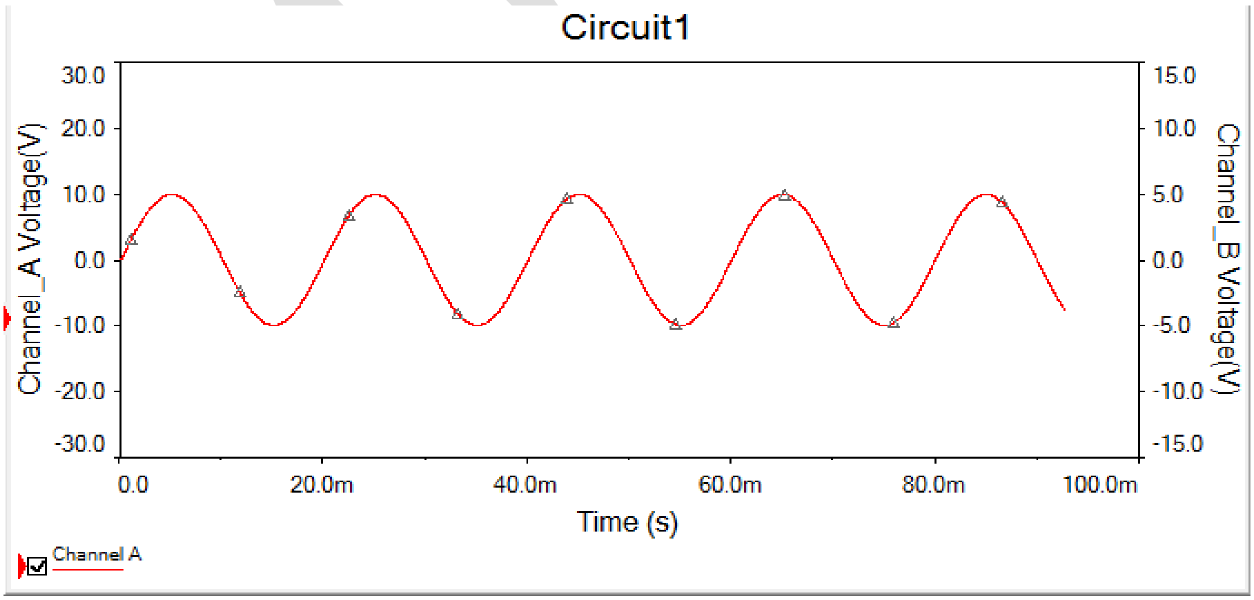
SCR No. →	T_1	T_2	T_3	T_4
Initial Value	0	0	0	0
Final Value	10	10	10	10
Delay Time	0 (m sec)	0(m sec)	10(m sec)	10(m sec)
Rise Time	1(n sec)	1(n sec)	1(n sec)	1(n sec)
Fall Time	1(n sec)	1(n sec)	1(n sec)	1(n sec)
Pulse width	10 (m sec)	10 (m sec)	10 (m sec)	10 (m sec)
Time Period	20 (m sec)	20 (m sec)	20 (m sec)	20 (m sec)

Circuit Diagram for f:

Cyclo converter – f



Expected Waveform for f:

