NED University of Engineering & Technology

Department of Electrical Engineering

LAB MANUAL

For the course

POWER ELECTRONICS
(EE-313) For T.E.(EE)

Instructor name:_____

Student name:_____

Roll no: _____ **Batch:**_____

Semester: _____ **Year:**_____

To be filled by lab technician

Attendance: Present out of _____ Lab sessions

Attendance Percentage _____

To be filled by Lab Instructor

Lab Score Sheet

Roll No.	Rubric based Lab I	Rubric based Lab II	Rubric based Lab III	Rubric based Lab IV	Rubric based Lab V	Rubric based Lab VI	OEL/PBL Rubric Score A	Final LAB Rubric Score B	Attendance Percentage C	Final weighted Score for MIS System [10(A)+10(B)+5(C)]/25 Round to next higher multiple of 5

EE-313 PE Rubric Based Labs: 2, 3, 4, 5, 8, 9

Note: All Rubric Scores must be in the next higher multiple of 5 for correct entry in MIS system.

LAB MANUAL

For the course

POWER ELECTRONICS
(EE-313) For T.E.(EE)

Content Revision Team:

Dr. M. Javed, Engr. M Uzair, Engr. Hammad ud Din

Last Revision Date:

Approved By

The Board of Studies of Department of Electrical Engineering

_____ _____

_____ _____

_____ _____

SAFETY RULES

1. Please don't touch any live parts.
2. Never use an electrical tool in a damp place.
3. Don't carry unnecessary belongings during performance of practicals (like water bottle, bags etc).
4. Before connecting any leads/wires, make sure power is switched off.
5. In case of an emergency, push the nearby red color emergency switch of the panel or immediately call for help.
6. In case of electric fire, never put water on it as it will further worsen the condition; use the class C fire extinguisher.

Fire is a chemical reaction involving rapid oxidation (combustion) of fuel. Three basic conditions when met, fire takes place. These are fuel, oxygen & heat, absence of any one of the component will extinguish the fire.

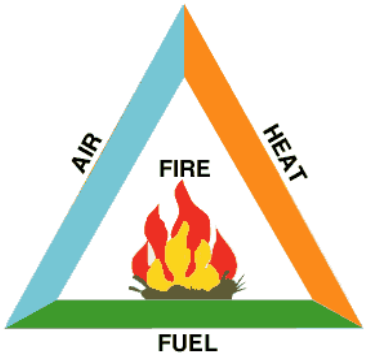


Figure: Fire Triangle

A(think ashes): paper, wood etc

B(think barrels): flammable liquids

C(think circuits): electrical fires

If there is a small electrical fire, be sure to use only a Class C or multipurpose (ABC) fire extinguisher, otherwise you might make the problem worsen.

The letters and symbols are explained in left figure. Easy to remember words are also shown.

***Don't** play with electricity, Treat electricity with respect, it deserves!*

CONTENTS

LAB SESSION 01

Purpose:

Introduction

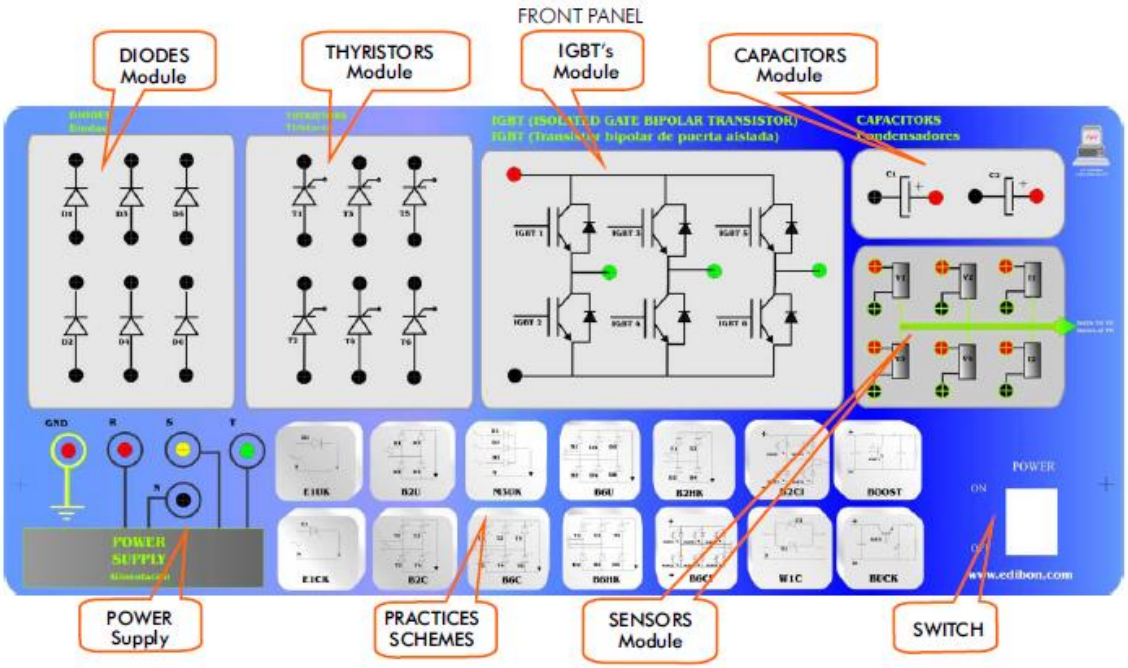
Apparatus:

- SACED TECNEL (Software)
- TECNEL
- RCL3R Load module

Theory:

In electrical drives lab, we will use TECNEL/B hardware & RCL3R Load module. The front panel of Tecnel/B consists of:

- Diodes module: 6 diodes.
- Thyristors module: 6 thyristors.
- IGBTS Module: 6 IGBTS.
- Capacitor module
- Sensors module: 4 Voltage sensors & 2 Current sensors.
- Power supply connections for Red Yellow Blue Phases (R,S, T), Neutral and Ground.
- Practices schemes.



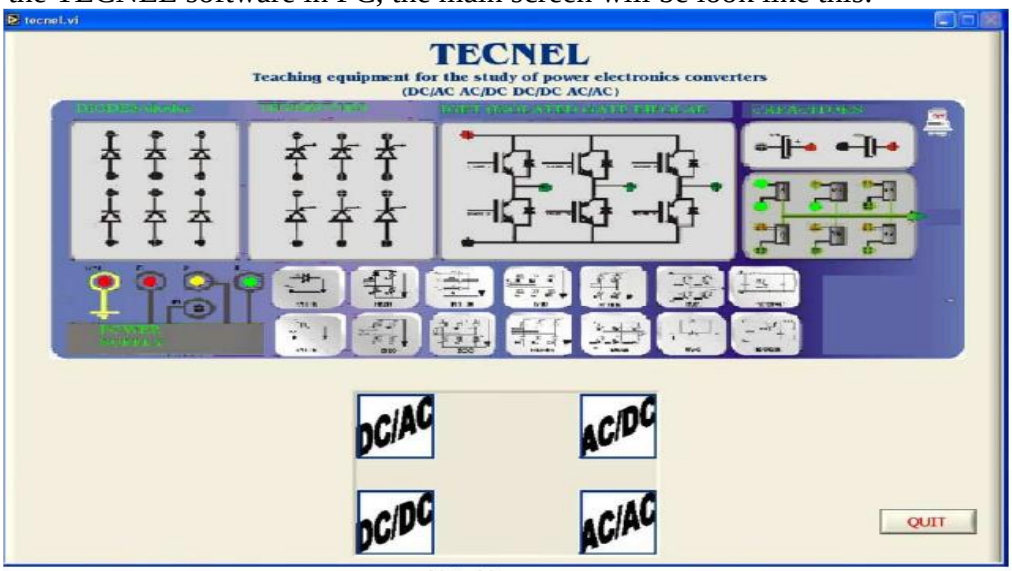
PROCESS DIAGRAM AND ELEMENTS ALLOCATION

RCL3R. Resistive, Inductive, and Capacitive Loads Module:
Our Resistive, Capacitive, and Inductive Loads Module (RCL3R) offers single and Three-phase resistances, inductances & capacitances.

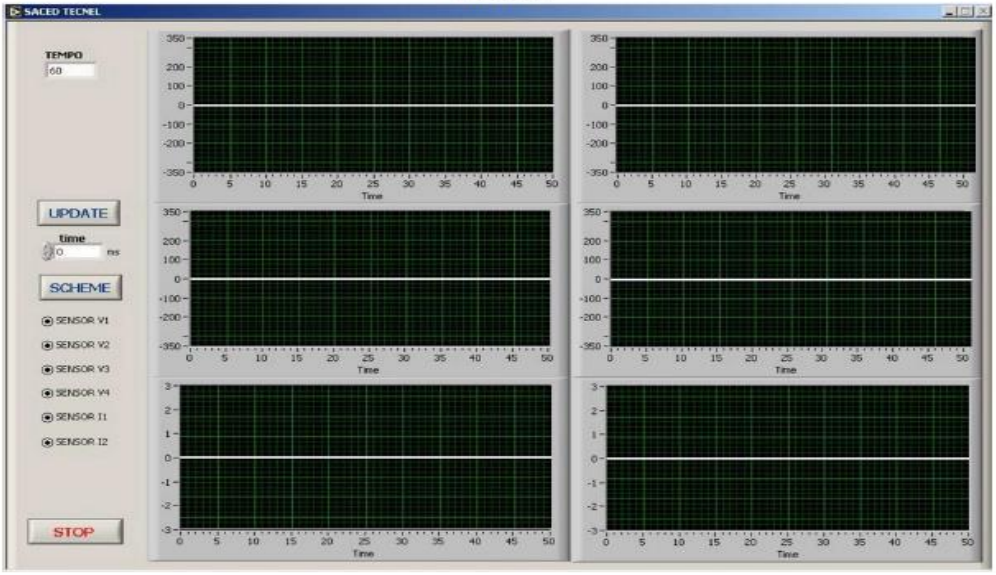
The values are as follows:

Variable resistive loads:	3 x [150 Ω (500 W)]
Fixed resistive loads:	3 x [150 Ω (500 W) + 150 x (500 W)]
Inductive loads:	3 x [0, 33, 78, 140, 193, 236 mH]. (230V /2 A)
Capacitive loads:	3 x [4 x 7 µF]. (400V)

Now load the TECNEL software in PC, the main screen will be look like this:



And the Plot screen will be look like this:



LAB SESSION 02

Object:

AC/DC Single-phase Not-Controlled Half-wave Rectifier with R load, R-L load and R-L load with FWD.

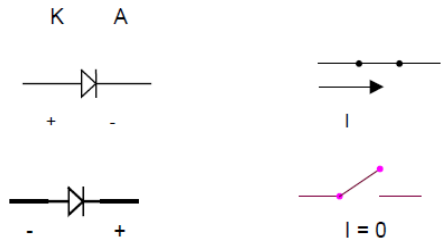
Apparatus:

- SACED TECNEL
- TECNEL or TECNEL/B
- RCL3R Load module
- Wires

Theory:

Single-phase half-wave not-controlled rectifiers:

Not-controlled rectifiers are constituted by diodes that, acts as not-controlled elements, provide a dependent output voltage of fixed magnitude. In half wave rectifiers, diode conducts only in half cycle of the input, otherwise open.



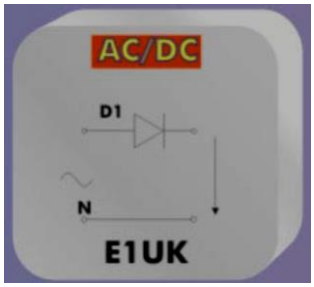
From a theoretical point of view, they may be considered as switches that are opened or closed depending on the direction of the voltage applied. That is, with a positive voltage between anode (A) and cathode (K) the switch is closed, and it is opened if the voltage is negative.

The behavior of the rectifier will depend considerably on the used load type, so we may have:

Pure resistive load (R), where the voltage is annulled when its direction changes.
Inductive load (R-L), where the conduction continues until the moment when the current in the coil is annulled, although the output voltage inverts its polarity.

In order to separate the output voltage and the load type, we may use the free wheeling diode (FWD), which avoids the inversion of polarization in the output voltage.

Circuit Diagram:



E1UK Model

Procedure:

1. Carry out the assembly E1UK shown in the above figure
2. Connect the respective load to its terminals one by one.

For R Load

Use Fixed R= 300ohms plus variable resistance in series.

And sample the following parameters:

Input voltage V1, Output voltage V2, Output current I2, Diode voltage V3 (as shown in figure)

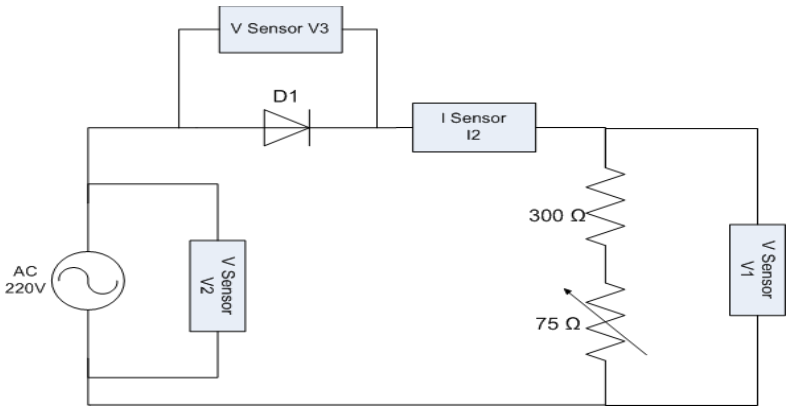


Figure: Uncontrolled Half Wave Rectifier R Load

For different values of R the RMS voltage will vary across the load, which can be calculated using multimeter.

S. No	Load Resistance	Vrms	Voltage Across Diode
1.	300 + 75 Ω		
2.	300 + 120 Ω		

For RL Load

Observe how the conduction angle increases as we increase L (0 to 238mH) with R=375Ω, measuring with the voltmeter the average output voltage.

S. No	Load Resistance	Vrms	Voltage Across Diode
1.	300 Ω + 75 Ω + 140mH		
2.	300 Ω + 75 Ω + 238mH		

Observe how the output current varies for different L values with R=375Ω. Save the different samples.

And sample the following parameters:
Input voltage V1, Output voltage V2, Diode voltage V3, Output current (load) I2 (as shown in figure)

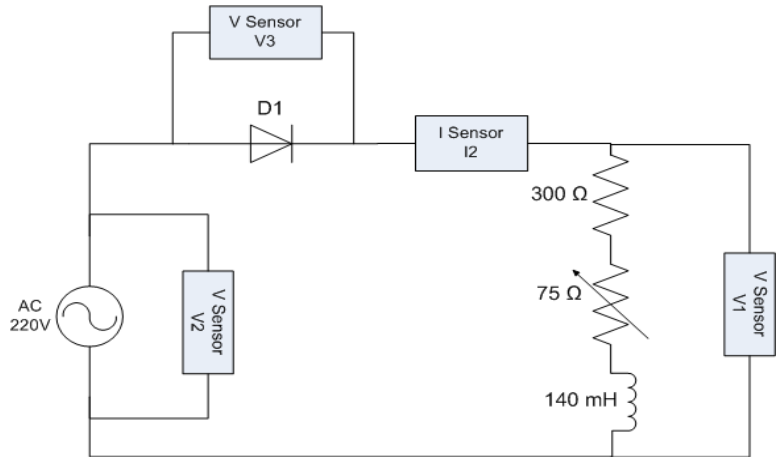


Figure: Uncontrolled Half Wave Rectifier RL Load

For RL Load with FWD

Observe how the conduction angle increases as we increase L (0 to 238mH) with R=350Ω, measuring with the voltmeter the average output voltage.

S. No	Load Resistance	Vrms	Voltage Across Diode	
			D1	D2
1.	300 Ω + 75 Ω + 140mH			
2.	300 Ω + 75 Ω + 238mH			

Observe how the output current varies for different L values with R=375Ω.

And sample the following parameters:
Input voltage V1, Output voltage V2, Output current I1, Diode Voltage V2

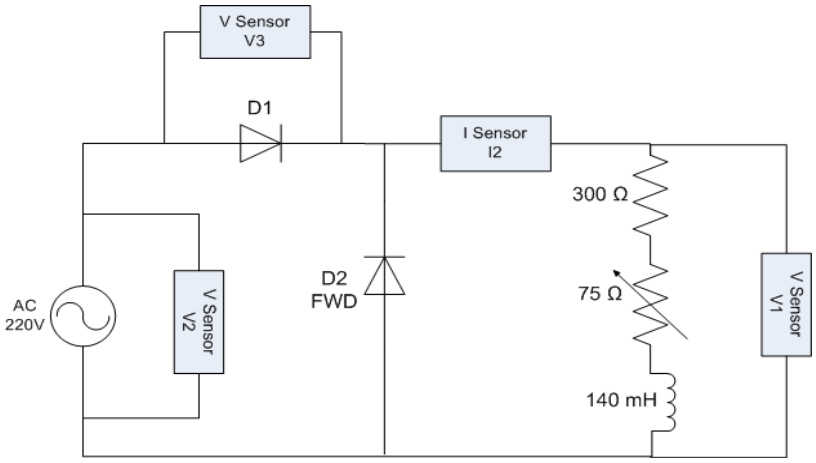


Figure: Uncontrolled Half Wave Rectifier RL Load

3. Load the SACED TECNEL program in PC and the window corresponding to this practice
   - Select Practice Option
   - "AC/DC" → "Single-phase Not-Controlled Halfwave Rectifier" option
4. Select the respective sample sensors

5. **Check the connections** and switch on the equipment.
6. Press the "Data Capture" button.
7. Visualize the parameters measured and save them in the corresponding file.
8. Switch off the equipment.

