GUJARAT TECHNOLOGICAL UNIVERSITY

Program Name: Bachelor of Engineering
Level: UG
Branch: Power Electronics
Subject Code: BE05024041
Subject Name: Power Electronics Design

w.e.f. Academic Year:	2024-25
Semester:	5
Category of the Course:	Professional Elective Course - 1

Prerequisite:	Power Electronics Devices, Circuits and Applications
Rationale:	The course Power Electronics Design equips students with practical design-oriented knowledge required to develop efficient and reliable power electronic systems. It covers the selection and operation of modern power semiconductor devices, including Si, SiC, and GaN, along with a detailed analysis of switching behaviour and losses. The course emphasizes gate driver design, passive component selection, and converter topology design, enabling students to translate theoretical concepts into real-world hardware solutions. It also introduces control techniques, sensing methods, and protection mechanisms essential for stable and safe system operation. Further, the course addresses thermal management, PCB layout practices, and EMI considerations, which are critical for high-performance and industry-compliant designs. Overall, the course prepares students for applications in renewable energy systems, electric vehicles, and industrial power supplies.

Course Outcomes:

Sr.No.	CO statement	Marks% weightage
CO-1	Analyze power semiconductor devices and their selection based on loss and thermal limits.	10
CO-2	Design gate driver circuits considering switching behavior, isolation, and protection.	20
CO-3	Design passive components including capacitors, inductors, and magnetic elements.	15
CO-4	Analyze AC–DC and DC–DC converters based on operation, stress, and efficiency.	20
CO-5	Apply control, PWM, sensing, and protection techniques for stable converter operation.	20
CO-6	Evaluate thermal performance, PCB layout, EMI, and safety aspects in power electronic systems.	15

Teaching and Examination Scheme:

Teaching / Learning Scheme (in Hours per semester)					Total Credits	Assessment Pattern and Marks					Total Marks
						Theory		Tutorial / Practical			
L	T	P	PBL *	Total no of hours per semester		ESE (E)	PA / CA (M)	PA/ CA (I)	PBL (I)	ESE (V)	
45	0	30	15	90	3	70	30	20	30	50	200

**** Problem-Based Learning (PBL) aims to accommodate learning beyond the syllabus as per clause 9.4 of NBA manual.***

Where L = Lecture, T= Tutorial, P= Practical, TW/SL = Term-Work / Self-Learning, TH = Total Hours, ESE = EndSemester Examination, PA = Progressive Assessment.

Content:

Sr.No	Content	Total Hrs
1	**Power Semiconductor Devices & Selection:** Power diodes, MOSFETs, IGBTs: characteristics, switching behavior, Wide bandgap devices (Si, SiC, GaN): comparison & applications Loss mechanisms: conduction, switching, reverse recovery Safe Operating Area (SOA), thermal limits Switching transients: dv/dt, di/dt, ringing basics Device selection based on rating, efficiency, switching frequency	6
2	**Gate Driver Design:** Gate charge, capacitances, Miller plateau, Switching waveforms & dynamic behavior Driver topologies: low-side, high-side, bootstrap, Isolation: optocoupler, transformer, digital isolators, Selection of Gate resistance, Dead-time, Bootstrap capacitor, Gate driver protection (UVLO, desaturation concept—introduction)	6
3	**Passive Components & Energy Storage:** Capacitors: DC-link, ESR, ripple current, lifetime Inductors & transformers: basics, core materials, Inductor sizing & saturation limits, Core losses (conceptual: hysteresis + eddy currents), Winding effects (skin & proximity—intro level), Snubbers & clamp circuits	6
4	**AC–DC Conversion & Input Stage:** Single-phase and three phase rectifiers with and without filter, Ripple, DC output estimation, Input current waveform & harmonics, Power factor basics, EMI basics, EMI sources (conducted & radiated),EMI filters (CM/DM basics), Inrush current limiting, Component selection	6
5	**DC- DC Power Converter Topologies and Design:** Design of Non-Isolated Converterslike Buck, Boost, Buck–Boost inCCM and DCM modes. Concept and Design steps of Isolated Converters like Flyback and Forward converters, Half-Bridge and Full-Bridge DC- DC converters. Concept of Soft-Switching -ZVS, ZCS. Selection of topology considering Power level, Isolation requirement, Stress analysis on switches and diodes, Efficiency considerations and trade-offs in converter design	8
6	**Control, Sensing & Protection:** Control Techniques, Voltage mode control, Current mode control, PWM generation, Duty cycle control, Compensation, Need for compensators, Type I, II, III compensators, Stability basics (gain/phase margin) Sensing Methods- Current sensing: shunt, Hall-effect, Voltage sensing circuits Protection TechniquesOver-current protection (OCP), Over-voltage protection (OVP), Thermal shutdown Concept of small-signal modeling and control-to-output transfer function	9
7	**Thermal, PCB & System-Level Concepts:** Thermal Design Concepts: Thermal resistance network, Junction-to-ambient modelling, Heat sink selection, PCB Design: Layout for power loops, Gate drive loop minimization, Parasitics and their effects, overshoot & EMI linkage Safety & Standards: Creepage and clearance distances, Isolation requirements, Relevant standards (IEC basics)	4
	TOTAL	**45**

Suggested Specification table with Marks (Theory):(ForB.E.only)

Distribution ofTheoryMarks					
RLevel	ULevel	ALevel	NLevel	ELevel	CLevel
10	20	20	15	10	25

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 the above table.