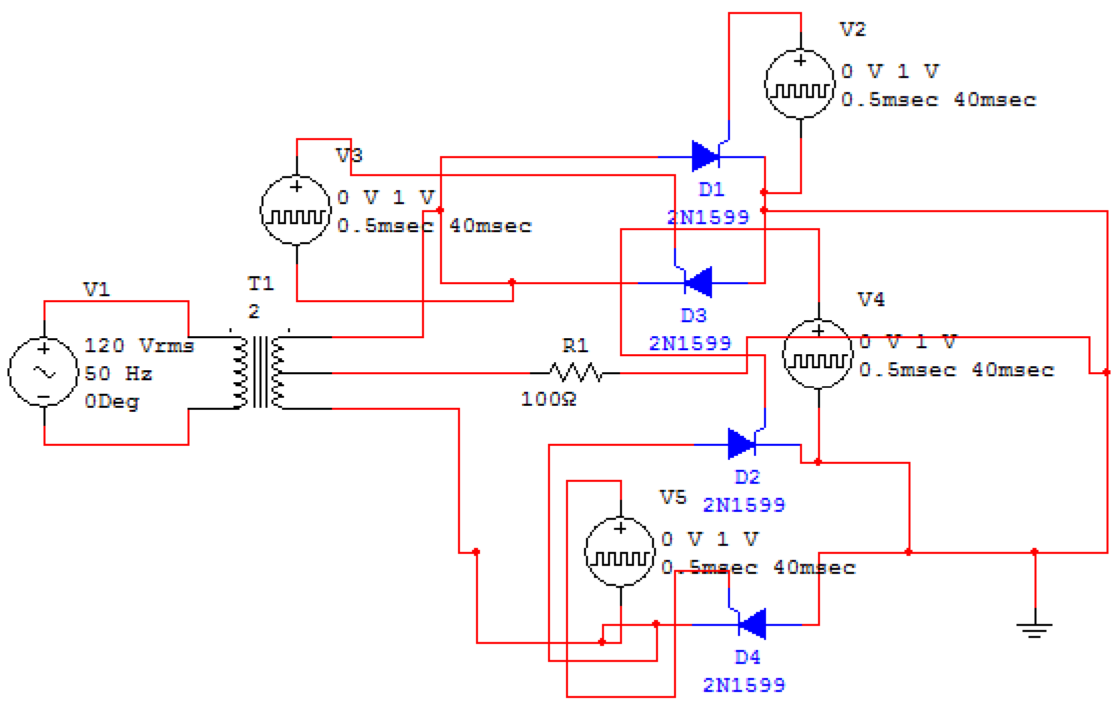


TRIGGERING PULSES FOR "F/2 "MODE OF OPERATION

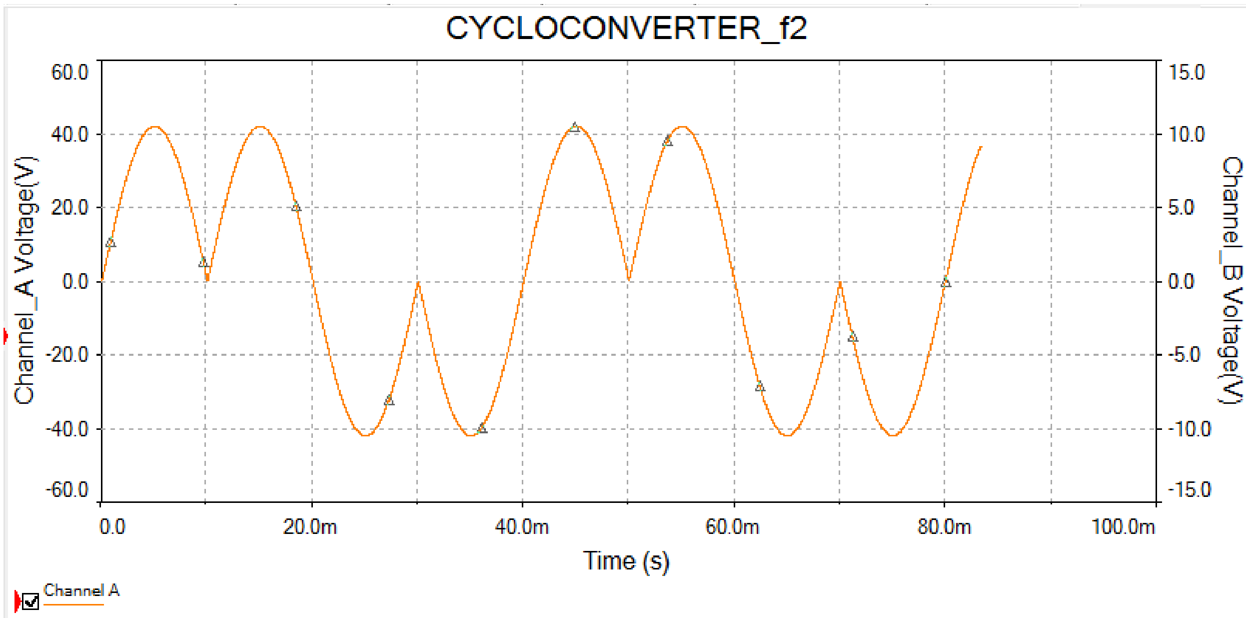
SCR No. →	**T_1**	**T_2**	**T_3**	**T_4**
Initial Value	0	0	0	0
Final Value	10	10	10	10
Delay Time	0 (m sec)	10(m sec)	30(m sec)	20(m sec)
Rise Time	1(n sec)	1(n sec)	1(n sec)	1(n sec)
Fall Time	1(n sec)	1(n sec)	1(n sec)	1(n sec)
Pulse width	10 (m sec)	10 (m sec)	10 (m sec)	10 (m sec)
Time Period	40 (m sec)	40 (m sec)	40 (m sec)	40 (m sec)

Circuit Diagram for f/2:

Cyclo converter - f/2



Expected Waveform for f/2:

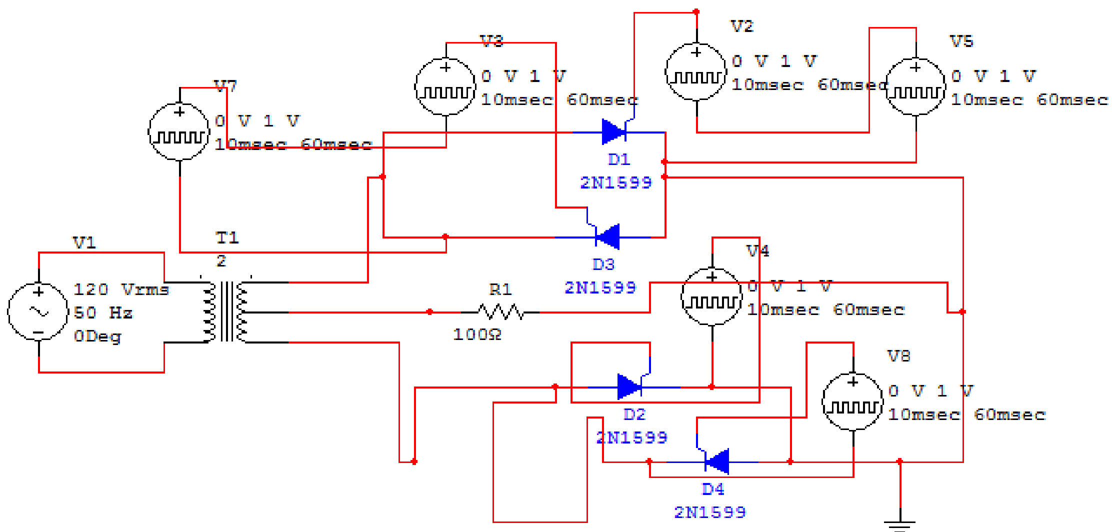


TRIGGERING PULSES FOR "F/3"MODE OF OPERATION

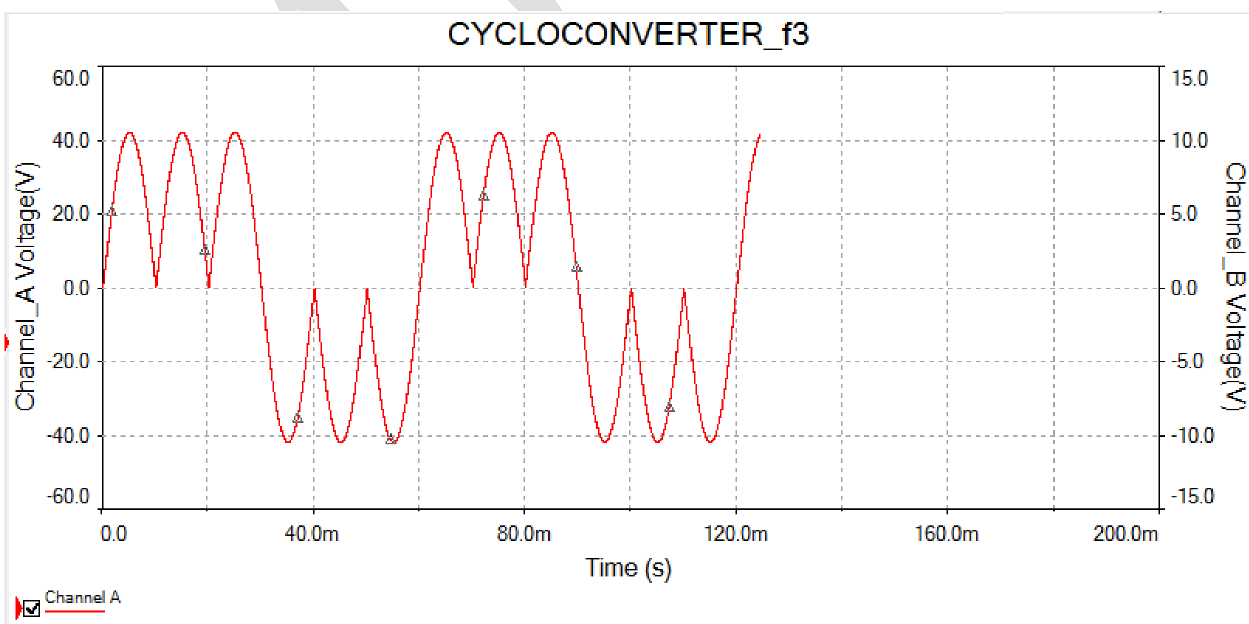
SCR No. →	**T_1**	**T_1**	**T_2**	**T_3**	**T_3**	**T_4**
Initial Value	0	0	0	0	0	0
Final Value	10	10	10	10	10	10
Delay Time	0 (m sec)	20 (m sec)	10(m sec)	30(m sec)	50(m sec)	40(m sec)
Rise Time	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)
Fall Time	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)
Pulse width	10 (m sec)	10 (m sec)	10 (m sec)	10 (m sec)	10 (m sec)	10 (m sec)
Time Period	60 (m sec)	60 (m sec)	60 (m sec)	60 (m sec)	60 (m sec)	60 (m sec)

Circuit Diagram for f/3:

Cyclo converter - f/3



Expected Waveform for f/3:

