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Note : Remove “Table of Content” before including in CP Book

Each Course Plan shall be printed and made into a book with cover page

Blooms Level in all sections match with A.2, only if you plan to teach / learn at higher levels

15EC73. POWER ELECTRONICS

A. COURSE INFORMATION

1. Course Overview

Degree:	BE	Program:	EC
Year / Semester :	4/7	Academic Year:	2019-20
Course Title:	Power Electronics	Course Code:	15EC73
Credit / L-T-P:	4-0-0	SEE Duration:	180 Minutes
Total Contact Hours:	50	SEE Marks:	80 Marks
CIA Marks:	20	Assignment	1 / Module
Course Plan Author:	Vanitha K S	Sign	Dt:
Checked By:		Sign	Dt:

2. Course Content

Module	Module Content	Teaching Hours	Module Concepts	Blooms Level
1	Introduction – Applications of Power Electronics, Power Semiconductor Devices, Control Characteristics of Power Devices, types of Power Electronic Circuits. Power Transistors: Power BJTs: Steady state characteristics. Power MOSFETs: device operation, switching characteristics, IGBTs: device operation, output and transfer characteristics.	10	Basics of Power Converters Diode Rectification	L3,L4
2	Thyristors – Introduction, Principle of Operation of SCR, Static AnodeCathode Characteristics of SCR, Two transistor model of SCR, Gate Characteristics of SCR, Turn-ON Methods, Turn-OFF Mechanism, Turn-OFF Methods: Natural and Forced Commutation – Class A and Class B types,Gate Trigger Circuit: Resistance Firing Circuit, Resistance capacitance firingcircuit.	10	Switching Operation Driver circuit	L3, l4
3	Controlled Rectifiers – Introduction, principle of phase controlled converter operation, Single phase full converters, Single phase dual converters. AC Voltage Controllers – Introduction, Principles of ON-OFF Control, Principle of Phase Control, Single phase control with resistive and	10	Switching Operation Firing Circuit	L3,l4

	inductive loads.			
4	DC-DC Converters – Introduction, principle of step-down operation and it's analysis with RL load, principle of step-up operation, Step-up converter with a resistive load, Performance parameters, Converter classification, Switching mode regulators: Buck regulator, Boost regulator, Buck-Boost Regulators.	10	Rectification using controlled rectifier Performance parameters	L3,l4
5	Pulse Width Modulated Inverters– Introduction, principle of operation,performance parameters, Single phase bridge inverters, voltage control of single phase inverters, current source inverters, Variable DC-link inverter, Boost inverter. Static Switches: Introduction, Single phase AC switches, DC Switches, Solid state relays, Microelectronic relays.	10	Principle Performance parameters	L4, L4

3. Course Material

Module	Details	Available
1	Text books	
1.	Mohammad H Rashid, Power Electronics, Circuits, Devices and Applications, 3rd/4th Edition, Pearson Education Inc, 2014, ISBN: 978-93-325-1844-5.	In LLB
2.	M.D Singh and K B Khanchandani, Power Electronics, 2nd Edition, Tata Mc-GrawHill, 2009, ISBN: 0070583897	
2	Reference books	
1.	L. Umanand, Power Electronics, Essentials and Applications, John Wiley India Pvt. Ltd, 2009.	In LIB
2.	Dr. P. S. Bimbhra, "Power Electronics", Khanna Publishers, Delhi, 2012.	
3	P.C. Sen, "Modern Power Electronics", S Chand &Co New Delhi, 2005.	

4. Course Prerequisites

SNo	Course Code	Course Name	Module / Topic / Description	Sem	Remarks	Blooms Level
1	15ELN15	Basic Electronics	1. Knowledge on Basic working	1	-	L2
	-	-		-		
2	15EC32	Analog Electronic Circuits	FET, MOSFET Construction, working, Characteristics	3	-	L3
					Plan Gap Course	

Note: If prerequisites are not taught earlier, GAP in curriculum needs to be addressed. Include in Remarks and implement in B.5.

B. OBE PARAMETERS

1. Course Outcomes

#	COs	Teach. Hours	Concept	Instr Method	Assessment Method	Blooms' Level
15EC73.1	Acquire the knowledge about fundamental concept and applications used in power electronic converters.	05	Basics of Power Converters	Lecture	Unit Test	L3 Apply
15EC73.2	Analyse the power diodes characteristics, types and their operation and the effect of power diode on RL circuit.	07	Diode Rectification	Lecture/ PPT	Assignment	L4 Analyze
15EC73.3	Understand the types, steady state, switching characteristics and their limitation of power transistors.	07	Switching Operation	Lecture	Assignment and unit Test	L3 Applying
15EC73.4	Design of gate and base drive circuit for turn-on and turn-off of power devices.	04	Driver circuit	Lecture / PPT	Assignment	L4 Analyze
15EC73.5	Describe the types of thyristors, characteristics and their limitations.	05	Switching Operationl	Lecture	unit test	L3 Apply
15EC73.6	Analyse the gate control requirement to produce firing pulses and to trigger the thyristor.	06	Firing Circuit	Lecture and Tutorial	Assignment	L4 Analyze
15EC73.7	Understand the principle of operation and designing of single phase and three phase controlled rectifier by producing firing pulses.	05	Rectification using controlled rectifier	Lecture	Assignment and Unit Test	L3 Apply
15EC73.8	Design and analyse the AC voltage controller	06	Performance parameters	Lecture	Assignment	L4 Analyze
15EC73.9	Understand the principle of operation of step up and step down chopper by varying the duty cycle.	06	Principle			L4 Analyze
15EC73.10	Design and analyse the single phase and three phase DC-AC converters	05	Performance parameters	Lecture	Assignment	L4 Analyze
-	**Total**	**61**	-	-	-	-

Note: Identify a max of 2 Concepts per Module. Write 1 CO per concept.

