



Estd:2008

# METHODIST

## COLLEGE OF ENGINEERING AND TECHNOLOGY

(Affiliated to Osmania University & Approved by AICTE, New Delhi)



### LABORATORY MANUAL

## POWER ELECTRONICS LABORATORY

BE, V Semester (CBCS): 2020-21

NAME: \_\_\_\_\_

ROLL NO: \_\_\_\_\_

BRANCH: \_\_\_\_\_

SEM: \_\_\_\_\_

DEPARTMENT OF ELECTRICAL AND ELECTRONICS  
ENGINEERING

---

*Empower youth- Architects of Future World*



**Estd:2008**

# **METHODIST COLLEGE OF ENGINEERING AND TECHNOLOGY**

---

## **VISION**

To produce ethical, socially conscious and innovative professionals who would contribute to sustainable technological development of the society.

## **MISSION**

To impart quality engineering education with latest technological developments and interdisciplinary skills to make students succeed in professional practice.

To encourage research culture among faculty and students by establishing state of art laboratories and exposing them to modern industrial and organizational practices.

To inculcate humane qualities like environmental consciousness, leadership, social values, professional ethics and engage in independent and lifelong learning for sustainable contribution to the society.

**DEPARTMENT  
OF  
ELECTRICAL AND ELECTRONICS ENGINEERING**

**LABORATORY MANUAL  
POWER ELECTRONICS LABORATORY**

**Prepared  
By**  
Mrs. A. Archana,  
Assistant Professor



# METHODIST

## COLLEGE OF ENGINEERING AND TECHNOLOGY

### DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

## VISION

To become a reputed centre for imparting quality education in Electrical and Electronics Engineering with human values, ethics and social responsibility.

## MISSION

- To impart fundamental knowledge of Electrical, Electronics and Computational Technology.
- To develop professional skills through hands-on experience aligned to industry needs.
- To undertake research in sunrise areas of Electrical and Electronics Engineering.
- To motivate and facilitate individual and team activities to enhance personality skills.



Estd:2008

# METHODIST

## COLLEGE OF ENGINEERING AND TECHNOLOGY

### DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

#### PROGRAM EDUCATIONAL OBJECTIVES

BE-Electrical Engineering graduates shall be able to:

- **PEO1.** Utilize domain knowledge required for analyzing and resolving practical Electrical Engineering problems.
- **PEO2.** Willing to undertake inter-disciplinary projects, demonstrate the professional skills and flair for investigation.
- **PEO3.** Imbibe the state of the art technologies in the ever transforming technical scenario.
- **PEO4.** Exhibit social and professional ethics for sustainable development of the society.



Estd:2008

# METHODIST

## COLLEGE OF ENGINEERING AND TECHNOLOGY

### DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

#### PROGRAM OUTCOMES

Engineering Graduates will have ability to:

- **PO1. Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of electrical and electronics engineering problems.
- **PO2. Problem analysis:** Identify, formulate, review research literature, and analyze complex electrical and electronics engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
- **PO3. Design/development of solutions:** Design solutions for complex electrical and electronics engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
- **PO4. Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
- **PO5. Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex electrical and electronics engineering activities with an understanding of the limitations.
- **PO6. The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional electrical and electronics engineering practice.
- **PO7. Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
- **PO.8 Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the electrical and electronics engineering practice.
- **PO9. Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
- **PO10. Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
- **PO11. Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
- **PO12. Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

#### PROGRAM SPECIFIC OUTCOMES

At the end of BE program Electrical and Electronics Engineering graduates will be able to:

- **PSO1.** Provide effective solutions in the fields of Power Electronics, Power Systems and Electrical Machines using MATLAB/MULTISIM.
- **PSO2.** Design and Develop various Electrical and Electronics Systems, particularly Renewable Energy Systems.
- **PSO3.** Demonstrate the overall knowledge and contribute for the betterment of the society.



Estd:2008

# METHODIST

## COLLEGE OF ENGINEERING AND TECHNOLOGY

### DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

#### I. PREREQUISITE(S):

Level	Credits	Semester	Prerequisites
UG	1	1	Power Electronics

#### II. SCHEME OF INSTRUCTIONS

Lectures	Tutorials	Practicals	Credits
0	0	2	1

#### III. SCHEME OF EVALUATION & GRADING

S. No	Component	Duration	Maximum Marks
	<b>Continuous Internal Evaluation (CIE)</b>		
1.	Internal Examination – I and II	1 hour each	25
	<b>CIE (Total)</b>		<b>25</b>
2.	<b>Semester End Examination</b> (University Examination)	3 hours	<b>50</b>
		<b>TOTAL</b>	<b>75</b>

% Marks Range	>=90	80 to < 90	70 to < 80	60 to < 70	50 to < 60	40 to < 50	< 40	Absent
Grade	S	A	B	C	D	E	F	Ab
Grade Point	10	9	8	7	6	5	0	-



Estd:2008

# METHODIST

## COLLEGE OF ENGINEERING AND TECHNOLOGY

### DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

#### COURSE OUTCOMES

After completing this course the student will be able to:

CO No.	Course Outcome	Taxonomy Level
C552.1	Classify and design different triggering circuits of SCR and MOSFET.	Create
C552.2	Analyze different commutation circuits of SCR	Analyze
C552.3	Explain and make use of controlled rectifiers to control the speed of DC motors	Apply
C552.4	Explain the applications of cyclo converters and AC voltage controllers	Apply
C552.5	Analyze Chopper circuits	Analyze
C552.6	Design and Simulate different power electronics circuits using MATLAB software	Create

#### MAPPING OF COs WITH POs & PSOs

Correlation Level: High – 3; Medium – 2; Low – 1

PO / CO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PS0 1	PSO 2	PSO 3
C552.1	3	3	3	-	-	-	-	3	3	3	-	-	2	2	3
C552.2	3	3	-	-	-	-	-	3	3	3	-	-	2	2	3
C552.3	3	2	-	-	-	-	-	3	3	3	-	-	2	2	3
C552.4	3	2	-	-	-	-	-	3	3	3	-	-	2	2	3
C552.5	3	3	1	-	-	-	-	3	3	3	-	-	2	2	3
C552.6	3	3	3	3	3	-	-	3	3	3	-	-	2	2	3
C552	3	2.6	2.3	3	3	-	-	3	3	3	-	-	2	2	3





Estd:2008

# METHODIST

## COLLEGE OF ENGINEERING AND TECHNOLOGY

### LABORATORY CODE OF CONDUCT

1. Students should report to the labs concerned as per the scheduled time table.
2. Students, who report late to the labs will not be permitted to perform the experiment scheduled for the day.
3. Students to bring a 100 pages note book to enter the readings /observations while performing the experiment.
4. After completion of the experiment, certification of the staff in-charge concerned, in the observation book is necessary.
5. Staff member in-charge shall evaluate for 25 marks, each experiment, based on continuous evaluation which will be entered in the continuous internal evaluation sheet.
6. The record of observations, along with the detailed procedure of the experiment performed in the immediate previous session should be submitted for certification by the staff member in-charge.
7. Not more than three students in a group would be permitted to perform the experiment on the equipment-based lab set up. However only one student is permitted per computer system for computer-based labs.
8. The group-wise division made at the start of the semester should be adhered to, and no mix up with any other group would be allowed.
9. The components required, pertaining to the experiment should be collected from the stores in-charge, after duly filling in the requisition form / log register.
10. After the completion of the experiment, students should disconnect the setup made by them, and return all the components / instruments taken for the purpose, in order.
11. Any damage of the equipment or burn-out of components will be charged at cost as a penalty or the total group of students would be dismissed from the lab for the semester/year.
12. Students should be present in the lab for the total time duration, as scheduled.
13. Students are required to prepare thoroughly, before coming to Laboratory to perform the experiment.
14. Procedure sheets / data sheets provided to the students, if any, should be maintained neatly and returned after the completion of the experiment.



Estd:2008

# METHODIST

## COLLEGE OF ENGINEERING AND TECHNOLOGY

### DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

#### DOS AND DON'TS IN THE LABORATORY

##### Dos

- All bags must be left at the indicated place.
- There must be at least two people in the laboratory while working on live circuits.
- Shoes and apron must be worn at all times.
- Consider all circuits to be "hot" unless proven otherwise.
- When making measurements, form the habit of using only one hand at a time.
- Be as neat as possible. Keep the work area and workbench clear of items not used in the experiment.
- Always check to see that the power switch is OFF before plugging into the outlet. Also, turn instrument or equipment OFF before unplugging from the outlet.
- When disassembling a circuit, first remove the source of power.
- The lab timetable must be followed strictly.
- Be PUNCTUAL for your laboratory session.
- Experiment must be completed within the given time.
- Noise must be kept to a minimum.
- Handle all apparatus with care.

##### Don'ts

- No part of a live circuit should be touched by the bare hand.
- No ungrounded electrical or electronic apparatus is to be used in the laboratory unless it is double insulated or battery operated.
- When unplugging a power cord, pull on the plug, not on the cable.
- Students are strictly PROHIBITED from taking out any items from the laboratory.

##### Before Leaving Lab:

- Place the stools under the lab bench.
- Turn off the power to all instruments.
- Return all the equipment to lab assistant.
- Turn off the main power switch to the lab bench.
- Please check the laboratory notice board regularly for updates.



Estd:2008

# METHODIST

## COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

### CONTENTS

<b>Sl. No.</b>	<b>Name of Experiment</b>
1	R, RC, UJT Trigger Circuits for SCR's.
2	Design of trigger circuits for single phase half - controlled and fully controlled bridge rectifiers
3	Study of SCR chopper
4	Study of forced commutation techniques of SCRs
5	Study of single-phase half and fully controlled rectifier
6	Study of single phase and three phase AC voltage controller
7	Study of single phase cycloconverter
8	Simulation of single-phase half and fully controlled rectifier
9	Simulation of single phase and three phase AC voltage controller
10	Simulation of single-phase inverter & three phase inverter
<b>Additional Experiments</b>	
11	V/f Control of AC drive
12	Simulation of single-phase cycloconverter
13	Simulation of MOSFET based chopper circuit

## Expt. No.1. R, RC, UJT Triggering Circuits for SCR's

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

**Apparatus:** R, RC & UJT firing module.

CRO, Load Rheostat

Digital Multi-meter

Patch chords

**Theory:**

### **R-Firing - Ref Fig 1**

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 while  $V_L$  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

$R_y$  will vary the firing angle

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

$R_b$  should be such that it causes minimum voltage drop across it.

For maximum supply voltage

$$R_{min} > V_{max} / I_{gm}$$

For voltage distribution

$$R_b \leq V_{gm} / (V_{max} - V_{gm})$$

### **RC- Firing – Ref Fig 2**

When  $V_s$  goes positive and the capacitor voltage  $V_C$  is equal to the gate triggering voltage  $V_{gt}$  ( $V_{gt} = V_{gmin} + V_{D1}$ ), 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.

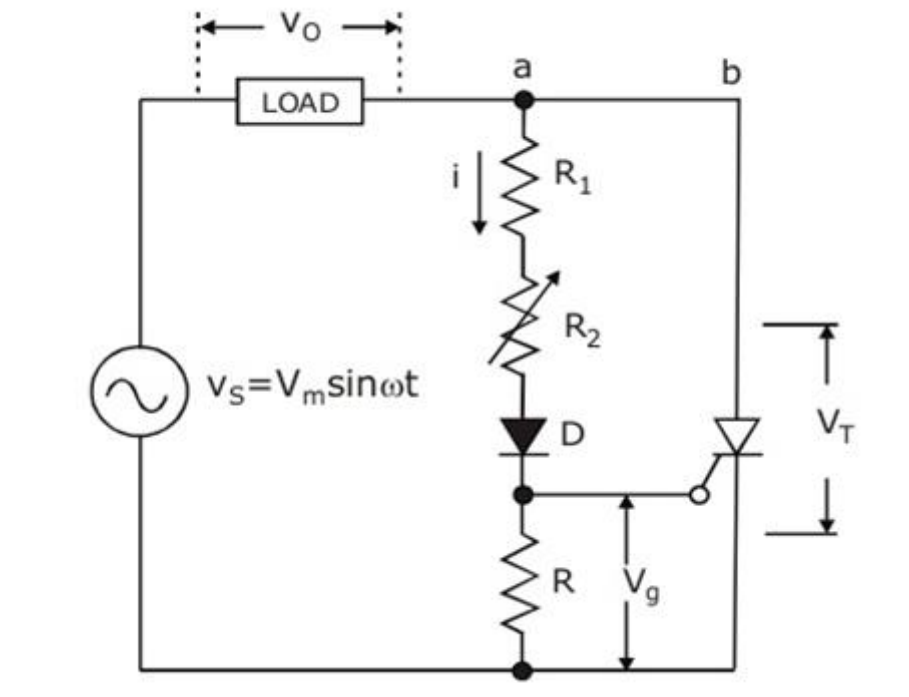
$$R_v C \geq 1.37/2 \text{ for Zero output voltage.}$$

$$R_v \leq (V_s - V_{gmin} - V_{D1}) / I_{gmin}$$

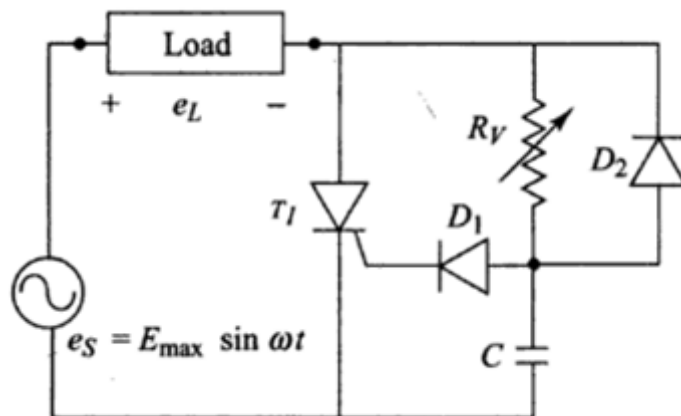
**UJT- Firing – Ref Fig 3**

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  $\eta V_Z$ , the Emitter-base<sub>1</sub> 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  $150^\circ$ . It can be used in Single phase controller, single phase half wave controlled converter, single phase controlled bridge rectifier, etc.

**Circuit Diagram:**



**Fig.1**



**Fig.2**

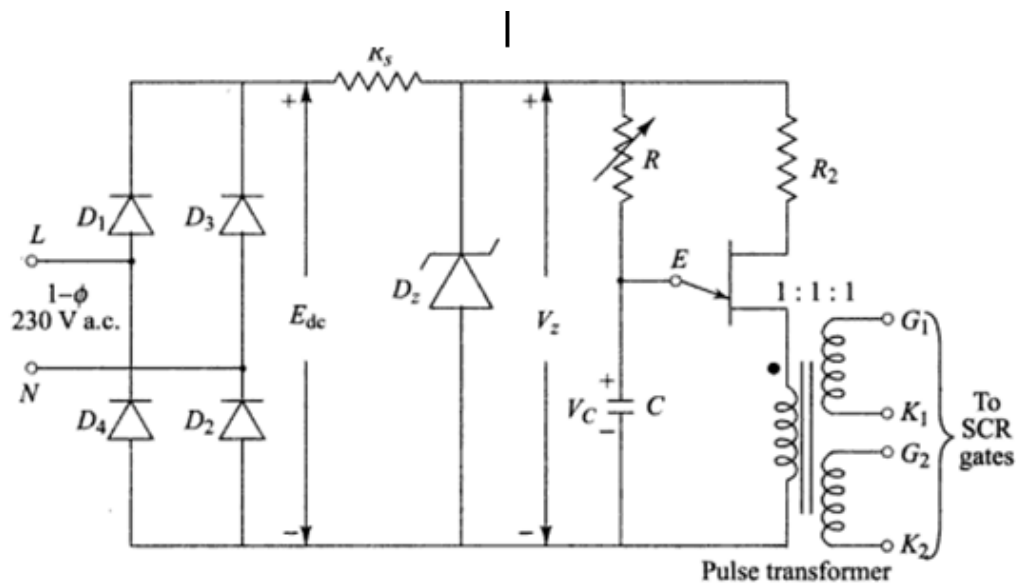


Fig.3

**Procedure:**

**R-Firing:**

1. Connect the input supply to the trainer module
2. Connect one end of the load rheostat to Ph terminal of 12V AC supply
3. Connect the other end of the load rheostat to SCR Anode terminal.
4. Connect the cathode (K) of SCR to the N terminal 12V AC supply
5. Connect A, K & G terminals of firing circuit to A, K & G of SCR respectively.
6. Connect CRO Probes across supply and across load rheostat.
7. Switch ON main supply to Kit and CRO and
8. Supply power to Kit by Power ON/OFF switch.
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 and compare with practical values.

$$V_{dc} = (\sqrt{2}V_s / 2\pi) (1 + \cos\alpha) = (V_m / 2\pi) (1 + \cos\alpha)$$

$$V_{rms} = (V_m/2) * \{ 1 - (\alpha/\pi) + [\sin(2\alpha)]/2 \}^{1/2}$$

**RC-Firing:**

1. Connect the input supply to the trainer module
2. Connect one end of the load rheostat to Ph terminal of 24V AC supply
3. Connect the other end of the load rheostat to SCR Anode terminal.
4. Connect the cathode (K) of SCR to the N terminal 24V AC supply
5. Connect A, K & G terminals of firing circuit to A, K & G of SCR respectively.
6. Connect CRO Probes across supply and across load rheostat.
7. Switch ON main supply to Kit and CRO and Supply power to Kit by Power ON/OFF switch.
8. Observe the waveform for input AC voltage & load voltage for different firing angles Plot the waveforms
9. Measure the DC voltage across the load & rms value of the input voltage using a multi-meter.
10. calculate the output voltage and compare the two values.

$$V_{dc} = (\sqrt{2}V_s / 2\pi) (1 + \cos\alpha) = (V_m / 2\pi) (1 + \cos\alpha)$$

$$V_{rms} = (V_m/2) * \{ 1 - (\alpha/\pi) + [\sin(2\alpha)]/2 \}^{1/2}$$

**UJT-Firing:**

1. Connect the input supply to the trainer module
2. Connect one end of the load rheostat to Ph terminal of 24V AC supply
3. Connect the other end of the load rheostat to SCR Anode terminal.
4. Connect the cathode (K) of SCR to the N terminal 24V AC supply
5. Connect supply terminals to rectifier circuit to convert AC to DC.
6. Connect the DC output of rectifier is give to the UJT trigger circuit at +,- terminals of triggering circuit.
7. Connect  $G_1$  &  $K_1$  terminals of UJT firing circuit to G & K 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 & Pulsating DC voltage
10. Observe the Zener diode voltage & capacitor voltage
11. Plot the waveforms
12. Repeat the experiment for various firing angles

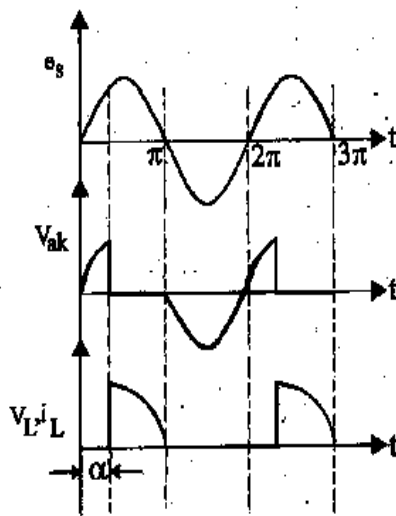
**Tabular Form:**

Sl.No	No. of divisions	Firing angle, $\alpha$	$V_o$ (practical in V)	$V_o = \frac{V_m}{2\pi}(1 + \cos\alpha)$ V
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				

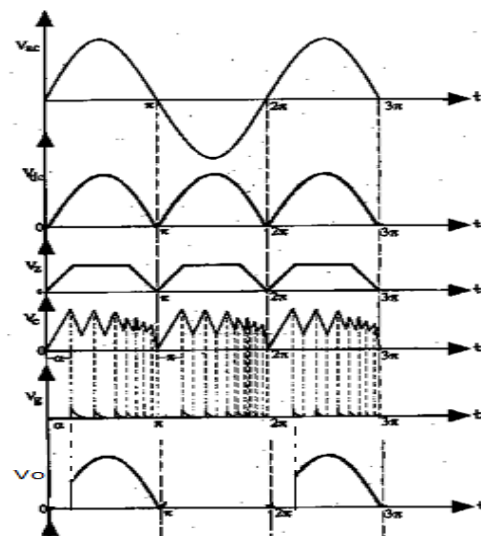
(Separate tabular column for each firing circuit)

Sample Calculations to be shown for each firing circuit

**Expected waveforms:**



**R & RC Firing**



**UJT Firing**

**Result:**

**Viva Questions:**

1. What is firing of a thyristor?
2. What is firing angle/delay angle?
3. What are the different turn on methods of SCR?
4. What is the firing angle range for a) R firing b) RC firing c) UJT firing
5. Why should the gate signal be removed after turn on?



## Expt No. 2. Design of trigger circuits for single-phase half-controlled and fully-controlled controlled bridge rectifiers

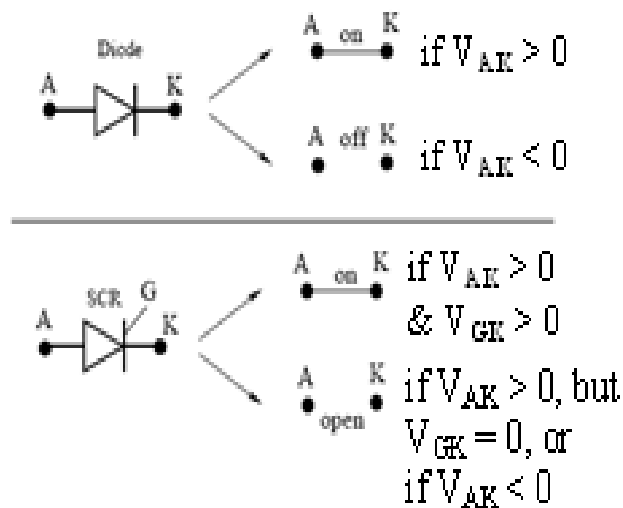
**Aim:** To study and design firing circuit parameters of single phase converter circuit.

### Theory:

Thyristors or Silicon Controlled Rectifiers (SCRs) are widely used as a switching device in the medium and large power levels starting from few kilowatts to several mega watts at voltage levels of few hundred to several kilovolt levels. Bipolar Junction Transistors (BJTs) and Metal Oxide Semiconductor Field Effect Transistors (MOSFETs) although have very fast switching characteristics compared to SCRs, their uses are limited to medium power levels at few hundred volts. Insulated Gate Bipolar Transistors (IGBTs) are switching devices which have positive points over the MOSFETs and thyristors. However, their higher cost and inability to work at very high voltages makes SCR a better choice even today, so far as line commutated converters are concerned.

### A. Thyristor & its conduction

A thyristor or SCR is a four layer device having three junctions J1, J2 and J3. Essentially three terminals named anode, cathode and gate are available as shown in Fig. 1(below) for external connections. Under the conditions a thyristor either conduct or not conduct, i.e., it allows current either to flow or not, is pictorially depicted in Fig. 1. A thyristor will be in reverse blocking mode if  $V_{AK} < 0$ , irrespective of the fact that a gate pulse is present or not. On the other hand the thyristor is said to be in the forward blocking mode, when  $V_{AK} > 0$  in absence of any gate pulse, some current will flow through the thyristor. In case of the thyristor is turning on either by exceeding the forward break-over voltage or by applying a gate pulse between gate and cathode, called forward conduction mode. Therefore if we want to use a SCR as a switching device, we must ensure that appropriate gate pulse is supplied between gate and cathode at desired instant of time.



**Fig.1 Symbols for Diode and Thyristor**

## B. Line Commutated Converters

Conversion of line frequency (50 Hz) a.c. to d.c. is carried out either by using a single phase bridge converter using four thyristors or 3-phase converter using six thyristors. A single phase fully controlled bridge with four thyristors is shown in Fig. 2. Appropriate pulses between the gates and cathodes of the thyristors T1 to T2 are to be supplied with a provision to vary the firing angle  $\alpha$ .

Fig. 2. Fully Controlled Converter with reference to the single phase converter circuit shown in Fig. 2, we note that when  $V_{AB} > 0$  or positive, two diagonally opposite thyristors T1 and T2 are forward biased and other two thyristors T3 and T4 are reversed biased. Therefore during intervals (i.e.  $0^\circ$  to  $180^\circ$ ) gate pulses are simultaneously applied to T1 and T2, both start conducting and load voltage  $V_L = V_{AB}$  and also T3 and T4 are reversed biased and cannot conduct at that period of time and vice versa (When T3 and T4 are switched on,  $V_L = V_{BA}$ ).