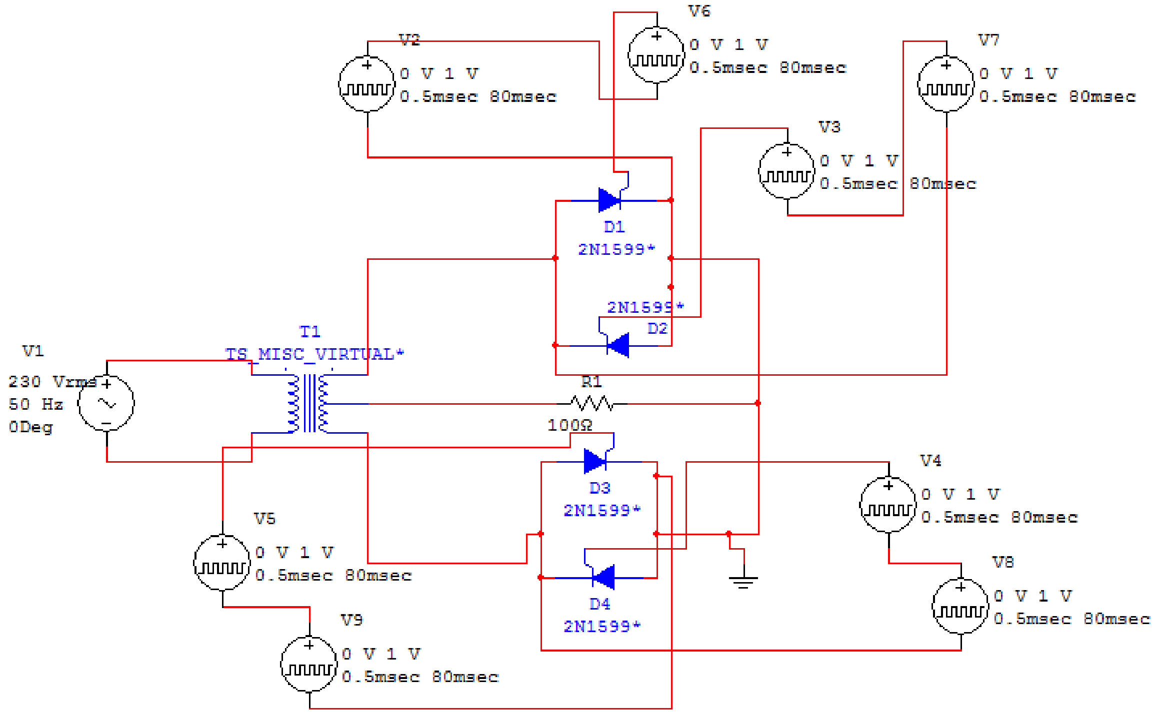


TRIGGERING PULSES FOR "F/4"MODE OF OPERATION

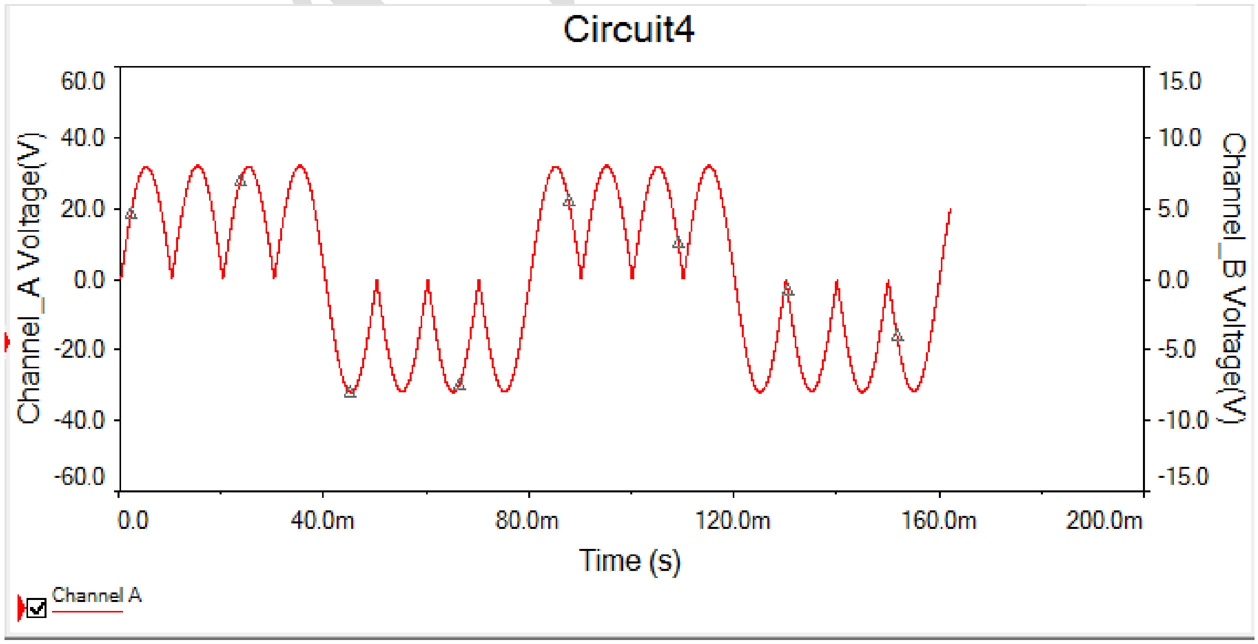
SCR No. →	**T_1**	**T_1**	**T_2**	**T_2**	**T_3**	**T_3**	**T_4**	**T_4**
Initial Value	0	0	0	0	0	0	0	0
Final Value	10	10	10	10	10	10	10	10
Delay Time	0 (m sec)	20(msec)	10(msec)	30(msec)	50(msec)	70(msec)	40(m sec)	60(m sec)
Rise Time	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)
Fall Time	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)	1(n sec)
Pulse width	10 (msec)	10(msec)	10(msec)	10(msec)	10(msec)	10(msec)	10 (m sec)	10 (m sec)
Time Period	80 (msec)	80(msec)	80(msec)	80(msec)	80(msec)	80(msec)	80 (m sec)	80 (m sec)

Circuit Diagram for f/4:

Cyclo converter - f/4



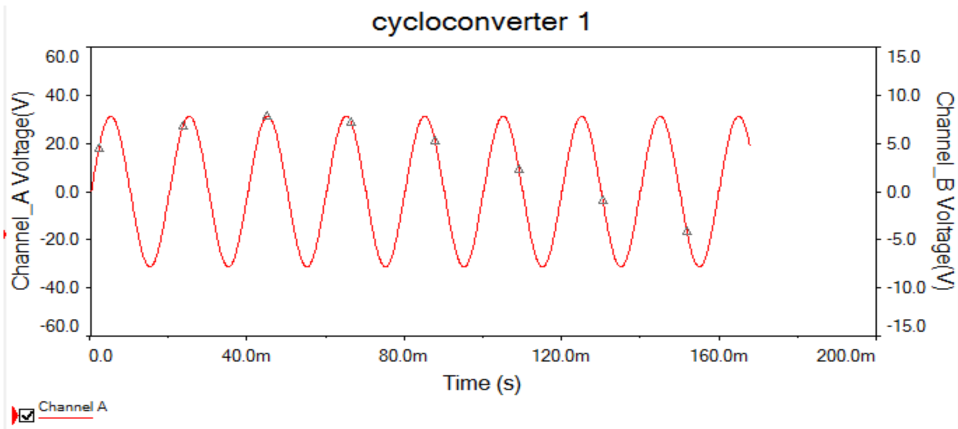
Expected Waveform for f/4:

