

GUJARAT TECHNOLOGICAL UNIVERSITY

POWER ELECTRONICS (24) POWER ELECTRONIC CIRCUITS-I SUBJECT CODE: 2152407 B.E. 5th SEMESTER

Type of course: Engineering Science (Electronics).

Prerequisite: 2132404: Principles of Power Electronics

Rationale: This subject focuses on the study of IGBT as Power Semiconductor Device, Protection & Drive Circuits for various Power Semiconductor Devices, Power Electronics Converters (AC-DC and DC-DC) and its analysis & applications in Electrical Engineering.

Teaching and Examination Scheme:

Teaching Scheme			Credits C	Examination Marks						Total Marks
L	T	P		Theory Marks			Practical Marks			
				ESE (E)	PA (M)		ESE (V)		PA (I)	
				PA	ALA	ESE	OEP			
4	0	2	6	70	20	10	20	10	20	150

Content:

Sr. No.	Content	Total Hrs	% Weightage
1	Power Semiconductor Devices: <ul style="list-style-type: none"> • Review of Various Power Semiconductor Devices like Power Diode, Power BJT, Thyristor, MOSFET, etc. • IGBT – Symbol – Construction – Principle and Working – IV Characteristics – Physics of Operation – Latchup in IGBT – Switching Characteristics – Rating and Specifications – Applications – Gate Drive circuits • A general comparison of Power Semiconductor Devices 	6	12
2	Device Control and Protection Circuits: <ul style="list-style-type: none"> • Concept of PWM and its Generation • Requirement of Drive Circuits for Various Devices • Design of Isolated and Non-Isolated Drive Circuits for Power Devices – Circuits for Different Protections like Over Voltage, Over Current, Short Circuit, $\frac{di}{dt}$, $\frac{dv}{dt}$ and its Design, Thermal Considerations Hard and Soft Switching of Power Semiconductor Devices	6	12
3	AC-DC converters (Uncontrolled): <ul style="list-style-type: none"> • Principle of Operation – Classification – Applications 	6	12

	<ul style="list-style-type: none"> • Single Phase Uncontrolled Rectifier: Half Wave and Full wave – Analysis on Different Types of Load – Working along with Necessary Waveforms • Three Phase Uncontrolled Rectifier: Half Wave, Full wave - Analysis on Different Types of Load – Working along with Necessary Waveforms – Working Principle of 6/12/24 Pulse Rectifiers 		
4	<p>AC-DC converters (Controlled):</p> <ul style="list-style-type: none"> • Single Phase Half Wave Controlled Rectifiers with R, RL, RLE Load – Single Phase Full Wave Controlled Rectifier with R, RL, RLE Load – Half and Full Controlled Bridge Rectifiers with R & RL Load • Three Phase Half Wave and Full Wave Controlled Rectifier with R & RL Load – Three Phase Half and Full Controlled Bridge Rectifier with R & RL Load – Dual Converter • Various Triggering Circuits for 1ϕ & 3ϕ Controlled Rectifiers like Inverse Cosine Method, UJT Firing Scheme, Transistorised Firing, Using Logic Gates 	8	16
5	<p>Thyristorized Choppers:</p> <ul style="list-style-type: none"> • Chopper – Principle of Operation – Control Strategies: TRC & CLC – Classification • Step Up Choppers – Step Up/Down Choppers – First Quadrant (Type A) Chopper – Second Quadrant (Type B) Chopper – Two Quadrant (Type A or Type C) Chopper – Two Quadrant (Type B or Type D) Chopper – Four Quadrant (Type E) Chopper • Principle of Working, Operation, Analysis and Applications of Jones Chopper and Morgan Chopper • Principle of Operation and Modes of Multiphase Choppers 	6	12
6	<p>DC-DC Converters:</p> <ul style="list-style-type: none"> • Importance & Requirement of DC Power Supply – Principle – Classification based on various criteria – Performance Parameters • Non-Isolated DC-DC Converters: Buck, Boost, Buck-Boost and Cuk Converters in CCM & DCM – Their Operation – Analysis on Different Loads and Control along with Necessary Waveforms • Working Principle and Waveforms of Luo, Sepic and Zeta Converter 	6	12
7	<p>Isolated DC-DC Converters:</p> <ul style="list-style-type: none"> • Requirement and Importance of Isolation in Power Electronics Circuit – Advantages • Circuit, Working along with Waveforms, Analysis and Efficiency of: Flyback – Forward – Push Pull – Half Bridge – Full Bridge Converters 	6	12
8	<p>Resonant Converters:</p> <ul style="list-style-type: none"> • Review of Resonance – Advantages – Principle of Operation of Resonant Converters – Classification • Series and Parallel Resonant Converters • ZVS and ZCS Resonant Converters – Types (L & M) – Working Principle – Waveforms – Analysis – Comparison 	6	12

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
15	30	15	20	20	--

Legends: R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

Reference Books:

1. Power Electronics: Converters, Applications and Design by Mohan, Undeland and Robbins, Wiley India
2. Power Electronics: Circuits, Devices and Applications, Third edition by M. H. Rashid, PHI
3. Power Electronics by M.D. Singh & K B Khanchandani, TMH
4. Power Electronics by Barry Williams, CRC Press
5. Integrated Power Electronic Converters and Digital Control by Ali Emadi, CRC Press
6. Power Electronics by Philips T. Krein, Oxford
7. Power Electronics by Dr. P. S. Bhimbra, Khanna publishers
8. Power Electronics by M. S. Jamil Asghar, PHI
9. Power Electronics by P C Sen, TMH
10. Principles of Power Electronics by Kassakian, Schlecht & Verghese
11. The Essence of Power Electronics by Ross, Prentice Hall
12. Advanced DC to DC Converters by Fang Lin Luo & Hong Ye, CRC Press
13. Power Supply Cookbook by Marty Brown, Newnes
14. The Power Electronics Handbook by T L Skvarenina, CRC Press
15. Power Electronics Handbook by M H Rashid, Academic Press