## C. Necessity of getting synchronizing pulses

Typical waveform of the supply voltage, gate pulses

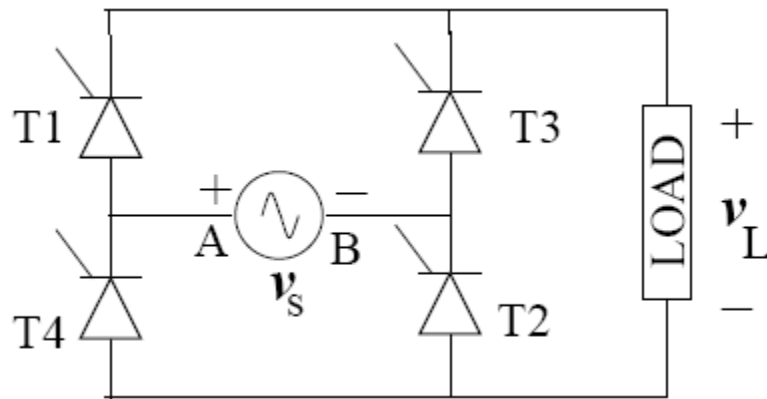
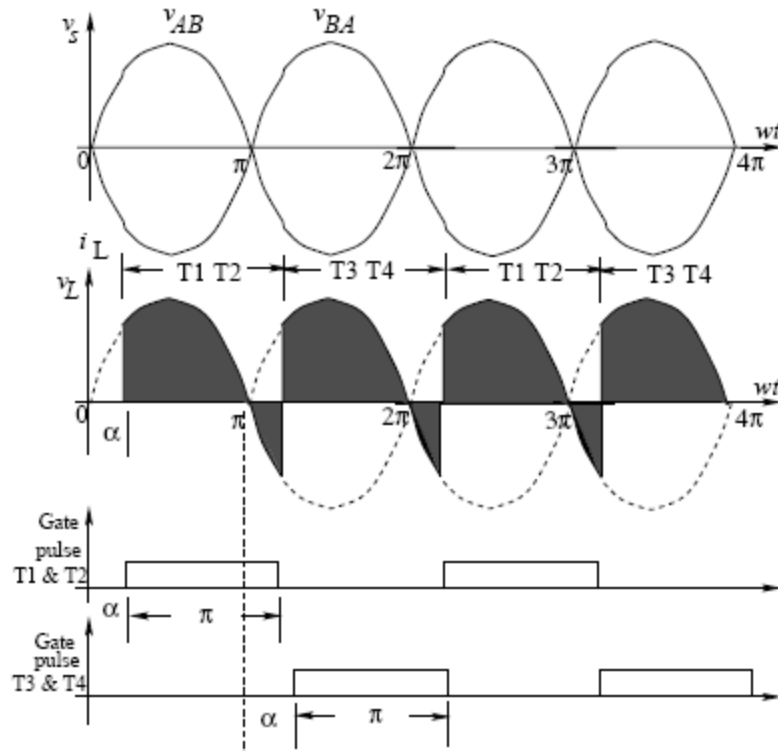


Fig. 2 Fully Controlled Converter

## D. Necessity of getting synchronizing pulses

Typical waveform of the supply voltage, gate pulses necessary are shown in Fig. 3. From the Fig. 3, it is quite clear how the firing angle  $\alpha$  is to be fixed and measured. For T1 and T2,  $\alpha$  is to be measured from the instant when  $V_{AB}$  is zero and going towards positive. Similarly T3 and T4,  $\alpha$  is to be measured from the instant  $V_{BA}$  is zero and going towards positive. Thus we see that for successful operation of the fully controlled bridge, the gate pulses to be properly synchronized with the a.c. power supply. It is noted that each thyristor conducts for  $180^\circ$  only.



**Fig. 3 Typical waveforms of a single phase converter**

### E. Expression for the output voltage

Assuming the rms value of the supply voltage to be  $V_s$ , the output voltage  $V_0$  can be obtained below. The output current has been assumed to be continuous which is true for most of the cases.  $\omega$  is the angular frequency of supply a.c. voltage.

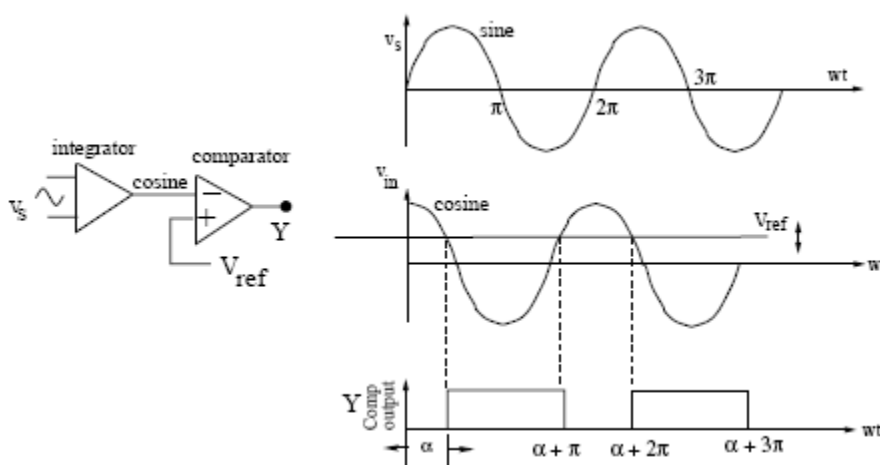
$$\begin{aligned}
 V_o &= \frac{1}{\pi} \int_{\alpha}^{\alpha+\pi} \sqrt{2}V_s \sin \omega t d(\omega t) \\
 &= \frac{2\sqrt{2}}{\pi} V_s \cos \alpha \\
 \therefore V_o &= 0.9 V_s \cos \alpha
 \end{aligned}$$

### F. Popular methods of generating firing pulses

1) Using ramp signal: In this scheme a ramp signal is generated in synchronism with the a.c. supply.  $V_s$  by using two comparators and an approximate ramp generator circuit using a transistor and capacitors as described in Fig. 4. The first comparator translates the input sinusoidal voltage into a square wave voltage. When the square wave voltage is high, the transistor (P-N-P type) collector-base junction is forward biased; the transistor is non-conducting stage (off) and the capacitor charges exponentially giving ramp rise of the voltage at the output. However, as soon as the square voltage is negative, transistor becomes on due to collector-base junction is reverse biased and the capacitor discharges sharply giving a saw tooth like waveform as shown in Fig. 4. This triangular voltage can now be compared by the

second comparator with a variable reference d.c. voltage ( $V_{ref}$ ) to get the firing pulse signal at Y. The value of  $\alpha$  can be varied in the range  $0^{\circ} \leq \alpha \leq 180^{\circ}$  by changing the value of the reference voltage ( $V_{ref}$ ).

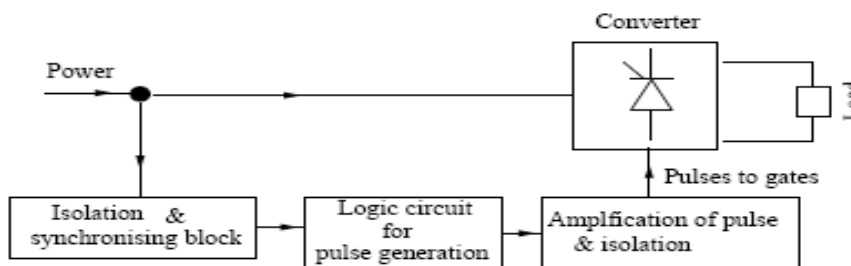
2) Using cosine control: In this interesting scheme, the supply voltage  $V_s$  is first integrated to obtain a cosine wave as shown in Fig. 5. The cosine wave so obtained is compared with a reference d.c. voltage ( $V_{ref}$ ). Therefore square pulses will be generated at the output terminal Y of the comparator. The signal at Y is synchronized with the pulse and is delayed from the supply zero crossing by an angle  $\alpha$ . obviously, the value of  $\alpha$  can be varied a range of  $0^{\circ} \leq \alpha \leq 180^{\circ}$ .



**Fig.4 Basic idea of ramp scheme**

**G. Basic building blocks**

Basic blocks which will be necessary to implement any firing control scheme in a converter circuit are shown in Fig.6. The figure demonstrates with the help of a single line diagram, the major blocks necessary to generate *firing* pulses for any scheme. The converter is organized from a.c. power. Since the firing pulses must be synchronized with the a.c. supply, a.c. power also goes to the *isolation and synchronizing* blocks. Isolation is essential as because the control circuit uses very low power devices such as various chips, logic gates etc. The logic circuit block uses few logic gates to implement a particular firing scheme. The strength of the pulse obtained from logic gates may not be sufficient to drive the gate of a thyristor, so amplification of the pulse along with isolation is used at final stage as shown Fig. 6.



**Fig. 6 Basic block of firing control circuit**

## II. BLOCK DIAGRAM REPRESENTATION OF COSINE CONTROL SCHEME

The emphasis of this experiment is the implementation of cosine control scheme. Let  $V_{ab}$  be the supply voltage feeding the converter for which the control pulses are to be generated. With the help of a step down centre tapped transformer,  $V_{ab}$  is transformed into two power level voltage  $V_{a0}$  and  $V_{b0}$ . For obvious reason  $V_{a0}$  and  $V_{b0}$  will be  $180^\circ$  out of phase as shown in Fig.7. Generating  $V_{a0}$  and  $V_{b0}$  T1 & T2 are to be fired when  $V_{a0}$  is positive and T3 & T4 are to be fired when  $V_{b0}$  is positive. For T1 & T2 the firing angle  $\alpha$  is to be measured from the instant when  $V_{a0}$  is zero and increasing in the positive direction. The range of variation of  $\alpha$  is  $0^\circ$  to  $180^\circ$ . Similarly for T3 & T4 the firing angle  $\alpha$  is to be measured from the instant when  $V_{b0}$  is zero and increasing in the positive direction. Basic idea for generating necessary pulses for T1 & T2 and T3 & T4 can be understood by referring figures 7, 8 and 9. With reference to Fig. 8 the signal  $V_{a0}$  is integrated with the help of Integrator -1 and a cosine wave will be obtained. This cosine wave is compared with a variable d.c. voltage  $V_r$  using a comparator-1.

Noting that  $V_r$  is connected to the +ve terminal of the comparator-1, the output of the comp-1 will be square wave and it goes to high state from the instant when  $V_r$  becomes greater than the cosine voltage value. However the width of the pulse will vary as  $V_r$  is varied. Our first aim will be to make the width of the pulse to be  $180^\circ$ . This is achieved in the following way. The output of the Comp-1 is fed to a block mono-1. Output of the mono will be a pulse of small width at positive going edge of the input square wave. The output of mono-1 will thus give small pulses separated by  $360^\circ$ .

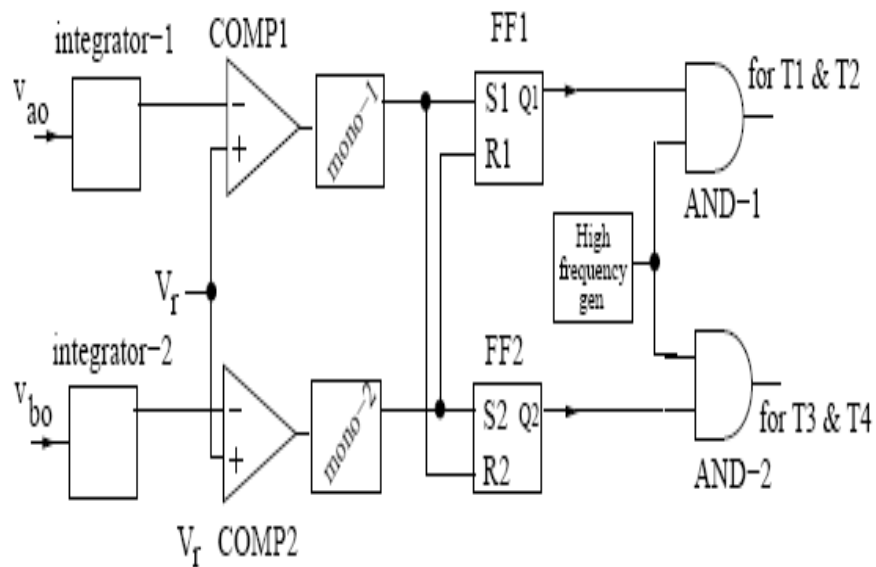
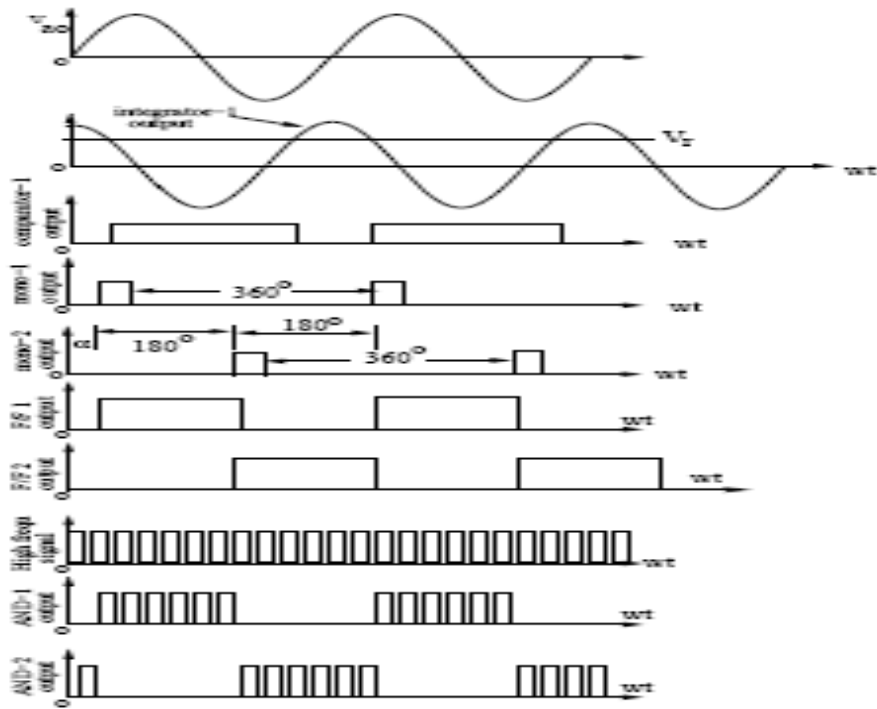


Fig. 8 Basic blocks for cosine control scheme



**Fig. 9 Waveforms at different points in the circuit of Fig.8**

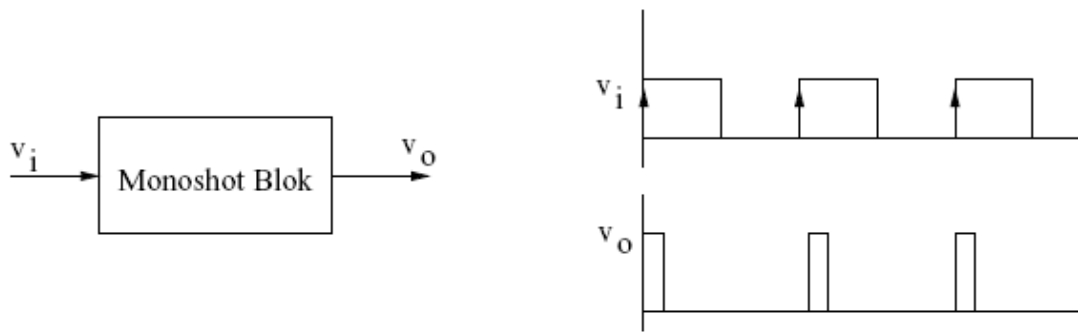
The voltage  $V_b$  is similarly processed, i.e., it is integrated then compared with the same variable d.c. with the help of comparator-2, output of COMP-2 will be a square wave and will be shifted by  $180^\circ$  from the output square wave of COMP-1. This is because of the fact that  $V_b$  lags  $V_a$  by  $180^\circ$ . The output of the COMP-2 is now fed to a block mono-2. Output of mono-2 will be a pulse of small width at positive going edge of the input square wave. The output of MONO-2 will thus give small pulses separated by  $360^\circ$ . This is important to know that the fixed width pulse waveforms at the output of mono-1 and mono-2 are shifted by  $180^\circ$  as shown in Fig. 9. The outputs of mono-1 and mono-2 can be used in conjunction with two S-R flip flops so as to generate two square waves each having a fixed width of  $180^\circ$  and mutually separated by  $180^\circ$ .

### III. DESCRIPTION OF THE EACH BLOCK

In this section detail of each block is discussed separately. The type of components used and their connections are also explained.

#### A. Input transformer to get $V_a$ and $V_b$

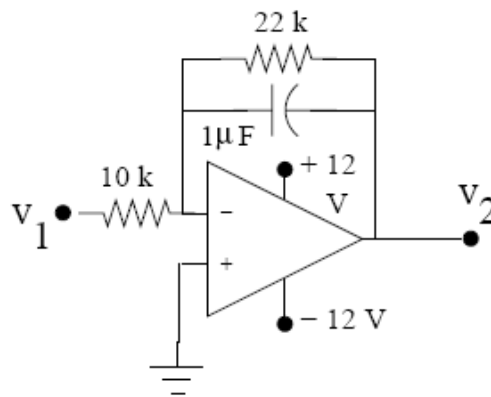
A 220/6-0-6 V 50 Hz control transformer is selected for the purpose of stepping down the 220 V supply to a level of 6-0-6 V with the help of the centre tapped secondary as shown in Fig. 10.



**Fig. 10 Input transformer for the control circuit**

**B. Integrator to get cosine wave**

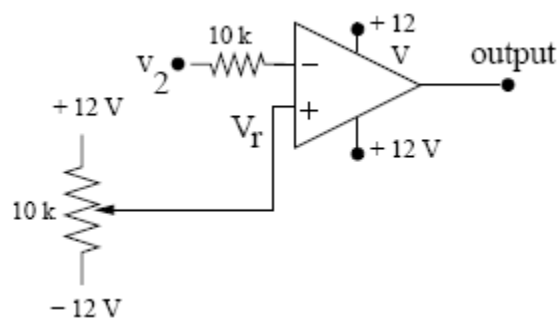
Popular IC 741 is used along with some resistor and capacitor to realize integrator function out of it. The values of different circuit parameters are shown in Fig. 11.  $\pm 12$  V d.c. supply required for the chip is obtained from a separate d.c. source. The ground point of the d.c. supply is connected to the common ground point zero (0) of the center tapped transformer. Signal V2 will be obtained as integration of small V1, i.e., for our purpose we will get small V2. Another identical integrator is used to integrate Vb0 as explained earlier.



**Fig. 11 Integrator using OP AMP 741**

**C. Comparator producing variable width pulse**

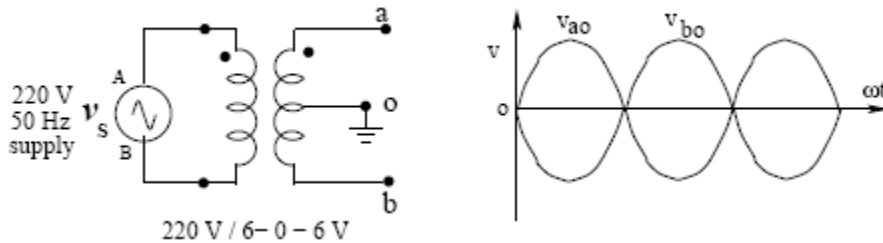
An OP AMP (741 IC) is used to realize the comparator block by inverting terminal IC 741, the variable d.c. voltage  $V_r$  is applied to the non inverting terminal or positive terminal, the cosine signal is obtained from the output of the integrator block as connected.  $V_r$  is fed from the output of a 10 K $\Omega$  variable resistor terminal. The input to the pot is the  $\pm 12$  V supply as shown in Fig 12.



**Fig. 12 Comparator using OP AMP IC 741**

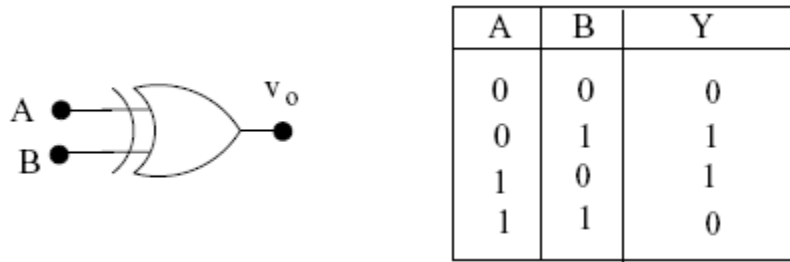
### D. Monoshot block using Exclusive OR Gate

A Monoshot block is supposed to produce thin pulses when the input rectangular input signal  $V_i$  changes state from 0 to 1 as shown in Fig. 13, a Monoshot block is shown with input signal  $V_i$  and with the desired output signal  $V_0$ .



**Fig. 13 Characteristics of a Monoshot**

The truth table and representation of Exclusive OR Gate is shown in Fig. 14. In Exclusive OR gate, the output is high or 1 when one of the inputs is high (1) or odd matching with the others and the output is low or 0 when both the inputs are same or even nature.



**Fig. 14 Exclusive OR Gate & its Truth Table**

### E. SR Flip flops to get $180^\circ$ width pulse

In the previous section we have seen that the variable width pulse obtain from the comparator output is converted into a train of thin pulses separated by  $360^\circ$  at the output of the Monoshot in Fig. 15.



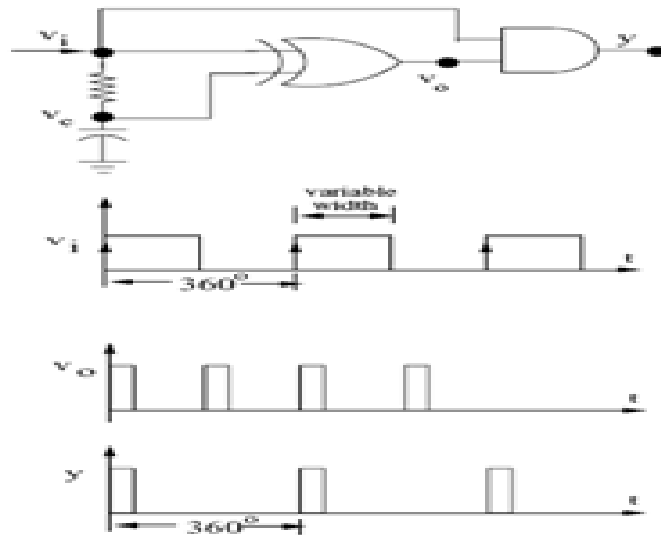


Fig. 15 Final circuit for Monoshot

#### F. ANDing the rectangular pulse with frequency using 555 timer

The rectangular voltage signals obtain from the flip flops 1 and 2 are complementary which means separated by  $180^\circ$  as desired. In our case where the supply frequency is 50 Hz, the time period of the signals will be 20 ms and for 10 ms it will remain high and for rest of the 10 ms it will be low. Outputs of the flip flops cannot however, be connected directly to between the gate and cathode of a thyristor, and because the output from a TTL (Transistor-Transistor-Logic) chip will not be able to supply the necessary current required by the gate circuit of a thyristor. Apart from this, we require isolation between the control circuit and power circuit. Therefore with the help of a transistor and a pulse transformer these two objectives of strengthening the pulse and providing the isolation are met. The idea is depicted in Fig. 16.

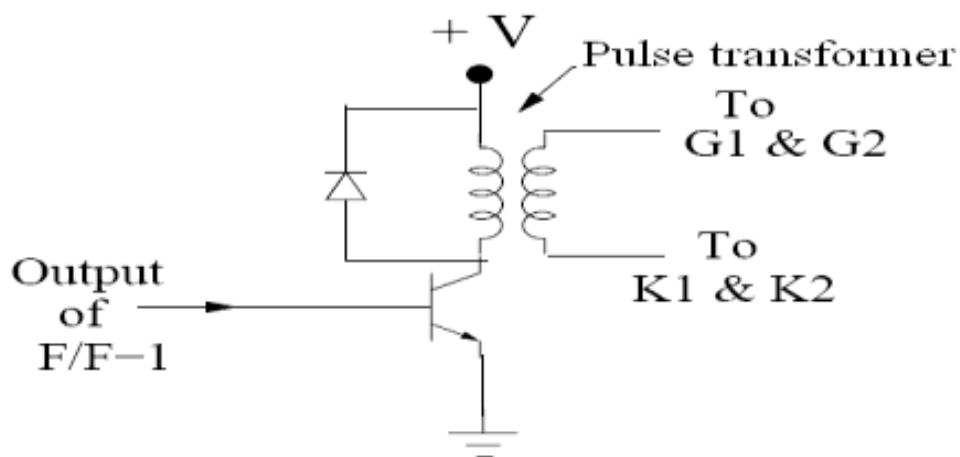


Fig. 16 Showing amplification & isolation circuit.



### Expt. No. 3. Study of Chopper

**Aim:** To study the working of chopper circuit and its time ratio controls (TRC).

**Apparatus:**

1. MOSFET based Buck Boost converter
2. DC regulated power supply 0-30V/2A
3. Rheostat
4. CRO
5. Connecting wires
6. Multimeter

**Theory:**

Chopper converts fixed DC voltage to variable DC voltage through the use of semiconductor devices. The DC to DC converters have gained popularity in modern industry. Some practical applications of DC to DC converter include armature voltage control of DC motors converting one DC voltage level to another level, and controlling DC power for wide variety of industrial processes. The time ratio controller (TRC) is a form of control for DC to DC conversion.

Time ratio controller (TRC) or chopper is basically a semiconductor switch as shown in fig. MOSFET is connected between the source and the load. The switch is closed and opened periodically such that the load is connected to, and disconnected from, the supply alternatively. Thus the average voltage impressed on the load is controlled by controlling the ratio of ON state interval to one cycle duration.

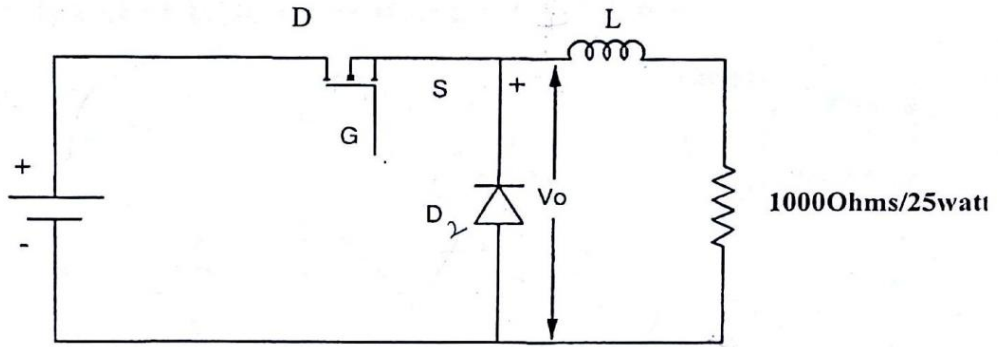
The most important factor that governs the performance of the chopper is the duty ratio. The duty ratio can be controlled by changing the on period duration by keeping frequency constant. Changing the frequency of the chopper introduces different harmonics at different frequencies. At some frequency of operation the harmonic contents are larger than the tolerable limits. Therefore fixed frequency choppers with a variable on period technique are generally used. Two types of choppers can be constructed using a MOSFET. One is step-up chopper and other one is step-down chopper.