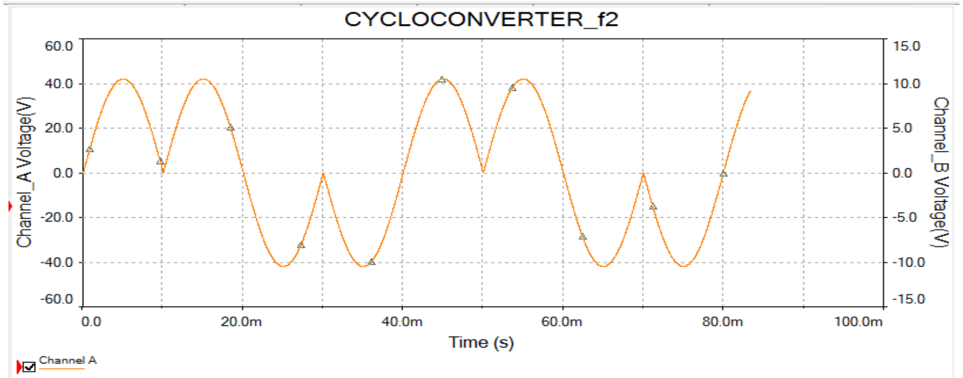


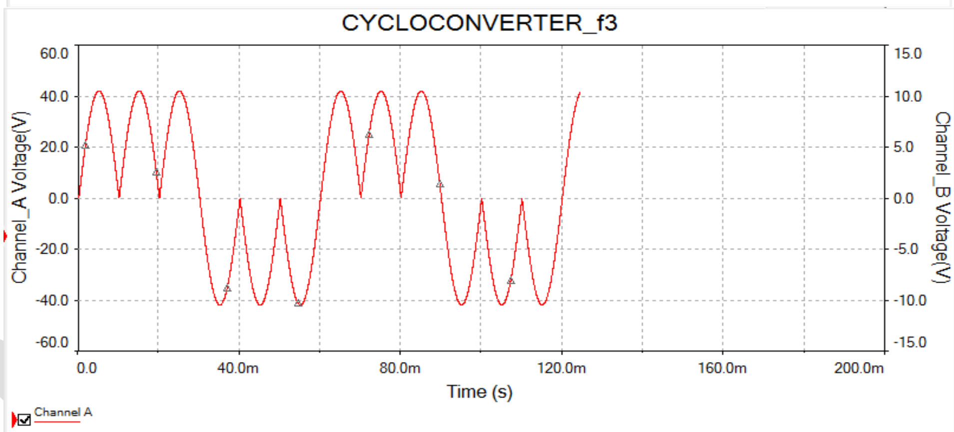
Result: The multisim software is learnt and the waveforms of Cycloconverter with R-Load are observed for f, f/2, f/3, f/4 modes of operation.

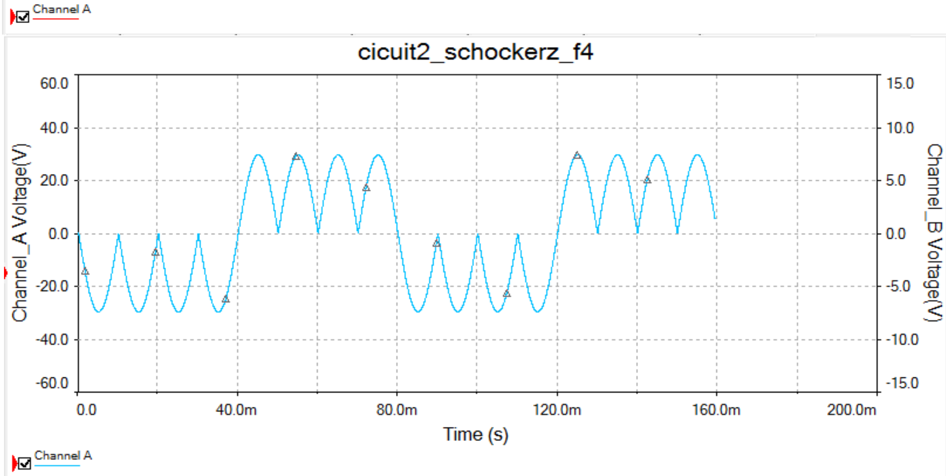
Discussion of Result:

- Comment on Time Period and frequency with reference to input frequency for different levels of output frequency.


cycloconverter 1
60.0
40.0
20.0
0.0
-20.0
-40.0
-60.0
Channel_A Voltage(V)
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
Channel_B Voltage(V)
0.0
40.0m
80.0m
120.0m
160.0m
200.0m
Time (s)
Channel A


CYCLOCONVERTER_f2
60.0
40.0
20.0
0.0
-20.0
-40.0
-60.0
Channel_A Voltage(V)
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
Channel_B Voltage(V)
0.0
20.0m
40.0m
60.0m
80.0m
100.0m
Time (s)
Channel A


CYCLOCONVERTER_f3
60.0
40.0
20.0
0.0
-20.0
-40.0
-60.0
Channel_A Voltage(V)
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
Channel_B Voltage(V)
0.0
40.0m
80.0m
120.0m
160.0m
200.0m
Time (s)
Channel A


cicuit2_schockerz_f4
60.0
40.0
20.0
0.0
-20.0
-40.0
-60.0
Channel_A Voltage(V)
15.0
10.0
5.0
0.0
-5.0
-10.0
-15.0
Channel_B Voltage(V)
0.0
40.0m
80.0m
120.0m
160.0m
200.0m
Time (s)
Channel A

VIVA QUESTIONS

V-I CHARACTERISTICS OF SCR

1. What is a Thyristor?

Ans) Thyristor is derived from the properties of a Thyratron tube and a Transistor. It is used as another name for SCR'S. They are power Semiconductor devices used for power control applications.

2. What are SCR's?

SCR's is Silicon controlled Rectifiers. They are basically used as Rectifiers

3. Draw the structure of an SCR?

4. What are the different methods of turning on an SCR?

*Anode to cathode voltage is greater than break over voltage.

*Gate triggering *When dv/dt exceeds permissible value.

*Gate cathode junction is exposed to light.

5. What is Forward break over voltage?

The voltage Vak at which the SCR starts conducting is called as Forward Break over voltage Vbo. This happens when the junction J2 undergoes Avalanche breakdown due to high reverse bias on junction J2.

6. What is Reverse break over voltage?

If the reverse voltage is increased more than a critical value, avalanche Breakdown will occur at J1 and J3 increasing the current sharply. This is Reverse break over voltage VBO.

7. Why is Vbo greater than VBR?

In SCR the inner two p-n regions are lightly doped due to which the thickness of the depletion region at junction J2 is higher during forward bias than that of J1 and J3 under reverse bias.