Question:

Define the following terms:

1. Ripple Factors:

_____
_____
_____
_____

2. Harmonics:

_____
_____
_____
_____

3. Fundamental Frequency:

_____
_____
_____
_____

4. Power Factor:

_____
_____
_____
_____

5. Rectifiers:

_____
_____
_____
_____

Waveforms:

R LOAD

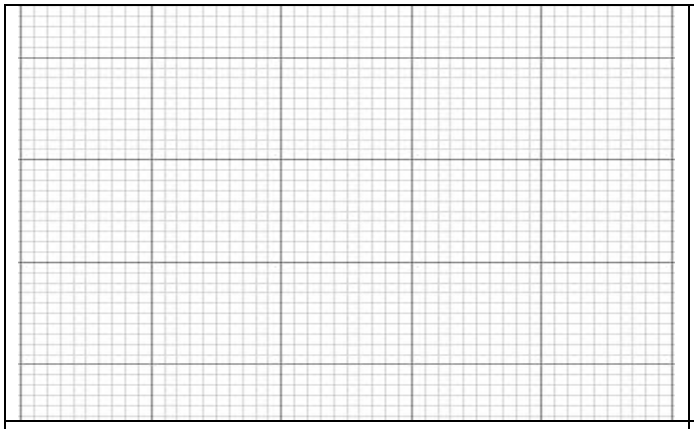


Fig: Input Voltage

Fig: Output Voltage across R Load

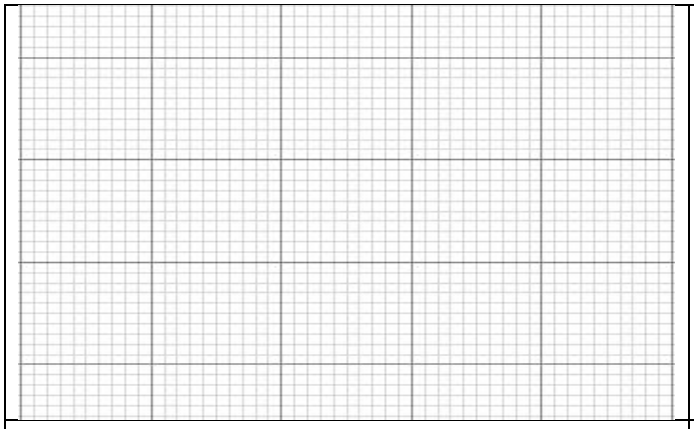


Fig: Load Current I_L

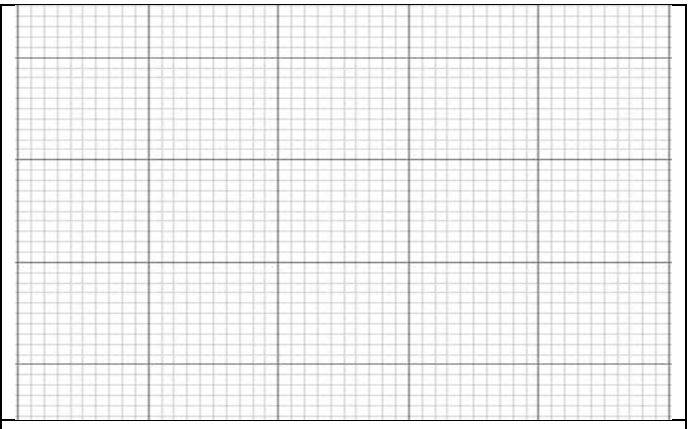


Fig: Output Voltage across Diode

R-L LOAD

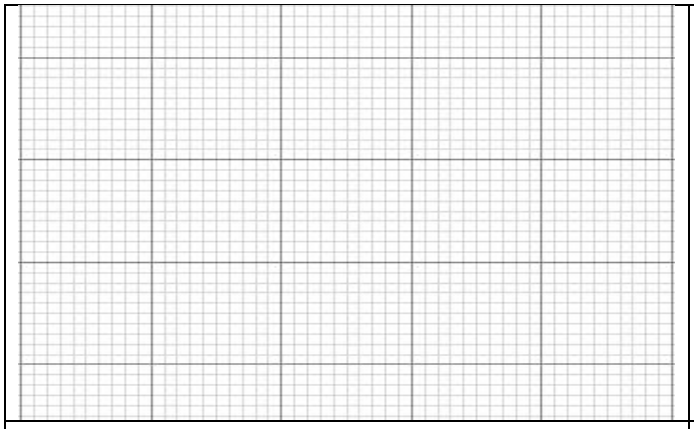


Fig: Input Voltage

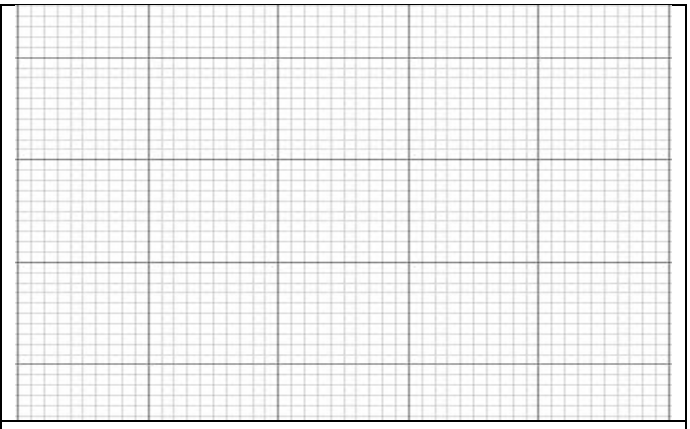


Fig: Output Voltage across R Load

Fig: Load Current I_L

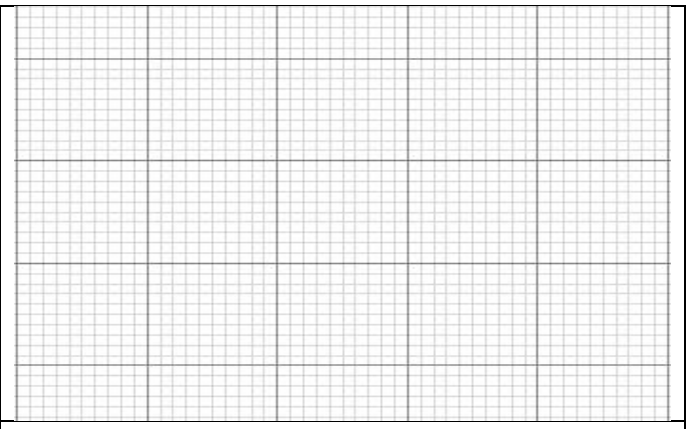


Fig: Output Voltage across Diode D1

R-L LOAD WITH FWD

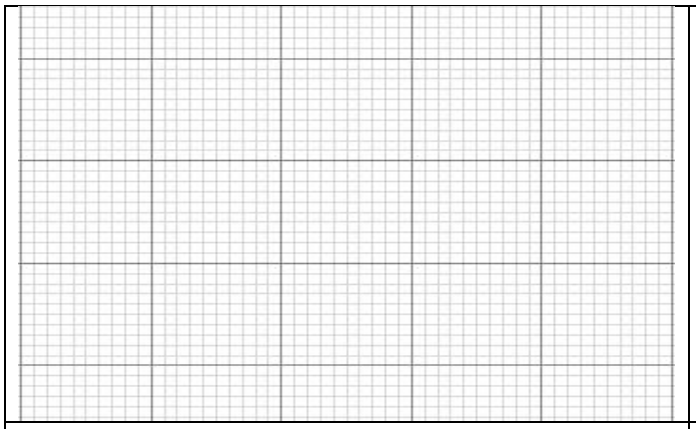


Fig: Input Voltage

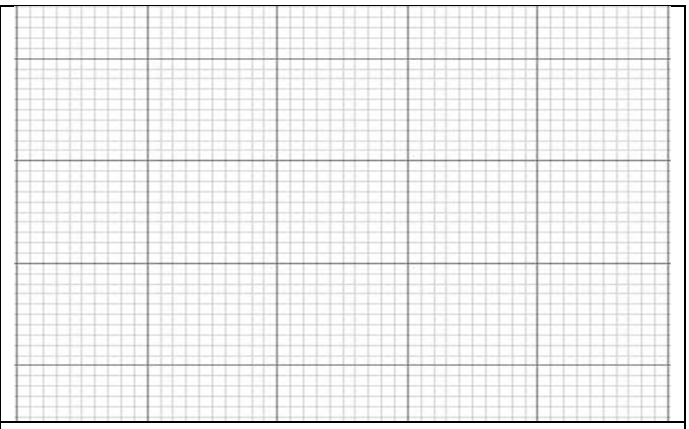


Fig: Output Voltage across R-L Load

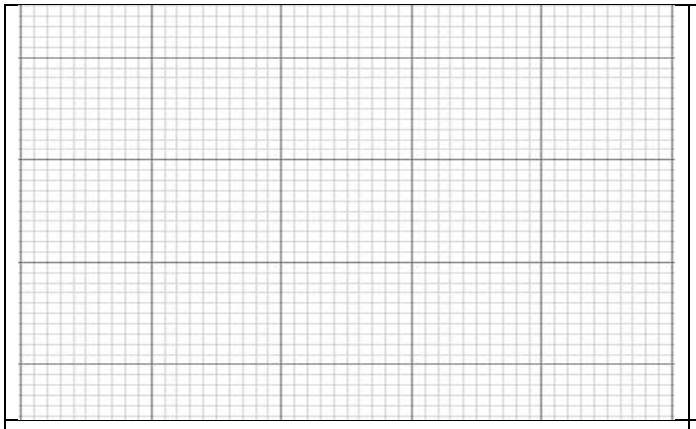


Fig: Load Current I_L

Fig: Diode Voltage

NED University of Engineering & Technology
Department of Electrical Engineering

Course Code and Title: _____

Laboratory Session: No._____ Date: _____

Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
Equipment Identification Sensory skill to identify equipment and/or its component for a lab work. 10 %	Not able to identify the equipment. 0	--	--	--	Able to identify equipment as well as its components. 40
Equipment Use Sensory skills to describe the use of the equipment for the lab work. 15%	Never describes the use of equipment. 0	Rarely able to describe the use of equipment. 15	Occasionally describe the use of equipment. 30	Often able to describe the use of equipment. 45	Frequently able to describe the use of equipment. 60
Procedural Skills Displays skills to act upon sequence of steps in lab work. 15%	Not able to either learn or perform lab work procedure. 0	Able to slightly understand lab work procedure and perform lab work. 15	Able to somewhat understand lab work procedure and perform lab work. 30	Able to moderately understand lab work procedure and perform lab work. 45	Able to fully understand lab work procedure and perform lab work. 60
Response Ability to imitate the lab work on his/her own. 15%	Not able to imitate the lab work. 0	Able to slightly imitate the lab work. 15	Able to somewhat imitate the lab work. 30	Able to moderately imitate the lab work. 45	Able to fully imitate the lab work. 60
Observation's Use Displays skills to perform related mathematical calculations using the observations from lab work. 15%	Not able to use lab work observations into mathematical calculations. 0	Able to slightly use lab work observations into mathematical calculations. 15	Able to somewhat use lab work observations into mathematical calculations. 30	Able to moderately use lab work observations into mathematical calculations. 45	Able to fully use lab work observations into mathematical calculations. 60
Safety Adherence Adherence to safety procedures. 10%	Doesn't adhere to safety procedures. 0	Slightly adheres to safety procedures. 10	Somewhat adheres to safety procedures. 20	Moderately adheres to safety procedures. 30	Fully adheres to safety procedures. 40
Equipment Handling Equipment care during the use. 10%	Doesn't handle equipment with required care. 0	Rarely handles equipment with required care. 10	Occasionally handles equipment with required care 20	Often handles equipment with required care. 30	Handles equipment with required care. 40
Group Work Contributes in a group-based lab work. 10%	Never participates. 0	Rarely participates. 10	Occasionally participates and contributes. 20	Often participates and contributes. 30	Frequently participates and contributes. 40
Total Points (Out of 400)					
Weighted CLO (Psychomotor Score)	(Points /4)				
Remarks					
Instructor's Signature with Date:					

LAB SESSION 03

Object:

AC/DC Single-phase Not-Controlled Full wave Rectifier with R load and R-L load.

Apparatus:

- SACED TECNEL
- TECNEL or TECNEL/B
- RCL3R Load module
- Wires

Theory:

Single-phase full-wave not-controlled rectifiers:

By the use of four diodes, rectifier circuit performance can be greatly improved. The entire supply voltage wave is utilized to impress current through the load.

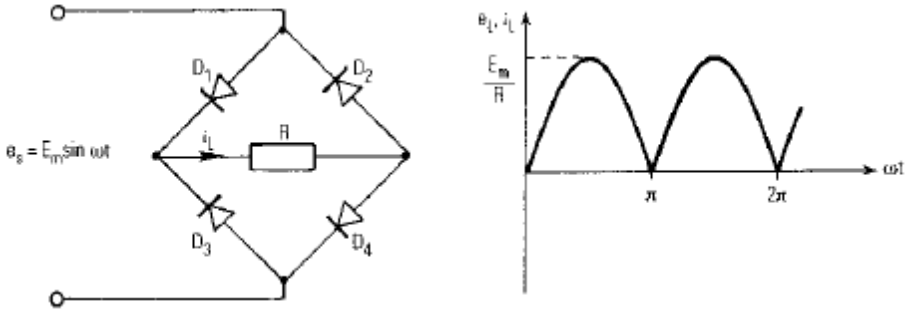
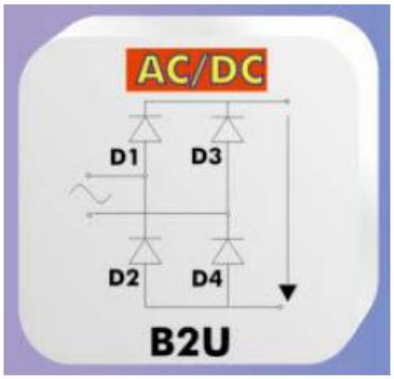


Figure: Single-phase, full-wave diode rectifier:
(a) circuit diagram and (b) load voltage and current waveforms for *R* load.

The behavior of the rectifier will depend considerably on the used load type, i.e. R Load or RL Load.

Circuit Diagram:



B2U Model

Property	Half-wave bridge	Full-wave bridge
Average load current	$\frac{I_m}{2}$	$\frac{2}{\pi}\frac{E_m}{R}$
RMS load current	$\frac{E_m}{2R}$	$\frac{E_m}{\sqrt{2R}}$
Power	$\frac{E_m^2}{4R}$	$\frac{E_m^2}{2R}$
RMS supply current	$\frac{E_m}{2R}$	$\frac{E_m}{\sqrt{2R}}$
Power factor	$\frac{1}{\sqrt{2}}$	1.0
Ripple factor of load current	1.21	0.47

Table 1: Single-Phase Diode Rectifier Circuits with Resistive Load

Procedure:

9. Carry out the assembly B2U shown in the above figure
10. Connect the respective load to its terminals one by one.

For R Load

Use Fixed R= 300ohms plus variable resistance in series.

And sample the following parameters:
Input voltage V1, Output voltage V2, Output current I2, Diode voltage V3 (as shown in figure)

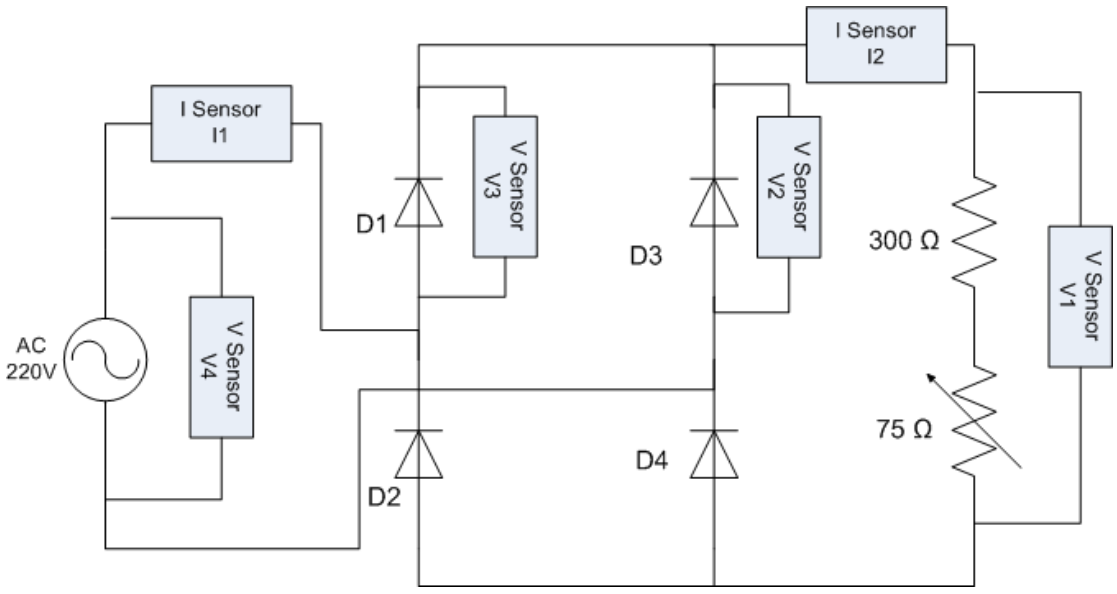


Figure: Uncontrolled Full Wave Rectifier with R load

And measure the following quantities

S. No	Load Resistance	Vrms	Voltage Across D1
1.	300 + 75 Ω		
2.	300 + 120 Ω		

For RL Load
Observe how the conduction angle increases as we increase L (0 to 238mH) with R=375Ω, measuring with the voltmeter the average output voltage.

S. No	Load Impedance	Vrms	Voltage Across Diode
1.	300 Ω + 75 Ω + 140mH		
2.	300 Ω + 75 Ω + 238mH		

Observe how the output current varies for different L values with R=375Ω. Save the different samples.

And sample the following parameters:
Input voltage V1, Output voltage V2, Diode voltage V3, Output current (load) I2 (as shown in figure)

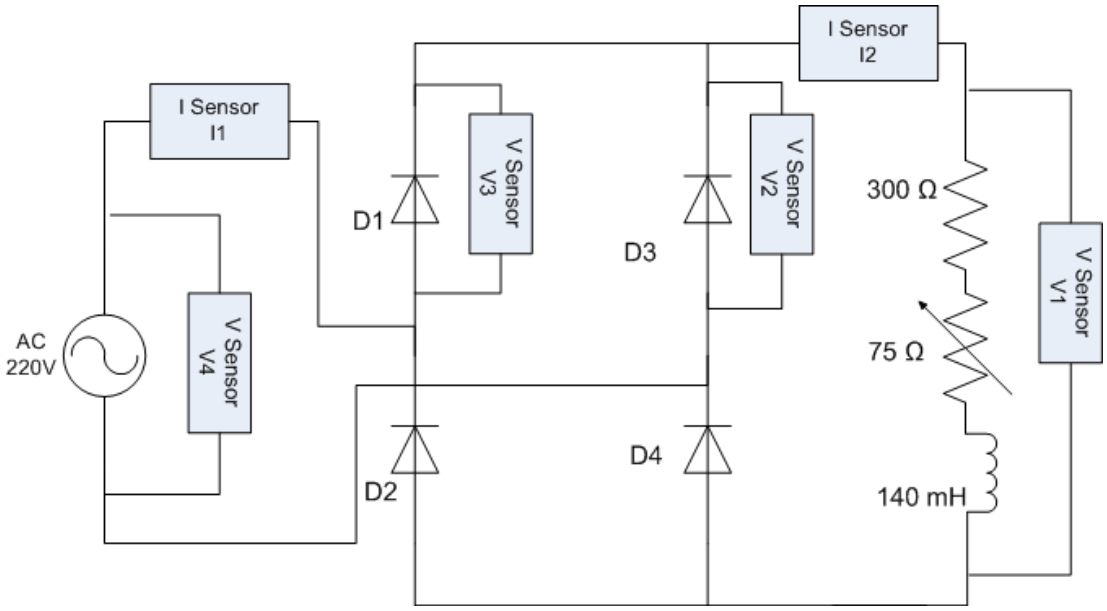


Figure: Uncontrolled Full Wave Rectifier with RL load

11. Load the SACED TECNEL program in PC and the window corresponding to this practice
    - Select Practice Option
    - "AC/DC" → "Single-phase Not-Controlled Halfwave Rectifier" option
12. Select the respective sample sensors
13. **Check the connections** and switch on the equipment.

