GUJARAT TECHNOLOGICAL UNIVERSITY

Bachelor of Engineering
Subject Code: 3142409
Semester – IV
Subject Name: BASIC POWER ELECTRONICS DEVICES, CIRCUITS AND APPLICATIONS

Type of course:

Prerequisite: Basic Electronics, Circuit Theory, Elements of Electrical Engineering

Rationale: The aim of this subject is to introduce the basic theory of power semiconductor devices and their practical applications in power electronics. This course will provide strong foundation for further study of power electronic circuits and systems.

Teaching and Examination Scheme:

Teaching Scheme			Credits	Examination Marks				Total Marks
				Theory Marks		Practical Marks		
L	T	P	C	ESE (E)	PA (M)	ESE (V)	PA (I)	
3	1	2	5	70	30	30	20	150

Content:

Sr. No.	Content	Total Hrs
1	**Power Electronics – An Introduction:** Electrical Energy: Characteristics and Storage – Need for Energy Conversion and Power Processing Power Electronics: Need and Role in Energy Conversion – History – Power Electronics System – Its Building Blocks and Components – Linear Electronics versus Power Electronics – Interdisciplinary Nature of Power Electronics – Power Electronics Applications Power Electronics Switch – Ideal and Practical Switch Characteristics – Losses in Practical Switch – Concept of Safe Operating Area (SOA) – Specifications – Semiconductor Materials Used – Classification and Comparison of Power Switches Pulse Width Modulation – Principle and Concept – Duty Cycle – Digital Nature of PWM and Control of Power Devices by PWM	6

2	**Uncontrolled Devices:** **Power Semiconductor Diodes:** Basic Structure – VI Characteristics-Switching Characteristics – Specifications & Ratings – Reverse Recovery Characteristics – Classification – Application of Power Diodes Construction, Characteristics and Applications of Various Diodes like General Purpose Diode – Schottky Diode – Fast Recovery Diode – Zener Diode – Comparison Between General Power Diode and Power Diode – Switching Characteristics of Diode – Series and Parallel Operation of Diode.	6
3	**Semi Controlled Devices:** **Thyristors:** Introduction – VI Characteristics – Construction – The Two Transistor Model – Turn ON Methods – Switching Characteristics – Gate Characteristics – SOA – Ratings – Protection – Series and Parallel Operation – Gate Drive Circuits-Types – Construction, Characteristics and Applications of Various Types of Thyristors Like SCR, DIAC, TRIAC, LASCR, RCT, MCT, SITH, GTO, PUT, IGCT, etc. Thyristor Commutation – Requirement of Commutation – Types: Class A, Class B, Class C, Class D, Class E & Class F.	6
4	**Fully Controlled Devices:** **Power Bipolar Junction Transistors:** Construction: Vertical Power Transistor Structure – Physics of Operation – VI Characteristics – Switching Characteristics – Breakdown in Transistors (Primary and Secondary) – Difference Between Signal and Power BJT – Losses – SOA – Ratings – Specifications – Basic Driving Circuits – Soft and Hard Switching of Transistor – Protection Circuits – Driver Circuits – Applications like Power Darlington, Power Supplies, Power Switch, etc. – Series and Parallel Operation of Power BJT **Power FETs:** Field Effect Transistor – Principle – The Field Effect – Construction and Operation – VI Characteristics – Gate Control – Applications – Ratings – Specifications Power MOSFET – Types – Construction – Difference – Equivalent Circuit – VI Characteristics – Physics of Operation – Gate Control – Field Effect – Switching Characteristics – Limitations – Losses – SOA – Ratings and Specifications – Protection –	12

	Gate Drive Circuits – Applications – Parallel Operation of MOSFETs – Comparison between Power MOSFET and Power BJT Introduction to WBG (SiC/GaN) MOSFETs and its Comparison with Si MOSFETs – Advantages – Drawbacks – Applications **IGBT:** Basic Structure – Operation – VI Characteristics – Switching Characteristics – Gate Drive requirement – SOA – Gate Driver Circuit – IGBT Protection – Ratings and Application – Series and Parallel Operation	
5	**Basic Power Electronics Circuits:** Introduction to Power Electronics Converters – Classification – Basic Principle of Operation – AC-DC Converters (Rectifiers) – DC-DC Converters – DC-AC Converters (Inverters) – AC-AC Converters – Applications	4
6	**Protection of Power Devices and Circuits:** Protection of Semiconductor Power Switches – Basics of Thermal Requirements and Protection (dv/dt and di/dt Protection – Snubber Circuits – OV and OC Protections) – Concept of EMI (With Reference to False Triggering of Power Switches) – EMI Shielding	6

Suggested Specification table with Marks (Theory): (For BE only)

Distribution of Theory Marks					
R Level	U Level	A Level	N Level	E Level	C Level
30	**35**	**20**	**10**	**5**	**0**

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: Essentials and Applications by L. Umanand, Wiley India.

3	Power Electronics: Circuits, Devices and Applications, Third edition by M. H. Rashid, PHI.
4	Power Electronics by Dr. P. S. Bhimbra, Khanna Publishers.
5	Power Electronics by Philips T. Krein, Oxford.
6	Power Electronics by M. S. Jamil Asghar, PHI.
7	Datasheets and application notes of various semiconductor manufacturers.

Course Outcomes:

At the end of the course, student should be able to:

Sr. No.	CO statement	Topics Mapped	Marks % weightage
CO-01	Obtain characteristics of power devices through simulation and experiment.	1, 2, 3, 4	30%
CO-02	Demonstrate the required essential protection design for power switch.	2, 3, 4, 6	30%
CO-03	Design primarily the device and circuit selection for given application.	2, 3, 4, 5	15%
CO-04	Integrate the basic blocks required for power electronic circuits and applications.	1, 5	25%

Suggested List of Experiments:

1	To simulate and study ideal switch characteristics.
2	To simulate and verify static and dynamic characteristics of various switch.
3	To study Pulse Width Modulation (PWM)
4	To study and obtain characteristics of Diode and Power Diode.
5	To study and obtain switching characteristics of BJT / Power BJT.
6	To study and obtain characteristics of Power Zener diode.
7	To study and obtain switching characteristics of Power MOSFET.
8	To study and obtain characteristics of SCR.

9	To study and obtain characteristics of TRIAC.
10	To study Thyristor commutation techniques: Class A, B, C, D, E & F.
11	To study base drive circuits for Power BJT.
12	To study base drive circuits for power MOSFET / SiC MOSFET.
13	To study gate drive circuits for SCR and TRIAC.
14	To simulate and verify the operating principle of basic power electronics converters.
15	To study and simulate snubber circuits.

Major Equipment:

Oscilloscope, Isolated Channel Power Scope, Power Devices Trainer Kits, Multi-meters, Variable Power Supply, 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)
- Fritzing for bread board/GP board wiring planning (http://fritzing.org/download)

Web-based tools for design:
- http://www.fairchildsemi.com/support/design-tools/power-supply-webdesigner/
- http://www.ti.com/lsds/ti/analog/webench/overview.page
- https://www.circuitlab.com/editor/

Learning website:
- http://www.datasheetcatalog.com/
- http://nptel.iitm.ac.in/courses.php
- http://ocw.mit.edu/
- http://www.electrical-engineering-portal.com
- https://swayam.gov.in/