8. What are modes of working of an SCR?

Reverse blocking mode, Forward blocking mode and Forward conduction mode are the modes of working of an SCR.

9. Draw the V-I characteristics of SCR.

Ans) Refer figure 1.1(a)

10. Why does high power dissipation occur in reverse blocking mode?

High power dissipation occurs because as voltage increases beyond Vbr current increases rapidly.

11. Why shouldn't positive gate signal be applied during reverse blocking Mode?

If we apply positive gate signal J3 becomes forward biased. Reverse leakage current increases and Thyristor gets damaged due to large power dissipation.

12. Explain reverse current Ire?

When cathode voltage is positive, J2 is forward biased; J1 and J3 are reverse biased. The thyristors will be in reverse blocking state and reverse leakage current Ire flows.

13. What happens when gate drive is applied?

When gate drive is applied avalanche breakdown occurs at J2 causing excessive flow of charges and hence current surge. This turns the SCR into conduction state faster i.e. the Thyristor turns on at lower and lower anode to cathode voltages, which are less than Vbo.

14. Differentiate between holding and latching currents?

Holding current is the minimum amount of current below, which SCR does not conduct. It is associated with the presence of gate terminal and concerns turn off condition.

Latching current is the minimum amount of current required for the SCR to conduct. It is associated with absence of gate terminal and concerns turn on process. It is greater than holding current.

15. Why is dv/dt technique not used?

As this causes false triggering even when gate or voltage Vak is not applied, dv/dt technique is not used. Snubbed circuit, which is combination of a C, avoids this and R .The capacitor is placed in parallel with SCR.

16. What sided?

At the time of turn on, anode current increases rapidly. This rapid variation is not spread across the junction area of the thyristors. This creates local hotspots in the junction and increases the junction temperature and hence device may be damaged. This is avoided by connecting an inductor in series with an SCR.

17. Why should the gate signal be removed after turn on?

This prevents power loss in the gate junction.

18. Is a gate signal required when reverse biased?

No, otherwise SCR may fail due to high leakage current.

19. What are different types of firing circuits to trigger SCR?

*R firing circuit.
*RC firing circuit.
*UJT firing circuit.
*Digital firing circuit.

20. What type of triggering is used in SCR?

Pulse triggering.

21. What is offset current?

When anode voltage is made positive, J1 and J3 are forward biased, J2 is reverse biased. The Thyristor is in forward blocking or off state condition and the leakage current is known as offset current Io.

22. What are the advantages of SCR?

*Very small amount of gate drive is required since SCR is regenerative device.
*SCR's with high voltage and current ratings are available.
*On state losses are reduced.

23. What are the disadvantages of SCR's?

*Gate has no control once the SCR is turned on.
*External circuits are required to turn off the SCR.
*Operating frequencies are very low.
*Snubber (RC circuits) is required for dv/dt protection.

24. What are applications of SCR?

*SCR's are best suitable for controlled rectifiers.
*AC regulators, lighting and heating applications.
*DC motor drives, large power supplies and electronic circuit breakers.

25. What is the difference between an IGBT and SCR?

IGBT comprises of a BJT and a MOSFET where as an SCR comprises of two BJT's.

26. Can we replace a SCR by a microprocessor by writing a program to exhibit characteristics of SCR?

No, we can verify or test the working of SCR using microprocessor but we cannot replace it practically.

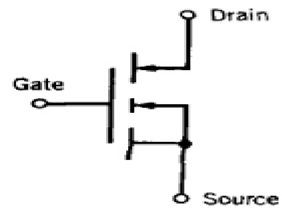
****

CHARACTERISTICS OF MOSFET

1. **What are MOSFET's?**

   Metal oxide silicon di-oxide field effect transistor is a voltage-controlled device. The parts of MOSFET are gate, drain and source.

2. **Draw the symbol of MOSFET.**



3. What is the difference between MOSFET and BJT?

The MOSFET is a voltage controlled device where as BJT is a current controlled device.

4. What is the difference between JFET and MOSFET?

There is no direct contact between the gate terminal and the n-type channel of MOSFET.

5.Draw the structure of MOSFET?

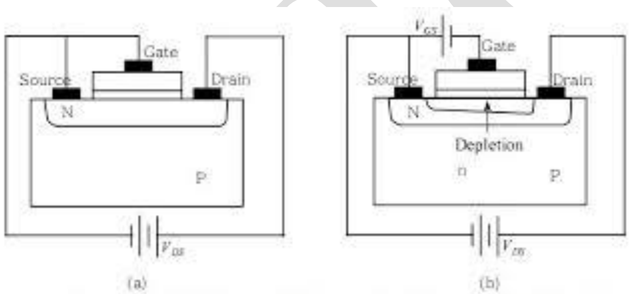


Figure 2: The Structure of a Depletion Type MOSFET and its Operation

6.What are the two types of MOSFET?

*Depletion MOSFET - N channel in p substrate. -P channel in n substrate. *Enhancement mosfet –virtual n channel in p substrate -Virtual p channel in n substrate.

7. What is the difference between depletion and enhancement MOSFET?

The channel in the centre is absent for enhancement type MOSFET but the channel is present in depletion type MOSFET. The gate voltage can either be positive or negative in depletion type MOSFET's but enhancement MOSFET responds only for positive gate voltage.

8. How does n-drift region affect MOSFET?

The n- drift region increases the onstage drop of MOSFET and also the thickness of this region determines the breakdown voltage of MOSFET.

9. How are MOSFET's suitable for low power high frequency applications?
MOSFET's have high on state resistances due to which losses increase with the increase in the power levels. Their switching time is low and hence suitable for low power high frequency applications.

10. What are the requirements of gate drive in MOSFET?
*The gate to source input capacitance should be charged quickly. *MOSFET turns on when gate source input capacitance is charged to sufficient level. *The negative current should be high to turn off MOSFET.

11. Draw the switching model of MOSFET.

12. What is rise time and fall time?
The capacitor Cgs charges from threshold voltage to full gate voltage Vgsp. The time required for this charging is called rise time. During this period, drain current rises to full value. The capacitor Cgs keeps on discharging and its voltage becomes equal to threshold voltage Vt.The time required for this discharge Cgs from Vgsp to Vt is called fall time.

13. What is pinch off voltage?
The voltage across gate to source at which the drain to source current becomes zero is called pinch off voltage.

14. In which region does the MOSFET used as a switch?
In the linear region.

15. Which parameter defines the transfer characteristics?
The Tran conductance Gm=Id/Vgs .

16. Why are MOSFET's mainly used for low power applications?
MOSFET's have high on state resistance Rds. Hence for higher currents; losses in the MOSFET's are substantially increased. Hence MOSFET's are substantially increased. Hence, MOSFET's are mainly used for low power applications.

17.How is MOSFET turned off?
To turn off the MOSFET quickly, the negative gate current should be sufficiently high to discharge gate source input capacitance.

18. What are the advantages of vertical structure of MOSFET?

*On state resistance of MOSFET is reduced.
*Width of the gate is maximized.
Hence, gain of the device is increased.

19. What are the merits of MOSFET?

* MOSFET's are majority carrier devices.
*MOSFET's have positive temperature coefficient, hence their paralleling is easy.
*MOSFET's have very simple drive circuits.
*MOSFET's have short turn on and turn off times; hence they operate at high frequencies.
*MOSFET's do not require commutation techniques.
*Gate has full control over the operation of MOSFET.