14. Press the "Data Capture" button.
15. Visualize the parameters measured and save them in the corresponding file.
16. Switch off the equipment.

Waveforms:

R LOAD

Fig: Input Voltage

Fig: Output Voltage across R Load

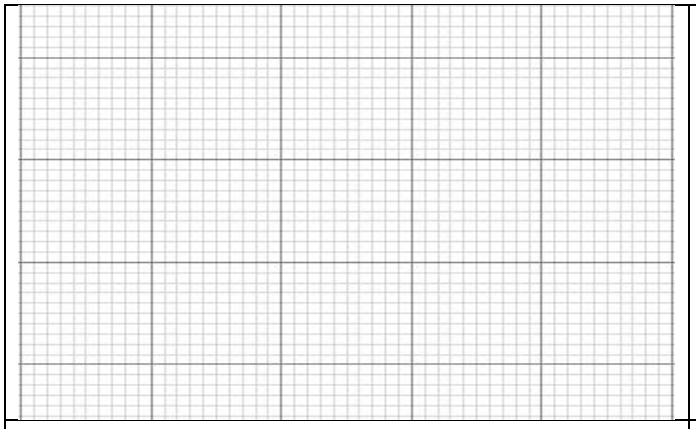


Fig: Load Current I_L

Fig: Supply Current I_S

Fig: Output Voltage across Diode D1

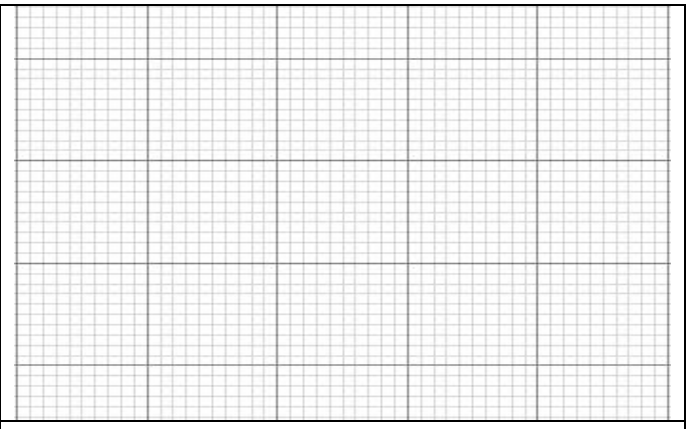


Fig: Output Voltage across Diode D3

R-L LOAD

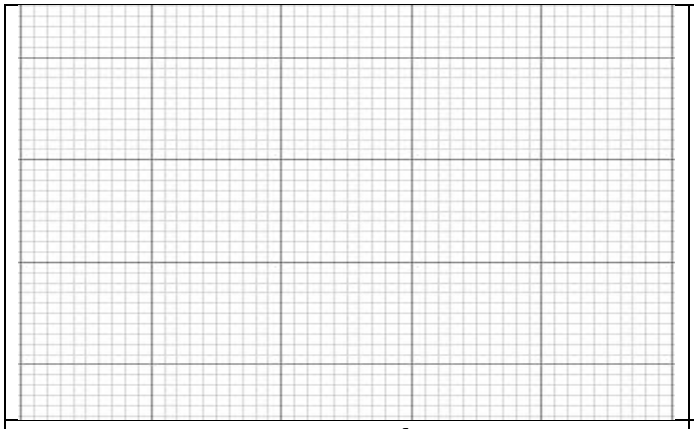


Fig: Input Voltage

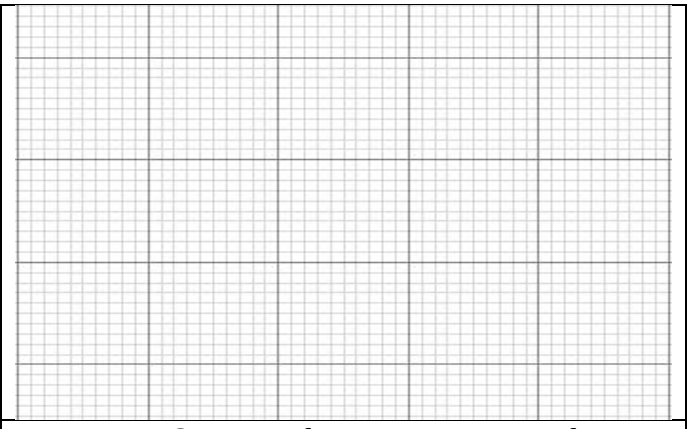


Fig: Output Voltage across RL Load

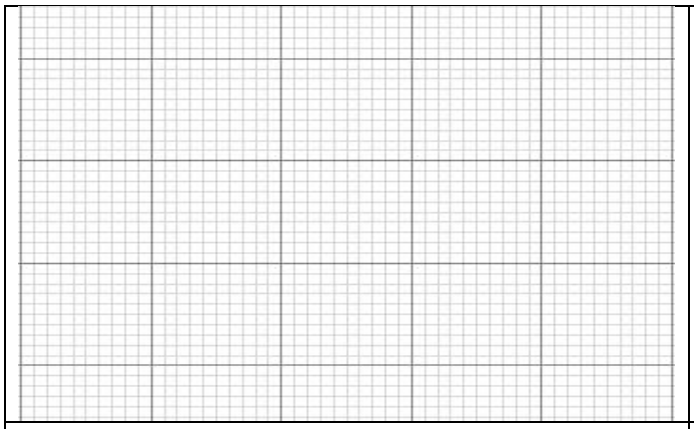


Fig: Load Current I_L

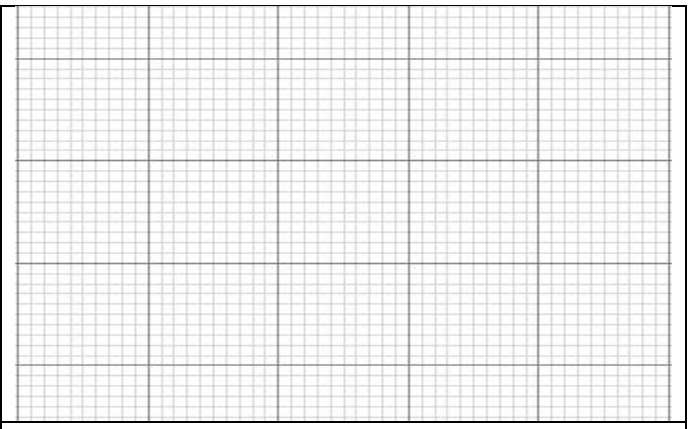


Fig: Supply Current I_S

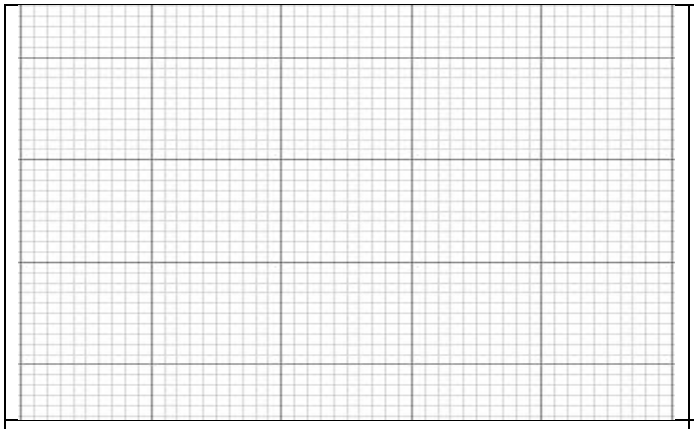


Fig: Output Voltage across Diode D1

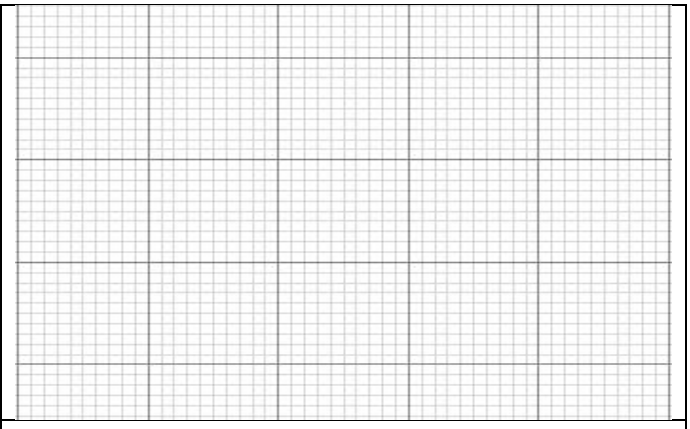


Fig: Output Voltage across Diode D3

NED University of Engineering & Technology
Department of Electrical Engineering

Course Code and Title: _____

Laboratory Session: No._____ Date: _____

Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
Equipment Identification Sensory skill to identify equipment and/or its component for a lab work. 10 %	Not able to identify the equipment. 0	--	--	--	Able to identify equipment as well as its components. 40
Equipment Use Sensory skills to describe the use of the equipment for the lab work. 15%	Never describes the use of equipment. 0	Rarely able to describe the use of equipment. 15	Occasionally describe the use of equipment. 30	Often able to describe the use of equipment. 45	Frequently able to describe the use of equipment. 60
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Response Ability to imitate the lab work on his/her own. 15%	Not able to imitate the lab work. 0	Able to slightly imitate the lab work. 15	Able to somewhat imitate the lab work. 30	Able to moderately imitate the lab work. 45	Able to fully imitate the lab work. 60
Observation's Use Displays skills to perform related mathematical calculations using the observations from lab work. 15%	Not able to use lab work observations into mathematical calculations. 0	Able to slightly use lab work observations into mathematical calculations. 15	Able to somewhat use lab work observations into mathematical calculations. 30	Able to moderately use lab work observations into mathematical calculations. 45	Able to fully use lab work observations into mathematical calculations. 60
Safety Adherence Adherence to safety procedures. 10%	Doesn't adhere to safety procedures. 0	Slightly adheres to safety procedures. 10	Somewhat adheres to safety procedures. 20	Moderately adheres to safety procedures. 30	Fully adheres to safety procedures. 40
Equipment Handling Equipment care during the use. 10%	Doesn't handle equipment with required care. 0	Rarely handles equipment with required care. 10	Occasionally handles equipment with required care 20	Often handles equipment with required care. 30	Handles equipment with required care. 40
Group Work Contributes in a group-based lab work. 10%	Never participates. 0	Rarely participates. 10	Occasionally participates and contributes. 20	Often participates and contributes. 30	Frequently participates and contributes. 40
Total Points (Out of 400)					
Weighted CLO (Psychomotor Score)	(Points /4)				
Remarks					
Instructor's Signature with Date:					

LAB SESSION 04

Object:

AC/DC Three-Phase Not-Controlled Half-wave Rectifier with R load & R-L load.

Apparatus:

- SACED TECNEL
- TECNEL or TECNEL/B
- RCL3R Load module
- Wires

Theory:

Three-phase half-wave not-controlled rectifiers:

Three-phase electricity supplies with balanced, sinusoidal voltages are widely available. It is found that the use of a three-phase rectifier system, in comparison with a single-phase system, provides smoother output voltage and higher rectifier efficiency. Also, the utilization of any supply transformers and associated equipment is better with poly-phase circuits. If it is necessary to use an output filter this can be realized in a simpler and cheaper way with a poly-phase rectifier.

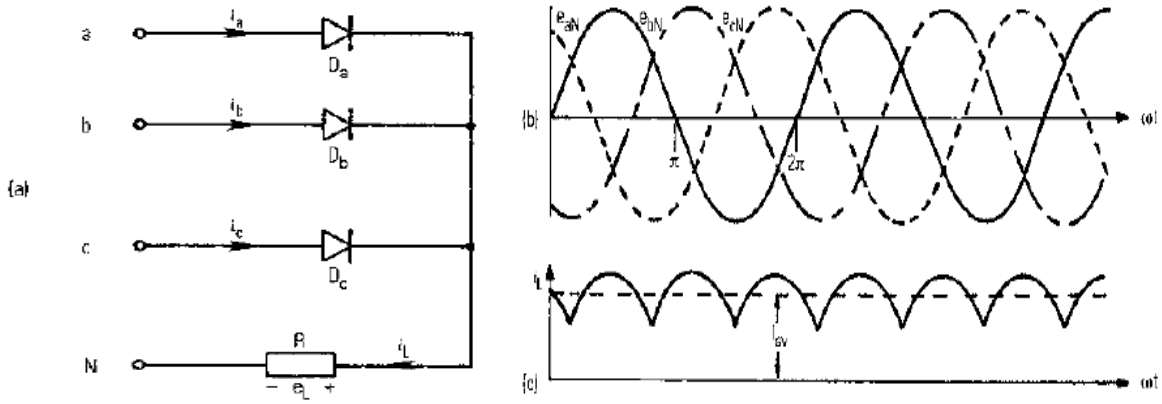
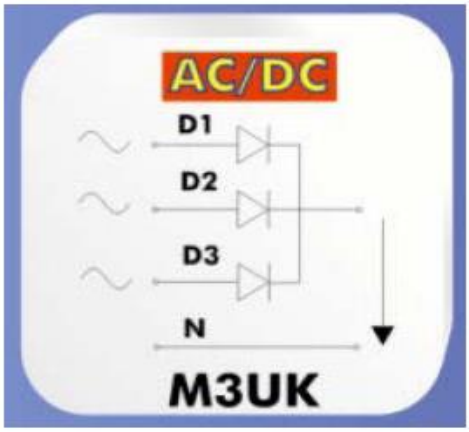


Figure: Three-phase, half-wave diode rectifier with resistive load: (a) circuit connection, (b) phase voltages at the supply, (c) load current.

			Resistive load	Highly inductive load
Three-pulse (half-wave) operation	Average load current		$0.27\frac{E_m}{R}$	$0.27\frac{E_m}{R}$
	RMS load current		$0.41\frac{E_m}{R}$	$0.27\frac{E_m}{R}$
	Load power		$0.07\frac{E_m}{R}$	$0.84\frac{E_m}{R}$
	RMS supply current		$0.85\frac{E_m}{R}$	$0.77\frac{E_m}{R}$
	Power factor		0.684	0.676
	Ripple factor	Load voltage	0.185	0.185
		Load current	0.185	0

Table: Three Phase Uncontrolled Rectifier with Ideal Supply

Circuit Diagram:



M3UK Model

Procedure:

17. Carry out the assembly M3UK shown in the above figure
18. Connect the respective load to its terminals one by one.

For R Load

Use Fixed R= 300ohms plus variable resistance in series.

And sample the following parameters:
Input voltage V2, Output voltage V1, Output current I1

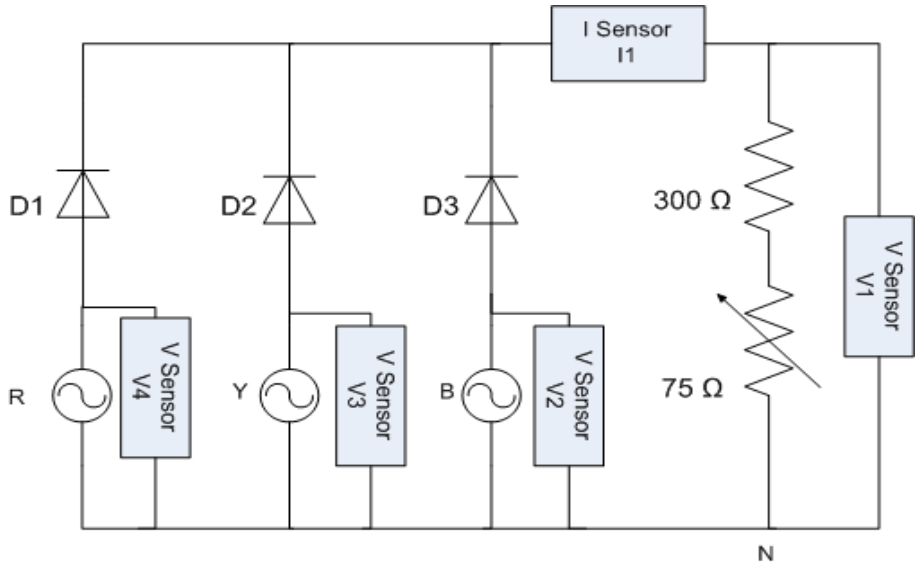


Figure: Uncontrolled Three Phase Full Wave Rectifier with R load

Also measure the following quantities using multi-meter.

S. No	Load Resistance	Vrms	Voltage Across D1
1.	300 + 75 Ω		
2.	300 + 120 Ω		

For RL Load
Observe how the conduction angle increases as we increase L (0 to 238mH) with R=375Ω, measuring with the voltmeter the average output voltage.

S. No	Load Impedance	Vrms	Voltage Across Diode
1.	300 Ω + 75 Ω + 140mH		
2.	300 Ω + 75 Ω + 238mH		

Observe how the output current varies for different L values with R=375 Ω. Save the different samples.