2. Course Applications

SNo	Application Area	CO	Level
1	Power diodes are used as isolating signals from supply.	CO2	L4
2	Power diodes can used as voltage reference, mixing and detection of signals	CO2	L4
3	Diode rectifiers can be used in controlling the size of the signal, used in lazer diodes.	CO2	L4
4	Transistors are used in audio amplifiers, sound reproduction, radio transmission	CO3	L3
5	BJT's are used in analog switches	CO3	L3
6	Transistors are used in low power logic gates, DC motor drives, AC motor drives	CO4	L4
7	Transistors are used in isolation circuit such as optocouplers and pulse transformers.	CO4	L4
8	Thyristors are used in Industrial application such as induction heating, dielectric heating and lamp dimming.	CO6	L4
9	Thyristors are used iin static AC /DC circuit breakers, tap changers	CO6	L4
10	TRIAC's are used in AC switches, starter circuit for lamps.	CO5	L3
11	Control rectifiers are used in speed control of DC motor, Universal motors, lamp dimming.	CO7	L3
12	AC voltage controllers are used in power generation, power transmission, electric heating, induction heating, cyclo converters, matrix converters, Electric welding.	CO8	L4
13	Choppers are used in railway traction, battery charges, switched capacitance filters, variable frequency drives, class D electronic amplifiers, battery operated electric cars.	CO9	L4
14	Inverters are used in HVDC power transmission at the receiving end, Uninterrupted power supply, Air conditioning, refrigeration, synchronverters, electroshock weapons	CO10	L4

Note: Write 1 or 2 applications per CO.

3. Articulation Matrix

(CO – PO MAPPING)

-	Course Outcomes	Program Outcomes											
#	COs	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	Level
15EC53.1	Acquire the knowledge about fundamental concept and applications used in power electronic converters.	3								3				L3
15EC53.2	Analyze the power diodes characteristics, types and their	3	3							3				L4

	operation and the effect of power diode on RL circuit.													
15EC53.3	Understand the types, steady state, switching characteristics and their limitation of power transistors.	3	3							3				L3
15EC53.4	Design of gate and base drive circuit for turn-on and turn-off of power devices.	3	3							3				L4
15EC53.5	Describe the types of thyristors, characteristics and their limitations.	3	2							3				L3
15EC53.6	Analyze the gate control requirement to produce firing pulses and to trigger the thyristor.	3	3	2						3				L4
15EC53.7	Understand the principle of operation and designing of single phase and three phase controlled rectifier by producing firing pulses.	3	3	2						3				L3
15EC53.8	Design and analyse the AC voltage controller	3	3											L4
15EC53.9	Understand the principle of operation of step up and step down chopper by varying the duty cycle.	3	3							3				L4
15EC53.10	Design and analyse the single phase and three phase DC-AC converters	3								3				L4
	Average													
Note: Mention the mapping strength as 1, 2, or 3														

4. Mapping Justification

Mapping		Justification	Mapping Level
CO	**PO**	**-**	**-**
CO1	PO1	Basics of semiconductor & converter circuits	L1
CO1	PO9	MOSFET,IGBT Lab experiment can be included in Assesment	L3
CO2	PO1	Basics of Switches	
CO2	PO2	Principle of SCR, MOSFET,IGBT	
CO2	PO9	Lab experiment cn be included in Assesment	
CO3	PO1	Basics of Transistors	

CO3	PO2	Operation of SCR	
CO3	PO9	SCR Lab experiment can be included in Assesment	
CO4	PO1	Basics of R,L & C	
CO4	PO2	Principle of gate voltage & gate current	
CO4	PO9	Latching current & holding Currents Lab experiment can be included in Assesment	
CO5	PO1	Basics of Rectifiers	
CO5	PO2	Types of converters	
CO5	PO9	TRIAC, DIAC Lab experiment can be included in Assesment	
CO6	PO1	Basics of AC voltage converter	
CO6	PO2	AC voltages with R, L loads	
CO6	PO3	Design Ac controllers with R ,RL loads	
CO6	PO9	Chopper Lab experiment can be included in Assesment	
C07	PO1	Basics of DC-DC converter	
CO7	PO2	Identify parameters of Choppers	
CO7	PO3	Analyze parameters by R, RL loads	
CO7	PO9	Ac voltage controlled Rectifier Lab experiment can be included in Assesment	
CO8	PO1	Basics of transformer	
CO8	PO2	Types of Choppers	
CO9	PO1	Basics of modulator& Inverter	
CO9	PO2	Compare phase, source & Current inverters	
CO9	PO9	Commutation, Lab experiment can be included in Assesment	
CO10	PO1	Basics of Static switches	
CO10	PO9	Inverter Lab experiment can be included in Assesment	

Note: Write justification for each CO-PO mapping.

5. Curricular Gap and Content

SNo	Gap Topic	Actions Planned	Schedule Planned	Resources Person	PO Mapping
1					
2					
3					
4					
5					

Note: Write Gap topics from A.4 and add others also.

6. Content Beyond Syllabus

SNo	Gap Topic	Actions Planned	Schedule Planned	Resources Person	PO Mapping
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Note: Anything not covered above is included here.

C. COURSE ASSESSMENT

1. Course Coverage

Module #	Title	Teaching Hours	No. of question in Exam						CO	Levels
			CIA-1	CIA-2	CIA-3	Asg	Extra Asg	SEE		
1	Introduction Power Diodes	12	2	-	-	1	1	2	CO1, CO2	L3, L4
2	Power Transistors	11	2	-	-	1	1	2	CO3, CO4	L3, L4
3	Thyristors	11	-	2	-	1	1	2	CO5, CO6	L3, L4
4	Controlled Rectifiers AC voltage controller	11	-	2	-	1	1	2	CO7, C08	L3, L4
5	DC-DC Converters DC-AC Converter	11	-	-	4	1	1	2	CO9, CO10	L4, L4
-	**Total**	**61**	**4**	**4**	**4**	**5**	**5**	**10**	**-**	**-**

Note: Distinct assignment for each student. 1 Assignment per chapter per student. 1 seminar per test per student.

2. Continuous Internal Assessment (CIA)

Evaluation	Weightage in Marks	CO	Levels

CIA Exam – 1	30	CO1, CO2, CO3, CO4	L3, L4, L3, L4
CIA Exam – 2	30	CO5, CO6, CO7, C08	L3, L4, L3, L4
CIA Exam – 3	30	CO9, CO10	L4, L4
Assignment – 1	05	CO1, CO2, CO3, CO4	L3, L4, L3, L4
Assignment – 2	05	CO5, CO6, CO7, CO8	L3, L4, L3, L4
Assignment – 3	05	CO9, CO10	L4, L4
Other Activities – define – Slip test		CO1 to Co9	L2, L3, L4 . ..
Final CIA Marks	**40**	**-**	**-**

Note : Blooms Level in last column shall match with A.2 above.