The *Power Electronics Design* syllabus demonstrates strong alignment with the UN's SDGs, directly contributing to SDGs 4, 7, 9, and 12 through its focus on advanced design, efficient energy conversion, and sustainable engineering practices. It further indirectly supports SDGs 8, 11, and 13 by enabling the development of high-efficiency, reliable, and environmentally responsible power electronic systems essential for modern infrastructure and low-carbon technologies.

SDG 4	Quality Education – direct alignment The syllabus develops core competencies in power electronics design, including devices, converters, control, and system-level considerations. It integrates analytical and practical skills (EMI, PCB, thermal), preparing students for modern engineering challenges.
SDG 7	Affordable & Clean Energy – direct alignment Topics such as AC–DC conversion, DC–DC converters, and efficiency optimization directly contribute to energy-efficient power conversion systems.Use of wide bandgap devices (SiC, GaN) supports high-efficiency and renewable energy applications like solar inverters and EV chargers.
SDG 8	Decent Work and Economic Growth The course equips students with industry-relevant skills in power electronics design, widely used in sectors like automotive, energy, and consumer electronics. It enhances employability and supports innovation-driven economic growth.
SDG 9	Industry, Innovation & Infrastructure -direct alignment Converter design, control techniques, and system-level integration form the backbone of modern industrial systems and power infrastructure. The syllabus promotes innovation in efficient power supplies, electric mobility, and smart energy systems.
SDG 11	Sustainable Cities & Communities -indirect alignment Efficient power conversion and EMI-aware design contribute to reliable energy systems used in smart grids, EV charging, and urban infrastructure. Reduced electromagnetic interference improves system compatibility in dense urban environments.
SDG12	Responsible Consumption & Production -direct alignment Emphasis on efficiency, loss reduction, and thermal management leads to optimized energy usage and reduced resource wastage. Design considerations such as component selection and lifetime estimation promote sustainable engineering practices.
SDG 13	Climate Action -indirect alignment Energy-efficient converters and reduced power losses directly lower carbon emissions in electrical systems. Applications in renewable energy integration and efficient power supplies support climate mitigation efforts.

Reference Books:

1. Muhammad H. Rashid, Power Electronics: Circuits, Devices and Applications, Pearson Education, New Delhi
2. Ned Mohan, Tore M. Undeland and William P. Robbins, Power Electronics: Converters, Applications and Design, John Wiley & Sons, Inc., New York
3. L Umanand, Power Electronics, Essentials & Applications, Wiley India
4. B. K. Bose, *Power Electronics and Motor Drives: Advances and Trends*, Academic Press (an imprint of Elsevier), Waltham, MA.
5. P. S. Bhimra, *Power Electronics*, Khanna Publishers
6. Philips T. Krein,Power Electronics, Oxford.
7. R. W. Erickson and D. Maksimović,*Fundamentals of Power Electronics*, Springer
8. B. K. Bose,*Modern Power Electronics and AC Drives*, Pearson.
9. Abraham I. Pressman and Keith Billings, *Switching Power Supply Design*, McGraw-Hill
10. Fang Lin Luo & Hong Ye,*Advanced DC to DC Converters*, CRC Press
11. M. S. Jamil Asghar,*Power Electronics*, PHI.
12. Research Papers on IEEE/IET/Science Direct etc.

List of Experiments:

1. Study of MOSFET/IGBT Switching Characteristics
    a. Plot V–I characteristics and switching waveforms
    b. Estimate turn-on/turn-off times
2. Study of Loss Estimation of Power Devices (Simulation)
    a. Calculate conduction and switching losses
    b. Compare Si vs SiC device performance
3. Design and Testing of Low-Side Gate Driver Circuit
    a. Gate resistor effect on switching speed
    b. Observe Miller plateau
4. Bootstrap-Based High-Side Driver Implementation (Simulation/Hardware)
    a. Study dead-time and shoot-through prevention
5. DC-Link Capacitor Ripple Current Analysis
    a. Measure ripple voltage and ESR effect
6. Inductor Design for DC-DC Converter
    a. Calculate inductance and verify ripple current
7. Snubber Circuit Design and Testing
    a. Compare waveforms with and without snubber
8. Single-Phase Bridge Rectifier with Filter
    a. Measure ripple and DC output
    b. Compare with theoretical values
9. Power Factor and Harmonic Analysis (Simulation)
    a. Observe input current distortion
    b. Study effect of filtering
10. Buck Converter Design and Implementation
    a. Verify duty cycle vs output voltage
11. Boost Converter Operation in CCM/DCM
    a. Observe mode transition
12. Flyback Converter (Simulation)

a. Study isolation and energy transfer

13. Efficiency Measurement of DC-DC Converter
    a. Evaluate losses and efficiency
14. Mini Project work:
    a. Design of a DC Power Supply for given specifications
    b. Design Optimization for Efficiency Improvement