And sample the following parameters:
Input voltage V1, Output voltage V2, Diode voltage V3, Output current (load) I2 (as shown in figure)

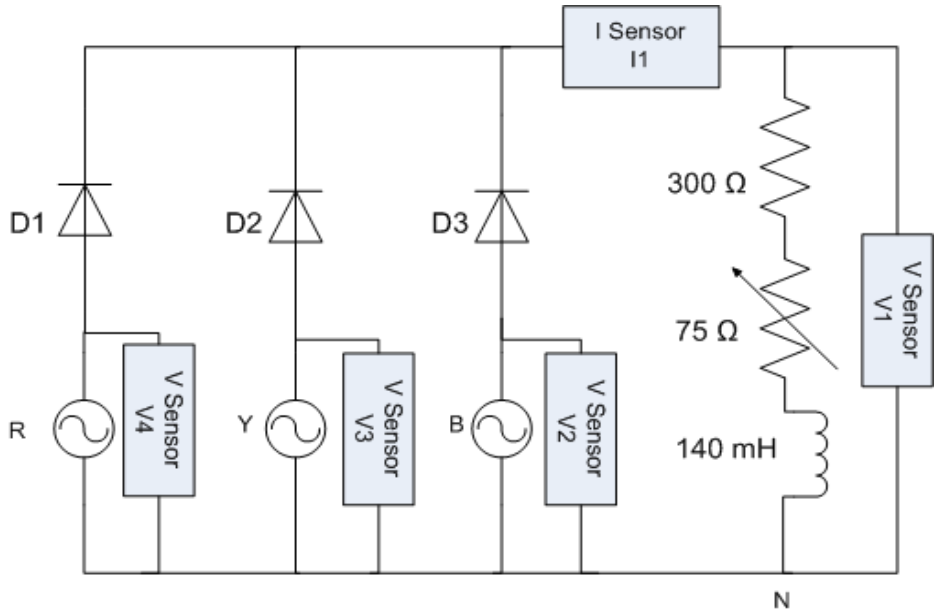


Figure: Uncontrolled Three Phase Full Wave Rectifier with RL load

19. Load the SACED TECNEL program in PC and the window corresponding to this practice
    - Select Practice Option
    - "AC/DC" → "Single-phase Not-Controlled Halfwave Rectifier" option
20. Select the respective sample sensors
21. **Check the connections** and switch on the equipment.
22. Press the "Data Capture" button.
23. Visualize the parameters measured and save them in the corresponding file.
24. Switch off the equipment.

Here you can also study and visualize what will be the effect of inverting the polarization of the three diodes.

Secondly suppose that, due to an over-voltage, one of the diodes is in open circuit. Study and visualize what effect provokes the output voltage.

Waveforms:

R LOAD

Fig: Input Voltages R,S,T

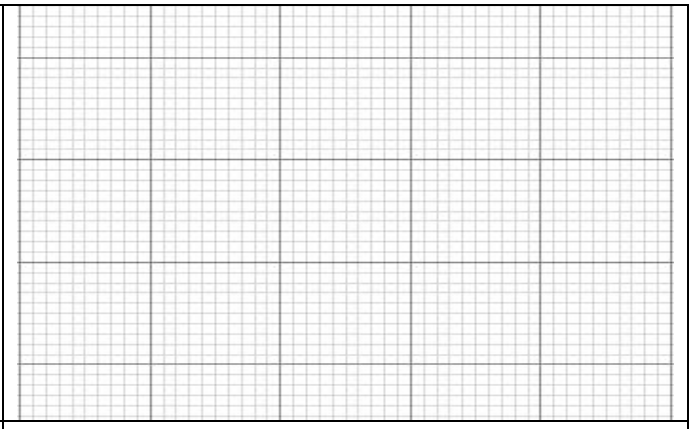


Fig: Output Voltage across R Load

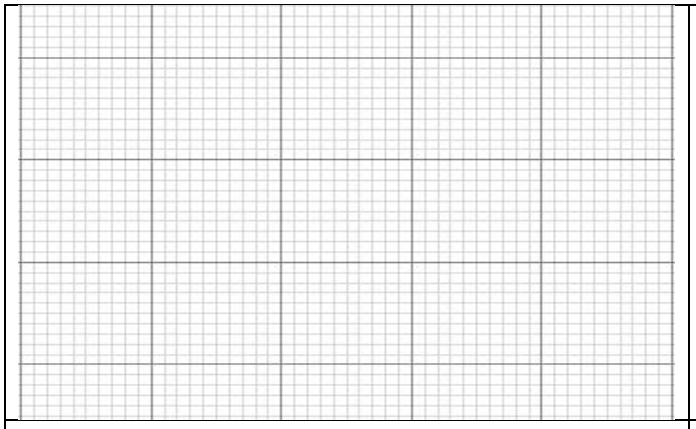


Fig: Load Current I_L

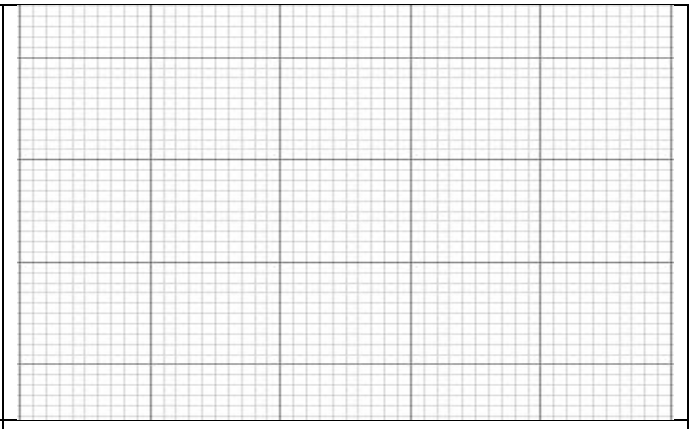


Fig: Output Voltage across Diode

R-L LOAD

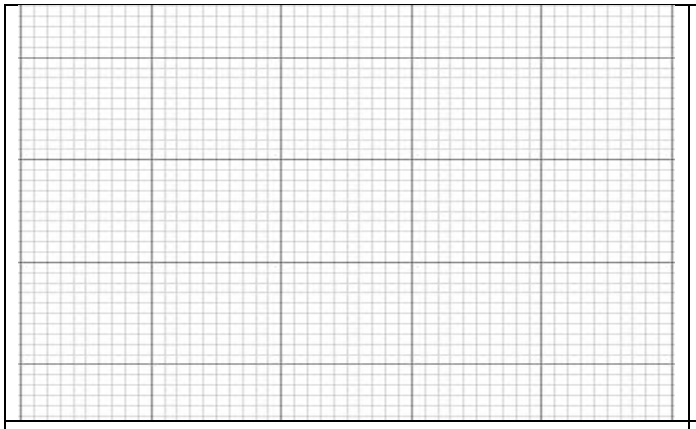


Fig: Input Voltages R,S,T

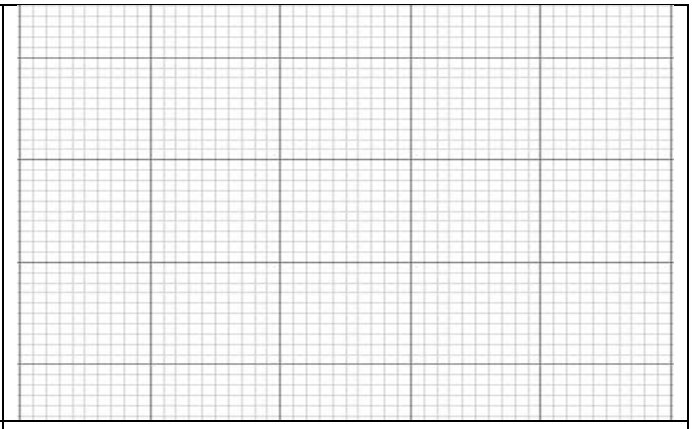


Fig: Output Voltage across R-L Load

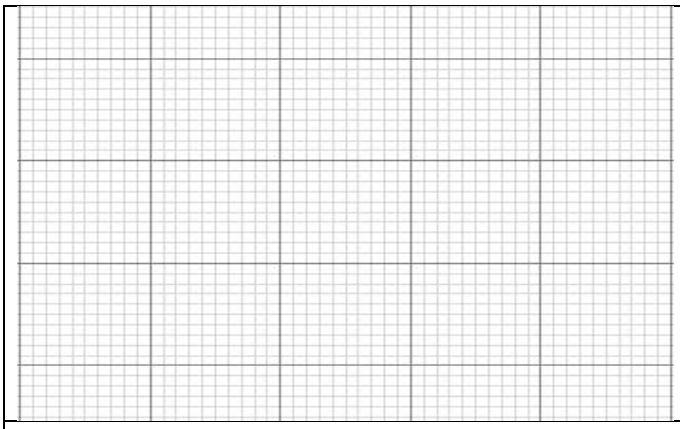
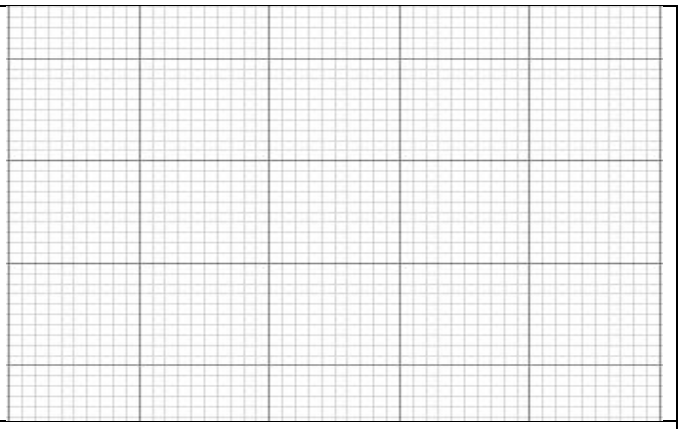
	

Fig: Load Current I_L	Fig: Output Voltage across Diode

NED University of Engineering & Technology
Department of Electrical Engineering

Course Code and Title: _____

Laboratory Session: No._____ Date: _____

Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
Equipment Identification Sensory skill to identify equipment and/or its component for a lab work. 10 %	Not able to identify the equipment. 0	--	--	--	Able to identify equipment as well as its components. 40
Equipment Use Sensory skills to describe the use of the equipment for the lab work. 15%	Never describes the use of equipment. 0	Rarely able to describe the use of equipment. 15	Occasionally describe the use of equipment. 30	Often able to describe the use of equipment. 45	Frequently able to describe the use of equipment. 60
Procedural Skills Displays skills to act upon sequence of steps in lab work. 15%	Not able to either learn or perform lab work procedure. 0	Able to slightly understand lab work procedure and perform lab work. 15	Able to somewhat understand lab work procedure and perform lab work. 30	Able to moderately understand lab work procedure and perform lab work. 45	Able to fully understand lab work procedure and perform lab work. 60
Response Ability to imitate the lab work on his/her own. 15%	Not able to imitate the lab work. 0	Able to slightly imitate the lab work. 15	Able to somewhat imitate the lab work. 30	Able to moderately imitate the lab work. 45	Able to fully imitate the lab work. 60
Observation's Use Displays skills to perform related mathematical calculations using the observations from lab work. 15%	Not able to use lab work observations into mathematical calculations. 0	Able to slightly use lab work observations into mathematical calculations. 15	Able to somewhat use lab work observations into mathematical calculations. 30	Able to moderately use lab work observations into mathematical calculations. 45	Able to fully use lab work observations into mathematical calculations. 60
Safety Adherence Adherence to safety procedures. 10%	Doesn't adhere to safety procedures. 0	Slightly adheres to safety procedures. 10	Somewhat adheres to safety procedures. 20	Moderately adheres to safety procedures. 30	Fully adheres to safety procedures. 40
Equipment Handling Equipment care during the use. 10%	Doesn't handle equipment with required care. 0	Rarely handles equipment with required care. 10	Occasionally handles equipment with required care 20	Often handles equipment with required care. 30	Handles equipment with required care. 40
Group Work Contributes in a group-based lab work. 10%	Never participates. 0	Rarely participates. 10	Occasionally participates and contributes. 20	Often participates and contributes. 30	Frequently participates and contributes. 40
Total Points (Out of 400)					
Weighted CLO (Psychomotor Score)	(Points /4)				
Remarks					
Instructor's Signature with Date:					

LAB SESSION 05

Object:

AC/DC Three-Phase Not-Controlled Full-wave Rectifier with R load & R-L load.

Apparatus:

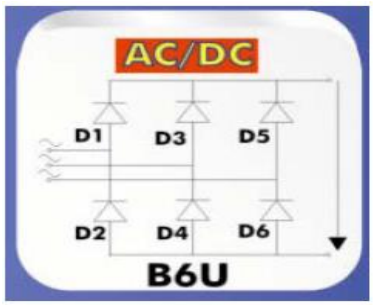
- SACED TECNEL
- TECNEL or TECNEL/B
- RCL3R Load module
- Wires

Theory:

Three-phase full-wave not-controlled rectifiers:

The basic full-wave uncontrolled (diode) rectifier circuit is shown in the following figure. Diodes D1, D3, and D5 are sometimes referred to as the upper half of the bridge, while diodes D2, D4, and D6 constitute the lower half of the bridge. As with half wave operation the voltages at the anodes of the diode valves vary periodically as the supply voltages undergo cyclic excursions. Commutation or switch-off of a conducting diode is therefore accomplished by natural cycling of the supply voltages and is known as natural commutation. The load current iL is unidirectional, but the supply currents are now bidirectional. In order to permit load current to flow, at least one diode must conduct in each half of the bridge. When this happens, the appropriate line-to-line supply point voltage is applied across the load. In comparison with the half-wave bridge, in which the supply-phase voltage is applied across the load, the full-wave bridge has the immediate advantage that the peak load voltage is_3 times as great.

Circuit Diagram:



B6U Model

Procedure:

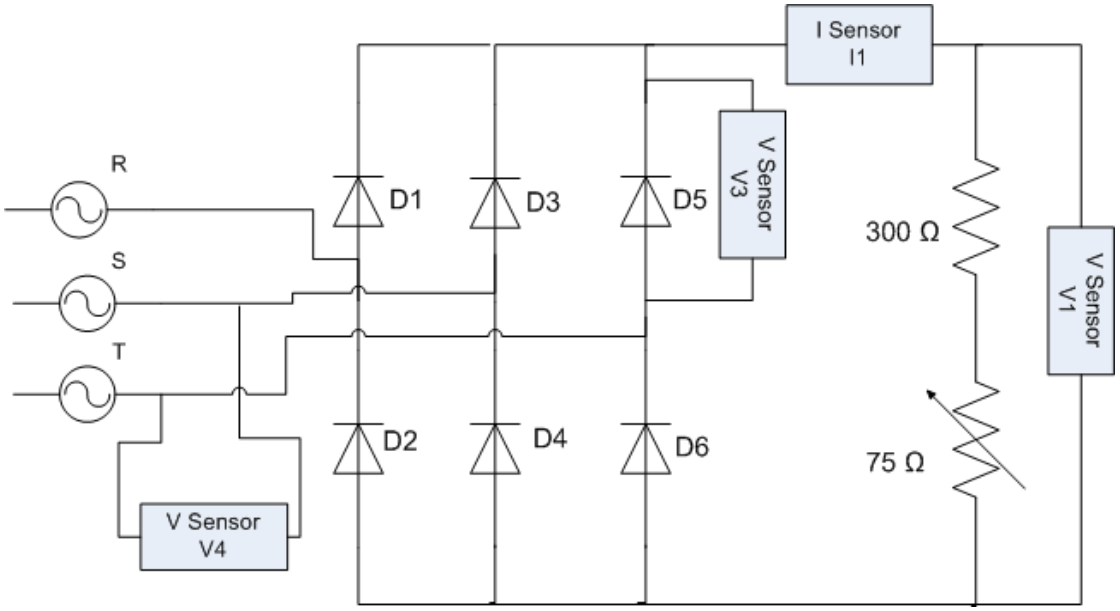
25. Carry out the assembly B6U shown in the above figure
26. Connect the respective load to its terminals one by one.

For R Load

Use Fixed R= 300ohms plus variable resistance in series.

And sample the following parameters:

Input voltage V4, Output voltage V1, Output current I1, Diode voltage V3 (as shown in figure)



Also measure the following quantities using multi-meter.

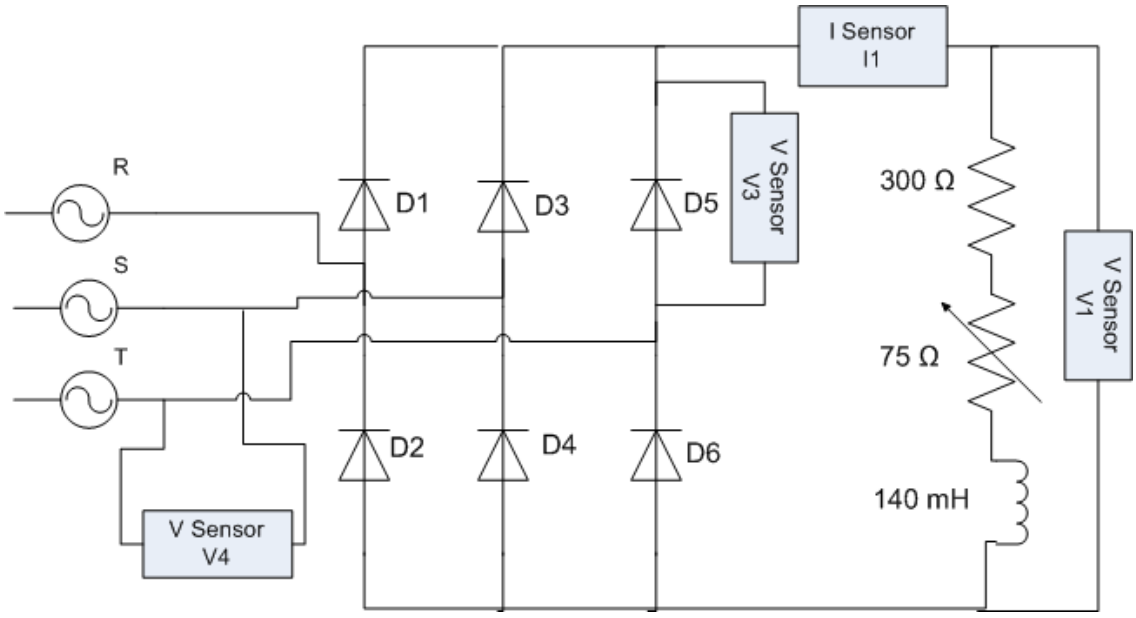
S. No	Load Resistance	Vrms	Voltage Across D1
1.	300 + 75 Ω		
2.	300 + 120 Ω		

For RL Load

Observe how the conduction angle increases as we increase L (0 to 238mH) with R=375Ω, measuring with the voltmeter the average output voltage.

S. No	Load Impedance	Vrms	Voltage Across Diode
1.	300 Ω + 75 Ω + 140mH		
2.	300 Ω + 75 Ω + 238mH		

Observe how the output current varies for different L values with R=375 Ω. Save the different samples.
And sample the following parameters:
Input voltage V4, Output voltage V1, Diode voltage V3, Output current (load) I1 (as shown in figure)



27. Load the SACED TECNEL program in PC and the window corresponding to this practice
    - Select Practice Option
    - "AC/DC" → "Three-phase Not-Controlled Full wave Rectifier" option
28. Select the respective sample sensors
29. **Check the connections** and switch on the equipment.
30. Press the "Data Capture" button.
31. Visualize the parameters measured and save them in the corresponding file.
32. Switch off the equipment.