20. What are demerits of MOSFET?

*On state losses in MOSFET are high.
*MOSFET's are used only for low power applications.
*MOSFET's suffer from static charge.

21. What are the applications of MOSFET?

*High frequency and low power inverters.
*High frequency SMPS.
*High frequency inverters and choppers.
*Low power AC and DC drives.

****

CHARACTERISTICS OF IGBT

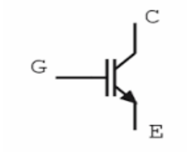
1. What is IGBT?

Insulated gate bipolar transistor is the latest device in power Electronics .It is obtained by combining the properties of BJT and MOSFET.

2. In what way IGBT is more advantageous than BJT and MOSFET?

*It has high input impedance of the MOSFET and has low on-state voltage drop.
*The turn off time of an IGBT is greater than that of MOSFET.
*It has low onstage conduction losses and there is no problem of second Breakdown as in case of BJT.
*It is inherently faster than a BJT.

3.Draw the symbol of IGBT.



4. Draw the equivalent circuit of IGBT.

5. What are on state conduction losses? How is it low in IGBT?

A high current is required to break the junctions in BJT. This results in On state conduction losses. The conduction losses in IGBT are proportional To duty cycle of the applied voltage. By reducing the duty cycle conduction losses can be reduced.

6. What is second breakdown phenomenon?

As the collector voltage drops in BJT there is an increase in collector Current and this substantially increase the power dissipation. This Dissipation is not uniformly spread over the entire volume of the device but is concentrated in highly localized regions where the local temperature may grow and forms the black spots. This causes the destruction of BJT. This is second breakdown.

7. What is switching speed?

The time taken to turn on or turn off a power device is called switching Speed.

8. Can we observe the transfer and collector characteristics of IGBT on CRO?

No. Because the waveform which is to be observed on the CRO should vary with respect to time otherwise we can see only a straight line on the CRO.

9. What are merits of IGBT?

*The drive is simple.
*Onstage losses are reduced.
*No commutation circuits are required.
*Gate has full control.
*Switching frequencies are higher.
*It has flat temperature coefficient.

10. What are demerits of IGBT?

*They have static charge problems.
*They are very costly.

11. What are the applications of IGBT's?

*Ac motor drives. (Inverters)
*Dc to Dc power supplies. (Choppers)
*UPS systems.
*Harmonic compensators.

12. Why is silicon used in all power semiconductor devices and why not? Germanium?
The leakage current in silicon is very small compared to germanium. The germanium is also more sensitive compared to silicon.

13. What is pinch off voltage?
When Vge is made negative, electrons in the n-channel get repelled Creating a depletion region resulting in a narrower effective channel. If Vge is made negative enough so as to completely eliminate the channel (High resistance, low current state), that value is called the pinch off Voltage.

14. What is threshold voltage?
Threshold voltage is the voltage Vge at which IGBT begins to conduct.
15. How is IGBT turned off?
An IGBT can turn off by discharging the gate by means of short circuiting it to the emitter terminal.

16. What is the rating of IGBT?
The current rating can be up to 400A, 1200V with switching frequency of 20 KHz.

****

Controlled HWR &FWR using R & RC Triggering circuit

1. **What is the maximum firing angle of R-triggering circuit and why?**
   The maximum firing angle is 90°. This is because the source voltage reaches maximum value of 90° point and the gate current has to reach Ig(min) some where between 0-90°. This limitation means that load voltage waveform can only be varied from $\alpha = 0°$ to $\alpha = 90°$.

2. What are the disadvantages of R triggering?
- Trigger angle α is greatly dependent on the SCR's Ig(min) and this value varies between SCR's and it is also temperature dependent.
- Maximum triggering angle achievable is 90°.

3. In R-triggering circuit why is Rmin is connected in series with variable resistor?

The limiting resistor Rmin is placed between anode and gate so that the peak gate current of the thyristor Igm is not exceeded.

4. What is the maximum firing angle of RC-triggering and why?

Maximum firing angle is 180°. This is because capacitor voltage and AC line voltage differ in phase. By adjusting the value of R it is possible to vary the delay in turning on the SCR from 0 to 10 msec and hence vary the firing angle from 0° to 180°.

****

UJT firing circuit for HWR and FWR circuits.

1. What is an UJT and draw its equivalent circuit?

UJT-uni junction transistor. It has only one type of charge carriers. It has three terminals emitter, base 1 and base 2. ('Duo base' as it has 2 bases)

2. Why is an UJT used in SCR firing circuit?

The voltage at base 1 of UJT is smaller than the voltage needed to trigger the Scrim the voltage is high, then it will trigger the SCR as soon as the ac supply is on.

3. Why is the isolation needed between Thyristor and firing circuit?

The trigger circuit operates at low power levels (5-20 volts) whereas thyristors operate at high voltage levels (250 volts). Hence if the Thyristor acts as a short the entire 250volts get applied across the firing circuit causing damage. Hence isolation is needed.

4. How is a pulse transformer different from other transformer?

A pulse transformer is one in which the input at the primary is current which is transformed into a pulse at the secondary. Thus it does not step-up and step-down as other transformers.

5. What are the features of pulse transformer?

The primary magnetizing inductance is high, coupling efficiency is high, and interwinding capacitance is low and has greater insulation.

6. What are the advantages of using pulse transformer?

*Multiple secondary windings allow simultaneous gating signals to series and parallel connected thyristors. *Control circuit and power circuit can be isolated.

7. Why i s UJT used in SCR firing circuit?

As the UJT works in a mode called as a relaxation oscillator i.e. UJT turns on or off depending on the charging and discharging of the capacitor. Time constant can be varied with Chance delay angle can be varied .The UJT thus gives a firing angle range of 0- 180.Vz is supply to UJT, the discharging current when passed through the pulse transformer triggers SCR with pulses.

8. Why is the zeenar diode used?

The zeenar diode provides a constant supply voltage for UJT. It enables synchronization with zero crossings. Zeenar diode acts as a regulator. The zeenar clamps the rectified voltage to vs. to prevent erratic firing. This sneer voltage acts as a supply for UJT relaxation oscillator.

9. What is meant by ramp control, open loop control or manual control with respect to UJT firing circuit?

Ramp control-The graph of time period in milliseconds with the firing angle in degrees is a ramp. The ramp slope can be controlled by the potentiometer. Manual control-The potentiometer in the kit can be used to get various firing angles. This is manual control.

10. What is a firing circuit?

It is a circuit, which is used to trigger a device at various instants of time.

11. Why a bridge rectifier is used?

The bridge rectifier gives a full wave rectified output, which is high in efficiency and least ripple factor.

12. What is the load used?

Load is high power dissipation resistor.

13. What is time constant of a circuit?

Time constant of a circuit=RC where R=resistance C=capacitance It gives the time of charging and discharging of a capacitor.

14. What are the merits of UJT firing circuit over RC triggering circuit?

* Firing angle remains stable.
*Advantages of pulse transformer.