Major Equipment:

1. Power Electronics Trainer Kits (Chopper trainer kits, DC–DC Converter, AC-DC Converter Trainer kits)
2. Isolated DC–DC Converter Trainer (Flyback / Forward / Push–Pull)
3. Digital Storage Oscilloscope (DSO) – with isolation probes
4. MATLAB/Simulink Software with Simscape Electrical Toolbox

List of Open-Source Software:

1. Scilab (https://www.scilab.org/) – An open-source alternative to MATLAB
2. PSIM (Free Version) / OpenModelica (https://openmodelica.org/) – For modelling and simulating power electronics circuits

List of learning websites:

1. MIT Open Course Ware (https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/)
2. CircuitLab (Free with limited access) (https://www.circuitlab.com/) – Web-based circuit simulator
3. Virtual Labs by IITs (Government of India Initiative) (https://vlab.co.in/) – Simulations and experiments related to Power electronics.
4. Reputed Research Journal Website

List of suggested activities for Problem-based Learning (PBL):

Sr. No.	PBL Category	Name of the activity	No. of hours	Evaluation Criteria
1	Industry / Research Laboratory Visit	Industry/Research laboratory Visit	Visit = 5hrs, Report preparation = 5hrs Total = 10hrs	Based on the report submitted. Report should contain observations and calculations based on industry/ lab data.
2	Video Based Learning	Technical Video-based learning related to the subject (MOOC/NPTEL Video)	Duration of video = 5hrs Report preparation = 5hrs Total = 10hrs	Report /presentation based on the video learning outcomes.
		Self-learning online course	Minimum duration of the course should be 10 hours.	Examination-based assessment at the end of course. Based on the certificate produced.
		Annotated Video Explanation of Concept/Problem	10hrs (Preparation + Recording + Submission)	Based on the accuracy of explanation, clarity, and presentation style.
3	Assignment/	Assignment writing.	5 assignments of	Based on the assignment

Sr. No.	PBL Category	Name of the activity	No. of hours	Evaluation Criteria
	Technical Writing / Research Writing	Numerical-based assignment is preferable.	2hrs each. Total = 10hrs	submitted.
		Blog or Technical Article Writing	10hrs (Research – 6hrs, Writing – 4hrs)	Based on originality, technical content, references cited, and clarity of communication.
4	Complex Problem-Solving targeting relevant SDGs. / Mini Project	Complex problem solving	Maximum 2 problem. Study of the problem and solution finding, Total = 15 hrs	Based on the depth of the solution submitted.
5	Research Paper Review / Analysis	Discussion on a research paper based on a relevant subject (SCOPUS Index/any reputed Journal)	5 research paper = 20 hrs	Summarize research paper and evaluation of critical parameters
6	Poster/ Chart/ Power point presentation	Poster/chart/power point preparation on technical topics	Duration = 6 hrs	Based on poster/chart preparation and presentation skills
7	Micro Project	Working/non-working model on technical topics	Working = 10hrsnon-working = 10hrs	Based on inter-department/external evaluation
8	Group Discussion / Quiz / Simulation	Group Discussion on emerging/trending technical topics based on the subject	Duration = 1 hrs each	Based on performance in group discussion, technical depth,knowledge etc.
		Online Technical Quizzes/Simulations	Multiple quizzes summing up to 10 hours	Based on quiz scores and the reflection report after each quiz.
9	Case Study Analysis / Seminar	Real-world case studies-based learning	Duration of data collection/study = 5hrs Report preparation = 5hrs Total = 10hrs	Based on in-depth study, technical depth, data collected, fact finding, etc.
10	Other	Patent Search and Innovation Gap Identification	10hrs (Search + Report)	Based on number of relevant patents analyzed and identification of innovation scope.

Note:

1. In alignment with Outcome-Based Education (OBE) and NBA accreditation requirements, the subject **Power Electronics Design incorporates**;
   - Mini Project – 10 Marks
   - Micro Project – 5 Marks

These activities are incorporated as integral Project-Based Learning (PBL) components. These activities are designed to foster experiential learning, encourage innovation, and strengthen problem-

solving skills by engaging students in practical applications of power converter design, simulation, and analysis. The inclusion of PBL ensures that learners develop higher-order cognitive abilities mapped to Bloom's taxonomy, while simultaneously enhancing teamwork, communication, and research competencies essential for professional engineering practice.

2. The hours allocated to specific activities should be proportionate to the total no. of PBL hours and marks.

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