Waveforms:

R LOAD

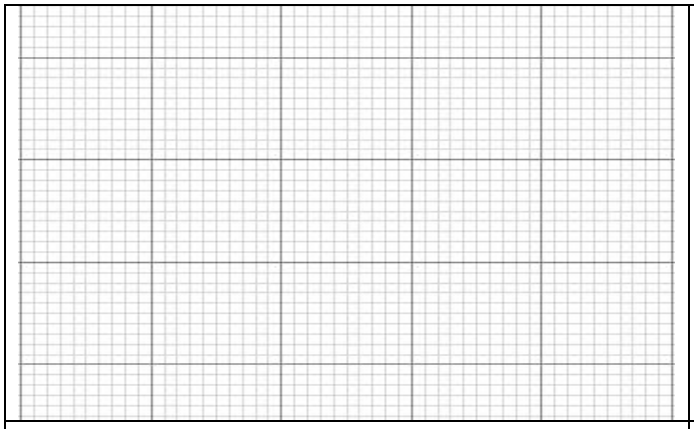


Fig: Input Voltage	Fig: Output Voltage across R Load

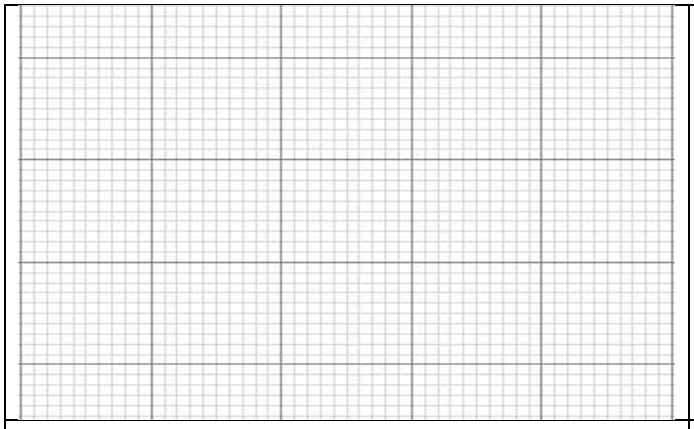
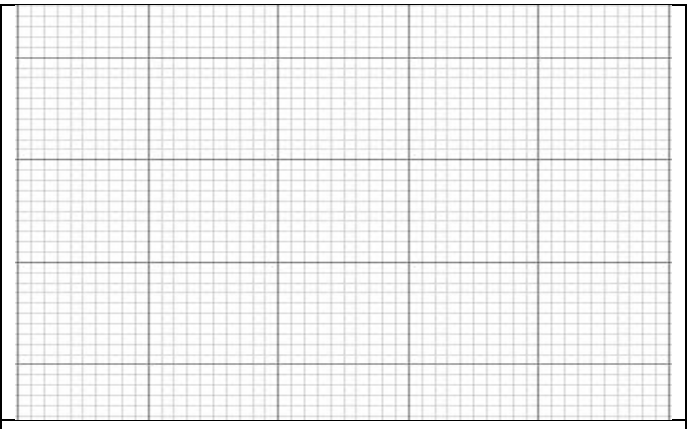

	

Fig: Load Current I_L	Fig: Output Voltage across Diode

R-L LOAD

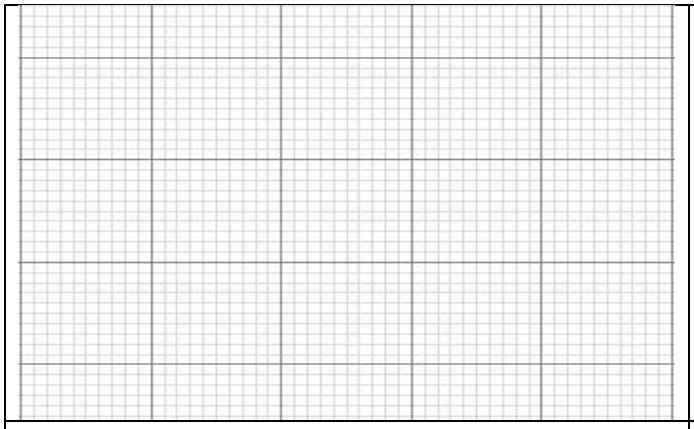
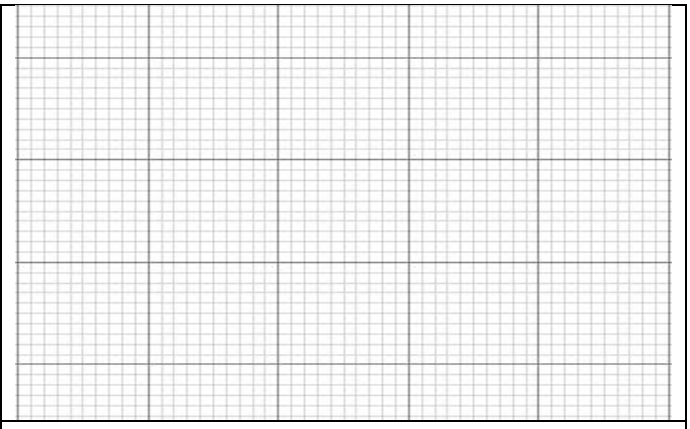
	

Fig: Input Voltage	Fig: Output Voltage across R Load

Fig: Load Current I_L with L=140mH

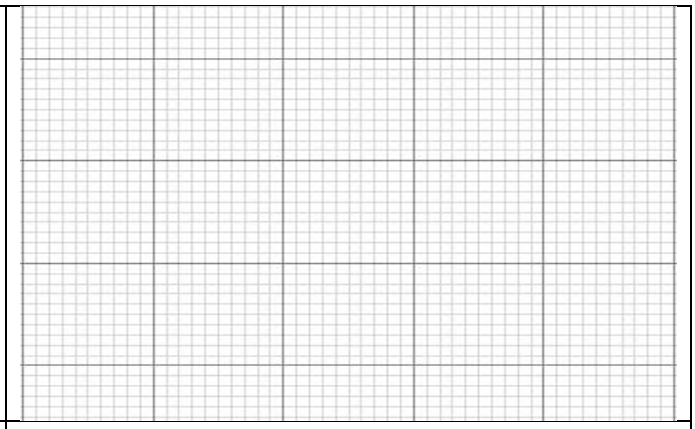


Fig: Load Current I_L with L=238mH

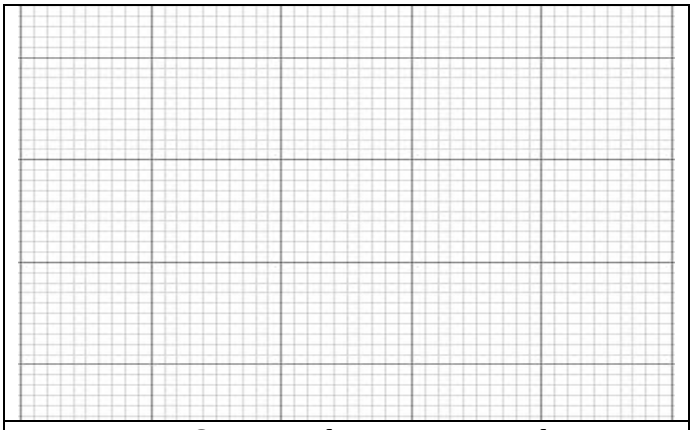


Fig: Output Voltage across Diode

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Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
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Equipment Identification Sensory skill to identify equipment and/or its component for a lab work. 10 %	Not able to identify the equipment. 0	--	--	--	Able to identify equipment as well as its components. 40
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Observation's Use Displays skills to perform related mathematical calculations using the observations from lab work. 15%	Not able to use lab work observations into mathematical calculations. 0	Able to slightly use lab work observations into mathematical calculations. 15	Able to somewhat use lab work observations into mathematical calculations. 30	Able to moderately use lab work observations into mathematical calculations. 45	Able to fully use lab work observations into mathematical calculations. 60
Safety Adherence Adherence to safety procedures. 10%	Doesn't adhere to safety procedures. 0	Slightly adheres to safety procedures. 10	Somewhat adheres to safety procedures. 20	Moderately adheres to safety procedures. 30	Fully adheres to safety procedures. 40
Equipment Handling Equipment care during the use. 10%	Doesn't handle equipment with required care. 0	Rarely handles equipment with required care. 10	Occasionally handles equipment with required care 20	Often handles equipment with required care. 30	Handles equipment with required care. 40
Group Work Contributes in a group-based lab work. 10%	Never participates. 0	Rarely participates. 10	Occasionally participates and contributes. 20	Often participates and contributes. 30	Frequently participates and contributes. 40
Total Points (Out of 400)					
Weighted CLO (Psychomotor Score)	(Points /4)				
Remarks					
Instructor's Signature with Date:					

LAB SESSION 06

Object:

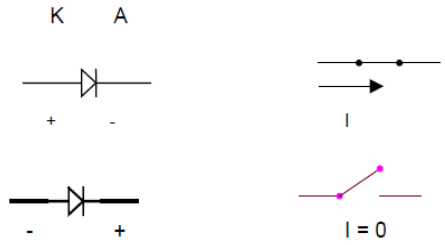
To Study the Firing Characteristics of Thyrister (SCR).

Apparatus:

- SACED TECNEL
- TECNEL or TECNEL/B
- RCL3R Load module
- Wires

Theory:

Single-phase half-wave not-controlled rectifiers:
Not-controlled rectifiers are constituted by diodes that, acts as not-controlled elements, provide a dependent output voltage of fixed magnitude. In half wave rectifiers, diode conducts only in half cycle of the input, otherwise open.

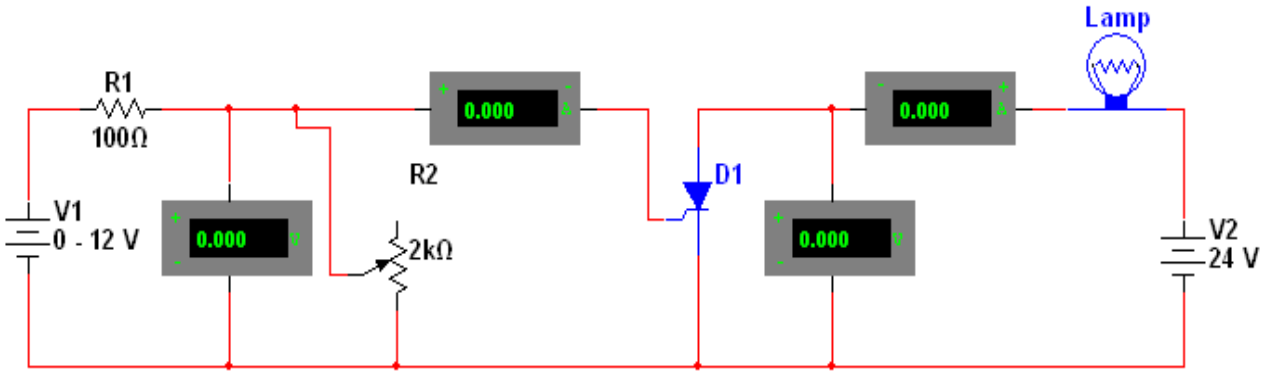


From a theoretical point of view, they may be considered as switches that are opened or closed depending on the direction of the voltage applied. That is, with a positive voltage between anode (A) and cathode (K) the switch is closed, and it is opened if the voltage is negative.

The behavior of the rectifier will depend considerably on the used load type, so we may have:
Pure resistive load (R), where the voltage is annulled when its direction changes.

Inductive load (R-L), where the conduction continues until the moment when the current in the coil is annulled, although the output voltage inverts its polarity.
In order to separate the output voltage and the load type, we may use the free wheeling diode (FWD), which avoids the inversion of polarization in the output voltage.

Circuit Diagram:



Procedure:

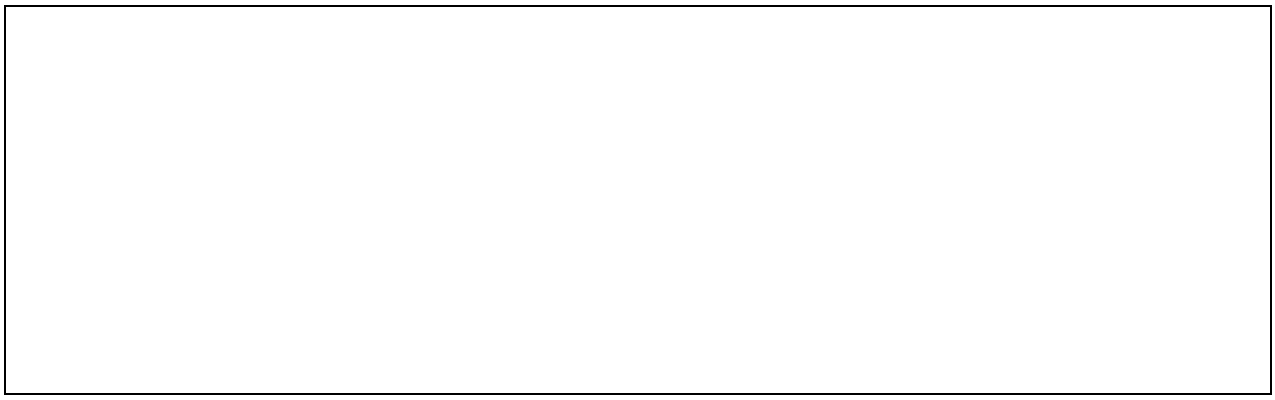
33. Carry out the assembly E1UK shown in the above figure
34. Connect the respective load to its terminals one by one.

For R Load

Use Fixed R= 300ohms plus variable resistance in series.

And sample the following parameters:

Input voltage V1, Output voltage V2, Output current I2, Diode voltage V3 (as shown in figure)

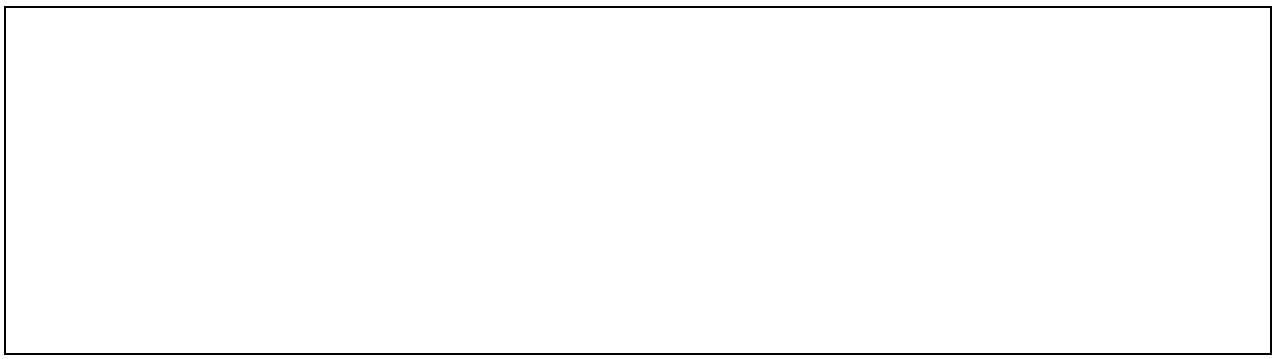


For RL Load

Observe how the conduction angle increases as we increase L (0 to 238mH) with R=350Ω, measuring with the voltmeter the average output voltage. Vav =

Observe how the output current varies for different L values with R=300. Save the different samples.

And sample the following parameters:
Input voltage V1, Output voltage V2, Diode voltage V3, Output current (load) I2 (as shown in figure)



For RL Load with FWD

Observe how the conduction angle increases as we increase L (0 to 238mH) with R=350Ω, measuring with the voltmeter the average output voltage.

Observe how the output current varies for different L values with R=300.

And sample the following parameters:
Input voltage V1, Output voltage V2, Output current I1, FWD Current I2

35. Load the SACED TECNEL program in PC and the window corresponding to this practice
    - Select Practice Option
    - "AC/DC" → "Single-phase Not-Controlled Halfwave Rectifier" option
36. Select the respective sample sensors
37. **Check the connections** and switch on the equipment.
38. Press the "Data Capture" button.
39. Visualize the parameters measured and save them in the corresponding file.
40. Switch off the equipment.