15. What are the advantages of UJT pulse trigger circuit?

The resistors, capacitors depend heavily on the trigger characteristics of the Thyristor used. The power dissipation is high due to prolonged pulse. But the pulse triggering can accommodate wide tolerances in triggering characteristics by instantaneously overdriving the gate. The power level in such circuits is lower as the triggering energy can be stored slowly and discharged rapidly when the triggering is required.

16. Why is UJT used as relaxation oscillator?
The UJT is used as a relaxation oscillator to obtain sharp, repetitive pulses with good rise time. Also it has good frequency stability against variation in the supply voltage and temperature.

17. What are the applications of UJT trigger circuits?
*Used to trigger SCR's in single-phase converters, single-phase ac regulators.
*Used in oscillators
*Used in timing circuits

18. What is valley voltage?
It is the voltage at which the UJT turns off and the capacitor starts charging again.

19. What is the discharging path if the capacitor?
The capacitor discharges through emitter, base and primary of the pulse transformer.

20. What is relaxation oscillator?
When the capacitor discharges to a valley voltage, the UJT turns off and capacitor starts charging again. This mode of working of UJT is called relaxation oscillator.
21. Draw the static characteristics of UJT.

22. What is negative resistance?
After the capacitor charges to Vp it starts discharging. During this period the voltage V decreases with increase in current, hence this portion of V-I characteristics is called negative resistance.

23. What is interring base resistance?
Inter base resistance is the resistance between 2 bases.

24. What is intrinsic stand off ratio?
Intrinsic stand off ratio=Rb1/(Rb1+Rb2). Its value ranges between .52 to .81.

25. What is the width of the triggering pulse?
TG=Rb1.C

26. Why are the capacitors CIF and C used?
Capacitor CIF is used to minimize the ripples and C is used for charging and discharging so that the trigger is eventually formed.

_________________________________*********__________________________________

AC VOLTAGE CONTROLLER

1. What is ac voltage controller?

If a Thyristor switch is connected between ac supply and load, the power flow can be controlled by varying the rms value of ac voltage applied to the load and this type of power circuit is known as an ac voltage regulator .

2. What are the applications of ac voltage controllers?

The most common applications of ac voltage controllers are: industrial heating, on-load transformer tap changing, light controls, speed control of polyphase induction motors and ac magnet controls.

3. What do you mean by sequence control?

The use of two or more stages voltages controllers in parallel for the regulation of output voltage.

4. Give the classification of ac voltage regulators.

They are classified as: 1.single phase controllers 2.three phase controllers Each type can be subdivided into unidirectional and bi-directional control.

5. What are the two types of control?

*on off control: Here Thyristor switches connect the load to the ac source for a few cycles of input voltage and then disconnect it for another few cycles. *phase angle control: Here Thyristor switches connect the load to the ac source for a portion of each cycle of input voltage.

6. Why are extra commutation components not required?

The ac voltage controllers have main supply as input. The SCR's in these controllers are turned off by natural commutation. Hence extra commutation components are not required. Therefore ac voltage controllers are simple and easy to implement if SCR's are used.

7. What is the difference between cycloconverters and ac voltage controllers?

In cycloconverters (ac to variable ac) frequency of output can be varied. In ac voltage controller's frequency of output is kept constant, just the output average value is controlled (on and off times varied).

8. What is diac firing circuit?

A diac firing circuit consists of a diac that is used to generate trigger pulses for the Thyristor diac can conduct in both directions and it does not have any control terminal in the form of a gate.

9. What are the merits and demerits of voltage controllers?

The merits are that they are simple without commutation circuits, high efficiency and less maintenance. The demerits are that the load current is asymmetric (phase control) and hence harmonics are present and intermittent supply of power in on-off control.

10. Why is the trigger source for the two Thyristor isolated from each other in a single-phase voltage controller?
When one Thyristor is on, the other should be off. Both the Thyristor should not conduct at a time.

****

SINGLE PHASE FULL CONTROLLED BRIDGE RECTIFIER FOR R & R-L LOAD

1. What is a full controlled rectifier?
It is a two-quadrant ac to dc converter. It has 4 thyristors and hence all of them can be controlled for rectification purpose. In a full converter the polarity of the output voltage can be either positive or negative but the output current has only one polarity.

2. What is a semi converter?
A semi converter is a one-quadrant converter and it has only one polarity of output voltage and current.

3. What is a dual converter?
A dual converter can operate in all 4 quadrants and both output voltage and current can be either positive or negative.

4. How can we control the output voltage of a single-phase full converter?
By varying the trigger angle.

5. What is MCB?
MCB-Miniature circuit breaker. This is used as switch, which opens or switches off when the voltage or current is above the rated value of that of MCB.

6. How many lines are there in single-phase system?
Two lines- 1line and 1neutral

7. What is the type of commutation used?
Line commutation.

8. What is rectification mode and inversion mode?

During the period alpha to 180( ) the input voltage Vs and input current Is are positive and the power flows from supply to the load. The converter is said to be operating in rectification mode. During the period 180 to 180+alpha the input voltage Vs and the input current Is positive and there will be reverse power flow from load to supply. The converter is said to be operating in inversion mode.

9. Where is full bridge converter used?

It is mainly used for speed control of dc motors.

10. What is the effect of adding freewheeling diode?

Freewheeling action does not takes place in single-phase full converter inherently as there are 4 thyristors and no diodes. From 180 to 180+alpha( ) free wheeling diode starts conducting. It is more forward biased compared to T1 and T2.Hence freewheeling diode conducts. The freewheeling diode is connected across the output Vo. Hence Vo=0 during freewheeling. The energy stored in the load inductance is circulated back to the load itself.

____________________________________*********____

DC Chopper

1. What are choppers?

A dc chopper converts directly from dc to dc and is also known as dc-dc converter.

2. What does a chopper consist of?

It can be a power transistor, SCR, GTO, power MOSFET, IGBT or a switching device.

3. On what basis choppers are classified in quadrant configurations?

The choppers are classified depending upon the directions of current and voltage flows. These choppers operate in different quadrants of V-I plane. There are broadly following types of choppers: class a chopper (first quadrant); class B (second quadrant) Class C and class D (two quadrant choppers), class C in II quadrant and I whereas class D in IV quadrants, and I class E is four quadrant operator.

4. What are different control strategies found in choppers?

The different control strategies are pulse width modulation, frequency modulation and current limit control, variable pulse width and frequency.

5. Explain the principle of operation of a chopper?

A chopper acts as a switch, which connects and disconnects the load, hence producing variable voltage.

6. What are the advantages of DC choppers?

* High ripple frequency, so small filters are required.
*Power factor is better.
*Efficiency is better.
*Small and compact.
*The dynamic response of choppers is fast due to switching nature of the device.

7. Define duty cycle.

The duty cycle of chopper controls its output voltage. The value of duty cycle lies between 0 and 1 and is given by Ton/(Ton+Toff).

8. How can ripple current be controlled?

Ripple current is inversely proportional to the frequency and hence can be controlled by having higher frequency.

9. What is step up chopper?

If the output average voltage is greater than the supply voltage, then the chopper is called step up chopper.

10. On what does the commutating capacitor value depend on?

It depends on the load current.