D1. TEACHING PLAN – 1

Module – 1

Title:	Divide and Conquer	Appr Time:	16 Hrs
a	***Course Outcomes***	–	**Blooms**
–	The student should be able to:	–	**Level**
1	Acquire the knowledge about fundamental concept and applications used in power electronic converters.	CO1	L3
2	Analyze the power diodes characteristics, types and their operation and the effect of power diode on RL circuit.	CO2	L4
b	***Course Schedule***	–	–
Class No	**Module Content Covered**	**CO**	**Level**
1	Introduction: Applications of Power Electronics,	C01	L3
2	Types of Power Electronic Circuits,	C01	L2
3	Peripheral Effects	C01	L3
4	Characteristics and Specifications of Switch.	C01	L3
5	Power Diodes: Introduction, Diode Characteristics	C02	L3
6	Reverse Recovery Characteristics, Power Diode Types, Silicon Carbide Diodes	C02	L3
7	Silicon Carbide Schottky Diodes, Diode Switched RL Load	C02	L4
8	Freewheeling Diodes with Switched RL Load.	C02	L4
9	Diode Rectifiers: Introduction	C02	L3
10	Single-Phase Full-Wave Rectifiers	C02	L4
11	Single-Phase Full-Wave Rectifier with RL Load,	C02	L4

12	Single-Phase Full-Wave Rectifier with a Highly Inductive Load	C02	L4
c	**Application Areas**	**CO**	**Level**
1	Power diodes are used as isolating signals from supply.	CO2	L4
2	Power diodes can used as voltage reference, mixing and detection of signals	CO2	L4
	Diode rectifiers can be used in controlling the size of the signal, used in lazer diodes.	CO2	L4
d	**Review Questions**	-	-
1	What are the advantages of static power converters?	CO1	L3
2	What are the peripheral effects of power electronics system?	CO2	L4
3	Explain the 2 modes of operation of freewheeling diode.	CO2	L4
4	Mention and explain the different types of power electronics converter system and also specify the form of input &output with waveform.	CO1	L3
5	What is a switch. What are the characteristics of an ideal switch.	CO2	L4
6	Explain the diode characteristics with different regions of operation.	CO2	L4
7	What are the difference between pn junction diode &schottky diode. With the help of neat diagram explain the reverse recovery characteristics of a diode.	CO2	L4
8	With the help of circuit diagram, explain the working of diode with RC and RL load.	CO2	L4
9	A diode circuit is shown in figure with R=44Ω and C=0.1μF. The capacitor has an initial voltage, Vco=Vc(t=0)=220V. If switch S1 is closed at t=0, determine (a) the peak diode current (b) the energy dissipated in the resistor R and (c) the capacitor voltage at t=2μs.	CO2	L4
11	Give the symbol and characteristic features of the following devices (I) SCR (II) IGBT (iii) TRIAC (iv) SIT	CO1	L4
e	**Experiences**	-	-
1		CO1	L2
2			
3			
4		CO3	L3
5			

Module – 2

Title:	Divide and Conquer	Appr Time:	10 Hrs
a	***Course Outcomes***	-	**Blooms**
-	The student should be able to:	-	**Level**
1	Understand the types, steady state, switching characteristics and their limitation of power transistors.	CO3	L3

2	Design of gate and base drive circuit for turn-on and turn-off of power devices.	CO4	L4
b	***Course Schedule***	–	–
Class No	**Module Content Covered**	**CO**	**Level**
13	Power Transistors: Introduction	CO3	L3
14	Power MOSFETs – Steady State Characteristics, Switching Characteristics Bipolar Junction	CO3	L3
15	Transistors – Steady State Characteristics	CO3	L3
16	Switching Characteristics	CO3	L3
17	Switching Limits, IGBTs, MOSFET	CO3	L3
18	Problems	CO3	L3
19	Gate Drive	CO4	L4
20	BJT Base Drive	CO4	L4
21	Isolation of Gate and Base Drives,	CO4	L4
22	Pulse transformers and Opto-couplers.	CO4	L4
23	Problems	CO4	L3
c	**Application Areas**	**CO**	**Level**
1	Transistors are used in audio amplifiers, sound reproduction, radio transmission	CO3	L3
2	BJT's are used in analog switches	CO3	L3
3	Transistors are used in low power logic gates, DC motor drives, AC motor drives	CO4	L4
4	Transistors are used in isolation circuit such as optocouplers and pulse transformers.	CO4	L4
d	**Review Questions**	–	–
12	Explain how anti saturation base control improves the switching performance of a BJT.	CO3	L3
13	With the help of switching waveforms explain the switching times of a power MOSFET.	CO4	L4
14	Give the construction, static characteristic, and applications of IGBT.	CO3	L2
15	Write the circuit diagrams and discuss the methods of providing isolation of gate / base circuits from power circuits.	CO4	L4
16	Give the applications of BJT?	CO4	L4
17	Differentiate between MOSFET and IGBT.	CO3	L5
18	Why are IGBT becoming popular in their application to controlled converters?	CO3	L2
19	With the help of neat diagram explain the operation of BJT.	CO3	L3
20	Explain the switching characteristics of MOSFET	CO3	L3

21	Explain the driver circuit and protection circuits for MOSFET.	CO4	L4
22	For the switching circuit shown below, calculate forced β of the transistor. Also calculate the ODF if the manufacturer specified β is 10. Calculate the power loss PT of the transistor. VCC = 100 V ; VB = 5 V ; RB =0.8 Ω ; RC =12 Ω ; VCE (Sat) = 1.0 V ; VBE (Sat) = 1.0 V	CO3	L3
23	What is the need for isolation of gate drive circuits?	CO4	L4
24	Explain the terms over drive factor (ODF) and forced beta (β) for a power transistor in switching application.	CO3	L3
25	Name and explain various switching limits in case of power BJTs. With a circuit diagram, explain anti saturation control of BJT. Mention the improvement and drawback of this arrangement.	CO4	L4
26	Explain different methods of providing gate and base drive isolation.	CO4	L4
e	**Experiences**	–	–
1		CO1	L2
2			
3			
4		CO3	L3
5			