Waveforms:

R LOAD

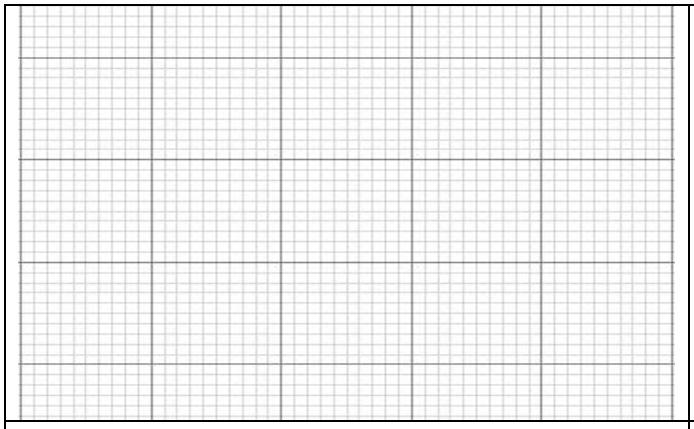


Fig: Input Voltage

Fig: Output Voltage across R Load

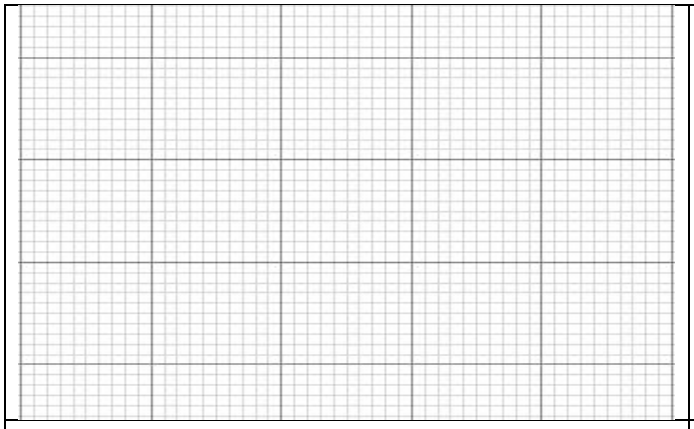


Fig: Load Current I_L

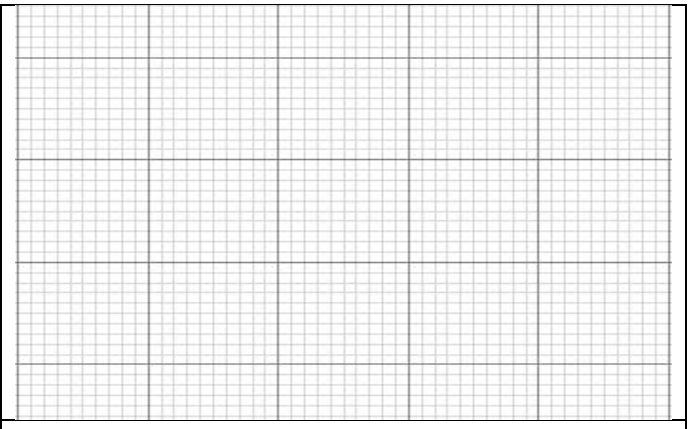


Fig: Output Voltage across Diode

R-L LOAD

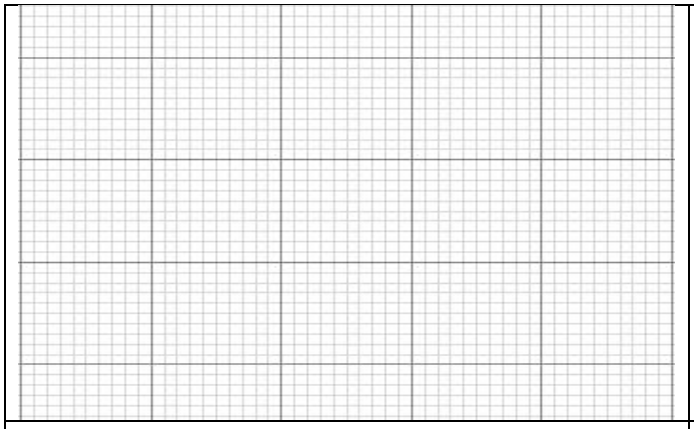


Fig: Input Voltage

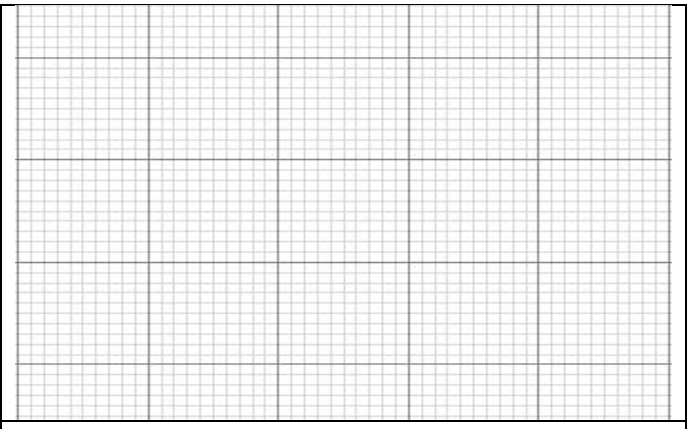


Fig: Output Voltage across R Load

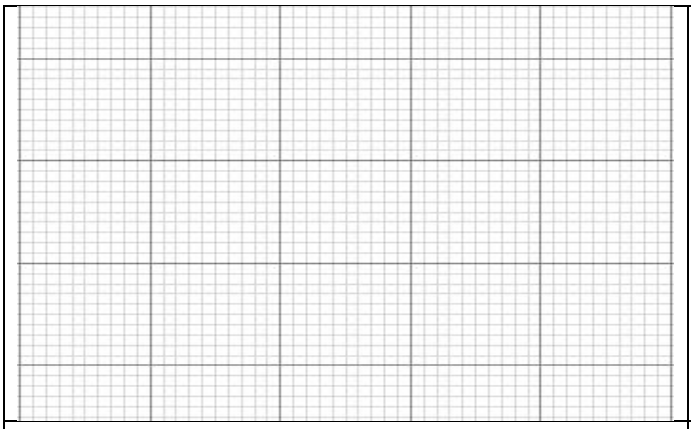


Fig: Load Current I_L

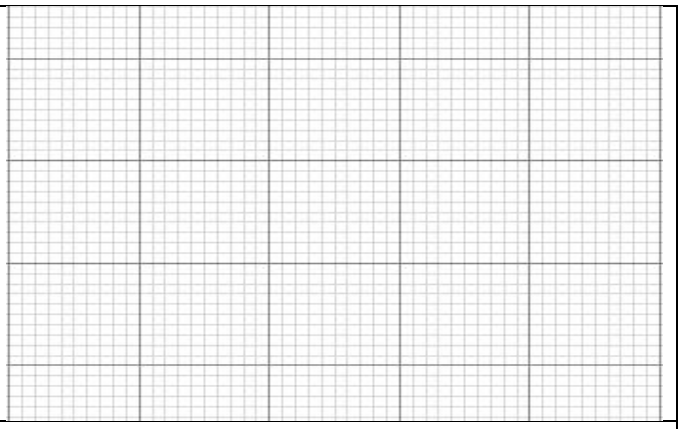


Fig: Output Voltage across Diode

R-L LOAD WITH FWD

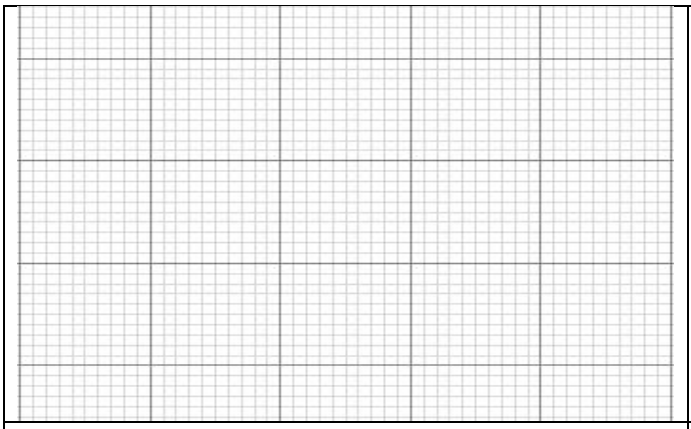


Fig: Input Voltage

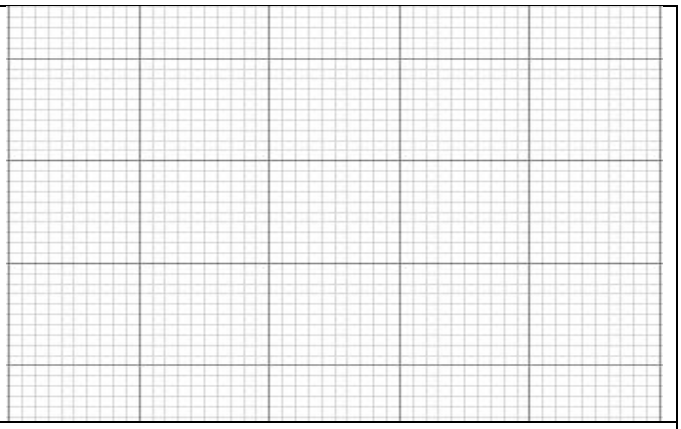


Fig: Output Voltage across R-L Load

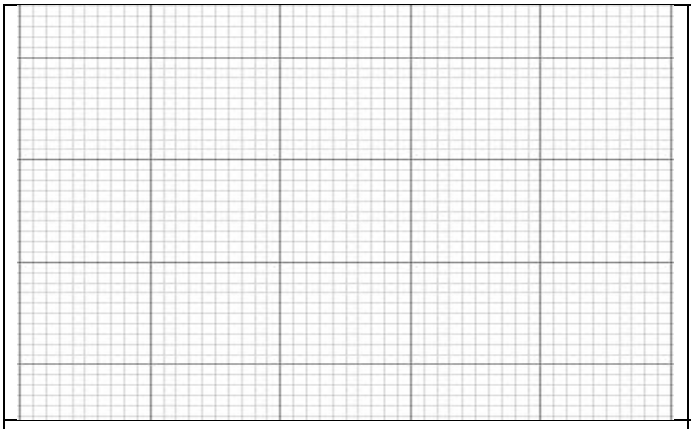


Fig: Load Current I_L

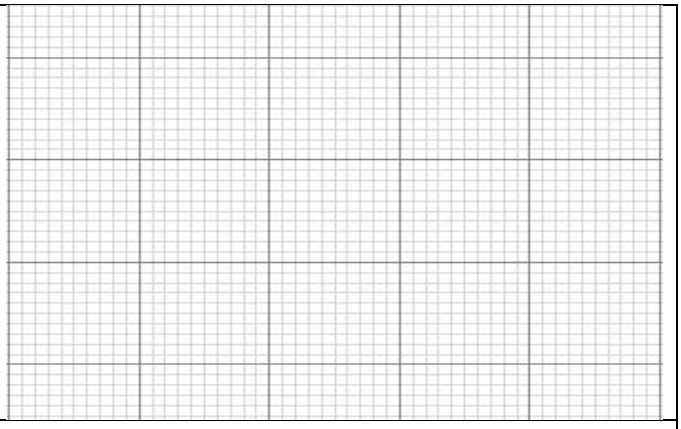


Fig: FWD Current I_D

LAB SESSION 07

Object:

To Study Alternating Current SCR application.

Apparatus:

- Cathode Ray Oscilloscope
- Vin = 0→ 12 V
- Vac = 24 V
- Circuit Board

Theory:

Thyristor conducts in positive half cycle. Because the Thyristor behaves as short circuit while conducting, so during this cycle a voltage V_L will appear across the Load.
For the negative half cycle the Thyristor is reverse biased so it behaves as an open circuit therefore no voltage develops across load.

Circuit Diagram:

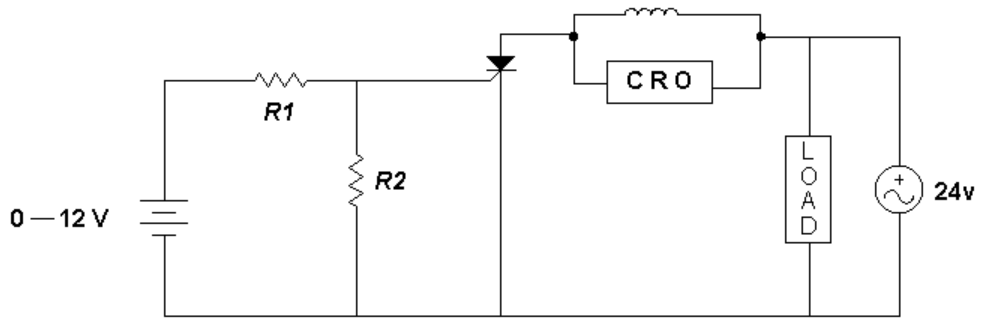


Figure:

Procedure:

41. Carry out the assembly E1UK shown in the above figure
42. Connect the respective load to its terminals one by one.

For R Load

Use Fixed R= 300ohms plus variable resistance in series.

Waveforms:

R LOAD

Fig: Input Voltage

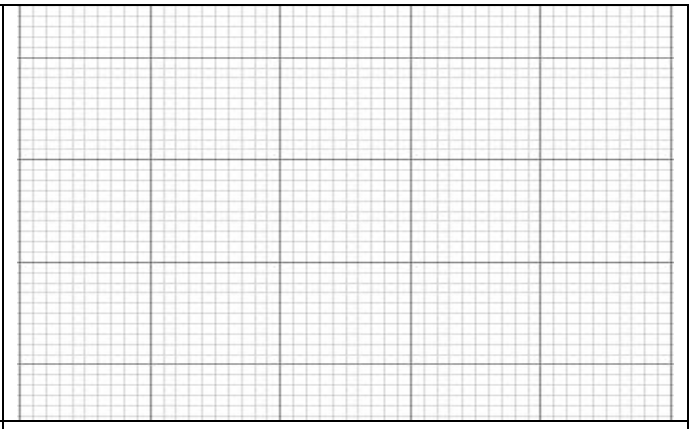


Fig: Output Voltage across R Load

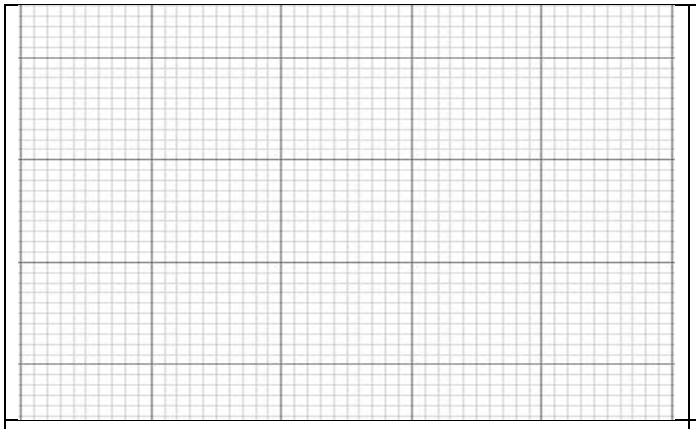


Fig: Load Current I_L

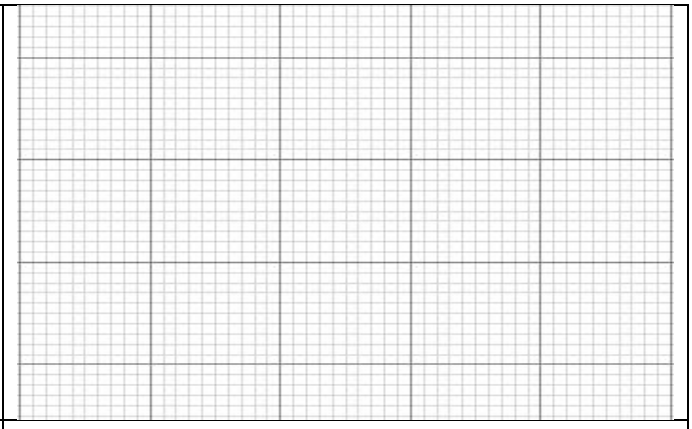


Fig: Output Voltage across Diode

LAB SESSION 08

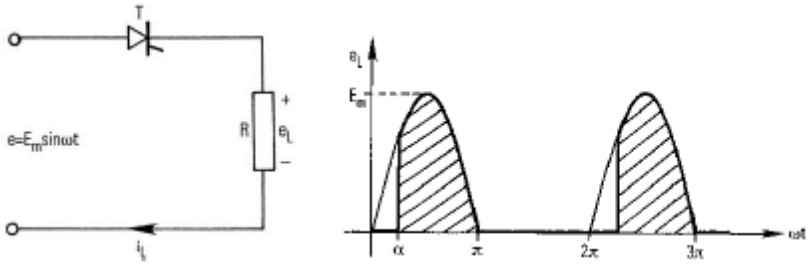
Object:

AC/DC Single-phase Controlled Half-wave Rectifier with R load, R-L load and R-L load with FWD.

Apparatus:

- SACED TECNEL
- TECNEL or TECNEL/B
- RCL3R Load module
- Wires

Theory:



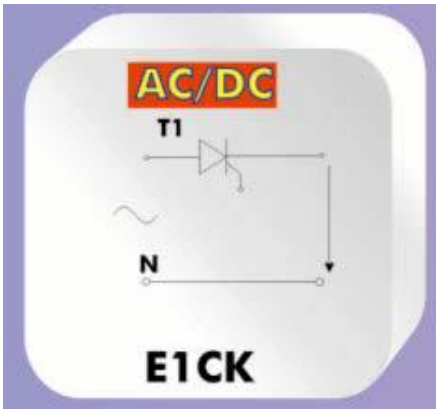
Single-phase half-wave controlled rectifiers:
Controlled rectifiers are constituted by thyristors that, acts as controlled elements, provide a dependent output voltage of fixed magnitude. In half wave controlled rectifiers, thyristor conducts only in half cycle of the input, where the duty cycle is controlled by the firing pulse given to the thyristor.

The behavior of the rectifier will depend considerably on the used load type, so we may have:
Pure resistive load (R), where the voltage is annulled when its direction changes.

Inductive load (R-L), where the conduction continues until the moment when the current in the coil is annulled, although the output voltage inverts its polarity.

In order to separate the output voltage and the load type, we may use the free wheeling diode (FWD), which avoids the inversion of polarization in the output voltage.

Circuit Diagram:



E1CK Model

Procedure:

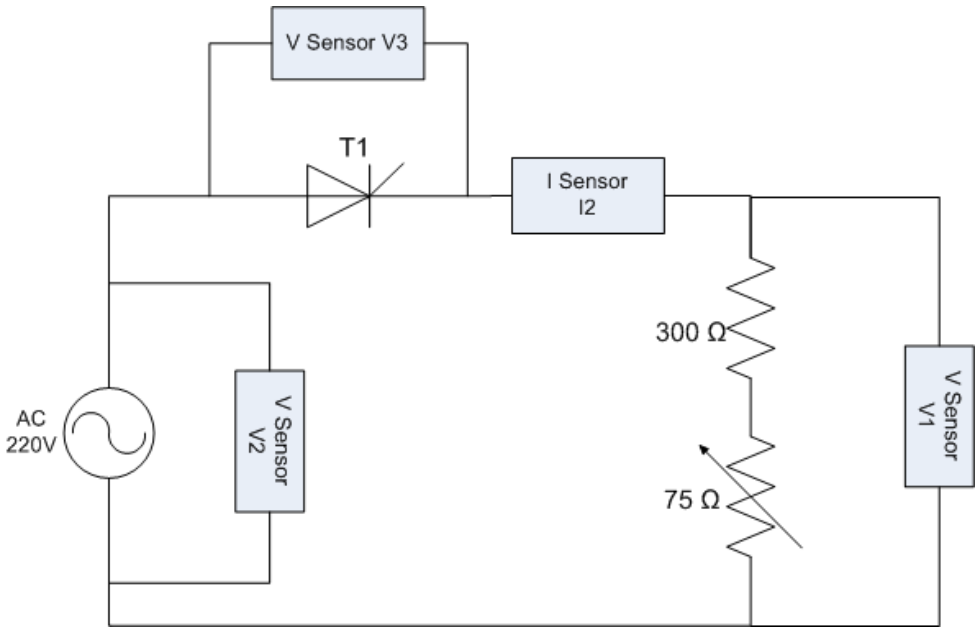
43. Carry out the assembly E1CK shown in the above figure
44. Connect the respective load to its terminals one by one.

For R Load

Use Fixed R= 300ohms plus variable resistance in series.

And sample the following parameters:

Input voltage V2, Output voltage V1, Output current I2, Thyristor voltage V3 (as shown in figure)



For different values of R the RMS voltage will vary across the load, which can be calculated using multimeter.