11. What are the disadvantages of choppers?

*They can operate only at low frequencies.
*The commutation time depends on the load current.
*The output voltage is limited to a minimum and maximum value beyond which we cannot get the output voltage.

12. How do they have high efficiency?

DC choppers uses switching principle, hence they have high efficiency.

13. What are the applications of dc choppers?

Battery operated vehicles, switched mode power supplies, traction devices, lighting and lamp controls, trolley cars, marine hoists, and forklift trucks. Mine haulers etc.

****

4-QUADRANT DRIVE

1. What is principle of dc motor?

An electric motor is a machine, which converts electrical energy into mechanical energy. Its action is based on the principle that when a current carrying conductor is placed in a magnetic field it experiences a mechanical force whose direction is given by flemings left hand rule and whose magnitude is given by F=BIL N.When the field magnets of a multipolar dc motor are excited and its armature conductors are supplied with current from supply mains they experience a force tending to rotate the armature .By Fleming's left hand rule it is noted that each conductor experiences a force which tends to rotates the armature in anticlockwise direction. These forces collectively produce a driving torque (or twisting moment), which sets the armature rotating.

2. How can the speed of the series motor controlled?

*flux control method -field diverters -Armature diverter
*variable resistance in series with the motor.

3. What are the advantages of field method?

*economical, more efficient
*It gives speeds more /above the normal speed.

4. What are the disadvantages of field method?

Commutation becomes unsatisfactory.

5. What are the factors controlling speed?

Speed can be controlled by controlling flux, resistance, voltage.

6. What is the significance of back emf?

When the motor armature rotates the conductors also rotates and hence cut flux. Therefore emf is induced and direction is in opposition with the applied voltage (Fleming's right hand rule). Because of its opposing direction it is referred to as back emf E_b. V has to drive I_a against the opposition of E_b. The power required to overcome this opposition is E_bI_a.

7. What is torque?

Torque is twisting or turning moment of a force about an axis. The torque developed by the armature of a motor is armature torque. The torque available for useful work is known as shaft torque (available at the shaft).

8. How can dc motors be classified?

*separately excited
*self excited.

9. What are the main losses in motors?

*stator losses
*rotor losses
*mechanical losses

10. Why are starter used in dc motor?

Initially Eb =0 and R is usuallly very small,therefore the armature current is very high which could damage the motor.Hence starters which is basically a resistance connected in series with the motor.

11. What is the parameter that is being varied by varying the firing angle?

The armature voltage is varied which inturn varies the speed of the motor by varying the firing angle.

12. What are the operating modes of dc motor?

Motoring, regenerative braking, dynamic braking, plugging.

________________________________*********_________________________________

1-PHASE INVERTER

1. What are inverters and what are its applications?

DC to AC converters is known as inverters. The function of an inverter is to change a DC input voltage into AC output voltage of desired magnitude and frequency. Inverters are widely used in industrial applications like variable speed AC motor drives, induction heating, stand-by power supplies and uninterrupted power supplies.

2. Why is the circuit called parallel inverter?

The circuit is called parallel inverter because the commutating capacitor is in parallel with the primary winding of the output transformer whose secondary is fed to the load.

3. What is the main classification of inverters?

Inverters can be broadly classified into two types namely, Single-phase inverters and three phase inverters. Each type can use controlled turn-on and controlled turn-off devices (eg. BJT’s and MOSFET’s etc) or forced commutation thyristors depending on application.

4. What is VFI and CFI?

An inverter is called a Voltage Fed Inverter (VFI) if the input voltage remains constant, a Current Fed Inverter (CFI) if the input current is maintained constant.

5. What is variable DC linked inverter?

An inverter is called variable DC linked inverter if the input voltage is controllable.

6. What is inverter gain?

The inverter gain may be defined as the ratio of the AC output to DC input voltage. Why the output voltage of an inverter is to be controlled? The output voltage of the inverter is to be varied as per the load requirement. Whenever the input DC varies the output voltage can change. Hence, these variations need to be compensated. The output voltage and frequency of an inverter is adjusted to keep voltage and frequency constant. Thus, the output voltage of an inverter is to be controlled.

7. What are the advantages and disadvantages of variable DC linked inverter?

Advantages: 1. Harmonic content does not change with output voltage.
2. Control circuit of an inverter is simple.

Disadvantages: 1. Additional chopper or control rectifier is required.
2. Efficiency of a circuit is reduced due to double conversion.
3. Transistors have to handle variable input voltages.

8. Compare between Voltage source and Current source inverters

Voltage source inverters :

1. Input is constant voltage.
2. Short circuit can damage the circuit.
3. Peak current of power-device depends on load.
4. Current wave forms depend on load.
5. Freewheeling diodes are required in case of inductive load.

Current source inverters:

1. Input is constant current.
2. Short circuit cannot damage the circuit.
3. Peak current of power-device is limited.
4. Voltage wave forms depend on load.
5. Freewheeling diodes are not required.

9. Explain the principle of variable DC linked inverter?

Harmonic content of the signal also changes if pulse width is varied. This problem is taken care by DC link inverter. Instead of varying the pulses of inverter, an input DC voltage is varied. Therefore rms value of output voltage is varied.

10. What is the commutation technique used in the parallel inverter?
Complementary commutation technique.

11. What is the role of the diodes D1 and D2?
Diodes D1 and D2 act as freewheeling diodes, they conduct when both SCR's turn off. They also provide a path for conduction.

12. Why is the inductor used?
The inductor does not allow drastic changes in current and hence provide di/dt protection.

13. From where does the inverter derive its dc power input?
It derives the dc power input from the inverter specific external VRPS.

______________________________________*********______________________________________

SERIES INVERTER

1. What are series inverters?
Inverters in which the commutating elements are permanently connected in series with the load resistance.

2. What are the commutating elements in the above circuit?
L and C are the commutating elements.

3. What is the condition for selecting commutating element?
They are selected in such a way that the current flow through series connected elements R, L, C is under damped

4. What are the drawbacks of a basic series inverter?
*If the inverter frequency exceeds the circuit ringing frequency the dc source will be short-circuited. *For output frequencies much smaller than the circuit ringing frequency, the load voltage is di started.
*The source current flows only during the period when the Thyristor T1 is conducting. This results in large ripple in the source current and peak current rating of the source inverters.

5. What are the applications of series inverters?
*Induction heating
*Fluorescent lighting

*Variable speed ac motor drives
*Aircraft power supplies
*UPS
*High voltage dc transmission lines

6. Why are the inductors L1, L2 and why are two capacitors needed?

*The resonant frequency, which is, if it is nearby inverter output frequency, commutation failure will take place. Hence it should be ensured that the capacitor and inductor are so chosen that it be not near to resonant frequency.

*Equal values of L1, L1' or C1, C1' to be chosen so that the uniform inverter output is maintained.

7. What are the waveforms (output) obtained in inverter?

The output voltage waveforms of ideal inverters are sinusoidal. But for practical inverters they are non sinusoidal and contain harmonics due to which the waveforms may be square wave or quassi square wave.

8. Why can't we see current waveforms on CRO?

The resistance of CRO is very high. Therefore the current measurement is incorrect. An attempt to reduce the resistance of CRO reduces the input impedance, which draws heavy current from the source.

****