**MOSFET Step-down Chopper (Forward/Buck Converter):** A Chopper is a high speed on/off semiconductor switch. It connects source to load and disconnects the load from source at a fast speed. A step-down chopper using MOSFET is shown in fig.1. During  $T_{ON}$  chopper is ON and load voltage is equal to source voltage  $V_s$ . During the interval  $T_{off}$ , chopper is off, load current flows through freewheeling diode FD and load voltage is zero during  $T_{off}$ . In this manner chopper load voltage is produced at the load terminals.

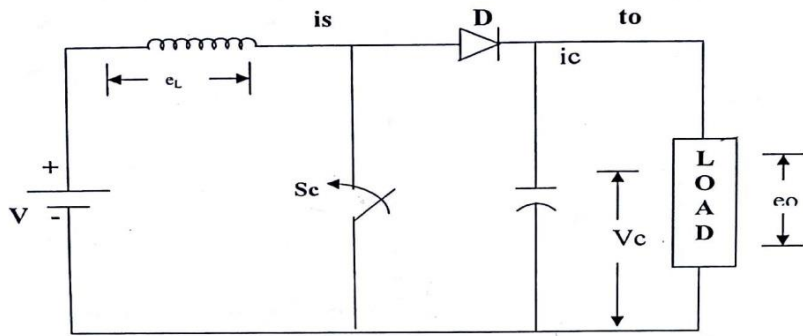
**MOSFET Step-up Chopper (Flyback/Boost Converter):** A step-up chopper using MOSFET is shown in fig.2. The chopper is connected in parallel with the load. When the chopper CH is on, inductor stores energy due to closed circuit path. When the chopper CH is off, as the inductor current cannot die down instantaneously, this current forced to flow through the diode and load for a time  $T_{off}$ . As current tends to decrease, polarity of the emf induced in L is reversed. As a result voltage across the load, given by  $V_0 = V_s + L \cdot (di/dt)$ , exceeds the source voltage  $V_s$ . In this manner, the circuit acts as a step-up chopper and the energy stored in L is released to the load.

**Circuit Diagram:**

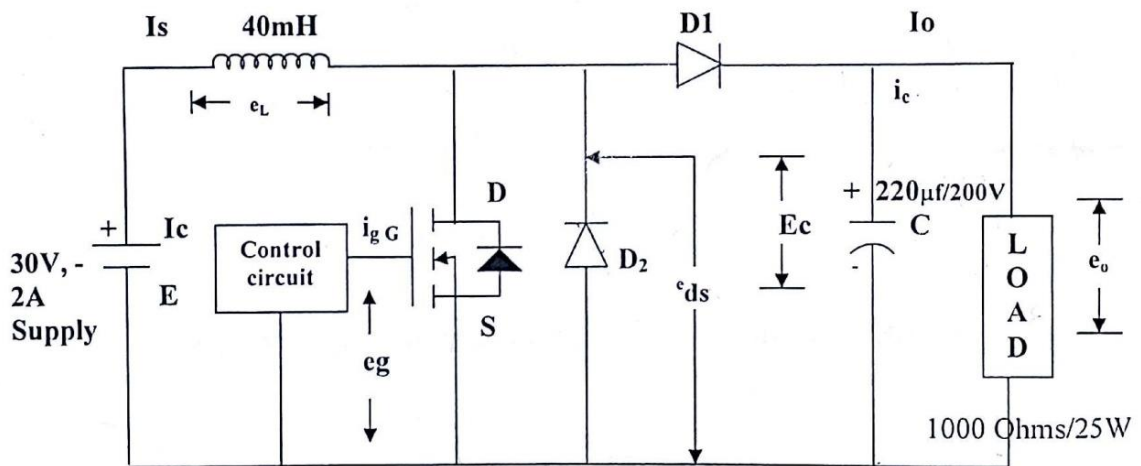
**BUCK CHOPPER:**



**BOOST CHOPPER:**



**Fig. 1**



**Fig. 2 Experimental Circuit**

**Procedure:**

**Buck chopper:**

- 1) Switch on the mains by the control circuit and observe the output by varying the frequency duty cycle, potentiometer.
- 2) Make the BUCK converter power circuit as shown in figure.
- 3) Then Connect the Driver OUTPUT to Gate of POEWR MOSFET as shown in figure. Connect R-Load of 25W Resistor provided in the circuit.
- 4) Connect DC input from regulated power supply (0-30V/2A) to input terminal. Apply small voltage (**10volts**).
- 5) Check all the connections and confirm connections made are correct before switching on the equipment.
- 6) Apply driver output pulses to the POWER MOSFET and observe the waveform by varying frequency and duty cycle.
- 7) Increase the input Voltage to rated voltage (30V) and observe the voltage waveform across LOAD and the MOSFET by varying frequency and duty cycle.
- 8) Output voltage and Current can be measured using DC Voltmeter or digital multimeter across Load points and DC Ammeter or digital multimeter in series with load points.
- 9) Bring the duty cycle and frequency to minimum, switch off driver circuit outputs, switch off DC power supply and finally switch off mains supply to the unit. Remove connections.

**Boost Chopper:**

- 1) Then connect the driver output to Gate and source of POWER MOSFET.
- 2) Make the BOOST converter power circuit as shown in figure.
- 3) Check all the connections and confirm connections made are correct before switching on the equipment.
- 4) Connect DC input from regulated power supply (0-30V/2A) to input terminal. Apply small voltage (**10 volts**). Connect R-load of 25 W resistor provided in the unit.
- 5) Switch ON the input switch in series with DC input.
- 6) Apply driver output pulses to the POWER MOSFET and observe the waveform at different points like across Load, Inductor, Capacitor and device with R-Load and observe the effect of change in T<sub>ON</sub> and T<sub>OFF</sub> periods of the power MOSFET (at particular frequency) by varying the duty cycle potentiometer.
- 7) Note down the voltage waveform across Load, Power MOSFET and across Inductor.
- 8) Change the frequency and repeat the experiment.
- 9) Bring the duty cycle and frequency to minimum, switch off DC power supply and finally switch off mains supply to the unit. Remove connections.

**Tabular Form:**

**Buck chopper:**

Frequency, f =-----Hz

Sl.No	V <sub>DC</sub> (Volts)	V <sub>L</sub> (Volts)	T <sub>ON</sub> (msec)	T <sub>OFF</sub> (msec)	DUTY cycle %
1.					
2.					
3.					
4.					
5.					
6.					
7.					

$$DUTY Cycle = \frac{T_{ON}}{T_{ON} + T_{OFF}} \times 100 \qquad V_o = V_s \times D. Cycle$$

**Boost chopper:**

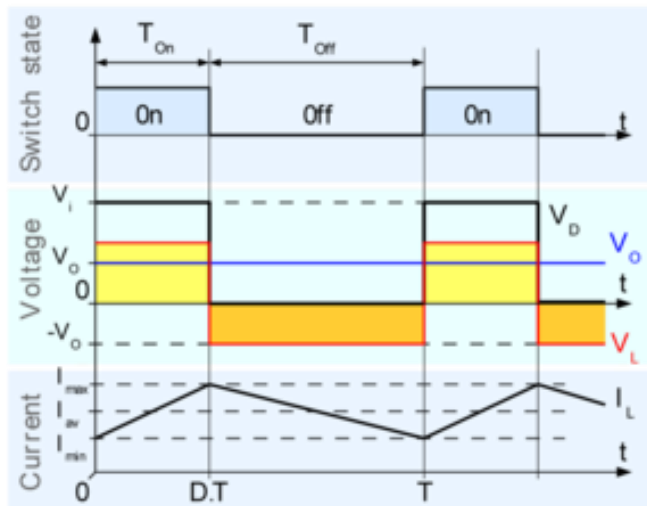
Frequency, f=-----Hz

Sl. No	V <sub>DC</sub> (Volts)	V <sub>L</sub> (Volts)	T <sub>ON</sub> (msec)	T <sub>OFF</sub> (msec)	DUTY cycle %
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					

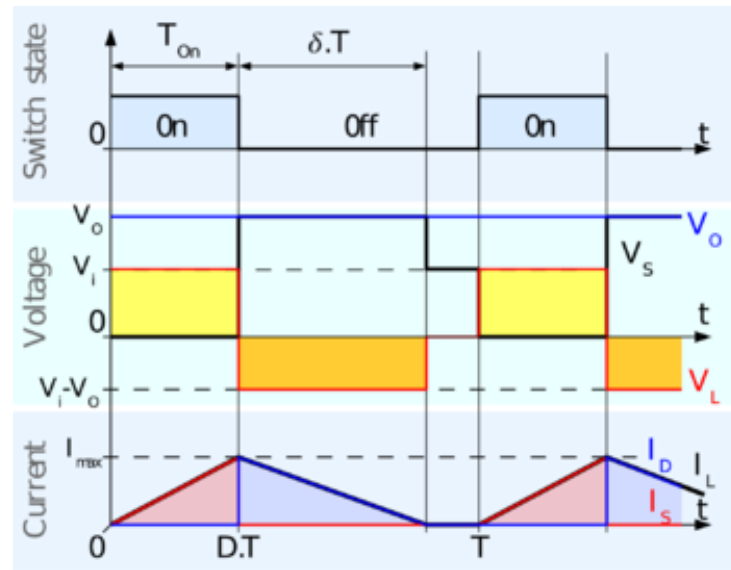
$$DUTY\ Cycle = \frac{T_{ON}}{T_{ON} + T_{OFF}} \times 100 \qquad V_o = \frac{V_s}{1 - D.Cycle}$$

**Expected Waveforms:**

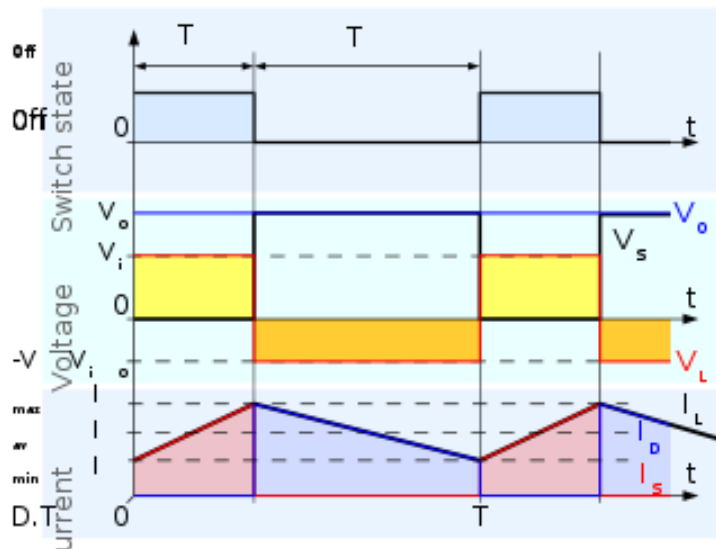
**BUCK (Step down) chopper:**



**BOOST (Step up) chopper with discontinuous mode:**



**BOOST (Step up) chopper with continuous mode:**



**Result:**

**Viva Questions:**

1. What is meant by DC chopper?
2. What do you mean by buck and boost chopper?
3. What is the difference between SCR chopper and dc-dc regulators?
4. Draw the circuit diagram of a current commutated chopper?
5. Design a voltage commutated chopper with the following specifications.
6. What is PWM technique in chopper?

## Expt. No. 4. Study of Forced Commutation techniques of SCR

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

**Apparatus:** Thyristor commutation trainer module,

Load rheostat,

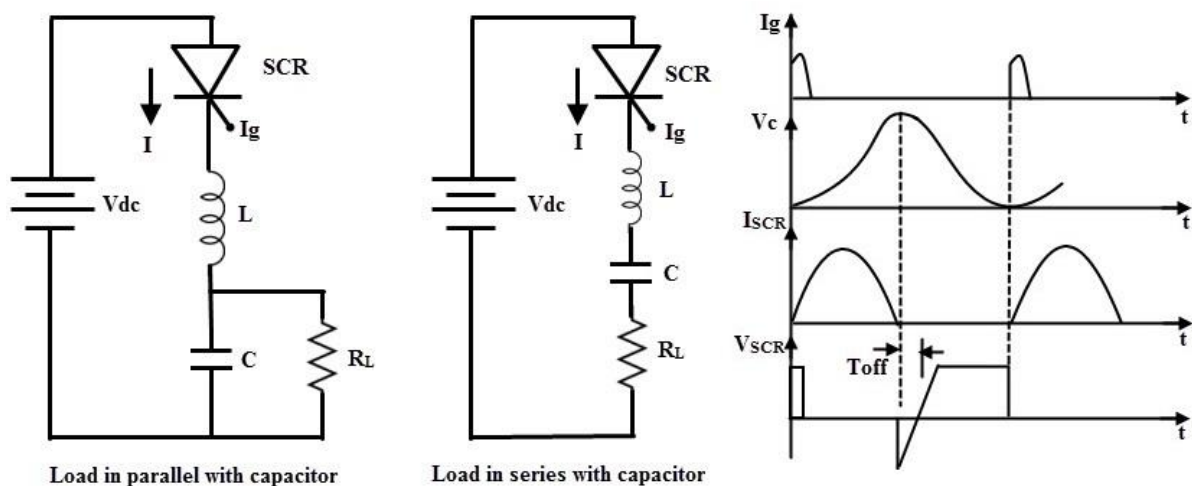
CRO & Patch chords

### Theory:

#### **Class A Commutation**

This is also known as self commutation, or resonant commutation, or load commutation. In this commutation, the source of commutation voltage is in the load. This load must be an under damped R-L-C supplied with a DC supply so that natural zero is obtained.

The commutating components L and C are connected either parallel or series with the load resistance R as shown in Fig. 1 with waveforms of SCR current, voltage and capacitor voltage.



**Fig. 1**

The value of load resistance and commutating components are so selected that they form an under damped resonant circuit to produce natural zero. When the thyristor or SCR is triggered, the forward current starts flowing through it and during this the capacitor is charged up to the value of  $E$ .

Once the capacitor is fully charged (more than the supply source voltage) the SCR becomes reverse biased and hence the commutation of the device. The capacitor discharges through the load resistance to make ready the circuit for the next cycle of operation. The time for switching OFF the SCR depends on the resonant frequency which, further depends on the L and C components.

This method is simple and reliable. For high frequency operation which is in the range above 1000 Hz, this type of commutation circuit is preferred due to the high values of L and C components.



### Class B Commutation

This is also a self-commutation circuit in which, commutation of SCR is achieved automatically by L and C components, once the SCR is turned ON. In this, the LC resonant circuit is connected across the SCR but not in series with load as in case of class A commutation and hence the L and C components do not carry the load current.

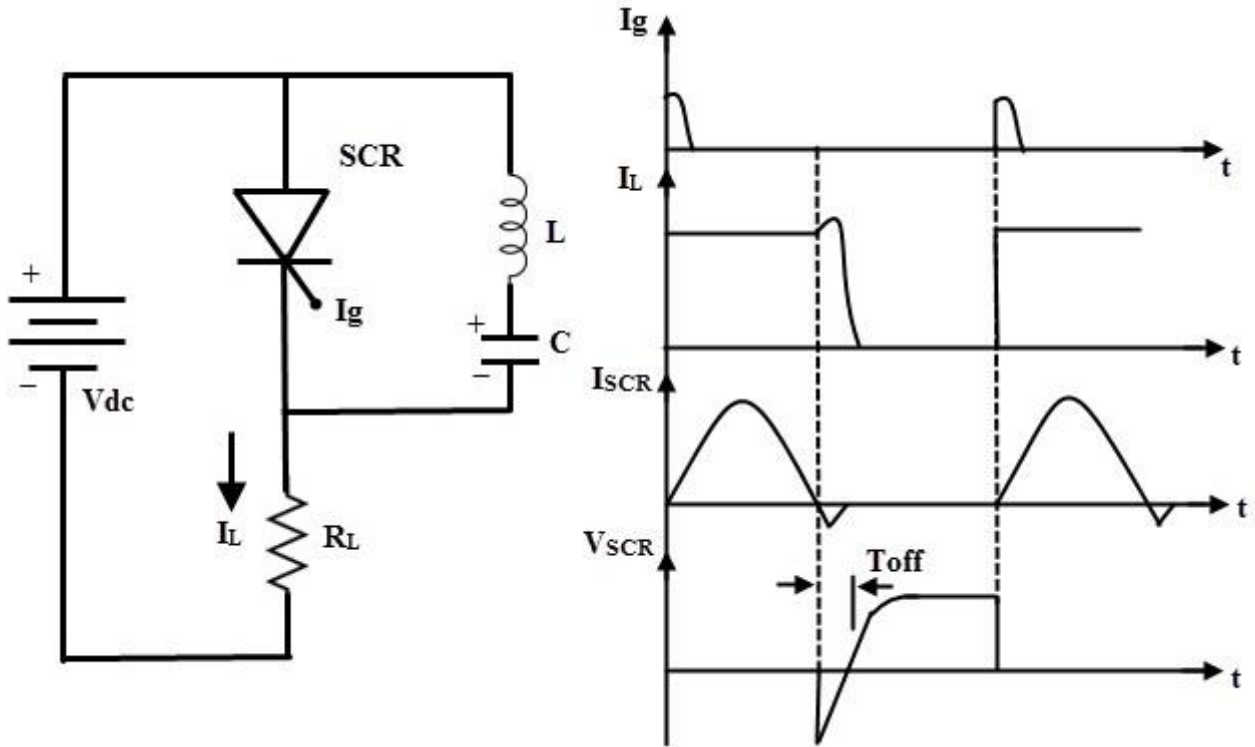


Fig.2

When the DC supply is applied to the circuit, the capacitor charges with an upper plate positive and lower plate negative up to the supply voltage  $E$ . When the SCR is triggered, the current flows in two directions, one is through  $E+ - SCR - R - E-$  and another one is the commutating current through L and C components.

Once the SCR is turned ON, the capacitor starts discharging through  $C+ - L - T - C-$ . When the capacitor is fully discharged, it starts charging with a reverse polarity. Hence, a reverse voltage applied across the SCR which causes the commutating current  $I_C$  to oppose load current  $I_L$ .

When the commutating current  $I_C$  is higher than the load current, the SCR will automatically turn OFF and the capacitor charges with original polarity.

In the above process, the SCR is turned ON for some time and then automatically turned OFF for some time. This is a continuous process and the desired frequency of ON/OFF depends on the values of L and C. This type of commutation is mostly used in chopper circuits.

### Class C Commutation

In this commutation method, the main SCR is to be commutated is connected in series with the load and an additional or complementary SCR is connected in parallel with main SCR. This method is also called as complementary commutation.

In this, SCR turns OFF with a reverse voltage of a charged capacitor. The figure below shows the complementary commutation with appropriate waveforms.

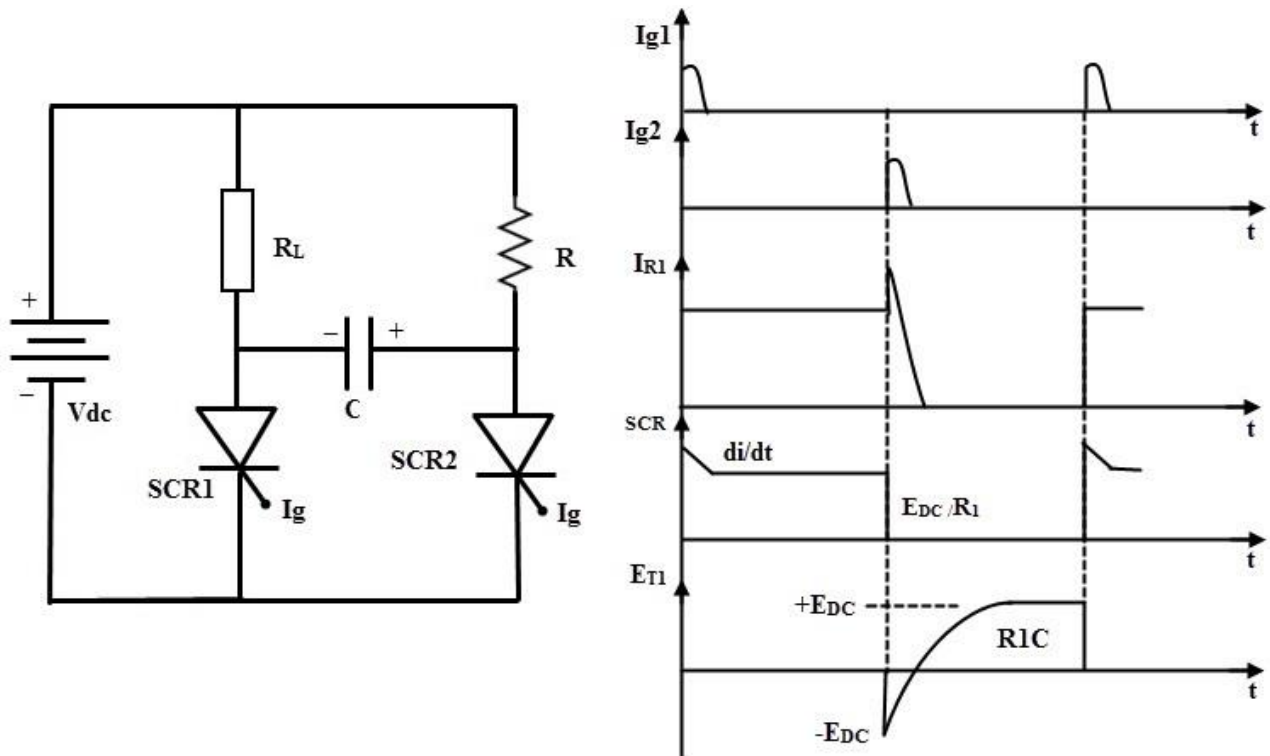


Fig. 3

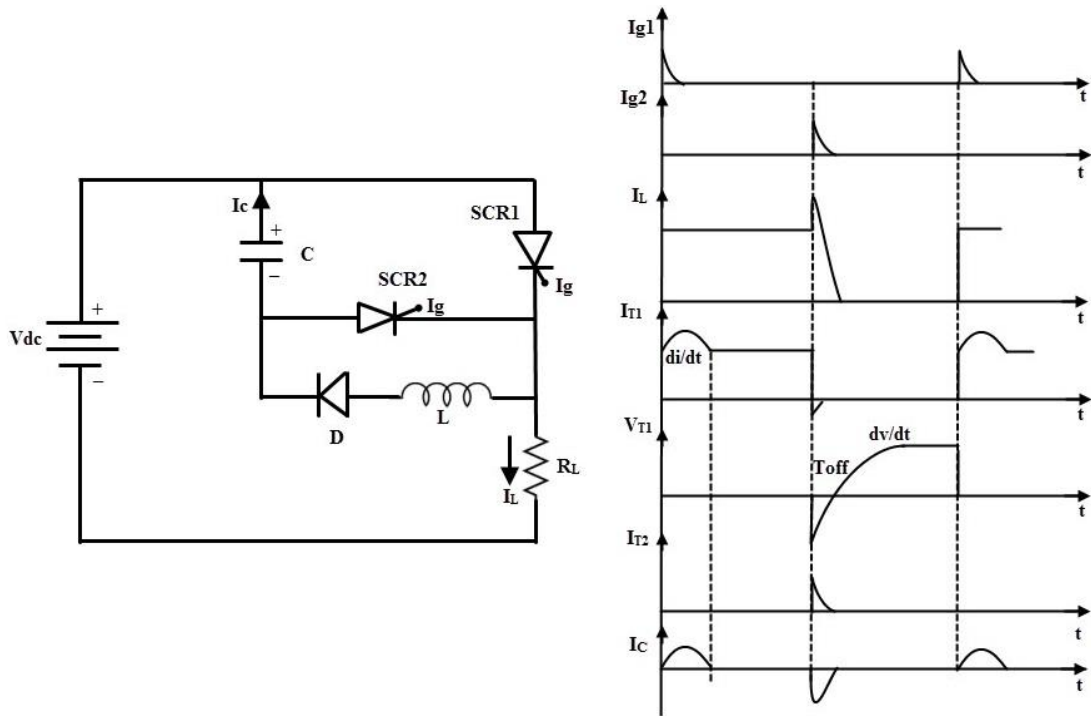
Initially, both SCRs are in OFF state so the capacitor voltage is also zero. When the SCR1 or main SCR is triggered, current starts flowing in two directions, one path is  $E+ - R1 - SCR1 - E-$  and another path is the charging current  $E+ - R2 - C+ - C- - SCR1 - E-$ . Therefore, the capacitor starts charging up to the value of  $E$ .

When the SCR2 is triggered, SCR is turned ON and simultaneously a negative polarity is applied across the SCR1. So this reverse voltage across the SCR1 immediately causes to turn OFF the SCR1. Now the capacitor starts charging with a reverse polarity through the path of  $E+ - R1 - C+ - C- - SCR2 - E-$ . Similarly, if the SCR 1 is triggered, discharging current of the capacitor turns OFF the SCR2.

This commutation is mainly used in single phase inverters with a centre tapped transformers. The Mc Murray Bedford inverter is the best example of this commutation circuit. This is a very reliable method of commutation and it is also useful even at frequencies below 1000Hz.

### Class D Commutation

This is also called as auxiliary commutation because it uses an auxiliary SCR to switch the charged capacitor. In this, the main SCR is commutated by the auxiliary SCR. The main SCR with load resistance forms the power circuit while the diode D, inductor L and SCR2 forms the commutation circuit.