After learning this course, the students should be able to:

1. Understand and compare different power semiconductor switches and be able to select appropriate power switch for different applications.
2. Understand IGBT as a power switch along with its construction, working, application and drive requirements.
3. Understand the concept of PWM and its importance.
4. Understand and be able to select, design and implement proper driving circuit for various power semiconductor switches.
5. Understand different types of controlled & uncontrolled AC-DC converters.
6. Understand different types of choppers and its applications.
7. Understand different types of DC-DC converters and its applications.

List of Experiments (Laboratory Work):

Objectives: The laboratory work is aimed at putting the theory learnt in class in practice and to show that the results are matched with theory closely. In this context, following are the core objectives for laboratory work of this subject.

- Differentiate the linear and nonlinear region of operation of various semiconductor devices

- Study and design driving circuits for various power semiconductor devices.
- Study and design protection circuits for various power semiconductor devices.
- Study the concept of PWM generation using basic methods.
- To understand the Hard and Soft switching of Power Semiconductor Devices.
- Develop the understanding of the working of different AC-DC converters.
- Develop the understanding of the working of different chopper circuits.
- Develop the understanding of the working of different DC-DC converters.

Directions for Laboratory work:

- ✓ The list of experiments is given as a sample.
- ✓ Minimum 10 experiments should be carried out.
- ✓ At least one experiment should be selected from each group.
- ✓ Similar laboratory work fulfilling the objectives can also be considered.
- ✓ Each experiment should be simulated before verifying practically.
- ✓ As far as possible, printed manual should be preferred so that students can concentrate in laboratory experiments and related study.

The sample list of experiments is given below.

Design Based (DP)/Open Ended Problems:

There are four experiment groups: A, B, C and D. Total 10 experiments from Group A, B & C should be carried out (At least two experiments from each group). Over and above 10 performance experiments, self-study work may be given to students. This includes study of datasheets, protection & driver circuits for power semiconductor switches, practical applications of different power electronics converters, etc.

Group A (IGBT):

1. To study and obtain characteristics IGBT.
2. To study and obtain switching characteristics of IGBT.
3. A general comparative study of power semiconductor devices.

Group B (Device Driver & Protection Circuits):

4. To study and design BJT driver and protection circuit.
5. To study and design MOSFET driver and protection circuit.
6. To study and design SCR driver and protection circuit.

Group C (AC-DC Converters):

7. To study different 1- ϕ uncontrolled & controlled rectifiers with R, RL & RLE load.
8. To study different uncontrolled & controlled 3- ϕ rectifiers with R, RL & RLE load.
9. To study various triggering circuits for 1- ϕ & 3- ϕ controlled rectifiers.

Group D (DC-DC Converters):

10. To study Buck, Boost, Buck-Boost, Cuk converter.
11. To study ZVS & ZCS resonant converter.
12. To study Class A/B/C/D/E, Jones & Morgans Chopper.

Major Equipment:

- GP PCB Board, Function Generator, AC & DC Power Supply, Oscilloscope, Power Electronics Trainer Kits, Multimeter, Various Kits for Experimental Setup, etc.

- Consumable Items: Various Power Semiconductor Switches, Various Control ICs, Various Ferrite Cores, Copper Wires for Inductors & Transformers, Soldering Iron, Desoldering Pump, Electronics Toolkit, etc.

List of Open Source Software/learning website:

Open Source Software:

- TINA-TI for circuit simulation (<http://www.ti.com/tool/tina-ti>)
- OSCAD for CAD application (<http://www.oscad.in/downloads>)
- Multisim for circuit simulation (<http://www.ni.com/multisim>)
- <http://sourceforge.net/projects/ktechlab/>
- <http://www.cburch.com/logisim/>

Web-based tools for design:

- www.st.com
- www.nxp.com
- www.irf.com
- www.infineon.com
- www.ti.com
- www.vishay.com
- www.linear.com
- <http://india.ni.com>
- <http://www.cosmoferrites.com>
- <http://www.tdk.com>
- <http://en.tdk.eu>
- <http://www.tdk.com/design-tools.php>
- <http://www.smeps.us/smepsdesign.html>
- <http://www.powersim.com>
- www.snubberdesign.com
- <https://www.circuitlab.com/editor>

Open source for Math Tools:

- <http://maxima.sourceforge.net>
- www.scilab.org
- www.sagemath.org
- www.gnu.org/software/octave/

Learning website:

- <http://www.datasheetcatalog.com>
- <http://nptel.iitm.ac.in/courses.php>
- <http://ocw.mit.edu>
- <http://www.smpstech.com>
- <http://www.ni.com/white-paper/14676/en/>
- http://www.irf.com/product/_/N~1nje1m
- http://www.allaboutcircuits.com/vol_3/chpt_3/4.html

- <http://www.deltapowersolutions.com/en/tps/rectifiers.php>
- <http://www.electrical-engineering-portal.com>

ACTIVE LEARNING ASSIGNMENTS: Preparation of power-point slides, which include videos, animations, pictures, graphics for better understanding theory and practical work – The faculty will allocate chapters/ parts of chapters to groups of students so that the entire syllabus to be covered. The power-point slides should be put up on the web-site of the College/ Institute, along with the names of the students of the group, the name of the faculty, Department and College on the first slide. The best three works should submit to GTU.