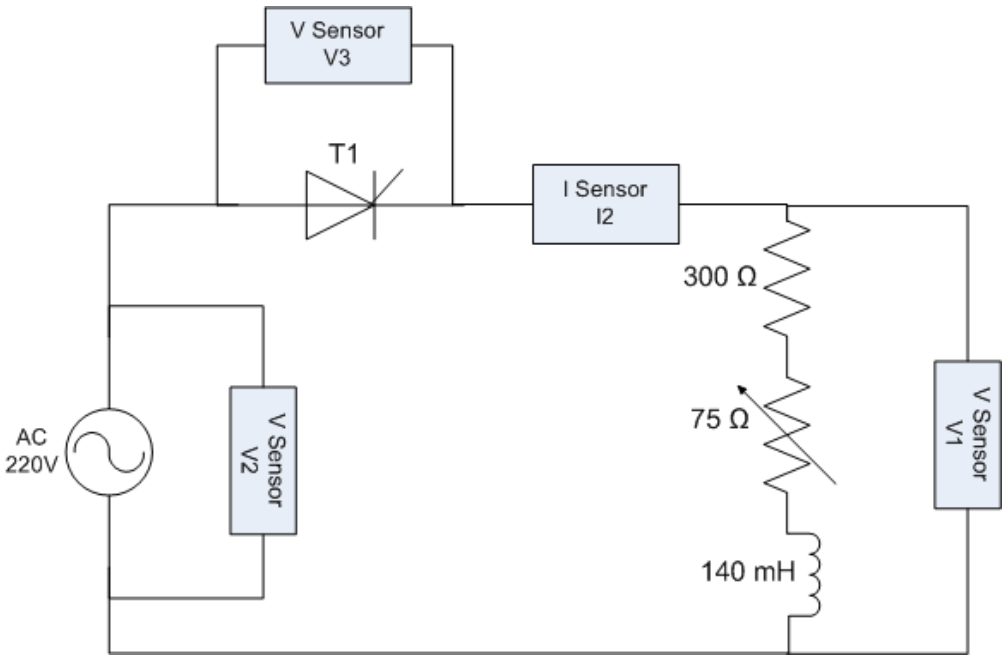
S. No	Load Resistance	Vrms	Voltage Across Thyristor
1.	300 + 75 Ω		
2.	300 + 120 Ω		

For RL Load

Observe how the output current varies for different L values with R=375 Ω. Save the different samples.

And sample the following parameters:
Input voltage V2, Output voltage V1, Thyristor voltage V3, Output current (load) I2 (as shown in figure)

S. No	Load Resistance	Vrms	Voltage Across Thyristor
1.	300 Ω + 75 Ω + 140H		
2.	300 Ω + 75 Ω + 238H		



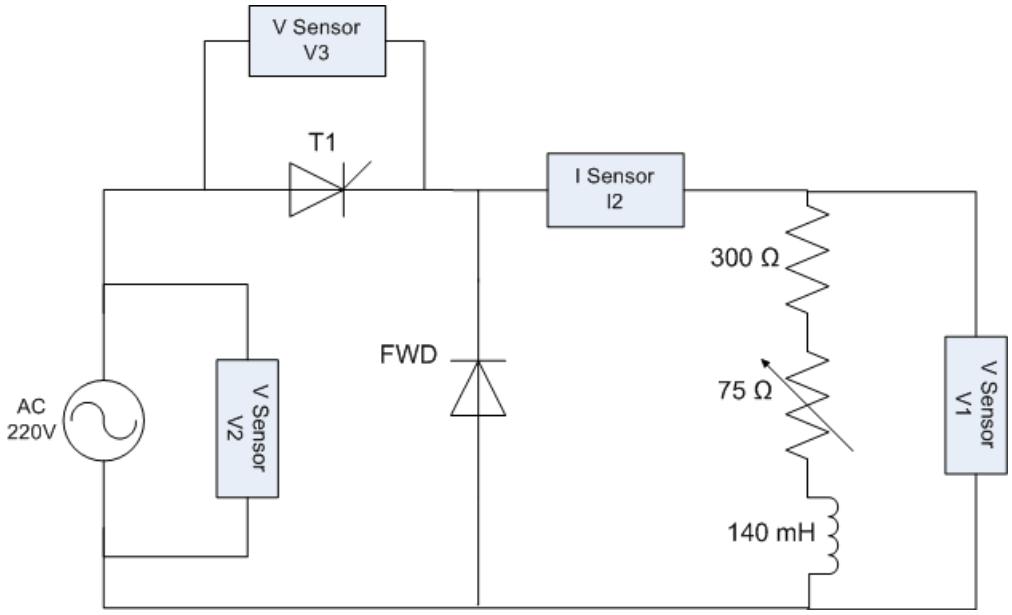
For RL Load with FWD

Observe how the conduction angle increases as we increase L (0 to 238mH) with R=350Ω, measuring with the voltmeter the average output voltage.

Observe how the output current varies for different L values with R=375 Ω.

And sample the following parameters:
Input voltage V2, Output voltage V1, Output current I2

S. No	Load Resistance	Vrms	Voltage Across Diode	
			T1	FWD
1.	300 Ω + 75 Ω + 140H			
2.	300 Ω + 75 Ω + 238H			



45. Load the SACED TECNEL program in PC and the window corresponding to this practice
    - Select Practice Option
    - "AC/DC" → "Single-phase Controlled Halfwave Rectifier" option
46. Select the respective sample sensors
47. **Check the connections** and switch on the equipment.
48. Press the "Data Capture" button.
49. Visualize the parameters measured and save them in the corresponding file.
50. Switch off the equipment.

Waveforms:

R LOAD

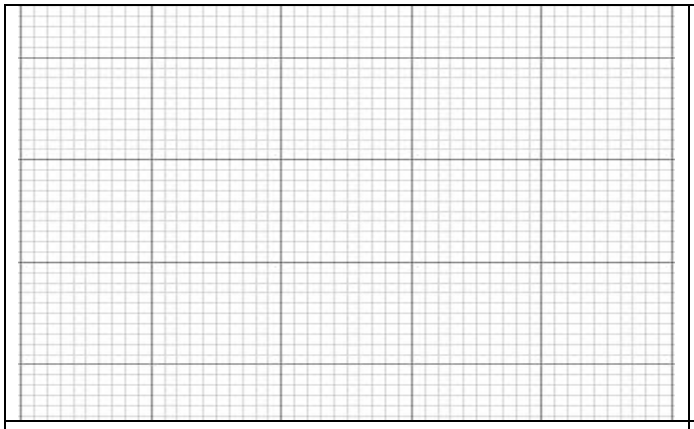


Fig: Input Voltage

Fig: Output Voltage across R Load

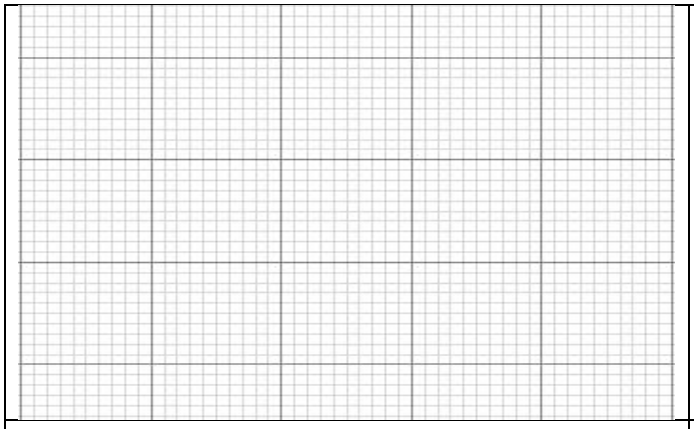


Fig: Load Current I_L

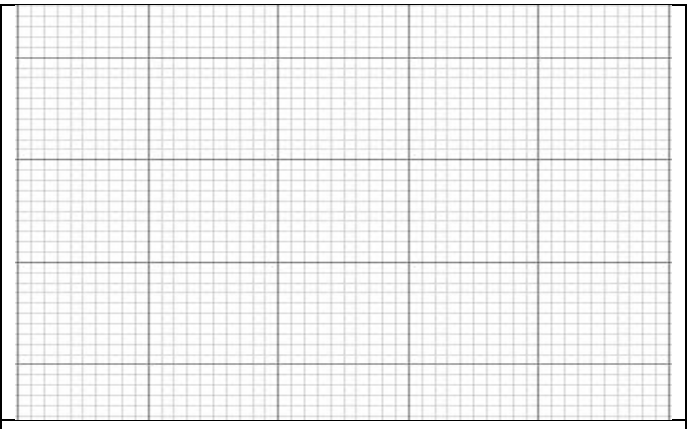


Fig: Output Voltage across Thyristor

R-L LOAD

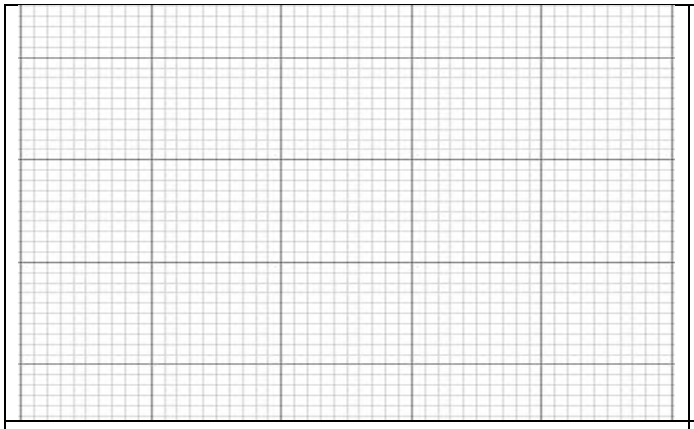


Fig: Input Voltage

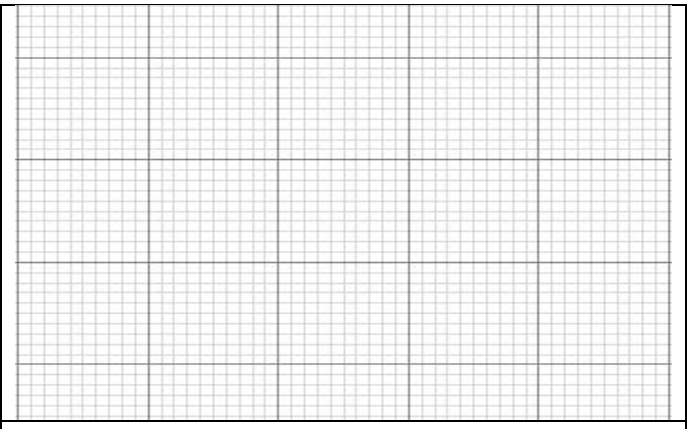


Fig: Output Voltage across R Load

Fig: Load Current I_L for 140 mH

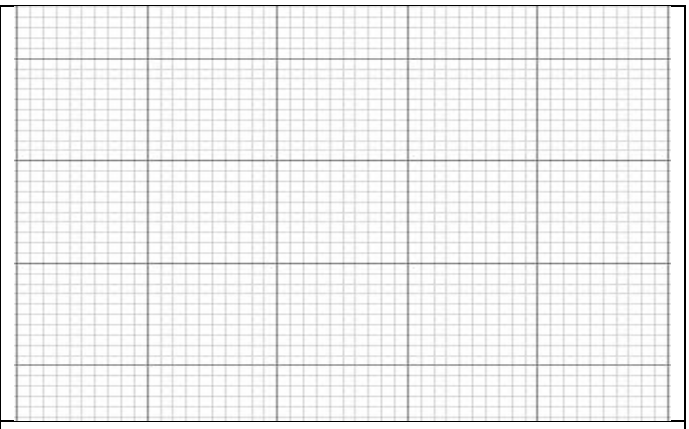


Fig: Load Current I_L for 238 mH

R-L LOAD WITH FWD

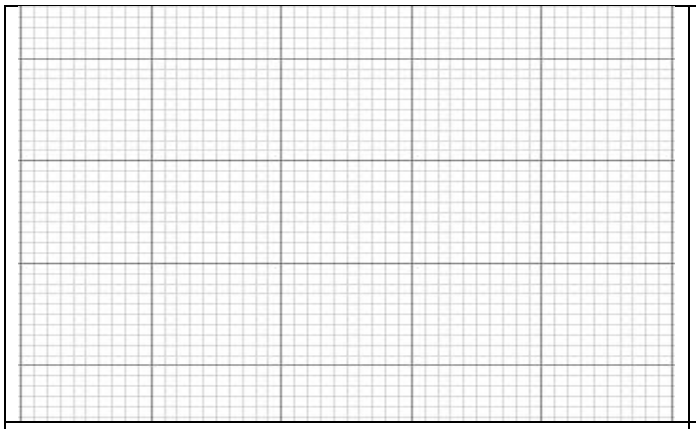


Fig: Input Voltage

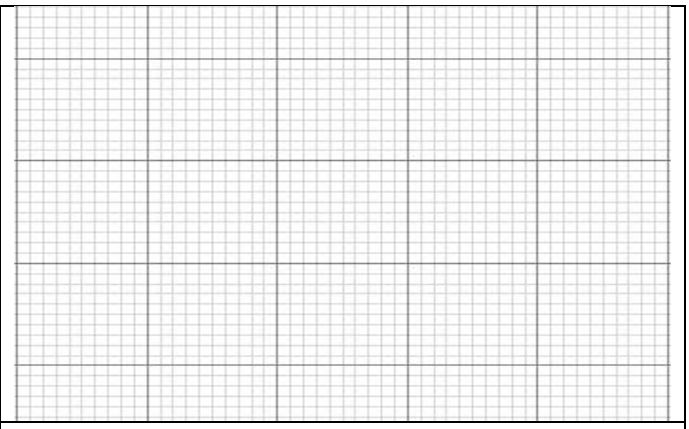


Fig: Output Voltage across R-L Load

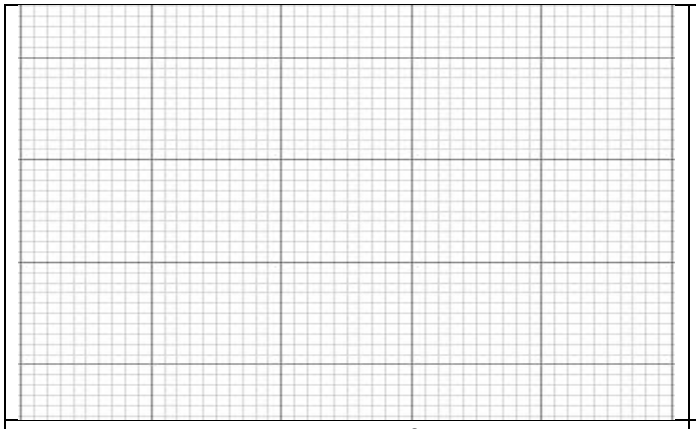


Fig: Load Current I_L for 140 mH

Fig: Load Current I_L for 238 mH

NED University of Engineering & Technology
Department of Electrical Engineering

Course Code and Title: _____

Laboratory Session: No._____ Date: _____

Psychomotor Domain Assessment Rubric-Level P3					
Skill Sets	Extent of Achievement				
	0	1	2	3	4
Equipment Identification Sensory skill to identify equipment and/or its component for a lab work. 10 %	Not able to identify the equipment. 0	--	--	--	Able to identify equipment as well as its components. 40
Equipment Use Sensory skills to describe the use of the equipment for the lab work. 15%	Never describes the use of equipment. 0	Rarely able to describe the use of equipment. 15	Occasionally describe the use of equipment. 30	Often able to describe the use of equipment. 45	Frequently able to describe the use of equipment. 60
Procedural Skills Displays skills to act upon sequence of steps in lab work. 15%	Not able to either learn or perform lab work procedure. 0	Able to slightly understand lab work procedure and perform lab work. 15	Able to somewhat understand lab work procedure and perform lab work. 30	Able to moderately understand lab work procedure and perform lab work. 45	Able to fully understand lab work procedure and perform lab work. 60
Response Ability to imitate the lab work on his/her own. 15%	Not able to imitate the lab work. 0	Able to slightly imitate the lab work. 15	Able to somewhat imitate the lab work. 30	Able to moderately imitate the lab work. 45	Able to fully imitate the lab work. 60
Observation's Use Displays skills to perform related mathematical calculations using the observations from lab work. 15%	Not able to use lab work observations into mathematical calculations. 0	Able to slightly use lab work observations into mathematical calculations. 15	Able to somewhat use lab work observations into mathematical calculations. 30	Able to moderately use lab work observations into mathematical calculations. 45	Able to fully use lab work observations into mathematical calculations. 60
Safety Adherence Adherence to safety procedures. 10%	Doesn't adhere to safety procedures. 0	Slightly adheres to safety procedures. 10	Somewhat adheres to safety procedures. 20	Moderately adheres to safety procedures. 30	Fully adheres to safety procedures. 40
Equipment Handling Equipment care during the use. 10%	Doesn't handle equipment with required care. 0	Rarely handles equipment with required care. 10	Occasionally handles equipment with required care 20	Often handles equipment with required care. 30	Handles equipment with required care. 40
Group Work Contributes in a group-based lab work. 10%	Never participates. 0	Rarely participates. 10	Occasionally participates and contributes. 20	Often participates and contributes. 30	Frequently participates and contributes. 40
Total Points (Out of 400)					
Weighted CLO (Psychomotor Score)	(Points /4)				
Remarks					
Instructor's Signature with Date:					

LAB SESSION 09

Object:

AC/DC Single-phase Controlled Full wave Rectifier with R load, R-L load and R-L load with FWD.

Apparatus:

- SACED TECNEL
- TECNEL or TECNEL/B
- RCL3R Load module
- Wires

Theory:

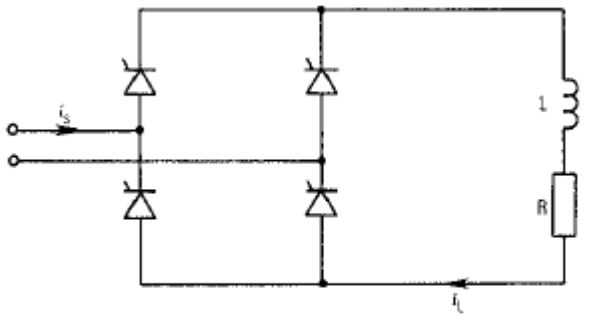


FIG. 21 Single-phase, full-wave controlled rectifier circuit with highly inductive load.

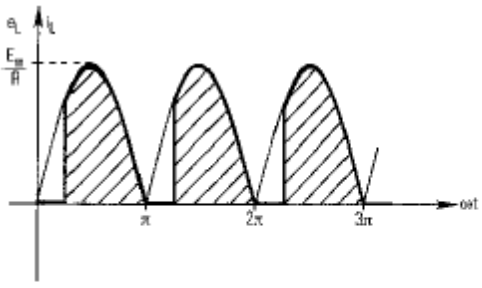


FIG. 5 Load voltage (and current) waveforms for single-phase, full-wave controlled rectifier with *R* load, $\alpha = 50°$.