**Fig. 4**

When the supply voltage  $E$  is applied, both SCRs are in OFF state and hence the capacitor voltage is zero. In order to charge the capacitor, SCR2 must be triggered first. So the capacitor charges through the path  $E+ - C+ - C- - SCR2 - R - E-$ .

When the capacitor is fully charged the SCR2 becomes turned OFF because no current flow through the SCR2 when capacitor is charged fully. If the SCR1 is triggered, the current flows in two directions; one is the load current path  $E+ - SCR1 - R - E-$  and another one is commutation current path  $C+ - SCR1 - L - D - C-$ .

As soon as the capacitor completely discharges, its polarities will be reversed but due to the presence of diode the reverse discharge is not possible. When the SCR2 is triggered capacitor starts discharging through  $C+ - SCR2 - SCR1 - C-$ . When this discharging current is more than the load current the SCR1 becomes turned OFF.

Again, the capacitor starts charging through the SCR2 to a supply voltage  $E$  and then the SCR2 is turned OFF. Therefore, both SCRs are turned OFF and the above cyclic process is repeated. This commutation method is mainly used in inverters and used in the Jones chopper circuit.

### **Class E Commutation**

This is also known as external pulse commutation. In this, an external pulse source is used to produce the reverse voltage across the SCR. The circuit below shows the class E commutation circuit which uses a pulse transformer to produce the commutating pulse and is designed with tight coupling between the primary and secondary with a small air gap.

If the SCR need to be commutated, pulse duration equal to the turn OFF time of the SCR is applied. When the SCR is triggered, load current flows through the pulse transformer. If the pulse is applied to the primary of the pulse transformer, an emf or voltage is induced in the secondary of the pulse transformer.

This induced voltage is applied across the SCR as a reverse polarity and hence the SCR is turned OFF. The capacitor offers a very low or zero impedance to the high frequency pulse.

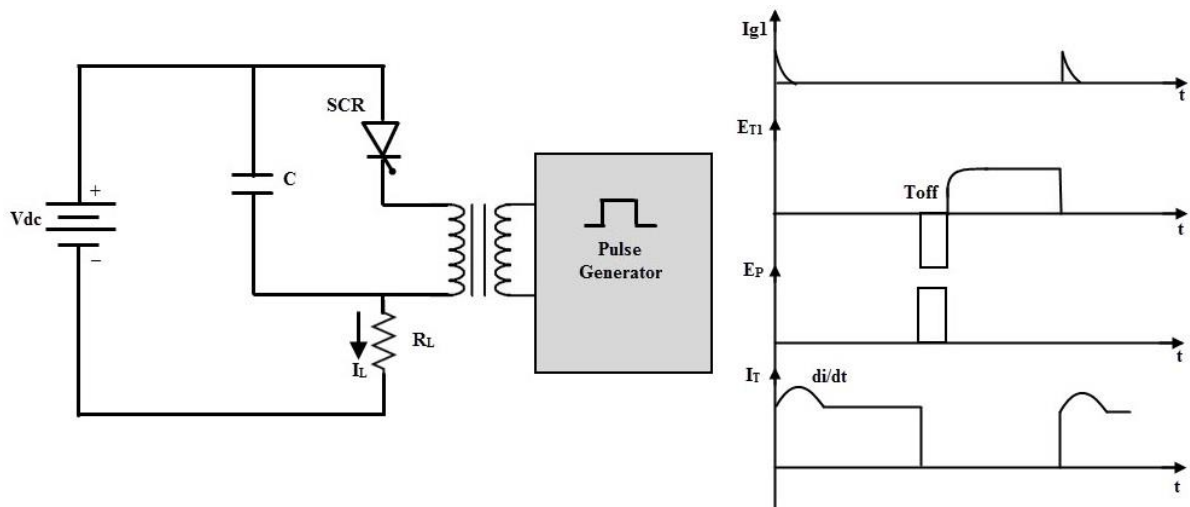
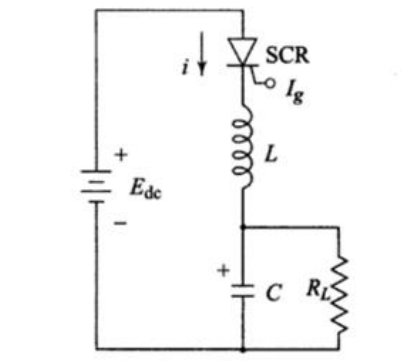


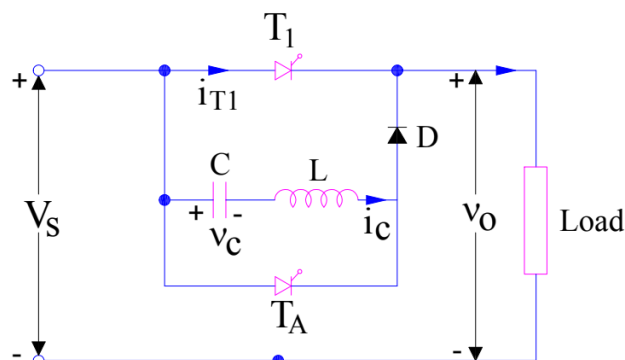
Fig. 5

**Circuit Diagram:**

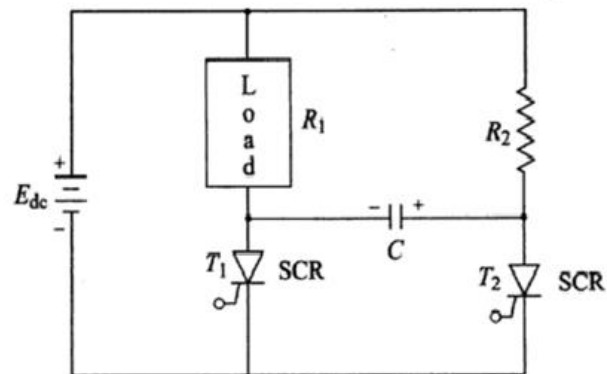
**Class A commutation circuit:**



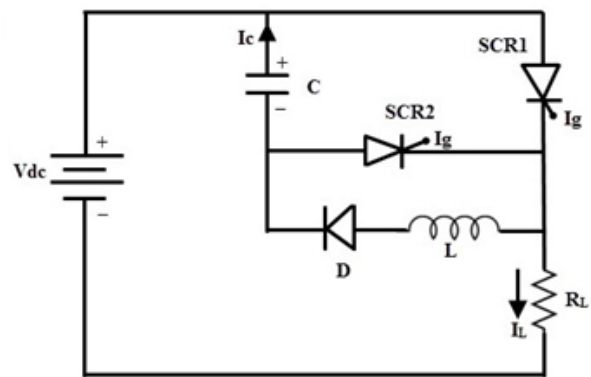
**Class B commutation circuit:**



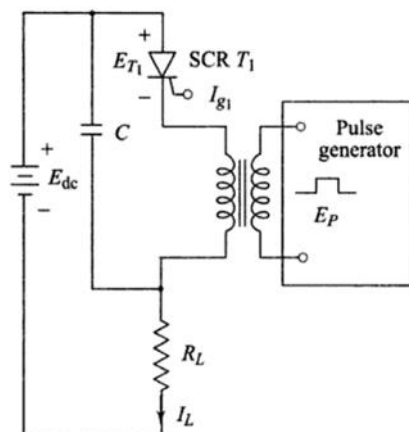
Class C commutation circuit:



Class D commutation circuit:



Class E commutation circuit:



**Procedure:**

**CLASS A:**

Connect circuit as shown in diagram on commutation kit.

Connect gate connections to SCR G, K terminals from triggering terminals G<sub>1</sub>, K<sub>1</sub> of triggering circuit.

Connect +15V DC regulated power Supply commutation kit.

Connect CRO probe across the load resistor R.

Switch on the trainer kit ON/OFF switch, 15V DC Supply, and triggering circuit.

Slowly vary the frequency knob and observe the waveforms & Plot them

**CLASS B:**

Connect circuit as shown in diagram on commutation kit.

Connect gate connections to main SCR T<sub>1</sub>, G, K terminals and auxiliary SCR TA, G, K terminals from triggering terminals G<sub>1</sub>, K<sub>1</sub> and G<sub>2</sub>, K<sub>2</sub> respectively of triggering circuit.

Connect CRO probe across the resistor R<sub>L</sub>.

Connect +15V DC regulated power Supply commutation kit.

Connect CRO probe across the load resistor R.

Switch on the trainer kit ON/OFF switch, 15V DC Supply, and triggering circuit.

Fix the frequency knob at certain value, vary the duty cycle knob gradually, and observe the waveforms & Plot them.

**CLASS C:**

Connect circuit as shown in diagram on commutation kit.

Connect gate connections to main SCR T<sub>1</sub>, G, K terminals and auxiliary SCR TA, G, K terminals from triggering terminals G<sub>1</sub>, K<sub>1</sub> and G<sub>2</sub>, K<sub>2</sub> respectively of triggering circuit.

Connect CRO probe across the resistor R<sub>L</sub>.

Connect +15V DC regulated power Supply commutation kit.

Connect CRO probe across the load resistors, capacitor C.

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 gradually, and observe the waveforms & Plot them

**CLASS D:**

Connect circuit as shown in diagram on commutation kit.

Connect gate connections to main SCR T1, G, K terminals and auxiliary SCR TA, G,K terminals from triggering terminals G<sub>1</sub>, K1 and G<sub>2</sub>,K2 respectively of triggering circuit .

Connect CRO probe across the load resistor R.

Switch on the trainer kit ON/OFF switch, 15V DC Supply, and triggering circuit.

Fix the frequency knob at certain value, vary the duty cycle knob gradually, and observe the waveforms & Plot them

**CLASS E:**

Connect circuit as shown in diagram on commutation kit.

Connect gate connections to SCR G, K terminals from triggering terminals G<sub>1</sub>, K1 of triggering circuit.

External pulse connection is given as shown in diagram by using pulse transformer.

Connect CRO probe across the resistor R<sub>L</sub>.

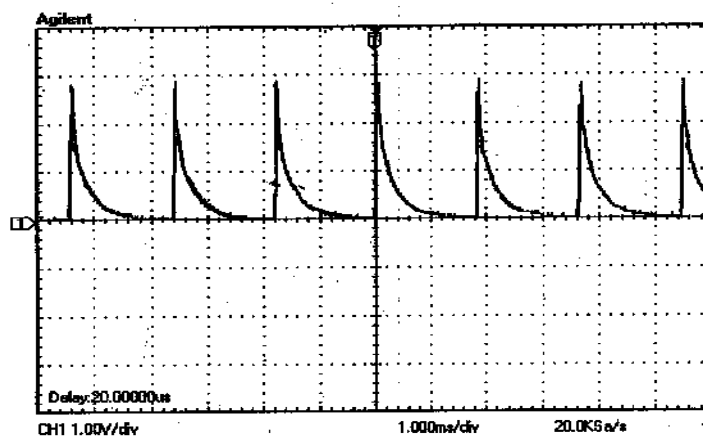
Connect +15V DC regulated power Supply commutation kit.

Switch on the trainer kit ON/OFF switch, 15V DC Supply, and triggering circuit.

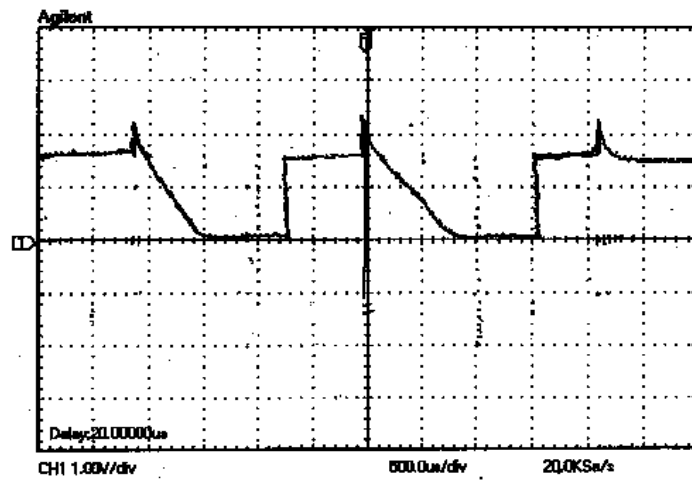
Fix the frequency knob at certain value, vary the duty cycle knob gradually, and observe the waveforms & Plot them.

**Expected waveforms:**

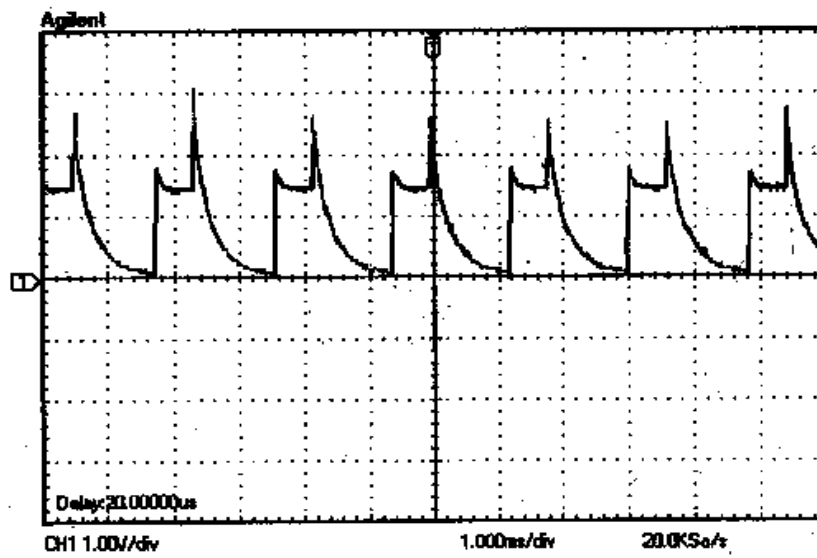
**iv. Output waveform of Class A Commutation**



## Output waveforms of class B commutation

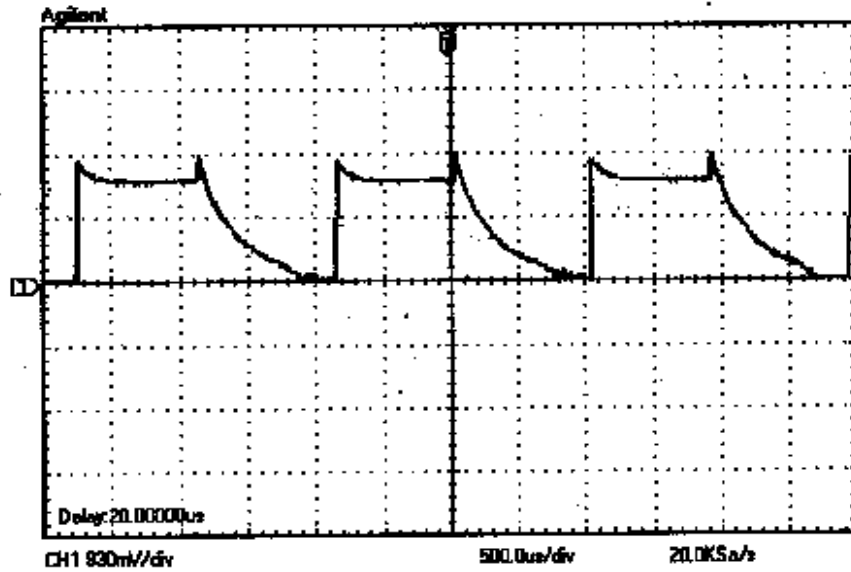


## Output waveforms of class C commutation

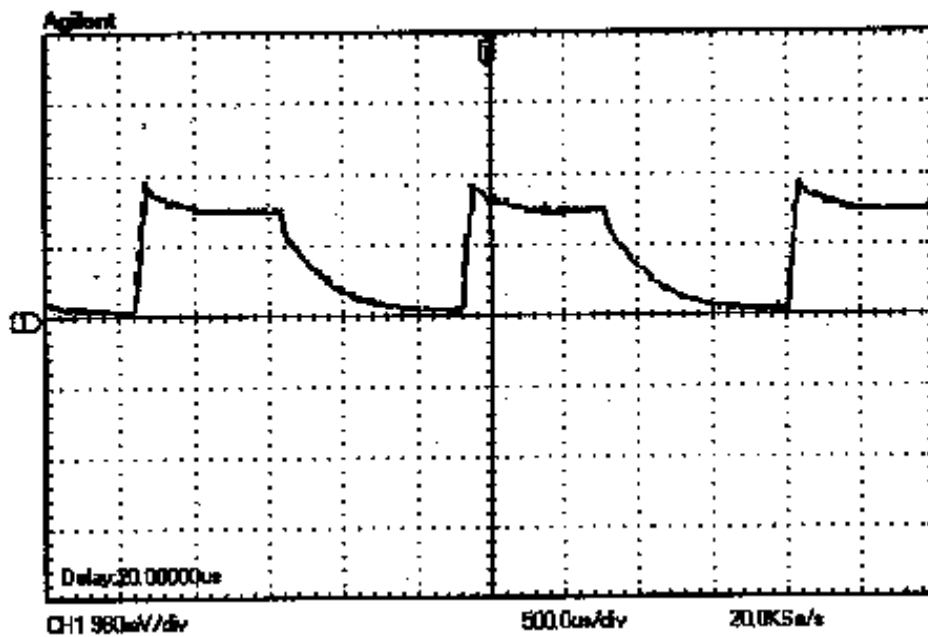




vii. Output waveform of Class D Commutation



viii. Output waveform of Class E Commutation



Result:

Viva Questions:

1. What is commutation?
2. What is the need for commutation of SCR?
3. Explain natural, forced commutation. Give examples.
4. What are the two conditions for turn off of SCR?
5. Differentiate between voltage commutation and current commutation?

## Expt. No.5. Study of Single Phase Half & Fully Controlled Rectifier

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

**Apparatus:** Single Phase bridge rectifier Module

Single Phase Triggering Module

Multimeter, Load Rheostat

CRO, Isolation Transformer

Patch chords

### Theory:

#### Single phase half-controlled rectifier with RL load:

Fig. 1 shows two alternative arrangements of 2-pulse half-controlled bridge converters with inductive load. The various voltage and current waveforms for both symmetric and asymmetric configurations are shown in Fig.2. Consider the symmetrical circuit configuration. As shown in Fig.1(a), thyristor T1 and diode D1 are turned-on at a firing angle  $\alpha$  in each positive half-cycle. From this instant  $\alpha$ , supply voltage appears across output terminals AB, through thyristor T1 and diode D1. Current flows through the path L-T1-A-L-R-B-D1-N. Here, the filter inductance  $L$  is assumed to be sufficiently large as to produce continuous load current. This current  $I_d$  is taken to be constant. Hence during positive half-cycle, thyristor T1 and diode D1 conducts.

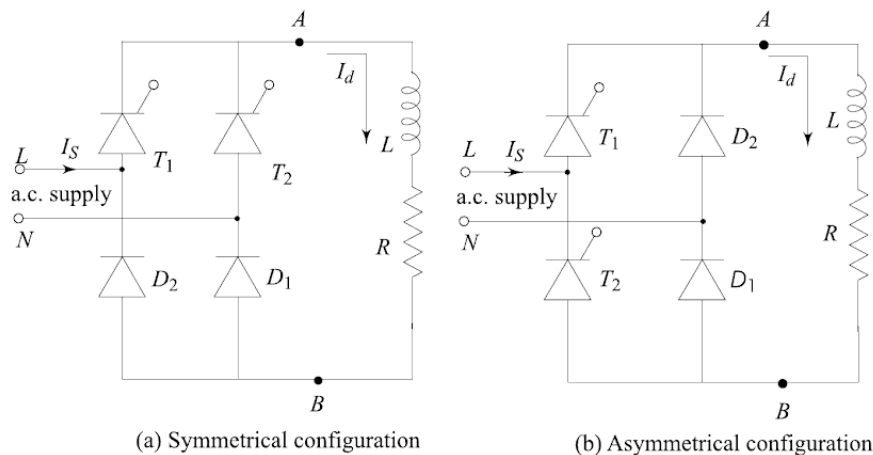


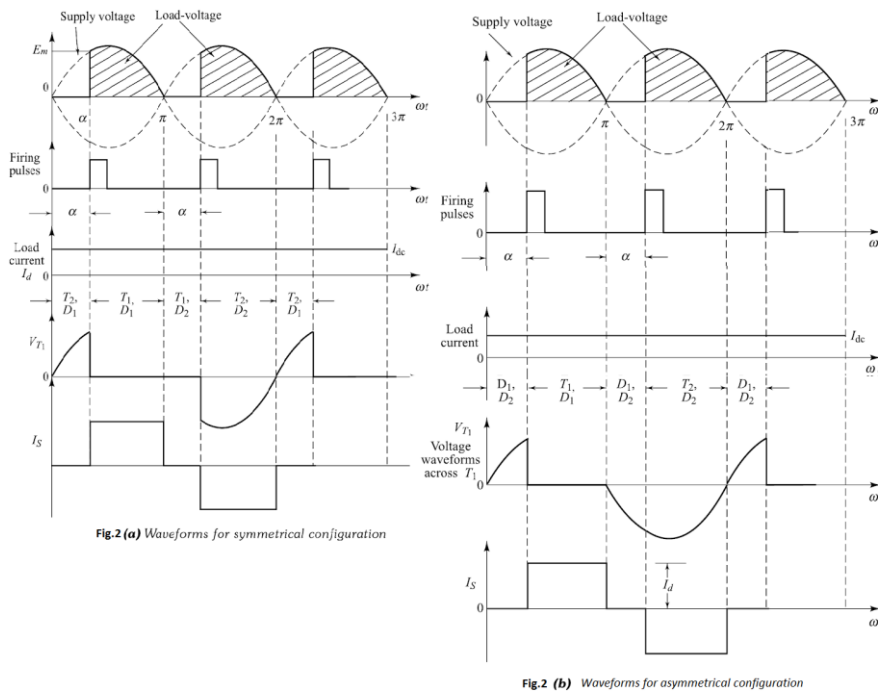
Fig.1

Now, when the supply voltage reverses at  $\omega t = \pi$ , the diode D2 is forward-biased since diode D1 is already conducting. The diode D2 then turns ON, and the load current passes through D2 and T1. The supply voltage reverse-biases D1 and turns it off. The load-current freewheels through the path R-B-D2-T1-A-L during the interval from  $\pi$  to  $(\pi + \alpha)$  in each supply-cycle.

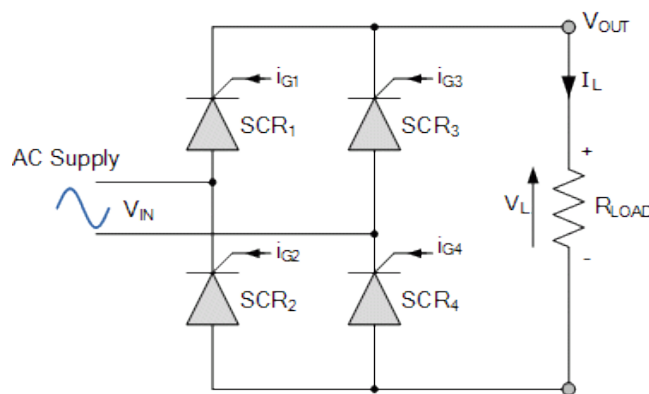
During the negative half-cycle, at the instant  $(\pi + \alpha)$ , a triggering-pulse is applied to the forward-biased thyristor T2. Thyristor T2 is turned ON. As thyristor T2 is turned ON, the supply voltage reverse-biases T1 and then turns it OFF by the line commutation. Therefore, the load-current flows through T2 and D2, the above-cycle repeats and the waveforms obtained are as shown in Fig.2(a), which are similar to that of fully-controlled converter with a freewheeling diode. Here, we have seen that the conduction period of thyristors and diodes are equal, therefore this circuit is called as the symmetrical configuration.

Now consider the circuit of Fig.1(b). During the positive half-cycle of the a.c. supply, thyristor T1 and diode D1 are forward-biased. As shown in Fig.1(b), thyristor T1 is turned ON at firing angle  $\alpha$ . Current flows through the path L-T1-A-L-R-B-D1-N. Hence, T1 and D1 conduct from  $\alpha$  to  $\pi$ . Similarly, T2 and D2 conduct from  $(\pi+\alpha)$  to  $2\pi$  in each negative half-cycle of the a.c. supply. The freewheeling action is provided by diodes D1 and D2 from 0 to  $\alpha$  and from  $\pi$  to  $(\pi+\alpha)$  in each supply cycle. In this converter configuration, the conduction periods of thyristors and diodes are unequal. Hence this circuit configuration is known as the asymmetrical configuration.

The thyristor conducts for a longer interval in the symmetrical circuit configuration. Therefore, the thyristors used in this circuit must have a higher average current-rating compared to those in the asymmetrical-circuit configuration.



**Single phase fully-controlled rectifier with R load:**



**Fig. 3**

Single phase fully controlled converters are obtained by replacing the diodes of an uncontrolled converter with thyristors. It is one of the most popular converter circuits and is widely used in the speed control of separately excited dc machines.

In a fully controlled converter the output voltage can be controlled by controlling the firing delay angle ( $\alpha$ ) of the thyristors. Thyristors T1 and T2 are fired together while T3 and T4 are fired 180° after T1 and T2. Depending on the load condition and the firing angle, a fully controlled bridge converter can operate either in the continuous conduction mode or in the discontinuous conduction mode.

In the continuous conduction mode, the load voltage depends only on the firing angle and not on load parameters. In the discontinuous conduction mode, the output voltage decreases with increasing load current. However, the output voltage is always greater than that in the continuous conduction mode for the same firing angle.