E1. CIA EXAM – 1

A. Model Question Paper – 1

Crs Code:	15EC73	Sem:	7	Marks:	30	Time:	75 minutes
Course:	Power Electronics						

-	-	**Note: Answer any 3 questions, each carry equal marks.**	**Marks**	**CO**	**Level**
1	a	What are the advantages of static power converters?	20	CO1	L1
	b	What are the peripheral effects of power electronics system?		CO1	L2
	c	Explain the 2 modes of operation of freewheeling diode.		CO2	L3
	d	Explain how anti saturation base control improves the switching performance of a BJT.		CO1	L1
2	a	With the help of switching waveforms explain the switching times of a power MOSFET.	20	CO1	L2
	b	Explain the diode characteristics with different regions of operation.		CO1	L4
	c	Write the circuit diagrams and discuss the methods of providing isolation of gate / base circuits from power circuits.		CO1	L3
	d	Give the applications of BJT?		CO1	L2
3	a	Give the construction, static characteristic, and applications of IGBT.	20	CO3	L1

	b	A diode circuit is shown in figure with R=44Ω and C=0.1μF. The capacitor has an initial voltage, Vco=Vc(t=0)=220V. If switch S1 is closed at t=0, determine (a) the peak diode current (b) the energy dissipated in the resistor R and (c) the capacitor voltage at t=2μs.		CO4	L2
	c	Give the symbol and characteristic features of the following devices (I) SCR (II) IGBT (iii) TRIAC (iv) SIT		CO1	L1
4	a	For the switching circuit shown below, calculate forced β of the transistor. Also calculate the ODF if the manufacturer specified β is 10. Calculate the power loss PT of the transistor. VCC = 100 V ; VB = 5 V ; RB =0.8 Ω ; RC =12 Ω ; VCE (Sat) = 1.0 V ; VBE (Sat) = 1.0 V	20	CO1	L2
	b	What is the need for isolation of gate drive circuits?		CO1	L2
	c	Explain the terms over drive factor (ODF) and forced beta (β) for a power transistor in switching application.		CO1	L1

b. Assignment -1

Note: A distinct assignment to be assigned to each student.

Model Assignment Questions							
Crs Code:	15EC73	Sem:	7	Marks:	5 / 10	Time:	90 – 120 minutes
Course:	Power Electronics						

Note: Each student to answer 2-3 assignments. Each assignment carries equal mark.

SNo	USN	Assignment Description	Marks	CO	Level
1		What are the advantages of static power converters?	5	CO1	L3
2		What are the peripheral effects of power electronics system?	5	CO2	L4
3		Explain the 2 modes of operation of freewheeling diode.	5	CO2	L4
4		Mention and explain the different types of power electronics converter system and also specify the form of input &output with waveform.	5	CO1	L3
5		What is a switch. What are the characteristics of an ideal switch.	5	CO2	L4
6		Explain the diode characteristics with different regions of operation.	5	CO2	L4
7		What are the difference between pn junction diode &schottky diode. With the help of neat diagram explain the reverse recovery characteristics of a diode.	5	CO2	L4
8		With the help of circuit diagram, explain the working of diode with RC and RL load.	5	CO2	L4
9		A diode circuit is shown in figure with R=44Ω and C=0.1μF. The capacitor has an initial voltage, Vco=Vc(t=0)=220V. If switch S1 is closed at t=0, determine (a) the peak diode current (b) the energy dissipated in the resistor R and (c) the capacitor voltage at t=2μs.	5	CO2	L4

10		Give the symbol and characteristic features of the following devices (I) SCR (II) IGBT (iii) TRIAC (iv) SIT	5	CO1	L4
11		Explain how anti saturation base control improves the switching performance of a BJT.	5	CO3	L3
12		With the help of switching waveforms explain the switching times of a power MOSFET.	5	CO4	L4
13		Give the construction, static characteristic, and applications of IGBT.	5	CO3	L2
14		Write the circuit diagrams and discuss the methods of providing isolation of gate / base circuits from power circuits.	5	CO4	L4
15		Give the applications of BJT?	5	CO4	L4
16		Differentiate between MOSFET and IGBT.	5	CO3	L5
17		Why are IGBT becoming popular in their application to controlled converters?	5	CO3	L2
18		With the help of neat diagram explain the operation of BJT.	5	CO3	L3
19		Explain the switching characteristics of MOSFET	5	CO3	L3
20		Explain the driver circuit and protection circuits for MOSFET.	5	CO4	L4
21		For the switching circuit shown below, calculate forced β of the transistor. Also calculate the ODF if the manufacturer specified β is 10. Calculate the power loss PT of the transistor. VCC = 100 V ; VB = 5 V ; RB =0.8 Ω ; RC =12 Ω ; VCE (Sat) = 1.0 V ; VBE (Sat) = 1.0 V	5	CO3	L3
22		What is the need for isolation of gate drive circuits?	5	CO4	L4
23		Explain the terms over drive factor (ODF) and forced beta (β) for a power transistor in switching application.	5	CO3	L3
24		Name and explain various switching limits in case of power BJTs. With a circuit diagram, explain anti saturation control of BJT. Mention the improvement and drawback of this arrangement.	5	CO4	L4
25		Explain different methods of providing gate and base drive isolation.	5	CO4	L4

D2. TEACHING PLAN - 2

Module - 3

Title:		Appr Time:	16 Hrs
a	***Course Outcomes***	-	**Blooms**
-	The student should be able to:	-	**Level**
1	Describe the types of thyristors, characteristics and their limitations.	CO5	L3
2	Analyze the gate control requirement to produce firing pulses and to	CO6	L4

	trigger the thyristor.		
b	***Course Schedule***		
Class No	**Module Content Covered**	**CO**	**Level**
1	Thyristors: Introduction	CO5	L3
2	Thyristor Characteristics,	CO5	L3
3	Two-Transistor Model of Thyristor	CO5	L3
4	Thyristor Turn-On	CO5	L3
5	Thyristor Turn-Off	CO5	L3
6	A brief study on Thyristor Types	CO6	L4
7	Series Operation of Thyristors	CO6	L4
8	Parallel Operation of Thyristors	CO6	L4
9	di/dt Protection, dv/dt Protection, DIACs	CO6	L4
10	Thyristor Firing Circuits- R firing circuit, RC firing circuit, digital firing circuit	CO6	L4
11	Unijunction Transistor.	CO6	L4
c	**Application Areas**	**CO**	**Level**
1	Thyristors are used in Industrial application such as induction heating, dielectric heating and lamp dimming.	CO6	L4
2	Thyristors are used iin static AC /DC circuit breakers, tap changers	CO6	L4
	TRIAC's are used in AC switches, starter circuit for lamps.	CO5	L3
d	**Review Questions**	-	-
1	Compare the features of BJT, MOSFET and SCR for use in power electronic circuits. Give the applications where these devices are preferred over others.	CO5	L3
2	Draw the I-V characteristics of SCR. Label the various voltages, current and the operating modes on this sketch?	CO5	L3
3	Enumerate the various methods by which thyristors be triggered into conduction?	CO5	L3
4	Define Latching and holding currents as applicable to an SCR? Show these currents on its state IV characteristics?	CO5	L3
5	Explain the switching characteristics of a Thyristor during turn on and turn off process?	CO5	L3
6	Discuss the two transistor model of a Thyristor? Derive an expression for the anode current and discuss there from the turn-on mechanisms of a thyristor?	CO5	L3
7	Explain how thyristors can be protected against dv/dt and di/dt ? what are the considerations for choosing circuit elements for protection?	CO6	L4
8	Using two transistor model, explain the switching action of a thyristor and significance of gate control. Also derive the expression	CO6	L4