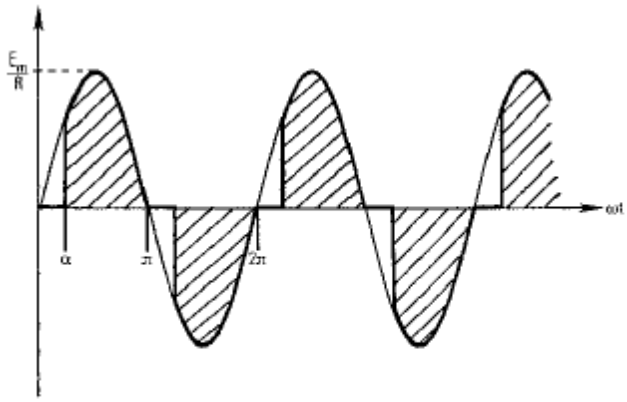


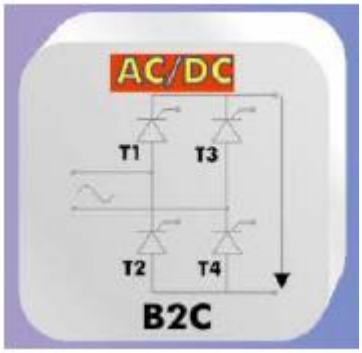
FIG. 6 Supply current waveforms for the single-phase, full-wave controlled rectifier with R load, $\alpha = 50°$.

Single-phase full-wave controlled rectifiers:
Controlled rectifiers are constituted by thyristors that, acts as controlled elements, provide a dependent output voltage of fixed magnitude.

The behavior of the rectifier will depend considerably on the used load type, so we may have:
Pure resistive load (R), where the voltage is annulled when its direction changes.

Inductive load (R-L), where the conduction continues until the moment when the current in the coil is annulled, although the output voltage inverts its polarity.

Circuit Diagram:



B2C Model

Procedure:

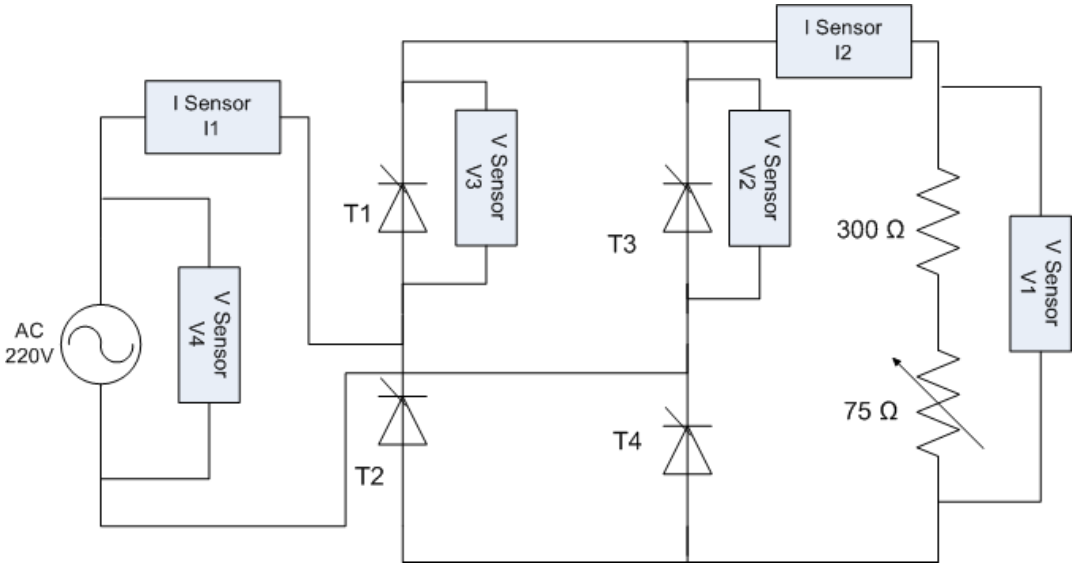
51. Carry out the assembly B2C shown in the above figure
52. Connect the respective load to its terminals one by one.

For R Load

Use Fixed R= 300ohms plus variable resistance in series.

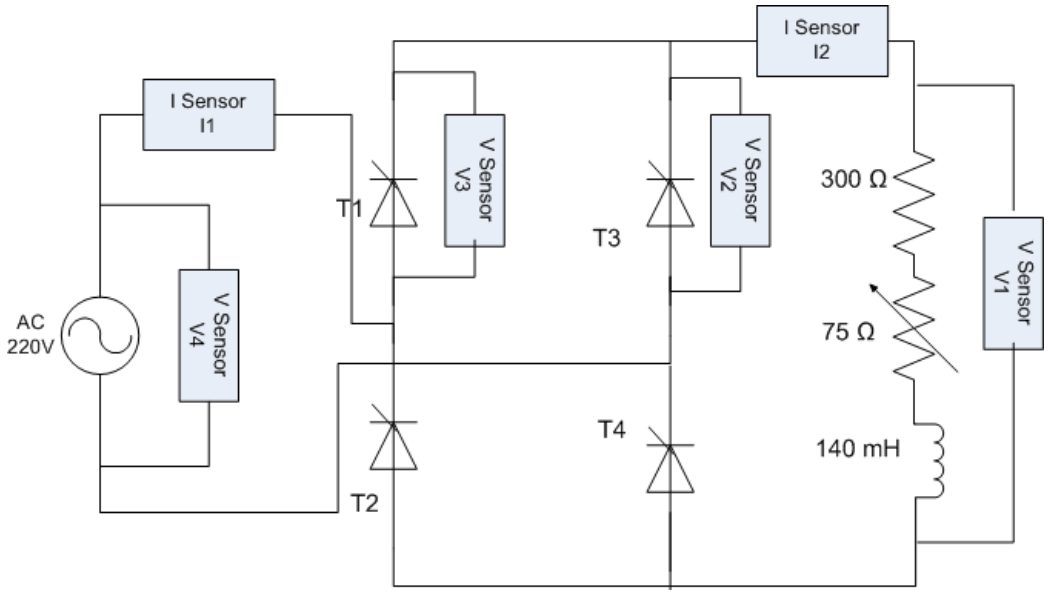
And sample the following parameters:

Input voltage V1, Output voltage V2, Output current I2, Diode voltage V3 (as shown in figure)



For RL Load

Sample the following parameters:
Input voltage V4, Output voltage V1, Diode voltage V3 and V2, Output current (load) I2 (as shown in figure), Input current I1.



Also measure the following quantities using multi-meter.

S. No	Load Resistance	Vrms	Voltage Across T1
1.	300 + 75 Ω		
2.	300 + 120 Ω		

For RL Load

Observe how the conduction angle increases as we increase L (0 to 238mH) with R=375Ω, measuring with the voltmeter the average output voltage.

S. No	Load Impedance	Vrms	Voltage Across Thyristor
1.	300 Ω + 75 Ω + 140H		
2.	300 Ω + 75 Ω + 238H		

Waveforms:

R LOAD

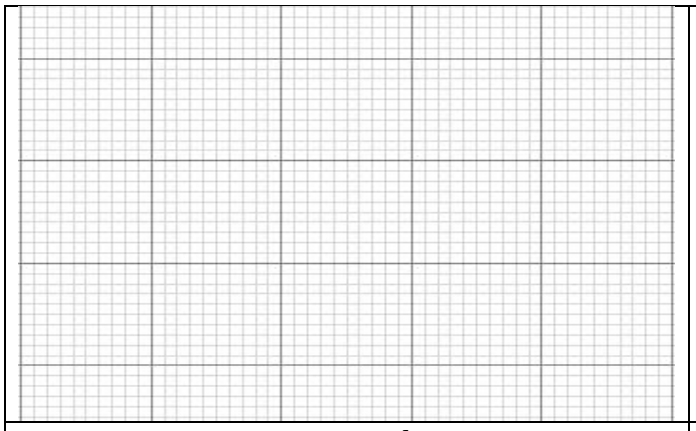


Fig: Input Voltage

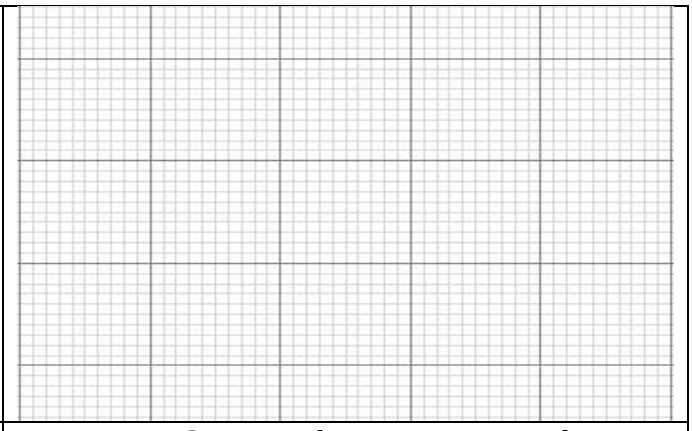


Fig: Output Voltage across R Load

Fig: Input Current

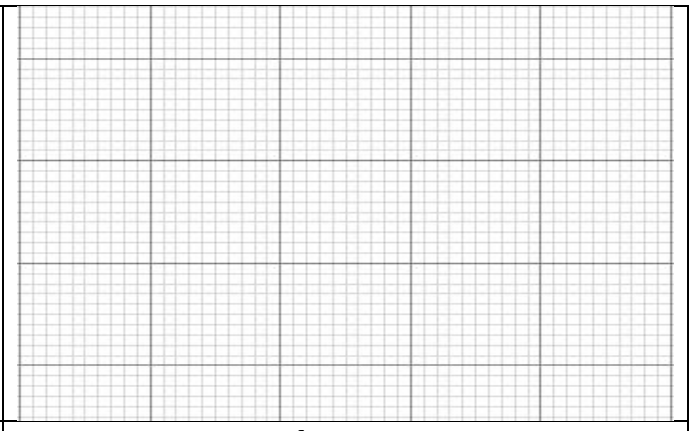


Fig: Voltage across T1

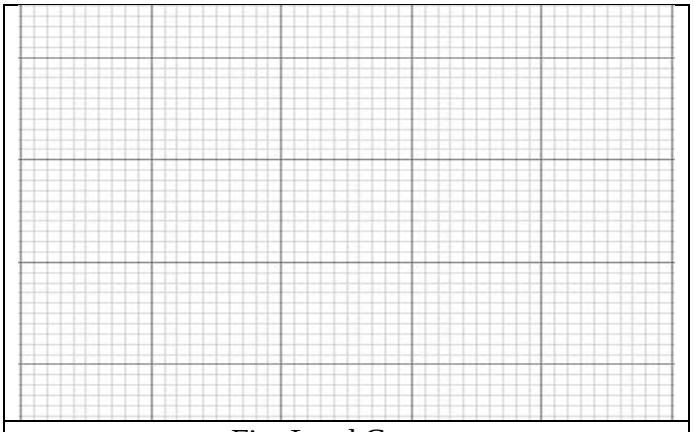


Fig: Load Current

R-L LOAD

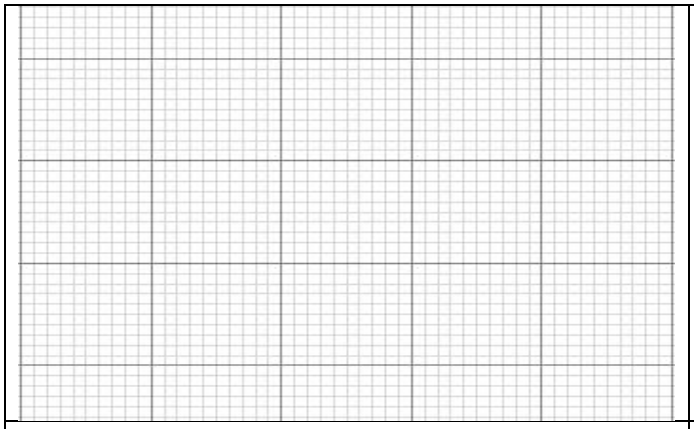


Fig: Input Voltage

Fig: Output Voltage across R-L Load

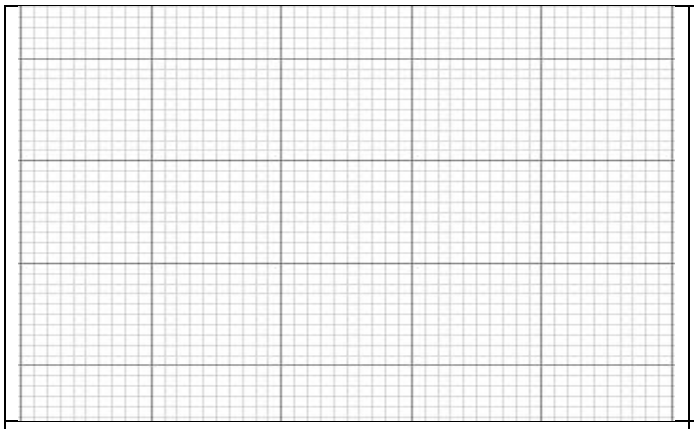


Fig: Input Current

Fig: Voltage across T1

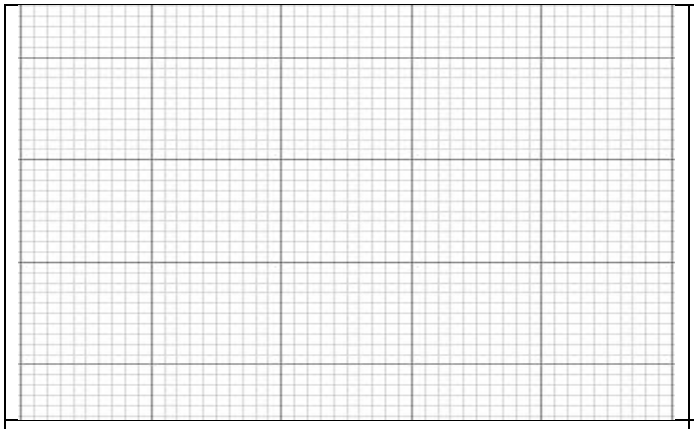


Fig: Load Current I_L (L=140 mH)

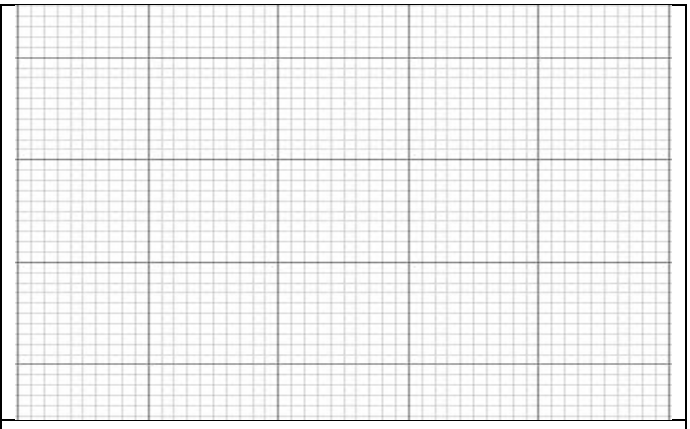


Fig: Load Current I_L (L=236 mH)

NED University of Engineering & Technology
Department of Electrical Engineering

Course Code and Title: _____

Laboratory Session: No._____ Date: _____

Psychomotor Domain Assessment Rubric-Level P3					
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	0	1	2	3	4
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Total Points (Out of 400)					
Weighted CLO (Psychomotor Score)	(Points /4)				
Remarks					
Instructor's Signature with Date:					

Open Ended Lab

To understand and design the working principle of a Cuk converter

Objective

To understand and design the working principle of a Cuk converter.

Components Required

- IC - 555 timer (1)
- Capacitors - 0.1 uF (2), 0.01 uF(1), 100 uF(1)
- Resistors - 100 K Pot. (1), 10 k (1), 1 k (2)
- Diodes - 1N4001-7 / 1N5818 (4)
- Inductor - You can use Pulse Transformer windings
- Transistor - 2N2222 (2)
- Veroboard

Introduction

As buck-boost converter, Cừk converter also follows the principle of step up and step down of mean voltages at the output. Cừk converter produces the output mean voltage either higher or lower than the input mean voltage. A simple configuration of Cừk converter is shown in figure 11.1.

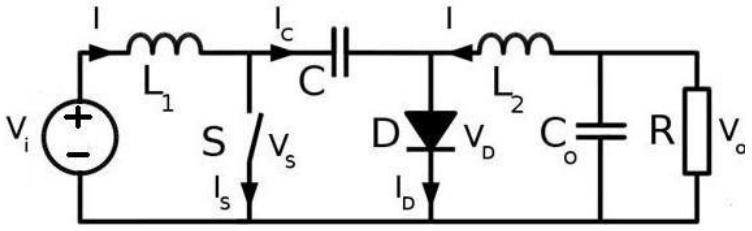

Figure 11.1: Cừk Converter

Cừk Converter

Cừk converter operates in two modes. During mode 1, when switch (S) is ON; an inductor (L_1) charge via switch and capacitor (C) behaves like a source and releases some of its energy via switch (S), capacitor (C_0) and inductor (L_2) at the output. During mode 2, when switch (S) is OFF; inductor (L_2) reverses its polarity and releases its energy via diode (D) at the output. Mean while, capacitor (C) charges via inductor (L_1) and diode (D). Through analytical analysis, the equation of output mean voltage is given as,

$$Vo = -Vs \frac{K}{1 - K}$$

Where, Vo represents output mean voltage, Vs represents input mean voltage and K is duty cycle. It can be noted that output voltage in Cừk converter is always the inverse of input voltage as apparent from output voltage equation.

Why Cừk converter when Buck-Boost converter is Available?

So, like the buck-boost converter, the Cừk converter can step the voltage either up or down, depending on the switching duty cycle. The main difference between the two is that because of the series inductors at both input and output, the Cừk converter has much lower current ripple. In fact by careful adjustment of the inductor values, the ripple in either input or output can be nulled completely.

Observation

- Fix duty cycle of switch at zero and measure V_{mean} across load
- Fix duty cycle of switch at 50% and measure V_{mean} across load.
- Fix duty cycle of switch at 20% and measure V_{mean} across load.
- Fix duty cycle of switch at 80% and measure V_{mean} across load.

1) Compute V_{mean} theoretically (as mentioned below) and compare the results with practical measurements.

For Cừk Converter

$$Vo = -Vs \frac{K}{1 - K}$$

Where, Vo represents the output mean voltage, Vs represents input mean voltage and K represents the duty cycle.

Calculation

For Cừk Converter

Task

Simulate Single Phase Full Bridge Inverter in Pspice or Simulink MATLAB.
Implement the hardware of the converter on Vero board. (Attach the waveforms).

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