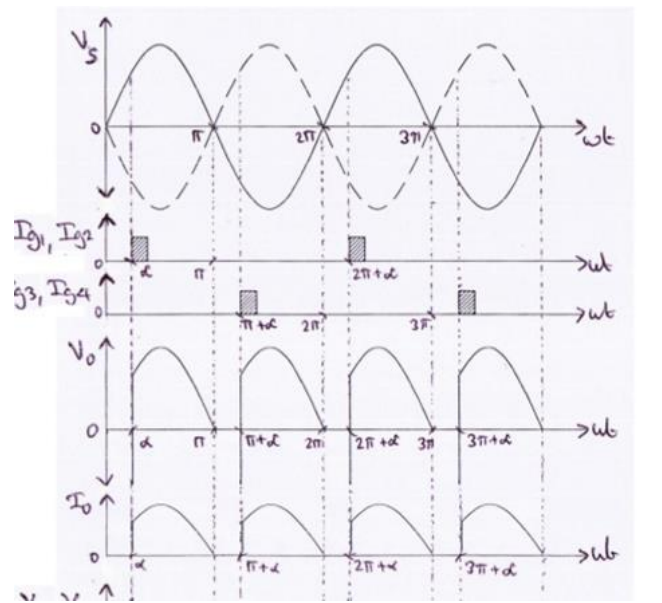
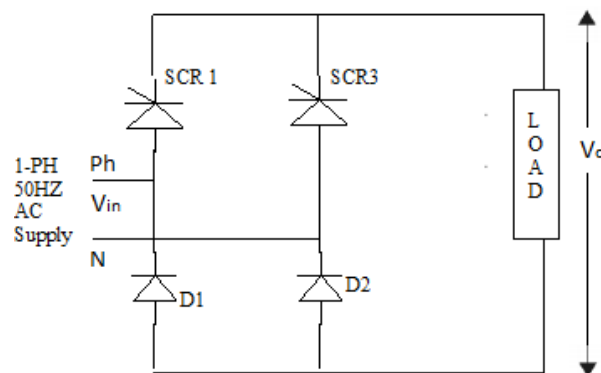


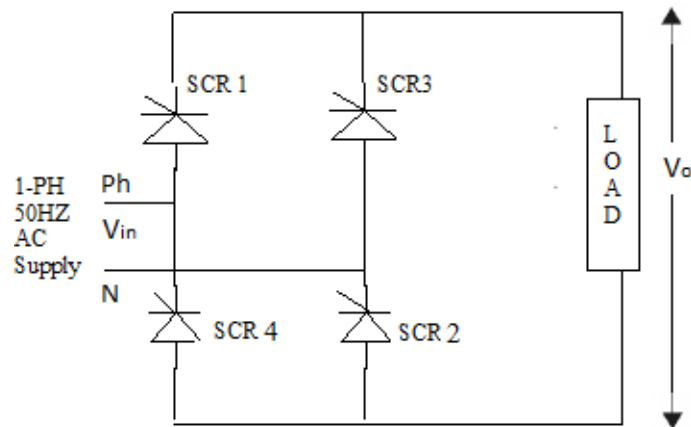
Fig. 4

**Circuit Diagram:**

**Half-Controlled Bridge Rectifier**



## Full-Controlled Bridge Rectifier



### Procedure:

- Make the connections as per the circuit diagram
- Connect the supply across the line and neutral terminal of the device module
- Connect the firing pulse from single phase firing circuit into single phase triggering module in a sequence G-G and K-K
- Connect the cathode terminal  $K_1-K_3$  of SCR<sub>1</sub> and SCR<sub>3</sub>
- Connect the anode terminals  $A_2-A_4$  of SCR<sub>2</sub> and SCR<sub>4</sub>
- Connect resistance terminal to  $A_2$ -and  $K_3$
- Connect the voltmeter and CRO across the load terminals
- Switch ON the single Phase triggering module and AC supply to rectifier Kit
- Adjust the firing angle by changing firing angle knob position.
- Tabulate the voltage and plot the graph for R load and RL load.

### Tabular Form:

#### Half-Controlled Rectifier

S.No	Firing angle, $\alpha$	$V_o$ (practical in V)	$V_o = \frac{V_m}{\pi}(1 + \cos\alpha)$ V
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			

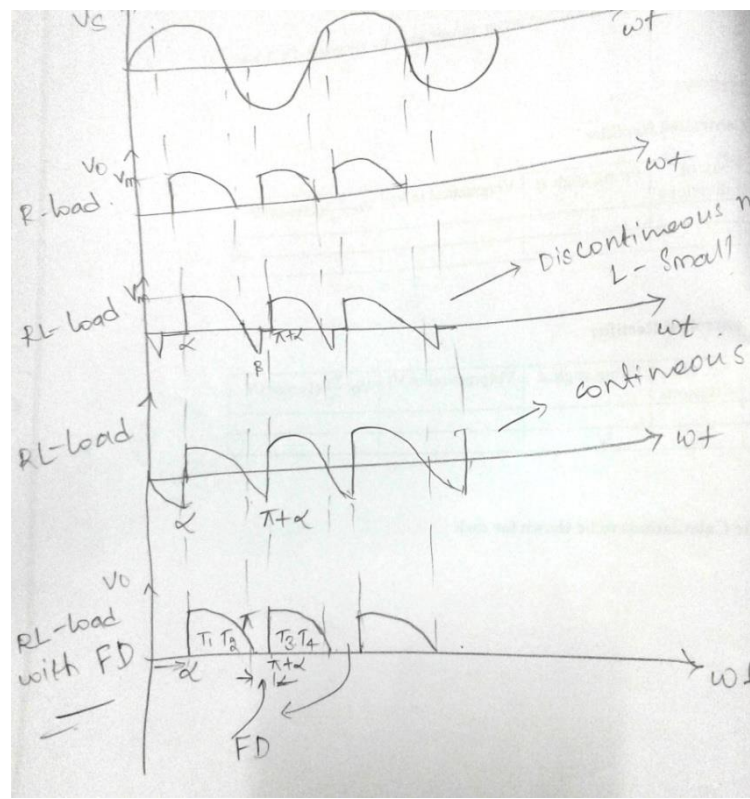
## Full-Controlled Rectifier

S.No	Firing angle, $\alpha$	$V_o$ (practical in V)	$V_o = \frac{2V_m}{\pi} \cos \alpha$ V
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			

Sample Calculations to be shown for each

### Expected waveforms:

#### Half Controlled Bridge Rectifier and Full Controlled Bridge Rectifier



### Result:

### Viva Questions:

1. Explain the basic purpose of a rectifier
2. What are the different types of rectifiers
3. Differentiate between HCR and FCR
4. Differentiate between HWR and FWR
5. Give some applications of rectifiers.

## Expt. No. 6. Study of Single Phase AC Voltage Controller

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

**Apparatus:** Trainer Kit

CRO, 24 V (or) 30V AC supply, load rheostat, inductance load

Patch chords

### **Theory:**

A single phase full wave ac voltage controller with a resistive load is shown in the figure below. It is possible to control the ac power flow to the load in both the half cycles by adjusting the trigger angle.

Hence, the full wave ac voltage controller is also referred to as to a bidirectional controller.

### **OPERATION**

#### **Mode-1- From 0 to $\pi$**

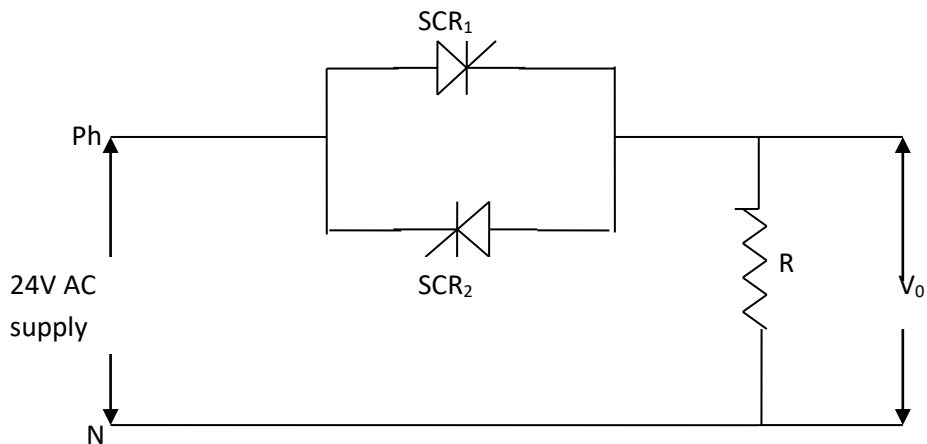
The thyristor T1 is forward biased during the positive half cycle of the input supply voltage. The thyristor T1 is triggered at a delay angle. Considering the ON thyristor T1 as an ideal closed switch the input supply voltage appears across the load resistor RL and the output voltage  $v_o=v_s$ . The load current flows through the ON thyristor T1 and through the load resistor RL in the downward direction during the conduction time of T1.

#### **Mode-2- From 0 to $\pi$**

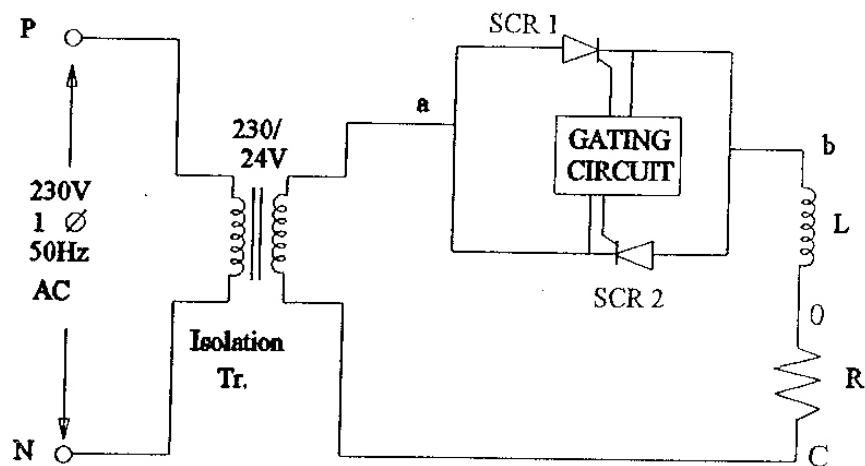
When the input voltage falls to zero the thyristor current (which is flowing through the load resistor RL) falls to zero and hence T1 naturally turns off . No current flows in the circuit. The thyristor T2 is forward-biased during the negative cycle of input supply and when thyristor T2 is triggered at a delay angle, the output voltage follows the negative half cycle of input .When T2 is ON, the load current flows in the reverse direction (upward direction) through T2. The time interval (spacing) between the gate trigger pulses of T1 and T2.The input supply voltage falls to zero and hence the load current also falls to zero and thyristor T2 turn off naturally.

## Circuit Diagram:

### AC Voltage Controller with R-Load:



### AC Voltage Controller with R-L Load:



## Procedure:

### AC Voltage Controller with R-Load

- Connect anode of SCR<sub>2</sub> to the cathode of SCR<sub>1</sub>
- Connect the 24V AC positive terminal to anode of SCR<sub>2</sub>
- Connect R load terminal between cathode of SCR<sub>1</sub> and 24V AC output.
- Connect the CRO across the load
- Connect the voltmeter across the load terminals
- Connect G<sub>2</sub> & K<sub>2</sub> of firing circuit to G<sub>2</sub> & K<sub>2</sub> of SCR<sub>2</sub>
- Switch ON the trainer kit
- Place the switch S<sub>2</sub> in SCR mode
- Switch ON the 24V AC supply
- Switch ON the denounce switch.
- Note down the peak value of voltage V<sub>m</sub>, triggering angle  $\alpha$  and conduction angle  $\gamma$
- By varying the firing angle the output can be varied
- Plot the graph V<sub>m</sub> versus  $\alpha$  and  $\gamma$



### AC Voltage Controller with **RL – Load**

- Connect R and L in series then connect the load terminals between cathode of SCR<sub>1</sub> and 24V ac input.
- Repeat the above steps
- Observe the waveforms

#### Tabular Form:

#### AC Voltage Controller with R-Load

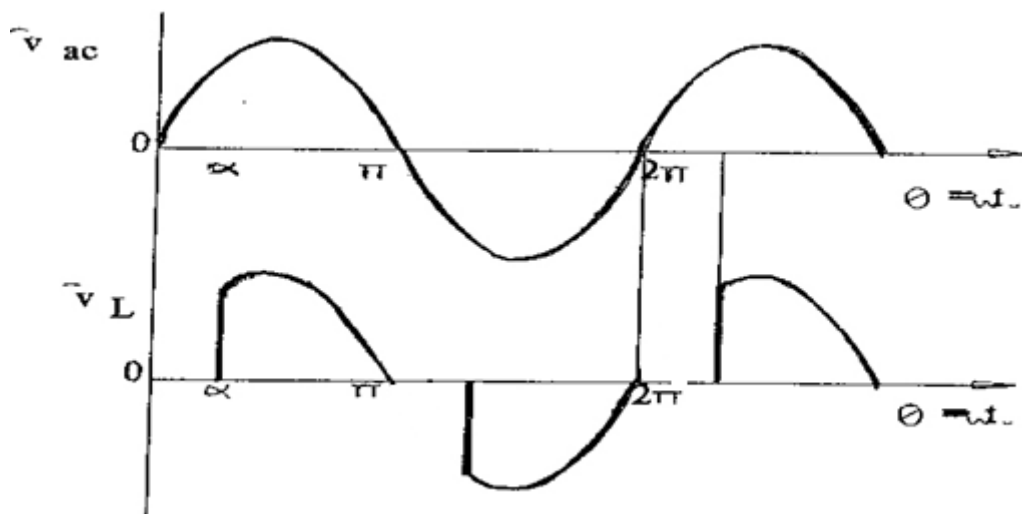
Sl. No.	Input Voltage	Firing Angle $\alpha$	Measured Output voltage ( V )	Calculated Output Voltage ( V )
1.				
2.				
3.				
4.				
5.				
6.				
7.				

#### AC Voltage Controller with RL Load

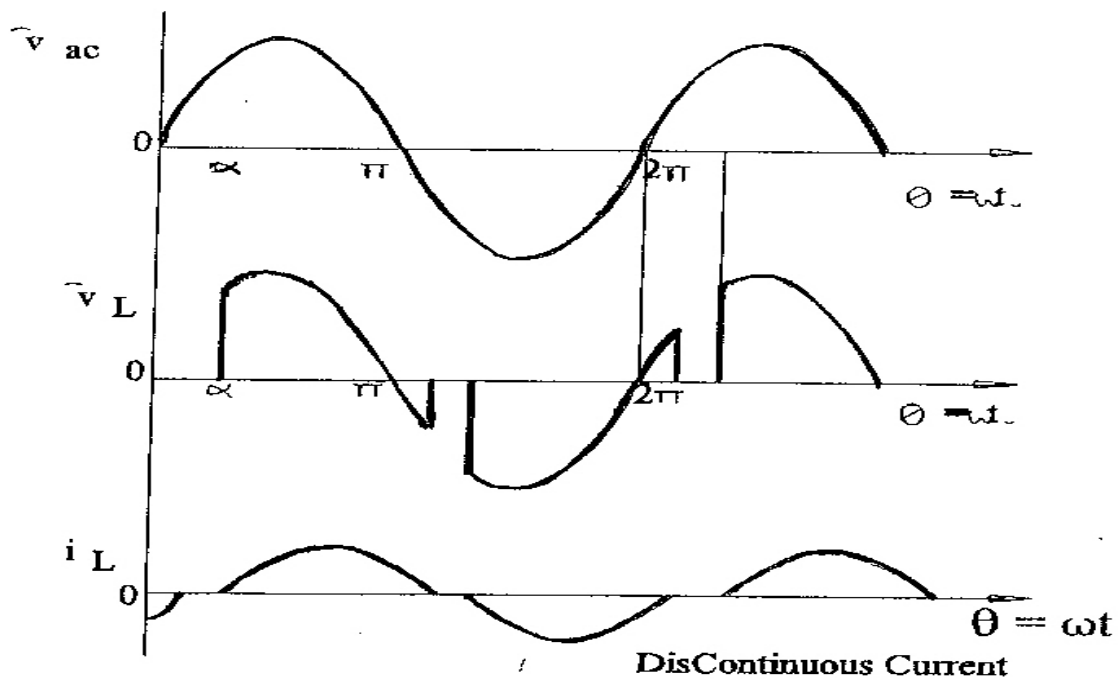
Sl. No.	Input Voltage	Firing Angle $\alpha$	Extinction angle $\beta$	Measured Output Voltage ( V )	Calculated Output Voltage ( V )
1.					
2.					
3.					
4.					
5.					
6.					
7.					

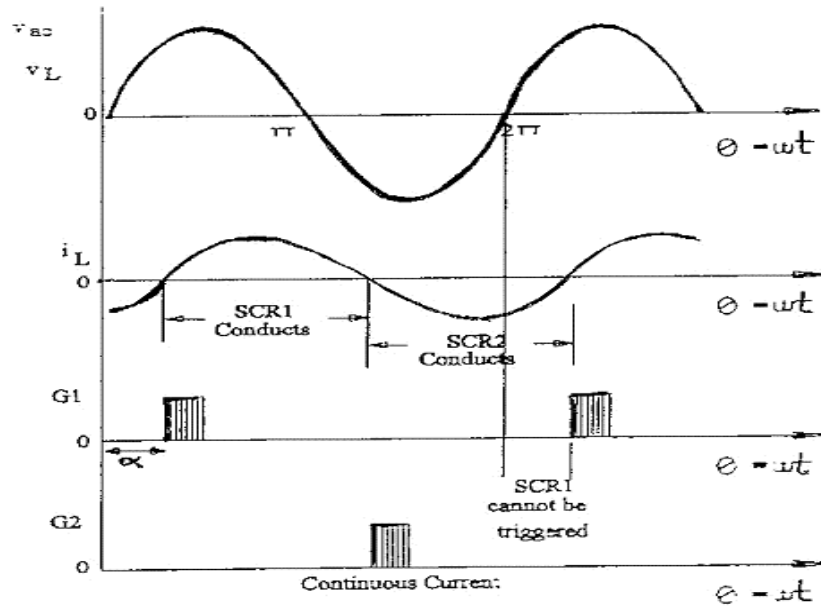
Expected waveforms:

AC Voltage Controller with R Load



AC Voltage Controller with RL Load





Continuous Current Mode

**Results:**

**Viva Questions:**

1. Explain basic purpose of AC voltage controller.
2. The ac voltage measured from multimeter in AC mode is RMS/AVG/MAX.
3. AC voltage changes output voltage with/without change in frequency.
4. For RL load, the output voltage is controllable only between triggering angles --- and ---.
5. Give some applications of AC voltage controller.

## Expt. No. 7. Study of Single Phase Cycloconverter

**Aim:** To construct a single phase cycloconverter circuit and to study its performance.

**Apparatus:** 230V / 30V-0-30V midpoint type transformer,

Cycloconverter power circuit,

Firing circuit,

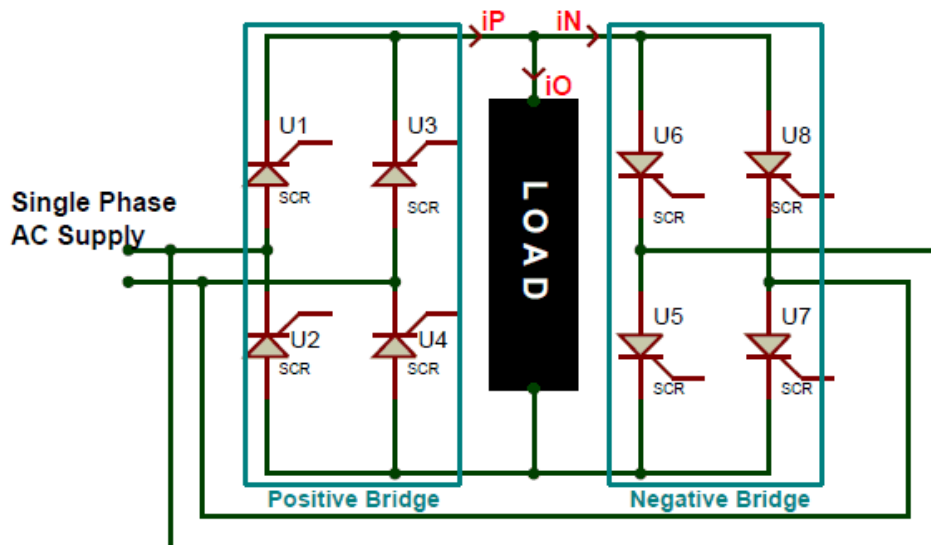
Load rheostat ,

Digital multimeter,

CRO & patch chord.

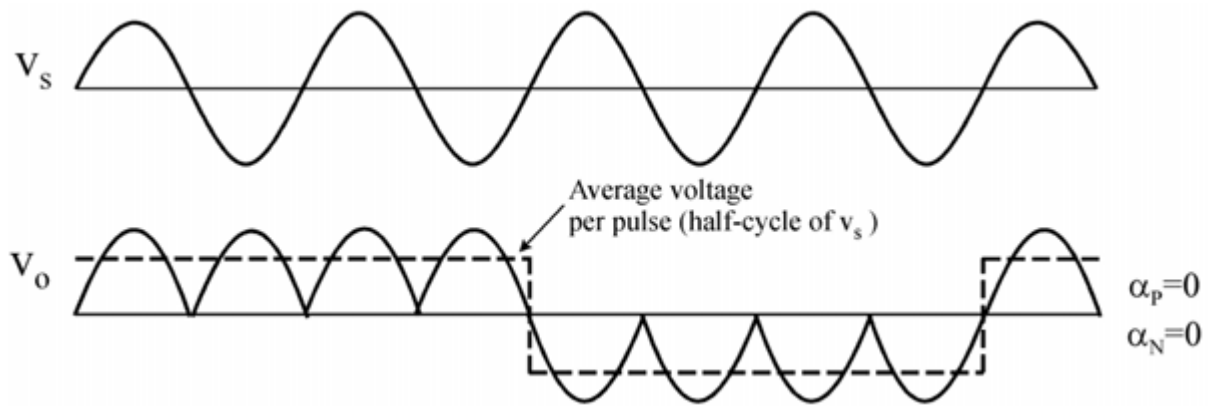
### Theory:

The Single Phase to Single Phase cycloconverter (CCV) has two pairs of full wave rectifier circuit, each consisting of four SCR. One set is placed straight while the other is placed in anti-parallel direction as shown on the picture below.



**Fig. 1**

All the gate terminals of the SCR's will be connected to a control circuit which, is not shown in the circuit above. This control circuit will be responsible for triggering the SCRs. To understand the working of the circuit let us assume that the input AC supply is of 50Hz frequency and the Load to be a pure resistive load and the firing angle of the SCR ( $\alpha$ ) to be  $0^\circ$ . Since the firing angle is at  $0^\circ$  the SCR when turned on will act like a diode in forward direction and when turned off will act like a diode in reverse direction. Let us analyze the waveform below to understand how frequency is stepped down using a CCV.



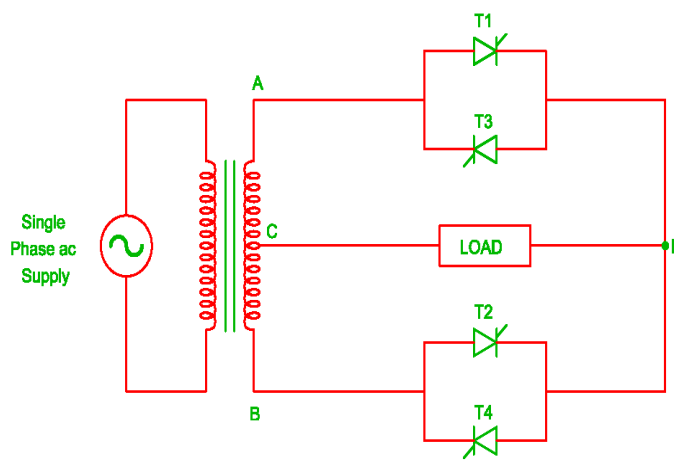
**Fig. 2**

The waveform of the supply voltage frequency is denoted by  $V_s$  and the wave form of the output voltage frequency is denoted by  $V_o$ . Here the supply voltage frequency is converted to  $1/4^{\text{th}}$  of its value. So to achieve that, for the first two cycles of the supply voltage, the positive bridge rectifier is used and for the following next two cycles, the negative bridge rectifier is used. Thus, four positive pulses in the positive region and then four in the negative region are required as shown in the output frequency waveform  $V_o$ . The current waveform for this circuit will be the same as voltage waveform since the load is assumed to be purely resistive. Although, the magnitude of the waveform will change based on the value of resistance of the load.

The output frequency is represented using the dotted line on the  $V_o$  waveform, since it changes polarity only for every two cycles of the input waveform the output frequency with  $1/4^{\text{th}}$  of the input frequency, in our case for an input frequency of 50Hz the output frequency will be  $(1/4 * 50)$  around 12.5Hz. This output frequency can be controlled by varying the triggering mechanism in the control circuit.

**Circuit Diagram:**

**Single Phase Cycloconverter:**



**FIG A : SINGLE PHASE TO SINGLE PHASE CYCLOCONVERTER**

**Procedure:-**

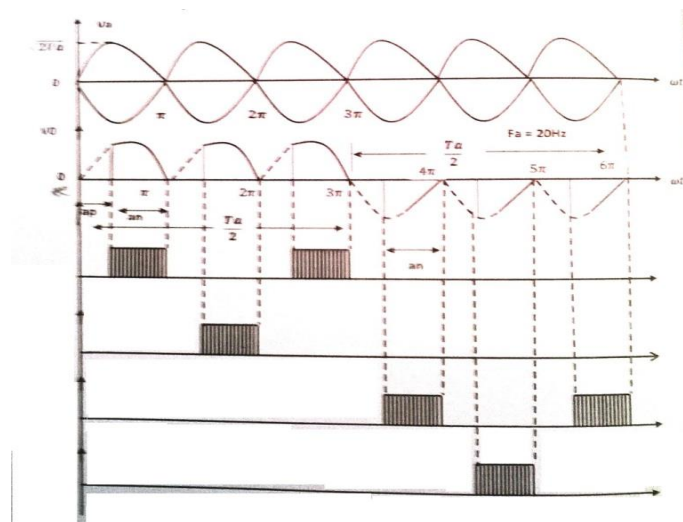
- 1) Make the connections as shown in the circuit of single phase cycloconverter with R load.
- 2) Gate cathode terminals of thyristors are connected to respective points on the firing module.
- 3) **Check all the connections and verify connections made are correct before switching on the equipment.**
- 4) Switch ON unit.
- 5) Output waveforms are to be observed on a CRO.
- 6) Vary firing angle and note down AC output voltage across load.
- 7) A graph of  $V_{ac}$  verses load voltage has to be plotted.
- 8) Repeat the above procedure for one more frequency.