	for anode current.		
9	Distinguish between: 1.) Latching current and Holding current, 2) Converter grade thyristor and inverter grade thyristor, 3) thyristor turn-off time and circuit turn-off time.	CO5	L3
10	The thyristor shown in the circuit below has a latching current of 20 mA and is fired by a gate pulse of 50 μs. Show that without the resistor R, the thyristor will fail to remain ON. Also find the maximum value of R to ensure firing.	CO5	L3
11	With relevant diagram and waveforms, explain UJT relaxation oscillator.	CO6	L4
12	Explain the following terms in brief with respect to SCR: i) Holding current; ii) Latching current; iii) di/dt rating; iv) dv/dt rating; v) PIV	CO5	L
13	With neat sketches, explain turn-on and turn-off characteristics of SCR.	CO6	
14	Explain in detail the following ratings of SCR – i) Average on state current ii) RMS on state current iii) I2t rating iv) Peak working reverse voltage v) Repetitive peak	CO6	
15	Design a UJT relaxation oscillator for triggering a SCR. The UJT has the following specifications: η= 0.7, Ip = 50 μA, Vv = 2 V, Iv = 6mA, VBB = 20 V, RBB = 7 kΩ and IEC = 2 mA. Also determine the limits for the output frequency of the oscillator	CO6	
e	**Experiences**	–	–
1		CO1	L2
2			
3			
4		CO3	L3
5			

Module – 4

Title:	Divide and Conquer	Appr Time:	16 Hrs
a	***Course Outcomes***	–	**Blooms**
–	The student should be able to:	–	**Level**
1	Understand the principle of operation and designing of single phase and three phase controlled rectifier by producing firing pulses.	CO7	L3
2	Design and analyse the AC voltage controller	CO8	L4
b	***Course Schedule***		
Class No	**Module Content Covered**	**CO**	**Level**
1	DC-DC Converters – Introduction, principle of step-down operation		
2	Step down converter analysis with RL load		

3	principle of step-up operation		
4	Step-up converter with a resistive load		
5	problems		
6	Performance parameters		
7	Converter classification		
8	Switching mode regulators: Buck regulator		
9	Boost regulator		
10	Buck-Boost Regulators.		
c	**Application Areas**	**CO**	**Level**
1	Control rectifiers are used in speed control of DC motor, Universal motors, lamp dimming.	CO7	L3
2	AC voltage controllers are used in power generation, power transmission, electric heating, induction heating, cyclo converters, matrix converters, Electric welding.	CO8	L4
d	**Review Questions**	-	-
1	For a single phase controlled rectifier with RL load, derive the expression for average and r.m.s values of output voltage with and without freewheeling diode. Also draw the waveforms of the output voltages in both the cases.	CO7	L1
2	What is the use of freewheeling diode in a converter circuit.	CO7	L3
3	Compare circulating and non circulating current modes dual converter.	CO8	L2
4	Write the effect of source impedance on performance of converters. Explain the operation of single-phase Fully-controlled bridge converter taking source impedance into account. Derive the expression for V&in terms of overlap angle and source inductance. Draw voltage and current waveforms.	CO7	L4
5	With the help of a neat diagram and associated wave forms, explain the operation of a single phase semi converter with RL load.	CO8	L5
6	A single phase full converter has a RL load having L = 6.5 mH, R = 0.5 Ω and E = 10 V. The input voltage is V = 120 sin 120 π t. Determine – (i) the load current IL at wt = α = 60o (ii) the average thyristor current IA (iii) the r.m.s thyristor current IR (iv) the rms output current IRMS and (v) the average output current IDC.		L3
7	Discuss Single phase Full wave Mid point converter.		L1
8	Discuss Single Phase Half wave current with RLE load.		L4
9	Discuss Single Phase Full wave full Bridge converters.		
10	Discuss Single Phase two pulse converter with Discontinuous load current.		
11	Discuss Single Phase symmetrical and Asymmetrical Semi-converters with the waveforms.		

e	Experiences	-	-
1		CO7	L2
2			
3			
4		CO8	L3
5			

E2. CIA EXAM – 2

a. Model Question Paper – 2

Crs Code:	15EC73	Sem:	7	Marks:	30	Time:	75 minutes
Course:	Power Electronics						

-	-	**Note: Answer any 2 questions, each carry equal marks.**	**Marks**	**CO**	**Level**
1	a	For a single phase controlled rectifier with RL load, derive the expression for average and r.m.s values of output voltage with and without freewheeling diode. Also draw the waveforms of the output voltages in both the cases.	20	CO5	L1
	b	What is the use of freewheeling diode in a converter circuit.			L2
	c	Discuss Single Phase two pulse converter with Discontinuous load current.		CO6	L3
	d	Discuss Single Phase symmetrical and Asymmetrical Semi-converters with the waveforms.			L1
2	a	Compare the features of BJT, MOSFET and SCR for use in power electronic circuits. Give the applications where these devices are preferred over others.	20	CO7	L2
	b	Draw the I-V characteristics of SCR. Label the various voltages, current and the operating modes on this sketch?			L4
	c	Enumerate the various methods by which thyristors be triggered into conduction?			L3
	d	Define Latching and holding currents as applicable to an SCR? Show these currents on its state IV characteristics?			L2
3	a	Discuss the two transistor model of a Thyristor? Derive an expression for the anode current and discuss there from the turn-on mechanisms of a thyristor?	20	CO8	L1
	b	Explain how thyristors can be protected against dv/dt and di/dt ? what are the considerations for choosing circuit elements for protection?		CO8	L2
	c	Using two transistor model, explain the switching action of a thyristor and significance of gate control. Also derive the expression for anode current.			L1