**Tabular Form:**

Sl. No.	Firing angle $\alpha$	Load voltage using AC voltmeter in volts	Load voltage using AC voltmeter in volts	Load voltage using AC voltmeter in volts
		f/2	f/3	f/4
1.	180°			
2.	150°			
3.	120°			
4.	90°			
5.	60°			
6.	30°			
7.	0°			

**Expected Waveform:**

**Cycloconverter for f/3 mode of operation:**



**Result :-**

**Viva Questions:-**

1. What are the applications of cycloconverter?
2. In cycloconverter, upto what range frequency can be reduced or increased.
3. What are the disadvantages of cycloconverter?
4. Classify cycloconverters.
5. Comment on the magnitude of ac output voltage of cycloconverter.

## **MATLAB**

MATLAB (matrix laboratory) is a fourth-generation high-level programming language and interactive environment for numerical computation, visualization and programming.

MATLAB is developed by Math Works.

It allows matrix manipulations; plotting of functions and data; implementation of algorithms; creation of user interfaces; interfacing with programs written in other languages, including C, C++, Java, and Fortran; analyze data; develop algorithms; and create models and applications.

It has numerous built-in commands and math functions that help you in mathematical calculations, generating plots and performing numerical methods.

### **MATLAB's Power of Computational Mathematics**

MATLAB is used in every facet of computational mathematics. Following are some commonly used mathematical calculations where it is used most commonly:

- Dealing with Matrices and Arrays
- 2-D and 3-D Plotting and graphics
- Linear Algebra
- Algebraic Equations
- Non-linear Functions
- Statistics
- Data Analysis
- Calculus and Differential Equations
- Numerical Calculations
- Integration
- Transforms
- Curve Fitting
- Various other special functions

### **Features of MATLAB**

Following are the basic features of MATLAB:

- It is a high-level language for numerical computation, visualization and application development.
- It also provides an interactive environment for iterative exploration, design and problem solving.
- It provides vast library of mathematical functions for linear algebra, statistics, Fourier analysis, filtering, optimization, numerical integration and solving ordinary differential equations.
- It provides built-in graphics for visualizing data and tools for creating custom plots.
- MATLAB's programming interface gives development tools for improving code quality and maintainability and maximizing performance.
- It provides tools for building applications with custom graphical interfaces.
- It provides functions for integrating MATLAB based algorithms with external applications and languages such as C, Java, .NET and Microsoft Excel.



## Uses of MATLAB

MATLAB is widely used as a computational tool in science and engineering encompassing the fields of physics, chemistry, math and all engineering streams. It is used in a range of applications including:

- Signal Processing and Communications
- Image and Video Processing
- Control Systems
- Test and Measurement
- Computational Finance
- Computational Biology

### The MATLAB environment

*Note:* From now on an instruction to press a certain key will be denoted by < >, e.g., pressing the enter key will be denoted as <enter>. Commands that should be typed at the prompt, will be written in courier font.

The MATLAB environment (on most computer systems) consists of menus, buttons and a writing area similar to an ordinary word processor. There are plenty of help functions that can be used. The writing area that is appeared when MATLAB is started is called the *command window*. In this window, the commands to MATLAB can be given. For example, if a program written in MATLAB has to be run, the program has to be typed in the command window by its name at the prompt. The command window is also useful in using MATLAB as a scientific calculator or as a graphing tool. If longer programs are to be written then, it more convenient to write the program code in a separate window, and then run it in the command window.

In the command window, a prompt that looks like >> is visible. Commands can be typed immediately after this prompt. Once the command are typed, press <enter> for MATLAB to perform. If a *command* that MATLAB is running has to be *interrupted*, type <ctrl> + <c>.

The commands typed in the command window are stored by MATLAB and can be viewed in the *Command History* window. To repeat a command that is already used, simply double-click on the command in the history window, or use the <up arrow> at the command prompt to iterate through the commands that is used until the command desired to repeat is reached.

Simulink is a simulation and model-based design environment for dynamic and embedded systems, integrated with MATLAB. Simulink, also developed by MathWorks, is a data flow graphical programming language tool for modeling, simulating and analyzing multi-domain dynamic systems. It is a graphical block diagramming tool with customizable set of block libraries. It allows you to incorporate MATLAB algorithms into models as well as export the simulation results into MATLAB for further analysis.

Simulink supports:

- system-level design
- simulation
- automatic code generation
- testing and verification of embedded systems

There are several other add-on products provided by MathWorks, third-party hardware and software products that are available for use with Simulink.

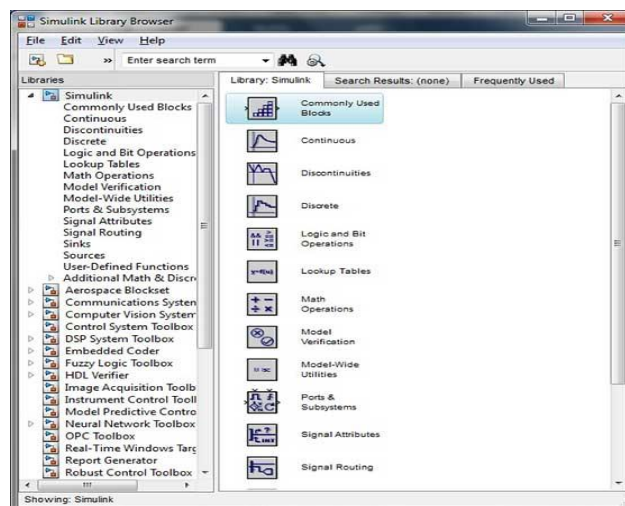
The following list gives brief description of some of them:

- **Stateflow** allows developing state machines and flow charts.
- **Simulink Coder** allows to automatically generating C source code for real-time implementation of systems.
- **xPC Target** together with **x86-based real-time systems** provides an environment to simulate and test Simulink and Stateflow models in real-time on the physical system.
- **Embedded Coder** supports specific embedded targets.
- **HDL Coder** allows to automatically generate synthesizable VHDL and Verilog
- **SimEvents** provides a library of graphical building blocks for modeling queuing systems

Simulink is capable of systematic verification and validation of models through modeling style checking, requirements traceability and model coverage analysis. Simulink Design Verifier allows you identify design errors and generates test case scenarios for model checking.

To open Simulink, type in the MATLAB work space: simulink

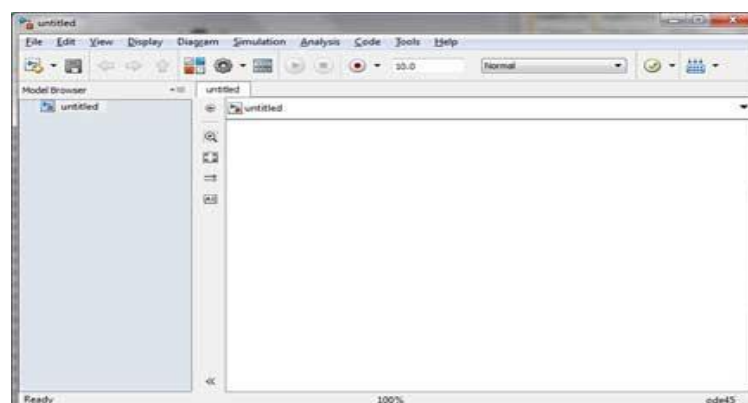
Simulink opens with the **Library Browser**. The Library Browser is used for building simulation models.



On the left side window pane, you will find several libraries categorized on the basis of various systems, clicking on each one will display the design blocks on the right window pane.

## Building Models

To create a new model, click the **New** button on the Library Browser's toolbar. This opens a new untitled model window



A Simulink model is a block diagram.

Model elements are added by selecting the appropriate elements from the Library Browser and dragging them into the Model window.

Alternately, the model elements can be copied and pasted into the model window.

## Expt. No. 8. Simulation of Single-Phase Half & Fully controlled Rectifier

**Aim:** To design and simulate single phase full converter and semi converter

**Apparatus:** MATLAB/SIMULINK software

### Simulation Blocks:-

AC voltage source, Thyristors, Pulse Generators (for Thyristor gate pulse) , Series RLC branch (for R and RL load) , Voltage and Current measurement blocks, Scope and Display blocks, Powergui block (Continuous).

### Theory:

#### Single phase half-controlled rectifier with RL load:

Figure 1 shows two alternative arrangements of 2-pulse half-controlled bridge converters with inductive load. The various voltage and current waveforms for both symmetric and asymmetric configurations are shown in Fig.1. Consider the symmetrical circuit configuration. As shown in Fig. 1(a), thyristor T1 is turned-on at a firing angle  $\alpha$  in each positive half-cycle. From this instant  $\alpha$ , supply voltage appears across output terminals AB, through thyristor T1 and diode D1. Current flows through the path L-T1-A-L-R-B-D1-N. Here, the filter inductance  $L$  is assumed to be sufficiently large as to produce continuous load current. This current  $I_d$  is taken to be constant. Hence during positive half-cycle, thyristor T1 and diode D1 conducts.

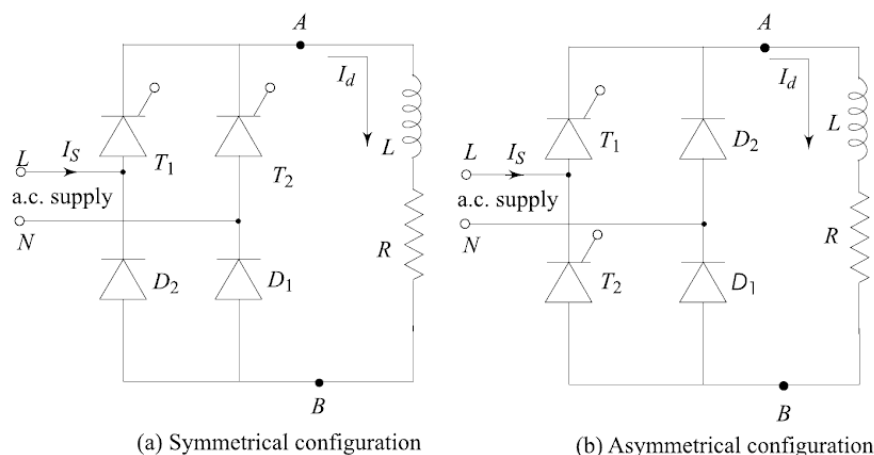


Fig.1

Now, when the supply voltage reverses at  $\omega t = \pi$ , the diode D2 is forward-biased since diode D1 is already conducting. The diode D2 then turns ON, and the load current passes through D2 and T1. The supply voltage reverse-biases D1 and turns it off. The load-current freewheels through the path R-B-D2-T1-A-L during the interval from  $\pi$  to  $(\pi + \alpha)$  in each supply-cycle.

During the negative half-cycle, at the instant  $(\pi + \alpha)$ , a triggering-pulse is applied to the forward-biased thyristor T2. Thyristor T2 is turned ON. As thyristor T2 is turned ON, the supply voltage reverse-biases T1 and then turns it OFF by the line commutation. Therefore, the load-current flows through T2 and D2, the above-cycle repeats and the waveforms obtained are as shown in Fig.2(a), which are similar to that of fully-controlled converter with a freewheeling diode. Here, the conduction period of thyristors and diodes are equal, therefore this circuit is called as the symmetrical configuration.

Now consider the circuit of Fig.1(b). During the positive half-cycle of the a.c. supply, thyristor T1 and diode D1 are forward-biased. As shown in Fig. 1(b), thyristor T1 is turned ON at firing angle  $\alpha$ . Current flows through the path L-T1-A-L-R-B-D1-N. Hence, T1 and D1 conduct from  $\alpha$  to  $\pi$ . Similarly, T2 and D2 conduct from  $(\pi + \alpha)$  to  $2\pi$  in each negative half-cycle of the a.c. supply.

The freewheeling action is provided by diodes D1 and D2 from 0 to  $\alpha$  and from  $\pi$  to  $(\pi+\alpha)$  in each supply cycle. In this converter configuration, the conduction periods of thyristors and diodes are unequal. Hence, this circuit configuration is known as the asymmetrical configuration.

The thyristor conducts for a longer interval in the symmetrical circuit configuration. Therefore, the thyristors used in this circuit must have a higher average current-rating compared to those in the asymmetrical-circuit configuration.

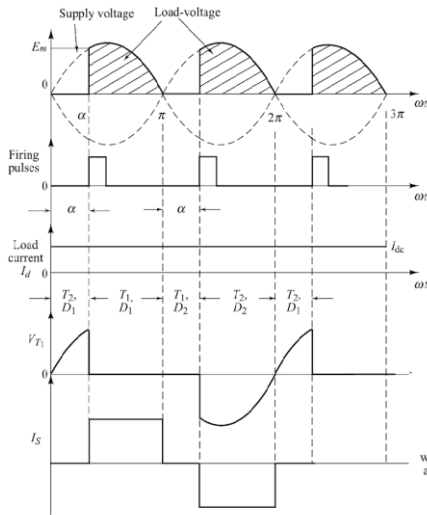


Fig.2 (a) Waveforms for symmetrical configuration

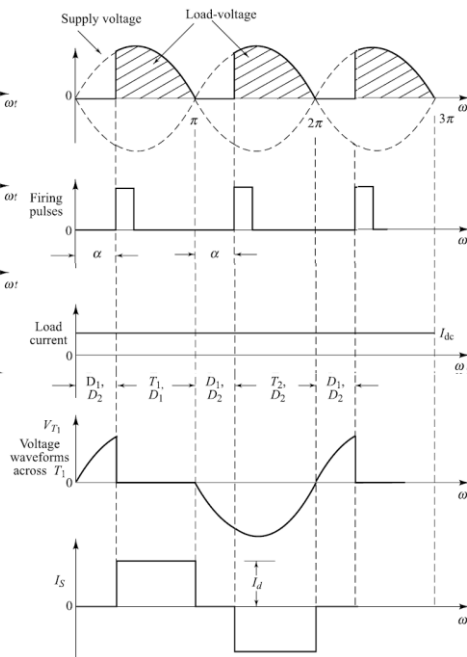


Fig.2 (b) Waveforms for asymmetrical configuration

**Single phase fully-controlled rectifier with R load:**

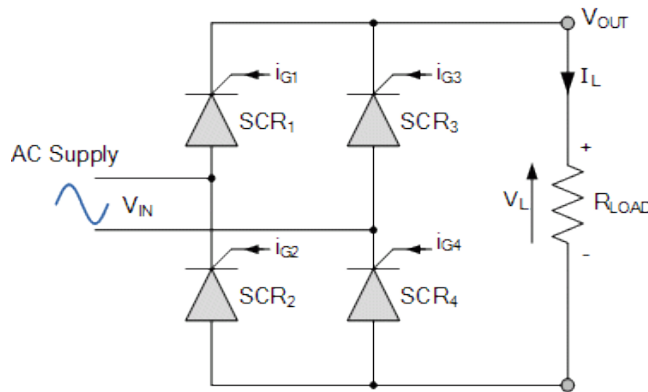


Fig. 3

Single phase fully controlled converters are obtained by replacing the diodes of an uncontrolled converter with thyristors. It is one of the most popular converter circuits and is widely used in the speed control of separately excited dc machines.

In a fully controlled converter, the output voltage can be controlled by controlling the firing delay angle ( $\alpha$ ) of the thyristors. Thyristors T1 and T2 are fired together while T3 and T4 are fired 180° after T1 and T2. Depending on the load condition and the firing angle, a fully controlled bridge converter can operate either in the continuous conduction mode or in the discontinuous conduction mode.

In the continuous conduction mode, the load voltage depends only on the firing angle and not on load parameters. In the discontinuous conduction mode, the output voltage decreases with increasing load current. However, the output voltage is always greater than that in the continuous conduction mode for the same firing angle.

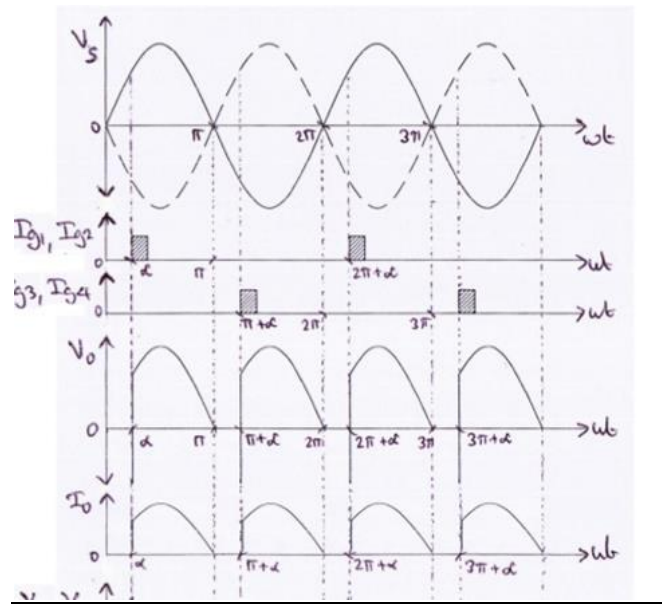
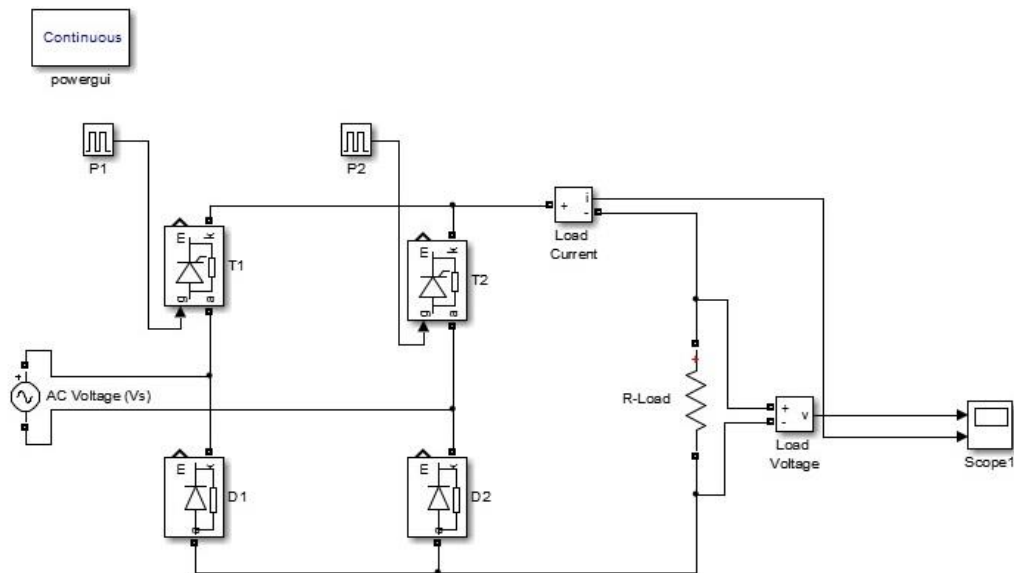


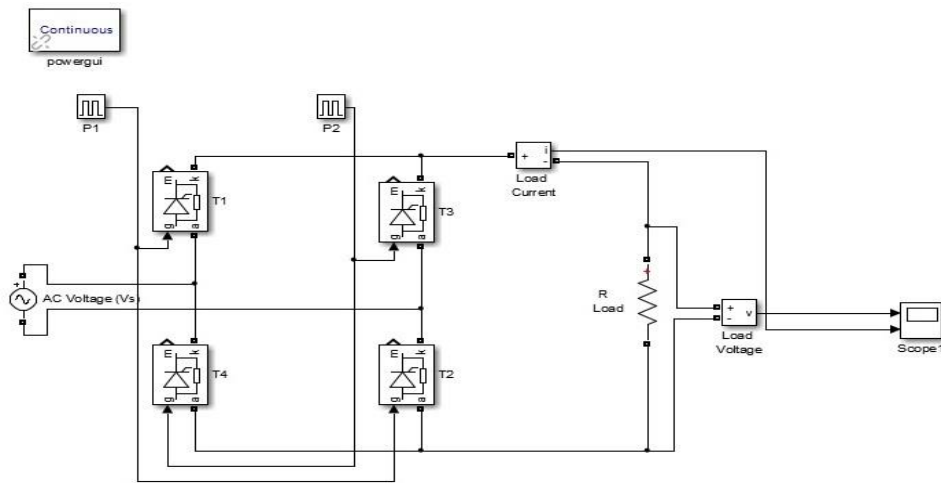
Fig. 4

**Circuit Diagram:**

**Semi-converter:-**



## Full-converter:-



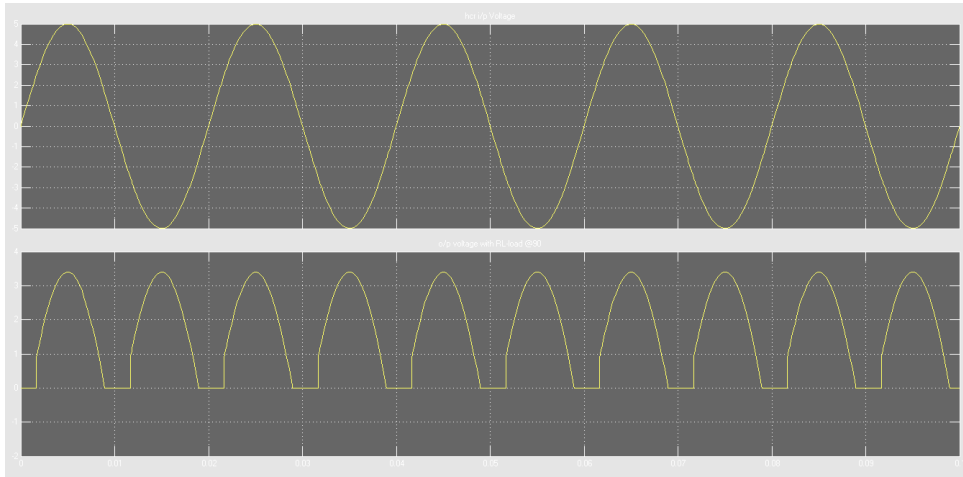
## Procedure:-

- 1) Create a new MATLAB model file and create the MATLAB model as shown in figure, corresponding to the single phase controlled rectifier circuit.
- 2) Give the run time value as 0.1 secs to obtain simulation results for 5 input cycles
- 3) ( $5 \times 1/50\text{HZ} = 0.1 \text{ sec}$ )
- 4) In pulse generator blocks, set different values for varying different firing angle.
- 5) Run the simulation model and obtain the results.
- 6) Repeat the simulation for different values of firing angle for both R and RL load.

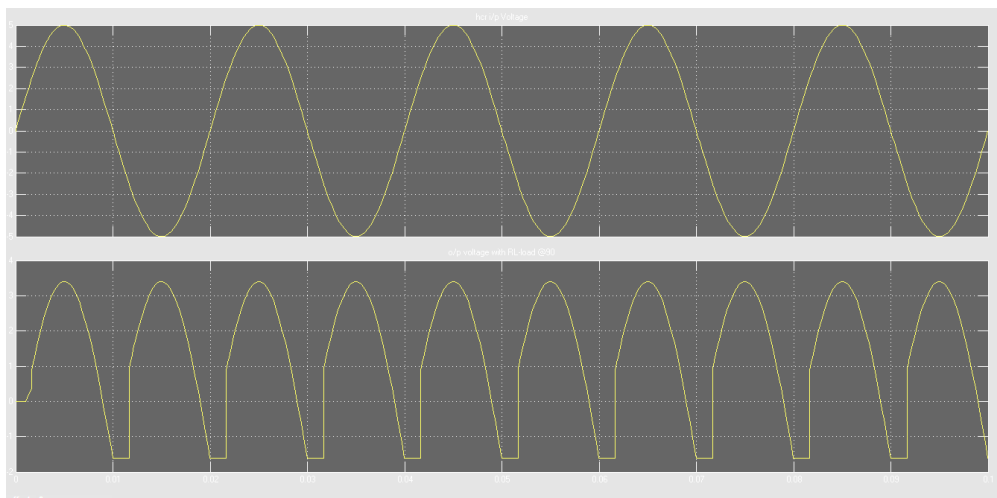
Operation	Path	Icon
Opening Simulink	<ol style="list-style-type: none"> <li>1. Click on the Simulink icon on Matlab taskbar</li> <li>2. Type Simulink on Matlab Command Window</li> </ol>	
Selecting New File	File -> New -> Model	
Selecting Source	Libraries -> SimpowerSystems -> electrical sources	AC Voltage Source
Selecting Thyristor	Libraries -> SimPowerSystems -> PowerElectronics -> Thyristor	Thyristor
Selecting Diode	Libraries -> SimPowerSystems -> PowerElectronics -> Diodes	Diode
Selecting Series RLC branch	Libraries -> SimpowerSystems -> Elements	Series RLC Load
Selecting Pulse Generater(Triggering)	Libraries -> Sources	Pulse Generator
Voltage Measurement	Libraries -> SimpowerSystems -> Measurement	Voltage Measurement
Current Mesurement	Libraries -> SimpowerSystems -> Measurement	Current Measurement
Scope	Libraries -> Sink	Scope

**Expected Waveforms:**

**Output voltage with R LOAD**



**Output voltage with RL LOAD**



**Result:-**

**Viva Questions:**

1. What is the difference between single phase full converter and half converter circuit?
2. What is the role of free-wheeling diode?
3. What is MATLAB?
4. What is the purpose of simulating in MATLAB software?
5. What are the advantages of MATLAB software?



## Expt. No. 9. Simulation of Single-Phase & Three-Phase AC Voltage Controller

**Aim:** To design and simulate single phase and three phase AC voltage controllers

**Apparatus:** MATLAB/SIMULINK software

### **Simulation Blocks:**

AC voltage source, Thyristors, Pulse Generators (for Thyristor gate pulse) , Series RLC branch (for R and RL load) , Voltage and Current measurement blocks, Scope and Display blocks, Powergui block (Continuous).

### **Theory:**

A single phase full wave ac voltage controller with a resistive load is shown in the figure below. It is possible to control the ac power flow to the load in both the half cycles by adjusting the trigger angle. Hence, the full wave ac voltage controller is also referred to as to a bidirectional controller.

### **OPERATION**

#### **Mode-1- From 0 to $\pi$**

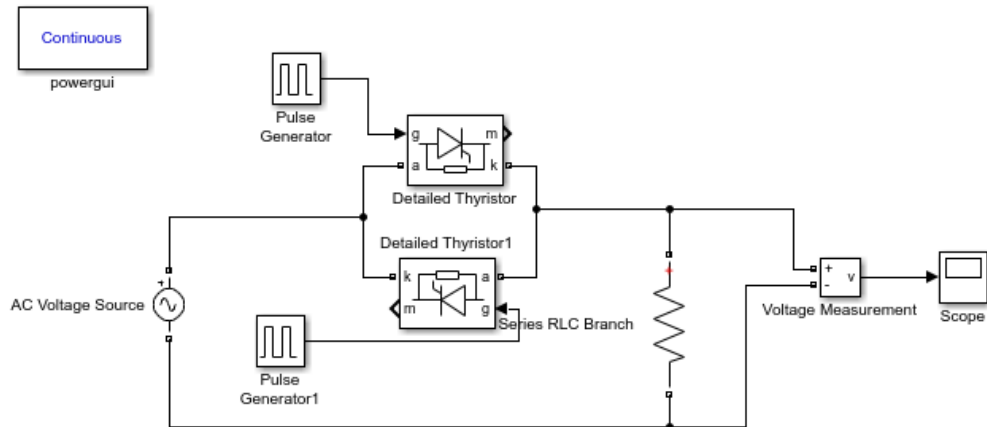
The thyristor T1 is forward biased during the positive half cycle of the input supply voltage. The thyristor T1 is triggered at a delay angle. Considering the ON thyristor T1 as an ideal closed switch the input supply voltage appears across the load resistor RL and the output voltage  $v_o = v_s$ . The load current flows through the ON thyristor T1 and through the load resistor RL in the downward direction during the conduction time of T1.

#### **Mode-2- From 0 to $\pi$**

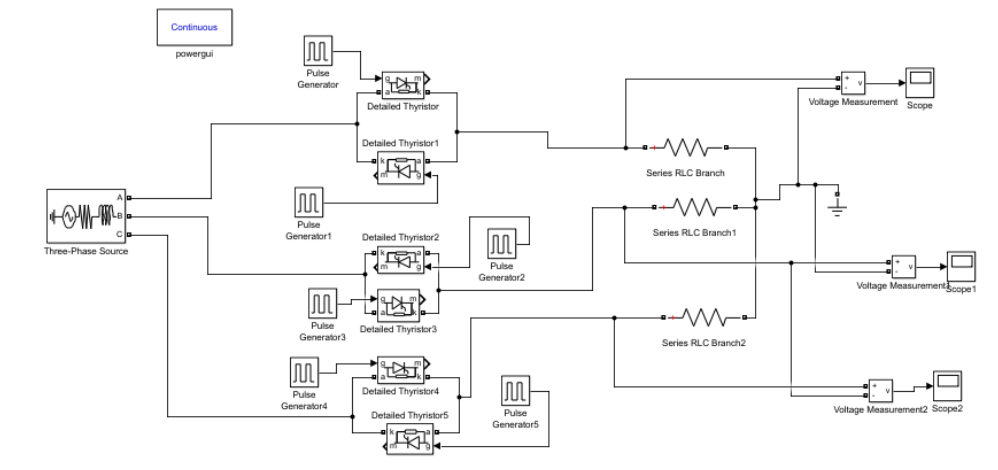
When the input voltage falls to zero the thyristor current (which is flowing through the load resistor RL) falls to zero and hence T1 naturally turns off . No current flows in the circuit. The thyristor T2 is forward biased during the negative cycle of input supply and when thyristor T2 is triggered at a delay angle, the output voltage follows the negative half cycle of input .When T2 is ON, the load current flows in the reverse direction (upward direction) through T2. The time interval (spacing) between the gate trigger pulses of T1 and T2. The input supply voltage falls to zero and hence the load current also falls to zero and thyristor T2 turn off naturally.

## Circuit Diagram:

### Single phase AC voltage controller with R-load:












### Three phase AC voltage controller with R load:



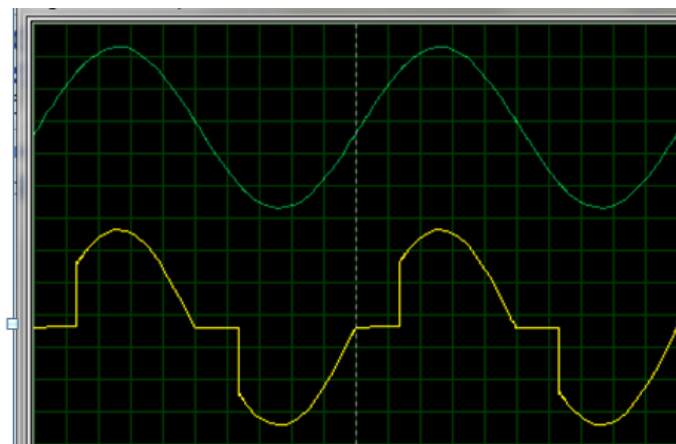
## Procedure:-

- 1) Create a new MATLAB model file and create the MATLAB model as shown in figure, corresponding to the single phase controlled rectifier circuit.
- 2) Give the run time value as 0.1 secs to obtain simulation results for 5 input cycles
  - a.  $(5 \times 1/50\text{HZ} = 0.1 \text{ sec})$
- 3) In pulse generator blocks, set different values for varying different firing angle.
- 4) Run the simulation model and obtain the results.
- 5) Repeat the simulation for different values of firing angle for both R and RL load.

Operation	Path	Icon
Opening Simulink	1. Click on the Simulink icon on Matlab taskbar 2. Type Simulink on Matlab Command Window	
Selecting New File	File -> New -> Model	
Selecting Source	Libraries -> SimpowerSystems -> electrical sources	 AC Voltage Source
Selecting Thyristor	Libraries -> SimPowerSystems -> PowerElectronics -> Thyristor	 Thyristor
Selecting Diode	Libraries -> SimPowerSystems -> PowerElectronics -> Diodes	 Diode
Selecting Series RLC branch	Libraries -> SimpowerSystems -> Elements	 Series RLC Load
Selecting Pulse Generater(Triggering)	Libraries -> Sources	 Pulse Generator
Voltage Measurement	Libraries -> SimpowerSystems -> Measurement	 Voltage Measurement
Current Mesurement	Libraries -> SimpowerSystems -> Measurement	 Current Measurement
Scope	Libraries -> Sink	 Scope

**Expected waveforms:**

**Single phase AC voltage controller with R-load:**



**Result:**

**Viva Questions:**

1. What is an AC Voltage regulator?
2. What is the difference between AC voltage regulator and rectifier?
3. What is MATLAB?
4. What is the purpose of simulating in MATLAB software?
5. What are the advantages of MATLAB software?

## Expt. No. 10. Simulation of Single-Phase and Three-Phase Inverter

**Aim:** To design and simulate single phase and three phase inverter

**Apparatus:** MATLAB/SIMULINK software

### **Simulation Blocks:-**

DC voltage source, IGBTs, Pulse Generators (for IGBTs gate pulse) , Series RLC branch (for R and RL load) ,Voltage and Current measurement blocks, Scope and Display blocks, Powergui block (Continuous).

### **Theory:**

An inverter refers to a power electronic device that converts power in DC form to AC form at the required frequency and voltage output.

Inverters are classified into two main categories –

- **Voltage Source Inverter VSIVSI** – The voltage source inverter has stiff DC source voltage that is the DC voltage has limited or zero impedance at the inverter input terminals.
- **Current Source Inverter CSICSI** – A current source inverter is supplied with a variable current from a DC source that has high impedance. The resulting current waves are not influenced by the load.

### **Single Phase Inverter:**

There are two types of single phase inverters – full bridge inverter and half bridge inverter.

### **Half Bridge Inverter**

This type of inverter is the basic building block of a full bridge inverter. It contains two switches and each of its capacitors has a voltage output equal to  $V_{dc}/2$ . In addition, the switches complement each other, that is, if one is switched ON the other one goes OFF.

### **Full Bridge Inverter**

This inverter circuit converts DC to AC. It achieves this by closing and opening the switches in the right sequence. It has four different operating states which are based on which switches are closed.

### **Three Phase Inverter:**

A three-phase inverter converts a DC input into a three-phase AC output. Its three arms are normally delayed by an angle of  $120^\circ$  to generate a three-phase AC supply. The inverter switches each has a ratio of 50% and switching occurs after every  $T/6$  of the time  $T$   $60^\circ$  angle interval  $60^\circ$  angle interval. The switches S1 and S4, the switches S2 and S5 and switches S3 and S6 complement each other.

The figure below shows a circuit for a three phase inverter. It is nothing but three single phase inverters put across the same DC source. The pole voltages in a three phase inverter are equal to the pole voltages in single phase half bridge inverter.

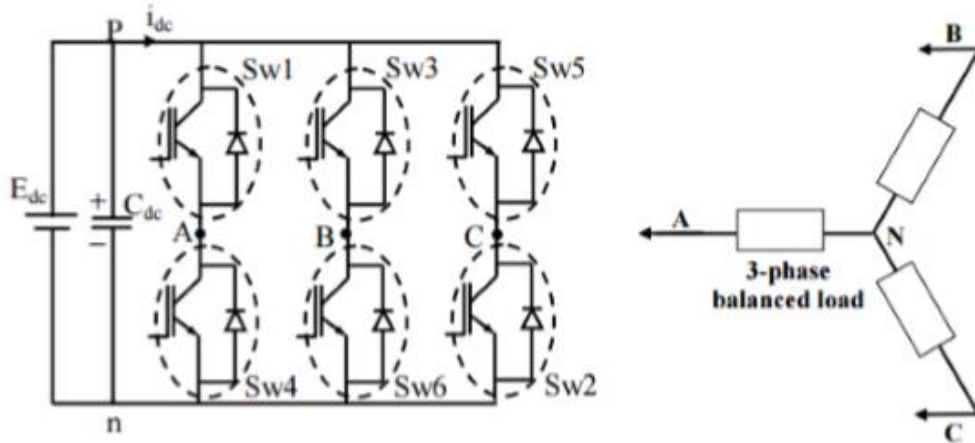


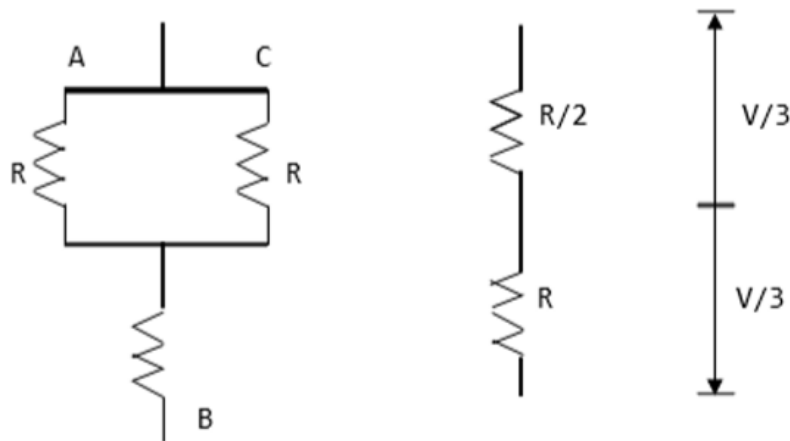
Fig. 1

The two types of inverters above have two modes of conduction – **180° mode of conduction** and **120° mode of conduction**.

**180° mode of conduction:**

In this mode of conduction, every device is in conduction state for 180° where they are switched ON at 60° intervals. The terminals A, B and C are the output terminals of the bridge that are connected to the three-phase delta or star connection of the load.

The operation of a balanced star connected load is explained in the diagram below. For the period 0° – 60° the points S1, S5 and S6 are in conduction mode. The terminals A and C of the load are connected to the source at its positive point. The terminal B is connected to the source at its negative point. In addition, resistances R/2 is between the neutral and the positive end while resistance R is between the neutral and the negative terminal.



The load voltages are gives as follows;

$$V_{AN} = V/3,$$

$$V_{BN} = -2V/3,$$

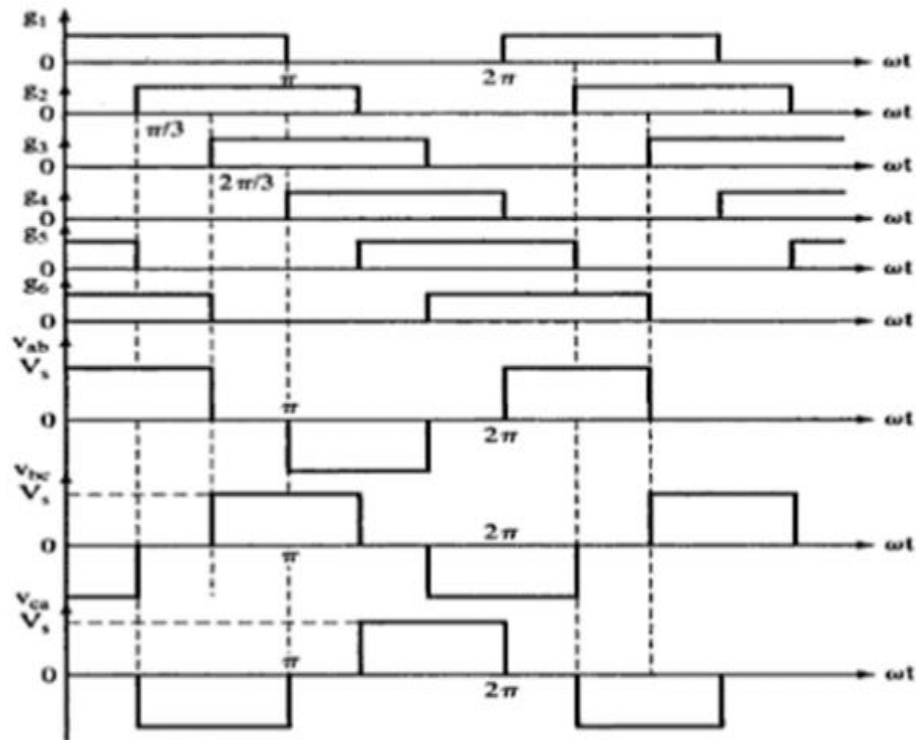
$$V_{CN} = V/3$$

The line voltages are given as follows;

$$V_{AB} = V_{AN} - V_{BN} = V,$$

$$V_{BC} = V_{BN} - V_{CN} = -V,$$

$$V_{CA} = V_{CN} - V_{AN} = 0$$



Waveforms for 180° mode of conduction

**120° mode of conduction:**

In this mode of conduction, each electronic device is in a conduction state for 120°. It is most suitable for a delta connection in a load because it results in a six-step type of waveform across any of its phases. Therefore, at any instant only two devices are conducting because each device conducts at only 120°.

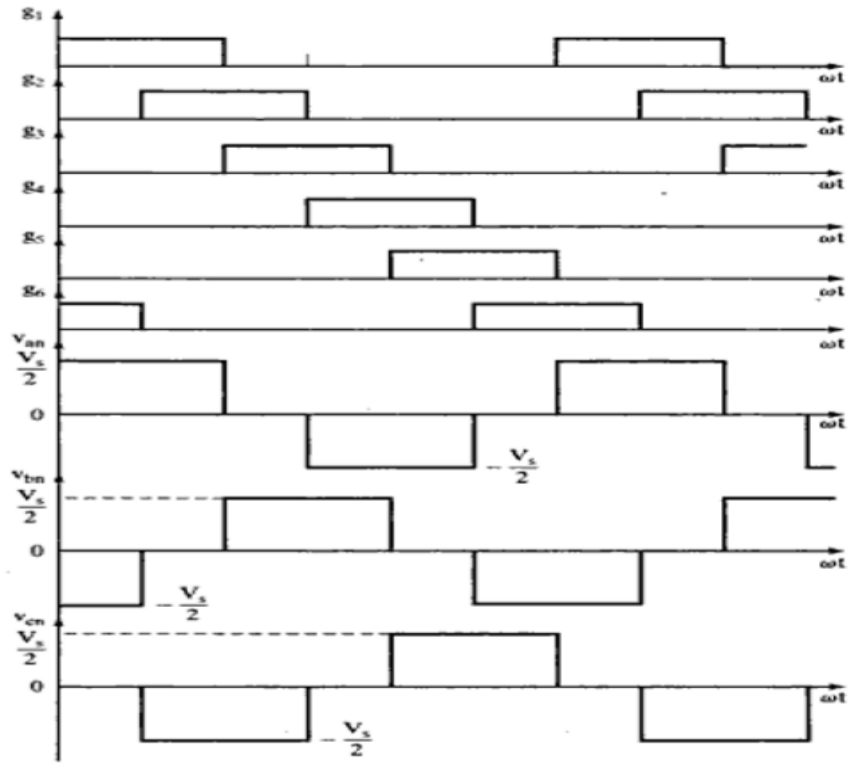
The terminal A on the load is connected to the positive end while the terminal B is connected to the negative end of the source. The terminal C on the load is in a condition called floating state. Furthermore, the phase voltages are equal to the load voltages as shown below.

Phase voltages = Line voltages

$$V_{AB} = V$$

$$V_{BC} = -V/2$$

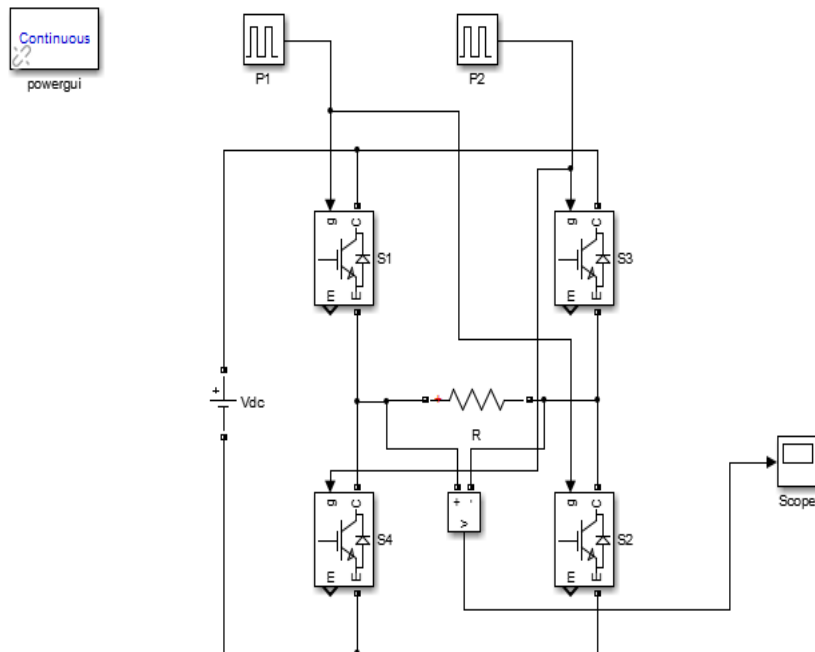
$$V_{CA} = -V/2$$



Waveforms for 120° mode of conduction

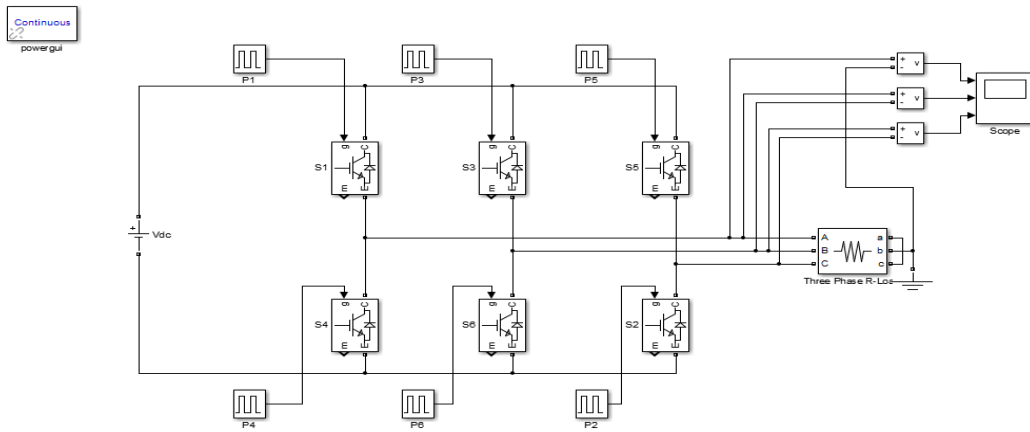
**Circuit Diagram:**

**Single phase inverter:**





**Three phase inverter:**



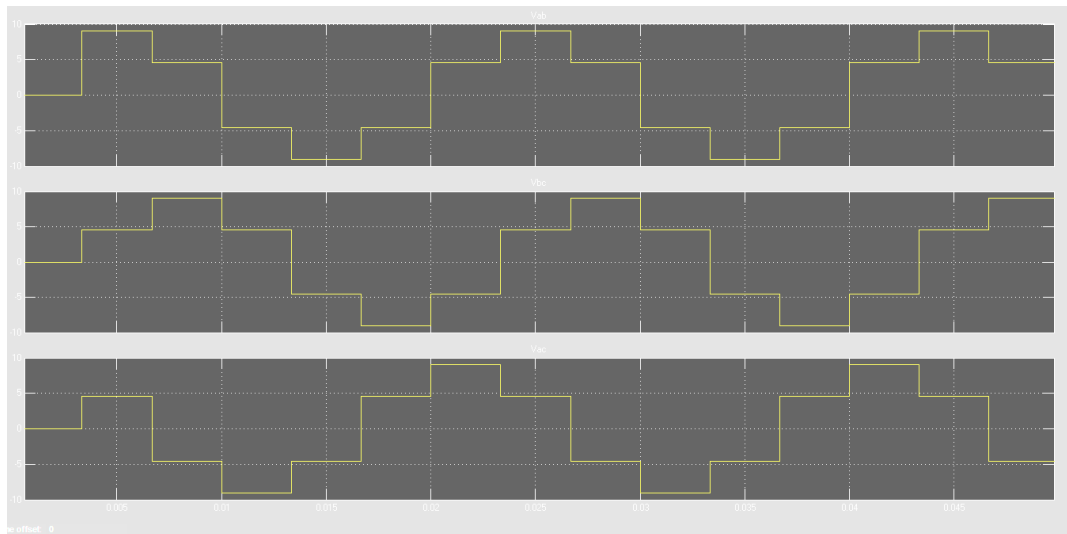
**Procedure:-**

- 1) Create a new MATLAB model file and create the MATLAB model as shown in figure, corresponding to the single phase controlled rectifier circuit.
- 2) Give the run time value as 0.1 secs to obtain simulation results for 5 input cycles
  - a.  $(5 \times 1/50\text{HZ} = 0.1 \text{ sec})$
- 3) In pulse generator blocks, set different values for varying different firing angle.
- 4) Run the simulation model and obtain the results.
- 5) Repeat the simulation for different values of firing angle for both R and RL load.

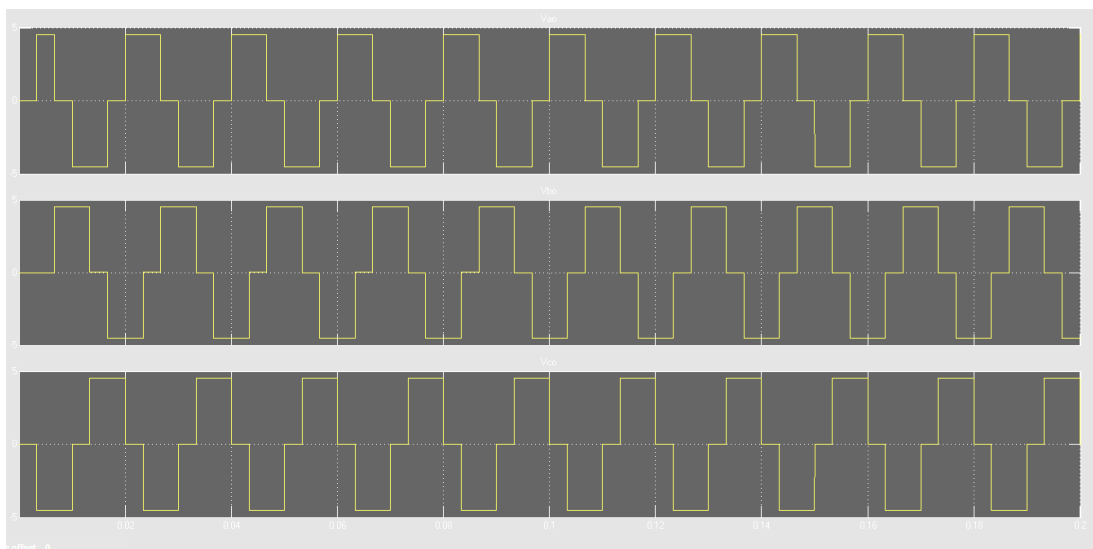
Operation	Path	Icon
Opening Simulink	1. Click on the Simulink icon on Matlab taskbar 2. Type Simulink on Matlab Command Window	
Selecting New File	File -> New -> Model	
Selecting Source	Libraries -> SimpowerSystems -> electrical sources	AC Voltage Source
Selecting Thyristor	Libraries -> SimPowerSystems -> PowerElectronics -> Thyristor	Thyristor
Selecting Diode	Libraries -> SimPowerSystems -> PowerElectronics -> Diodes	Diode
Selecting Series RLC branch	Libraries -> SimpowerSystems -> Elements	Series RLC Load
Selecting Pulse Generater(Triggering)	Libraries -> Sources	Pulse Generator
Voltage Measurement	Libraries -> SimpowerSystems -> Measurement	Voltage Measurement
Current Mesurement	Libraries -> SimpowerSystems -> Measurement	Current Measurement
Scope	Libraries -> Sink	Scope

**Expected waveforms:**

**Three phase inverter output line voltages:**



**Three phase inverter output phase voltages:**



**Result:**

**Viva Questions:**

1. What is an inverter?
2. What is the difference between three-phase inverter and single phase inverter?
3. What is MATLAB?
4. What is the purpose of simulating in MATLAB software?
5. What are the advantages of MATLAB software?