	d	Distinguish between: 1.) Latching current and Holding current, 2) Converter grade thyristor and inverter grade thyristor, 3) thyristor turn-off time and circuit turn-off time.			L2
4	a	With relevant diagram and waveforms, explain UJT relaxation oscillator.	20		L2
	b	Explain the following terms in brief with respect to SCR: i) Holding current; ii) Latching current; iii) di/dt rating; iv) dv/dt rating; v) PIV			L2
	c	With neat sketches, explain turn-on and turn-off characteristics of SCR.			L1
	d	Explain in detail the following ratings of SCR – i) Average on state current ii) RMS on state current iii) I2t rating iv) Peak working reverse voltage v) Repetitive peak			L3

b. Assignment – 2

Note: A distinct assignment to be assigned to each student.

Model Assignment Questions							
Crs Code:	15EC73	Sem:	7	Marks:	5 / 10	Time:	90 – 120 minutes
Course:	Power Electronics						
Note: Each student to answer 2-3 assignments. Each assignment carries equal mark.							

SNo	USN	Assignment Description	Marks	CO	Level
1		Compare the features of BJT, MOSFET and SCR for use in power electronic circuits. Give the applications where these devices are preferred over others.	6	CO5	L3
2		Draw the I-V characteristics of SCR. Label the various voltages, current and the operating modes on this sketch?	8	CO5	L3
3		Enumerate the various methods by which thyristors be triggered into conduction?	6	CO5	L3
4		Define Latching and holding currents as applicable to an SCR? Show these currents on its state IV characteristics?	6	CO5	L3
5		Explain the switching characteristics of a Thyristor during turn on and turn off process?	6	CO5	L3
6		Discuss the two transistor model of a Thyristor? Derive an expression for the anode current and discuss there from the turn-on mechanisms of a thyristor?	6	CO5	L3
7		Explain how thyristors can be protected against dv/dt and di/dt ? what are the considerations for choosing circuit elements for protection?	6	CO6	L2
8		Using two transistor model, explain the switching action of a thyristor and significance of gate control. Also derive the expression for anode current.	6	CO6	L2
9		Distinguish between: 1.) Latching current and Holding	6	CO5	L3

		current, 2) Converter grade thyristor and inverter grade thyristor, 3) thyristor turn-off time and circuit turn-off time.			
10		The thyristor shown in the circuit below has a latching current of 20 mA and is fired by a gate pulse of 50 μs. Show that without the resistor R, the thyristor will fail to remain ON. Also find the maximum value of R to ensure firing.	6	CO5	L3
11		With relevant diagram and waveforms, explain UJT relaxation oscillator.	6	CO6	L2
12		Explain the following terms in brief with respect to SCR: i) Holding current; ii) Latching current; iii) di/dt rating; iv) dv/dt rating; v) PIV	6	CO5	L2
13		With neat sketches, explain turn-on and turn-off characteristics of SCR.	6	CO6	L2
14		Explain in detail the following ratings of SCR – i) Average on state current ii) RMS on state current iii) I2t rating iv) Peak working reverse voltage v) Repetitive peak	6	CO6	L2
15		Design a UJT relaxation oscillator for triggering a SCR. The UJT has the following specifications: η= 0.7, Ip = 50 μA, Vv = 2 V, Iv = 6mA, VBB = 20 V, RBB = 7 kΩ and IEC = 2 mA. Also determine the limits for the output frequency of the oscillator	8	CO6	L3

D3. TEACHING PLAN – 3

Module – 5

Title:	Divide and Conquer	Appr Time:	16 Hrs
a	***Course Outcomes***	–	**Blooms**
–	The student should be able to:	–	**Level**
1	Understand the principle of operation of step up and step down chopper by varying the duty cycle.	CO9	L4
2	Design and analyse the single phase and three phase DC-AC converters	CO10	L4
b	***Course Schedule***		
Class No	**Module Content Covered**	**CO**	**Level**
1	Pulse Width Modulated Inverters- Introduction	CO9	L2
2	principle of operation, performance parameters	CO9	L3
3	Single phase bridge inverters	CO9	L3
4	voltage control of single phase inverters,	CO9	L3
5	current source inverters	CO9	L3
6	Variable DC-link inverter, Boost inverter.	CO9	L3
7	Static Switches: Introduction	CO10	L2
8	Single phase AC switches	CO10	L2

9	DC Switches, Solid state relays	CO10	L2
10	Microelectronic relays	CO10	L2
16			
c	**Application Areas**	**CO**	**Level**
1	Choppers are used in railway traction, battery charges, switched capacitance filters, variable frequency drives, class D electronic amplifiers, battery operated electric cars.	CO9	L4
2	Inverters are used in HVDC power transmission at the receiving end, Uninterrupted power supply, Air conditioning, refrigeration, synchronverters, electroshock weapons	CO10	L4
d	**Review Questions**	-	-
1	For a single phase controlled rectifier with RL load, derive the expression for average and r.m.s values of output voltage with and without freewheeling diode. Also draw the waveforms of the output voltages in both the cases.	CO9	L1
2	What is the use of freewheeling diode in a converter circuit.	CO9	L3
3	Compare circulating and non circulating current modes dual converter.	CO9	L2
4	Write the effect of source impedance on performance of converters. Explain the operation of single-phase Fully-controlled bridge converter taking source impedance into account. Derive the expression for V&in terms of overlap angle and source inductance. Draw voltage and current waveforms.	CO9	L4
5	With the help of a neat diagram and associated wave forms, explain the operation of a single phase semi converter with RL load.	CO9	L5
6	A single phase full converter has a RL load having L = 6.5 mH, R = 0.5 Ω and E = 10 V. The input voltage is V = 120 sin 120 π t. Determine – (i) the load current IL at wt = α = 60o (ii) the average thyristor current IA (iii) the r.m.s thyristor current IR (iv) the rms output current IRMS and (v) the average output current IDC.	CO10	L3
7	Discuss Single phase Full wave Mid point converter.	CO10	L2
8	Discuss Single Phase Half wave current with RLE load.	CO10	L2
9	Discuss Single Phase Full wave full Bridge converters.	CO10	L2
10	Discuss Single Phase two pulse converter with Discontinuous load current.	CO10	L2
11	Discuss Single Phase symmetrical and Asymmetrical Semi-converters with the waveforms.	CO10	L2
e	**Experiences**	-	-
1		CO10	L2
2			
3			