### Expt. No. 11. V/f control of AC drive

**Aim:** To study the speed control of 3-phase Induction motor in variable frequency V/f constant mode using 3-phase inverter.

#### Apparatus:

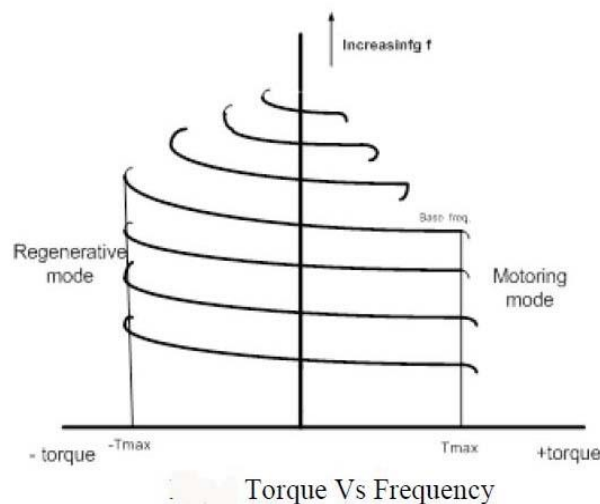
1. V/f control Trainer kit.
2. Three-phase induction motor.
3. Tachometer.
4. Digital multimeter.
5. Patch chords.

#### Theory:

Induction Machines, the most widely used motor in industry, have been traditionally used in open-loop control applications, for reasons of cost, size, reliability, ruggedness, simplicity, efficiency, less maintenance, ease of manufacture and its ability to operate in dirty or explosive conditions. However, because the induction machine requires more complex control methods, the dc machine has predominated in high performance applications. With developments in Micro-processors/DSPs, power electronics and control theory, the induction machine can now be used in high performance variable-speed applications.

The induction motor speed variation can be easily achieved for a short range by either stator voltage control or rotor resistance control. But both of these schemes result in very low efficiencies at lower speeds. The most efficient scheme for speed control of induction motor is by varying supply frequency. This not only results in scheme with wide speed range but also improves the starting performance.

If the machine is operating at speed below base speed, then v/f ratio is to be kept constant so that flux remains constant. This retains the torque capability of the machine at the same value. But at lower frequencies, the torque capability decrease and this drop in torque has to be compensated for increasing the applied voltage.



The above curve suggests that the speed control and braking operation are available from nearly zero speed to above synchronous speed. It is noted that V is kept constant above base speed and freq. is increasing. The variable frequency control provides good running and transient performance because of the following features:

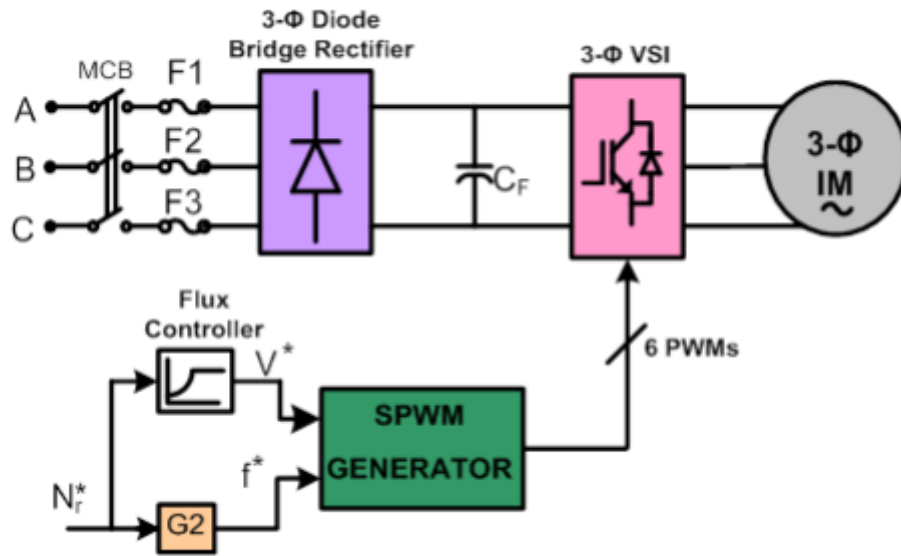
- (a) Speed control and braking operation are possible from zero to above base speed.

(b) During transients (starting, braking and speed reversal), the operation can be carried out at the maximum torque with reduced current giving good dynamic response.

(c) Copper losses are reduced; efficiency and power factor are high as the operation is in between synch. speed and max. torque point at all frequencies.

(d) Drop in speed from no load to full load is small.

**Circuit Diagram:**



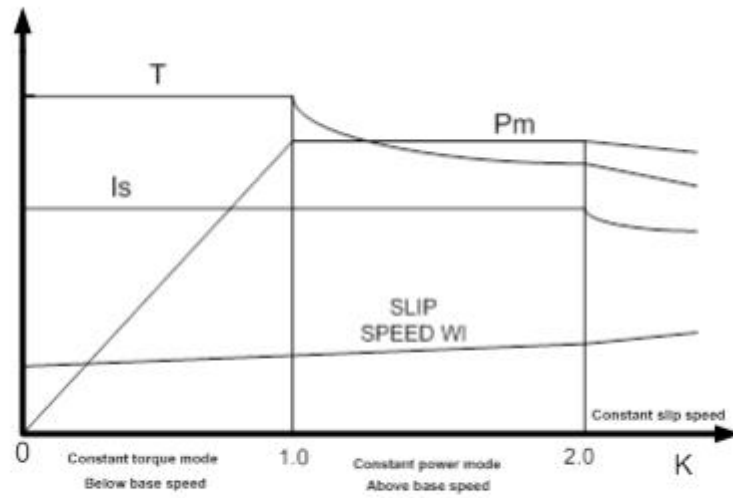
**Procedure:**

1. Connect the circuit diagram as per the circuit diagram.
2. Make sure that the connections are correct and switch on the AC supply.
3. Measure the speed of the induction motor.
4. Vary the frequency and the stator voltage applied to the motor such that, V/f ratio is constant.
5. Repeat step 4 and observe the speed of the induction.

**Tabular Form:**

Sl. No.	Stator Voltage ( V in Volts)	Frequency ( f in Hz)	V/f Ratio	Speed (Nr)
1.				
2.				
3.				
4.				
5.				
6.				
7.				

**Expected waveform:**



***Modes of operation and variation of  $i_s$ ,  $\omega_{sl}$ ,  $T$  and  $P_m$  with per unit frequency  $K$ .***

**Result:**

**Viva Questions:**

1. How does the speed of induction motor depend on stator voltage?
2. Which factor affects the speed of induction motor most?
3. Which parameter other than voltage is responsible for speed variation of IM?
4. Why should we keep  $v/f$  ratio constant?
5. Give the formula for speed of induction motor?
6. How does the speed of induction motor depend on frequency?
7. What is working principle of Induction motor?
8. What do you mean flux density?

## Expt. No. 12. Simulation of Single-Phase Cycloconverter

**Aim:** To design and simulate single phase cycloconverter.

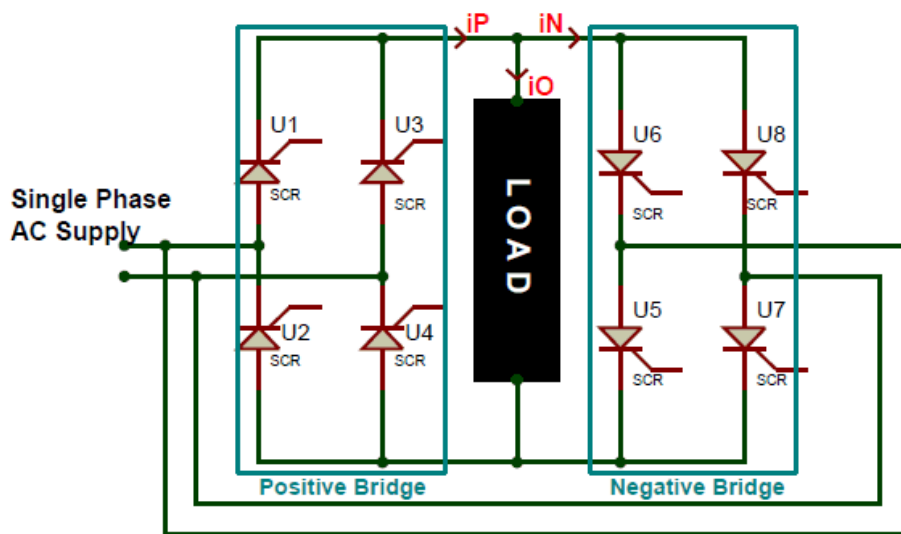
**Apparatus:** MATLAB/SIMULINK software

### Simulation Blocks:

AC voltage source, Thyristors, Pulse Generators (for Thyristor gate pulse) , Series RLC branch (for R and RL load) , Voltage and Current measurement blocks, Scope and Display blocks, Powergui block (Continuous).

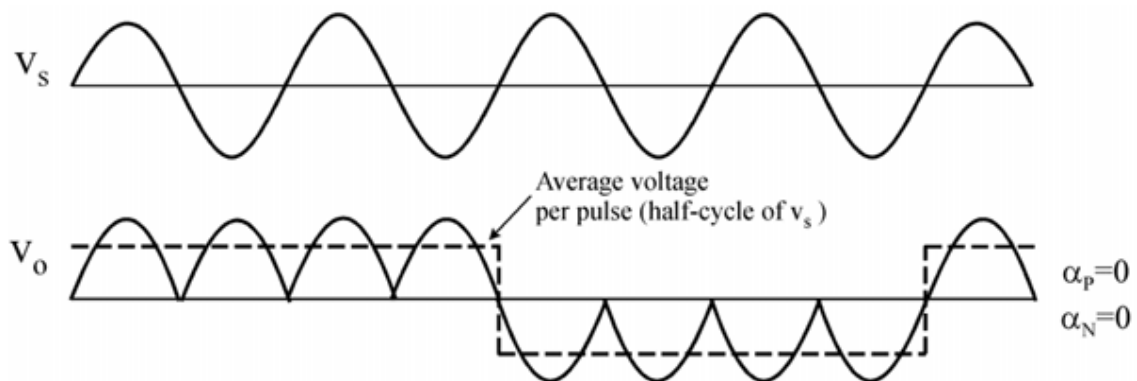
### Theory:

The Single Phase to Single Phase cycloconverter (CCV) has two pairs of full wave rectifier circuit, each consisting of four SCR. One set is placed straight while the other is placed in anti-parallel direction as shown on the picture below.



**Fig. 1**

All the gate terminals of the SCR's will be connected to a control circuit which, is not shown in the circuit above. This control circuit will be responsible for triggering the SCRs. To understand the working of the circuit let us assume that the input AC supply is of 50Hz frequency and the Load to be a pure resistive load and the firing angle of the SCR ( $\alpha$ ) to be  $0^\circ$ . Since the firing angle is at  $0^\circ$  the SCR when turned on will act like a diode in forward direction and when turned off will act like a diode in reverse direction. Let us analyze the wave form below to understand how frequency is stepped down using a CCV.



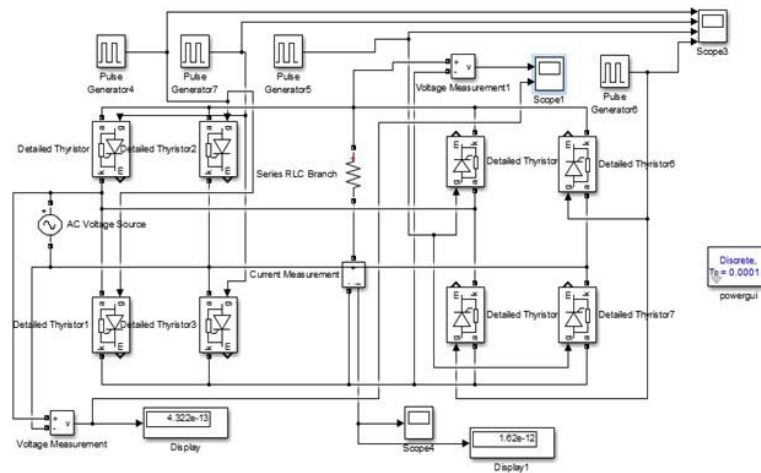
**Fig. 2**

The waveform of the supply voltage frequency is denoted by  $V_s$  and the waveform of the output voltage frequency is denoted by  $V_o$ . Here we are trying to convert the supply voltage frequency to  $1/4^{\text{th}}$  of its value. So to do that for the first two cycles of the supply voltage we will use the positive Bridge rectifier and for the following next two cycles we will use the negative bridge rectifier. Thus four positive pulses in the positive region and then four in the negative region are required as shown in the output frequency waveform  $V_o$ . The current waveform for this circuit will be the same as voltage waveform since the load is assumed to be purely resistive. Although the magnitude of the waveform will change based on the value of resistance of the load.

The output frequency is represented using the dotted line on the  $V_o$  waveform, since it changes polarity only for every two cycles of the input waveform the output frequency with  $1/4^{\text{th}}$  of the input frequency, in our case for an input frequency of 50Hz the output frequency will be  $(1/4 * 50)$  around 12.5Hz. This output frequency can be controlled by varying the triggering mechanism in the control circuit.



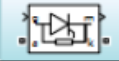

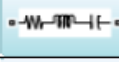

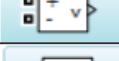
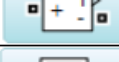

**Circuit Diagram:**

**Single phase cycloconverter with R-load:**



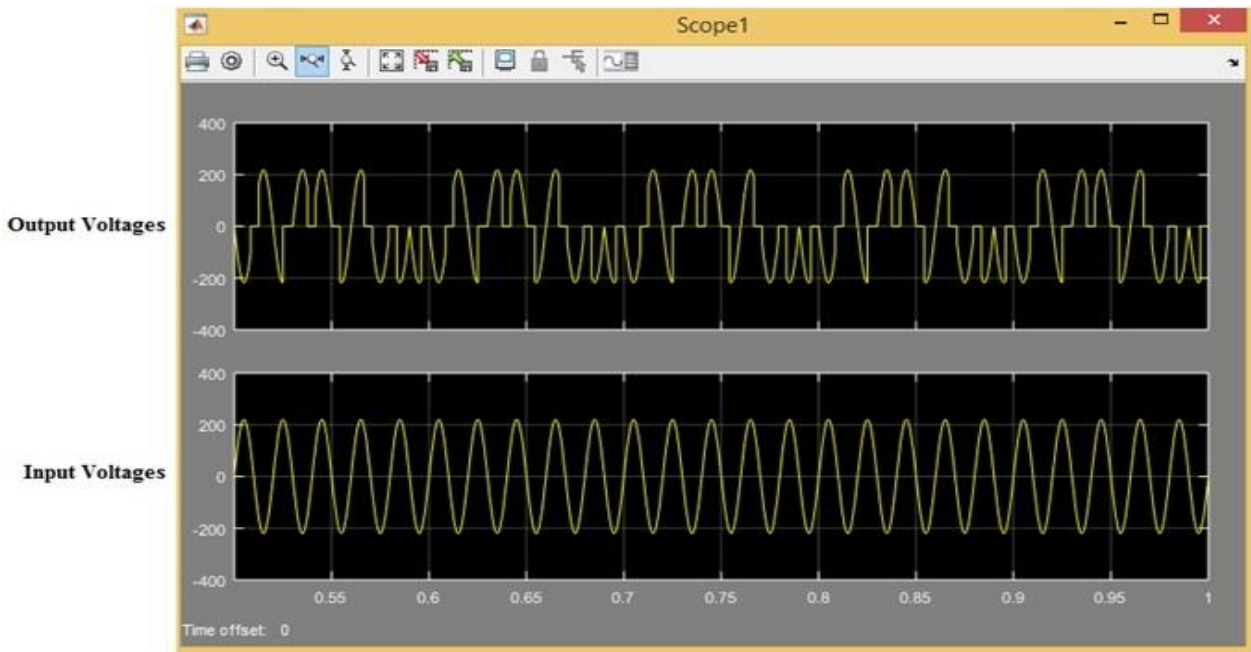
**Procedure:**

- 1) Create a new MATLAB model file and create the MATLAB model as shown in figure, corresponding to the single phase controlled rectifier circuit.
- 2) Give the run time value as 0.1 seconds to obtain simulation results for 5 input cycles
  - a.  $(5 \times 1/50\text{HZ} = 0.1 \text{ sec})$
- 3) In pulse generator blocks, set different values for varying different firing angle.
- 4) Run the simulation model and obtain the results.
- 5) Repeat the simulation for different values of firing angle for both R and RL load.

Operation	Path	Icon
Opening Simulink	1. Click on the Simulink icon on Matlab taskbar 2. Type Simulink on Matlab Command Window	
Selecting New File	File -> New -> Model	
Selecting Source	Libraries -> SimpowerSystems -> electrical sources	 AC Voltage Source
Selecting Thyristor	Libraries -> SimPowerSystems -> PowerElectronics -> Thyristor	 Thyristor
Selecting Diode	Libraries -> SimPowerSystems -> PowerElectronics -> Diodes	 Diode
Selecting Series RLC branch	Libraries -> SimpowerSystems -> Elements	 Series RLC Load
Selecting Pulse Generater(Triggering)	Libraries -> Sources	 Pulse Generator
Voltage Measurement	Libraries -> SimpowerSystems -> Measurement	 Voltage Measurement
Current Mesurement	Libraries -> SimpowerSystems -> Measurement	 Current Measurement
Scope	Libraries -> Sink	 Scope

**Expected waveforms:**

**Single phase Cycloconverter with R-load:**



**Result:**



**Viva Questions:**

1. What is an cycloconverter?
2. What is the difference between AC voltage regulator and cycloconverter?
3. What is MATLAB?
4. What is the purpose of simulating in MATLAB software?
5. What are the advantages of MATLAB software?
6. Classify cycloconverters.

## Expt. No. 13. Simulation of MOSFET based Chopper Circuit

**Aim:** To design and simulate MOSFET based Chopper circuit.

**Apparatus:** MATLAB/SIMULINK software

### Simulation Blocks:

AC voltage source, Thyristors, Pulse Generators (for Thyristor gate pulse) , Series RLC branch (for R and RL load) , Voltage and Current measurement blocks, Scope and Display blocks, Powergui block (Continuous).

### Theory:

Chopper converts fixed DC voltage to variable DC voltage with semiconductor devices. The DC to DC converters have gained popularity in modern industry. Some practical applications of DC to DC converter include armature voltage control of DC motors converting one DC voltage level to another level, and controlling DC power for wide variety of industrial processes. The time ratio controller (TRC) is a form of control for DC to DC conversion.

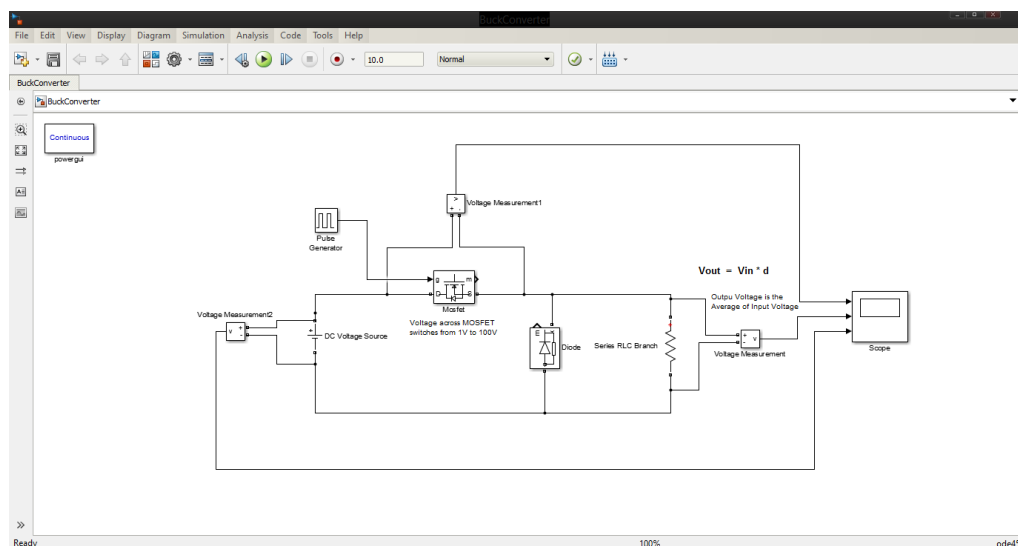
Time ratio controller (TRC) or chopper is a semiconductor switch as shown in fig. MOSFET is connected between the source and the load. The switch is closed and opened periodically such that the load is connected to, and disconnected from, the supply alternatively. Thus the average voltage impressed on the load is controlled by controlling the ratio of ON state interval to one cycle duration.

The most important factor that governs the performance of the chopper is the duty ratio. The duty ratio can be controlled by changing the on period duration by keeping frequency constant. Changing the frequency of the chopper introduces different harmonics at different frequencies. At some frequency of operation, the harmonic contents are larger than the tolerable limits. Therefore, fixed frequency choppers with a variable on period technique are generally used. Two types of choppers can be constructed using a MOSFET. One is step-up chopper and other one is step-down chopper.

**MOSFET Step-down Chopper (Forward/Buck Converter):** A Chopper is a high speed on/off semiconductor switch. It connects source to load and disconnects the load from source at a fast speed. A step-down chopper using MOSFET is shown in fig.1. During  $T_{ON}$  chopper is ON and load voltage is equal to source voltage  $V_s$ . During the interval  $T_{off}$ , chopper is off, load current flows through freewheeling diode FD and load voltage is zero during  $T_{off}$ . In this manner chopper load voltage is produced at the load terminals.





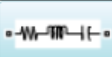




### Circuit Diagram:

#### MOSFET based Chopper with R-load:



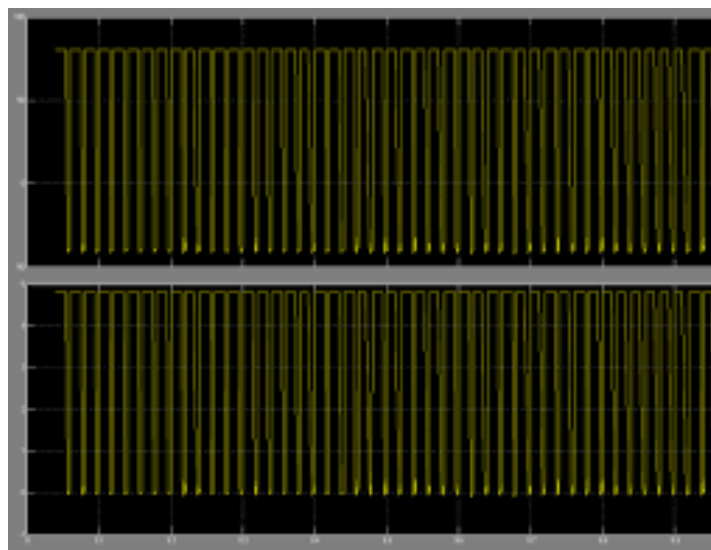
## Procedure:

- 1) Create a new MATLAB model file and create the MATLAB model as shown in figure, corresponding to the single phase controlled rectifier circuit.
- 2) Give the run time value as 0.1 secs to obtain simulation results for 5 input cycles
  - a.  $(5 \times 1/50\text{HZ}=0.1 \text{ sec})$
- 3) In pulse generator blocks, set different values for varying different firing angle.
- 4) Run the simulation model and obtain the results.
- 5) Repeat the simulation for different values of firing angle for both R and RL load.

Operation	Path	Icon
Opening Simulink	1. Click on the Simulink icon on Matlab taskbar 2. Type Simulink on Matlab Command Window	
Selecting New File	File -> New -> Model	
Selecting Source	Libraries -> SimpowerSystems -> electrical sources	 AC Voltage Source
Selecting Thyristor	Libraries -> SimPowerSystems -> PowerElectronics -> Thyristor	 Thyristor
Selecting Diode	Libraries -> SimPowerSystems -> PowerElectronics -> Diodes	 Diode
Selecting Series RLC branch	Libraries -> SimpowerSystems -> Elements	 Series RLC Load
Selecting Pulse Generater(Triggering)	Libraries -> Sources	 Pulse Generator
Voltage Measurement	Libraries -> SimpowerSystems -> Measurement	 Voltage Measurement
Current Mesurement	Libraries -> SimpowerSystems -> Measurement	 Current Measurement
Scope	Libraries -> Sink	 Scope

## Expected waveforms:

**MOSFET based Chopper with R-load:**



**Result:**

**Viva Questions:**

1. What is a Chopper?
2. What is the difference between chopper and inverter?
3. What is MATLAB?
4. What is the purpose of simulating in MATLAB software?
5. What are the advantages of MATLAB software?
6. Classify choppers.