4		CO9	L3
5			

E3. CIA EXAM – 3

a. Model Question Paper – 3

Crs Code:	15EC73	Sem:	7	Marks:	30	Time:	75 minutes
Course:	Power Electronics						

-	-	**Note: Answer any 2 questions, each carry equal marks.**	**Marks**	**CO**	**Level**
1	a	For a single phase controlled rectifier with RL load, derive the expression for average and r.m.s values of output voltage with and without freewheeling diode. Also draw the waveforms of the output voltages in both the cases.	20	CO5	L1
	b	What is the use of freewheeling diode in a converter circuit.			L2
	c	Discuss Single Phase two pulse converter with Discontinuous load current.		CO6	L3
	d	Discuss Single Phase symmetrical and Asymmetrical Semi-converters with the waveforms.			L1
2	a	Compare the features of BJT, MOSFET and SCR for use in power electronic circuits. Give the applications where these devices are preferred over others.	20	CO7	L2
	b	Draw the I-V characteristics of SCR. Label the various voltages, current and the operating modes on this sketch?			L4
	c	Enumerate the various methods by which thyristors be triggered into conduction?			L3
	d	Define Latching and holding currents as applicable to an SCR? Show these currents on its state IV characteristics?			L2
3	a	Discuss the two transistor model of a Thyristor? Derive an expression for the anode current and discuss there from the turn-on mechanisms of a thyristor?	20	CO8	L1
	b	Explain how thyristors can be protected against dv/dt and di/dt ? what are the considerations for choosing circuit elements for protection?		CO8	L2
	c	Using two transistor model, explain the switching action of a thyristor and significance of gate control. Also derive the expression for anode current.			L1
	d	Distinguish between: 1.) Latching current and Holding current, 2) Converter grade thyristor and inverter grade thyristor, 3) thyristor turn-off time and circuit turn-off time.			L2

4	a	With relevant diagram and waveforms, explain UJT relaxation oscillator.	20		L2
	b	Explain the following terms in brief with respect to SCR: i) Holding current; ii) Latching current; iii) di/dt rating; iv) dv/dt rating; v) PIV			L2
	c	With neat sketches, explain turn-on and turn-off characteristics of SCR.			L1
	d	Explain in detail the following ratings of SCR – i) Average on state current ii) RMS on state current iii) I2t rating iv) Peak working reverse voltage v) Repetitive peak			L3

b. Assignment – 3

Note: A distinct assignment to be assigned to each student.

Model Assignment Questions							
Crs Code:	15EC74	Sem:	I	Marks:	5 / 10	Time:	90 – 120 minutes
Course:	Design and Analysis of Algorithms						
Note: Each student to answer 2-3 assignments. Each assignment carries equal mark.							

SNo	USN	Assignment Description	Marks	CO	Level
1		For a single phase controlled rectifier with RL load, derive the expression for average and r.m.s values of output voltage with and without freewheeling diode. Also draw the waveforms of the output voltages in both the cases.	8	CO9	L1
2		What is the use of freewheeling diode in a converter circuit.	4	CO9	L3
3		Compare circulating and non circulating current modes dual converter.	6	CO9	L2
4		Write the effect of source impedance on performance of converters. Explain the operation of single-phase Fully-controlled bridge converter taking source impedance into account. Derive the expression for V&in terms of overlap angle and source inductance. Draw voltage and current waveforms.	8	CO9	L4
5		With the help of a neat diagram and associated wave forms, explain the operation of a single phase semi converter with RL load.	8	CO9	L5
6		A single phase full converter has a RL load having L = 6.5 mH, R = 0.5 Ω and E = 10 V. The input voltage is V = 120 sin 120 π t. Determine – (i) the load current IL at wt = α = 60o (ii) the average thyristor current IA (iii) the r.m.s thyristor current IR (iv) the rms output current IRMS and (v) the average output current IDC.	8	CO10	L3
7		Discuss Single phase Full wave Mid point converter.	6	CO10	L2
8		Discuss Single Phase Half wave current with RLE load.	6	CO10	L2
9		Discuss Single Phase Full wave full Bridge converters.	6	CO10	L2
10		Discuss Single Phase two pulse converter with Discontinuous load current.	6	CO10	L2

11		Discuss Single Phase symmetrical and Asymmetrical Semi-converters with the waveforms.	6	CO10	L2

F. EXAM PREPARATION

1. University Model Question Paper

Course:	Power Electronics					Month / Year	May /2018	
Crs Code	15EC73	Sem:	7	Marks:	100	Time:	180 minutes	
-	**Note**	Answer all FIVE full questions. All questions carry equal marks.				**Marks**	**CO**	**Level**
1	a	What are the advantages of static power converters?				20	CO1	L3
	b	What are the peripheral effects of power electronics system?					CO2	L4
	c	Explain the 2 modes of operation of freewheeling diode.					CO2	L4
	d	Mention and explain the different types of power electronics converter system and also specify the form of input &output with waveform.					CO1	L3
		OR						
-	a	Explain the diode characteristics with different regions of operation.				20	CO2	L4
	b	What are the difference between pn junction diode &schottky diode. With the help of neat diagram explain the reverse recovery characteristics of a diode.					CO2	L4
	c	With the help of circuit diagram, explain the working of diode with RC and RL load.					CO2	L4
	d	A diode circuit is shown in figure with R=44Ω and C=0.1μF. The capacitor has an initial voltage, Vco=Vc(t=0)=220V. If switch S1 is closed at t=0, determine (a) the peak diode current (b) the energy dissipated in the resistor R and (c) the capacitor voltage at t=2μs.					CO2	L4
2	a	Explain how anti saturation base control improves the switching performance of a BJT.				20	CO3	L3
	b	With the help of switching waveforms explain the switching times of a power MOSFET.					CO3	L4
	c	Give the construction, static characteristic, and applications of IGBT.					CO3	L2
	d	Write the circuit diagrams and discuss the methods of providing isolation of gate / base circuits from power circuits.					CO3	L4
		OR						
-	a	What is the need for isolation of gate drive circuits?				20	CO4	L3
	b	Explain the terms over drive factor (ODF) and forced beta (β) for a power transistor in switching application.					CO4	L4
	c	Name and explain various switching limits in case of power BJTs. With a circuit diagram, explain anti saturation control of BJT. Mention the improvement and drawback of this arrangement.					CO4	L2

	d	Explain different methods of providing gate and base drive isolation.		CO4	L4
		OR			
3	a	Give the applications of BJT?	20	CO5	L2
	b	Differentiate between MOSFET and IGBT.		CO5	L2
	c	Why are IGBT becoming popular in their application to controlled converters?		CO5	L2
	d	With the help of neat diagram explain the operation of BJT.		CO5	L2
-	a	Why are IGBT becoming popular in their application to controlled converters?	20	CO6	L2
	b	With the help of neat diagram explain the operation of BJT.		CO6	L3
	c	Explain the switching characteristics of MOSFET		CO6	L3
	d	Explain the driver circuit and protection circuits for MOSFET.		CO6	L4
4	a	The thyristor shown in the circuit below has a latching current of 20 mA and is fired by a gate pulse of 50 μs. Show that without the resistor R, the thyristor will fail to remain ON. Also find the maximum value of R to ensure firing.	20	CO7	L3
	b	With relevant diagram and waveforms, explain UJT relaxation oscillator.		CO7	L2
	c	Explain the following terms in brief with respect to SCR: i) Holding current; ii) Latching current; iii) di/dt rating; iv) dv/dt rating; v) PIV		CO7	L2
	d	With neat sketches, explain turn-on and turn-off characteristics of SCR.		CO7	L2
		OR			
-	a	Explain the following terms in brief with respect to SCR: i) Holding current; ii) Latching current; iii) di/dt rating; iv) dv/dt rating; v) PIV	6	CO5	L2
	b	With neat sketches, explain turn-on and turn-off characteristics of SCR.	6	CO6	L2
	c	Explain in detail the following ratings of SCR – i) Average on state current ii) RMS on state current iii) I2t rating iv) Peak working reverse voltage v) Repetitive peak	6	CO6	L2
	d	Design a UJT relaxation oscillator for triggering a SCR. The UJT has the following specifications: η= 0.7, Ip = 50 μA, Vv = 2 V, Iv = 6mA, VBB = 20 V, RBB = 7 kΩ and IEC = 2 mA. Also determine the limits for the output frequency of the oscillator	8	CO6	L3
5	a	Give the applications of BJT?	20	CO9	L2
	b	Differentiate between MOSFET and IGBT.		CO9	L2
	c	Why are IGBT becoming popular in their application to controlled converters?		CO9	L2
	d	With the help of neat diagram explain the operation of BJT.		CO9	L2
		OR			
	a	Why are IGBT becoming popular in their application to controlled	20	CO10	L2

		converters?			
	b	With the help of neat diagram explain the operation of BJT.		CO10	L3
	c	Explain the switching characteristics of MOSFET		CO10	L3
	d	Explain the driver circuit and protection circuits for MOSFET.		CO10	L4

2. SEE Important Questions

Course:		Power Electronics					Month / Year		May /2018	
Crs Code		15EC73	Sem:	7	Marks:	100	Time:		180 minutes	
	Note	Answer all FIVE full questions. All questions carry equal marks.						–	–	
Module	Qno.	Important Question						**Marks**	**CO**	**Year**
1	1	Explain the diode characteristics with different regions of operation.						6	CO2	
	2	What are the difference between pn junction diode &schottky diode. With the help of neat diagram explain the reverse recovery characteristics of a diode.						7	CO2	
	3	With the help of circuit diagram, explain the working of diode with RC and RL load.						6	CO2	
	4	A diode circuit is shown in figure with R=44Ω and C=0.1μF. The capacitor has an initial voltage, Vco=Vc(t=0)=220V. If switch S1 is closed at t=0, determine (a) the peak diode current (b) the energy dissipated in the resistor R and (c) the capacitor voltage at t=2μs.						6	CO2	
	5	Mention and explain the different types of power electronics converter system and also specify the form of input &output with waveform.						8		
2	1	Explain how anti saturation base control improves the switching performance of a BJT.						6	CO3	
	2	With the help of switching waveforms explain the switching times of a power MOSFET.						7	CO4	
	3	Give the construction, static characteristic, and applications of IGBT.						6	CO3	
	4	Write the circuit diagrams and discuss the methods of providing isolation of gate / base circuits from power circuits.						6	CO4	
	5	Explain different methods of providing gate and base drive isolation.						8	CO4	
3	1	Give the applications of BJT?						6		
	2	Differentiate between MOSFET and IGBT.						7		
	3	Why are IGBT becoming popular in their application to controlled converters?						6		
	4	With the help of neat diagram explain the operation of BJT.						6		
	5	Explain the driver circuit and protection circuits for MOSFET.						8		

4	1	The thyristor shown in the circuit below has a latching current of 20 mA and is fired by a gate pulse of 50 μs. Show that without the resistor R, the thyristor will fail to remain ON. Also find the maximum value of R to ensure firing.	6	CO7	
	2	With relevant diagram and waveforms, explain UJT relaxation oscillator.	7	CO7	
	3	With neat sketches, explain turn-on and turn-off characteristics of SCR.	6	CO6	
	4	Explain in detail the following ratings of SCR - i) Average on state current ii) RMS on state current iii) I2t rating iv) Peak working reverse voltage v) Repetitive peak	6	CO6	
	5	Design a UJT relaxation oscillator for triggering a SCR. The UJT has the following specifications: η= 0.7, Ip = 50 μA, Vv = 2 V, Iv = 6mA, VBB = 20 V, RBB = 7 kΩ and IEC = 2 mA. Also determine the limits for the output frequency of the oscillator	8	CO6	
5	1	For a single phase controlled rectifier with RL load, derive the expression for average and r.m.s values of output voltage with and without freewheeling diode. Also draw the waveforms of the output voltages in both the cases.	8	CO9	
	2	What is the use of freewheeling diode in a converter circuit.	4	CO9	
	3	Compare circulating and non circulating current modes dual converter.	6	CO9	
	4	Write the effect of source impedance on performance of converters. Explain the operation of single-phase Fully-controlled bridge converter taking source impedance into account. Derive the expression for V&in terms of overlap angle and source inductance. Draw voltage and current waveforms.	8	CO9	
	5	With the help of a neat diagram and associated wave forms, explain the operation of a single phase semi converter with RL load.	8	CO9	