

Identification	Subject	Power Electronics 8 ECTS credits
	Department	Physics and Electronics Department
	Program (Graduate)	Graduate
	Term	Fall 2026
	Instructor	Dr. Gulnaz Gahramanova
	Email:	g.gahramanova@ufaz.az
	Classroom/hours	15 Weeks, 4 contact hours per week (40 h Lecture + 20 h Lab/Practical)
Prerequisites	None	
Language	English	
Compulsory/Elective	Compulsory / Core Elective	
Textbooks and course materials	1. Daniel W. Hart, Power Electronics, McGraw-Hill Education, 2011. 2. Timothy L. Skvarenina, The Power Electronics Handbook, CRC Press, 2001. 3. Muhammad H. Rashid, Power Electronics Handbook, Academic Press, 2001 4. Robert W. Erickson and Dragan Maksimovic, Fundamentals of Power Electronics, 3rd ed., Springer, 2020. Software Tools: SIMetrix, NI Multisim or LTspice	
Course description	This graduate-level course provides an in-depth treatment of solid-state power conversion, high-frequency magnetics design, power semiconductor dynamics, dynamic modeling, and closed-loop feedback control. It covers modern energy conversion architectures including AC–DC rectifiers, non-isolated and isolated DC–DC converters, DC–AC inverters, and AC–AC controllers. Advanced topics active power factor correction (PFC), thermal management, and power electronics applications in renewable energy systems, electric vehicles (EVs), and smart grids. Hands-on laboratory experiments on hardware setups are complemented by computer simulations using SIMetrix and NI Multisim .	
Course objectives	• Master the operational mechanics and loss mechanisms of power semiconductor switches and protection circuits. • Analyze, design, and evaluate non-isolated and isolated DC–DC, AC–DC, DC–AC, and AC–AC switching converters. • Execute high-frequency magnetic component design (inductors and transformers) using the Area-Product (\$A_p\$) approach. • Formulate small-signal state-space average models to design closed-loop control loops (PID, Current-Mode Control). • Utilize simulation software (SIMetrix and Multisim) alongside real hardware test setups for circuit design and waveform verification.	
Learning Outcomes	In this course, students synthesize and design switch-mode DC–DC converters and isolated topologies under both Continuous and Discontinuous Conduction Modes (CCM/DCM). They learn to design high-frequency magnetic components based on core saturation limits, power loss density, and geometric constraints, while implementing advanced modulation techniques such as Sinusoidal PWM (SPWM) and	

	Space Vector PWM (SVPWM) for single-phase and three-phase inverters. Furthermore, students model and control closed-loop feedback systems for power converters utilizing Bode stability margins and both digital and analog controllers, ultimately simulating and benchmarking power electronic circuits in SIMetrix and Multisim to rigorously validate experimental hardware measurements.		
Teaching methods	Lecture & Group discussion		x
	Laboratory		x
Evaluation Criteria	Methods	Date/deadlines	Percentage (%)
	Midterm Exam	TBA	30
	Practical Assignments	At each laboratory session	20
	Design Project and Presentation.	During the semester	10
	Final Exam	TBA	40
	Total		100
Class Policy	Preparation for class The pedagogical structure of this course necessitates diligent individual study and external preparation. Course sessions are designed to emphasize the primary theoretical frameworks introduced in the text. Pre-class engagement with assigned chapters is essential to facilitate a comprehensive understanding of the material. Subsequent to each session, students should synthesize their notes and resolve pertinent problems, case studies, and sample examination questions located at the conclusion of each chapter. Withdrawal (pass/fail) This course strictly adheres to the grading ordinances of the School of Science and Engineering. Consequently, students are required to achieve a minimum threshold of 60% to secure a passing grade. In the event of an unsatisfactory result, the student will be mandated to repeat the course in the following academic term or year. Cheating/plagiarism Any instance of academic dishonesty or plagiarism during Quizzes, Midterms, or Final Examinations will result in the immediate nullification of the assessment. In such cases, the student will automatically be assigned a score of zero (0) without further consideration. Generative AI Policy (Partial Permission - Khazar University Rules, Art. 10.1.2): Generative AI tools (e.g., ChatGPT, Gemini) may be used strictly for language editing, proofreading, and simulation scripting syntax checks. AI-generated text must not exceed 25% of any written submission. The use of GAI during exams and quizzes is strictly prohibited. Full disclosure statements are required for any permitted GAI use. Practical Assignments. Assessment is conducted continuously during each laboratory session based on student participation, experimental execution, data analysis/results, oral questioning, and final discussion. Design Project and Presentation. Prepare one project work on the topics given by the teacher or chosen by students during the semester (with prototype and oral presentation). Individual or group project assigned by the instructor or selected by the student during the semester. Requires practical results		

		(prototype, experimental setup, or functional model) and a final oral presentation (once per semester)	
Tentative Schedule			
Week	Date/Day (tentative)	Topics	Textbook/Assignments
1	21.09.2026	Introduction to Power Electronic Systems & Switching Fundamentals of power conversion across alternating and direct current stages. Power electronics vs. linear/conventional electronics and the necessity of switching conversion. Ideal vs. practical switches with efficiency trade-offs and power density limits. Switching frequency selection in relation to passive component miniaturization and thermal management strategies.	[1] Chapter 1 p. 1–20 [2] Chapter 1 p. 18–25 [3] Chapter 1 p. 17–28 [4] Chapter 1 p. 1–11
2	28.09.2026	AC–DC Conversion (Single-Phase and Three-Phase Rectifiers) Single-phase rectifiers covering half-wave, full-wave, and bridge topologies under resistive, inductive, and capacitive filtering conditions. Three-phase rectifiers featuring three-phase diode bridge operation, average output voltage characteristics, ripple frequency evaluation, and comparative performance against single-phase systems. Rectifier performance metrics including output ripple, voltage stress, harmonic distortion, and input power factor.	[1] chapter 3–4 p. 65–170 [2] chapter 4 p. 152–192 [3] chapter 10 p. 148–183 [4] chapter 20 p. 849–865
3	05.10.2026	LAB 1 — Single-Phase Diode Rectifier Analysis & Characterization Pre-lab theoretical calculations for output voltage, current ratings, and filter capacitor sizing under nominal alternating current input. Hardware assembly of bridge rectifiers to measure terminal voltages, observe diode switching waveforms, and quantify output ripple. Simulation modeling to compare analytical calculations, simulated performance, and experimental hardware measurements.	[1] chapter 3–4 p. 65–170 [2] chapter 4 p. 152–192 [3] chapter 10 p. 148–183 [4] chapter 20 p. 849–865
4	12.10.2026	Power Semiconductor Devices (Diodes, Thyristors, MOSFETs, IGBTs & WBG) Diodes and thyristors, including static and dynamic current-voltage behavior, reverse recovery dynamics,	[1] Chapter 1 p. 5–20 [2] Chapter 1 p. 25–105 [3] Chapter 2–7 p. 29–127 [4] Chapter 4 p. 67–133

		silicon-controlled rectifier operation, triggering, and commutation. Transistor technologies covering power MOSFET and IGBT structures, operational regions, and comparative features. Wide-bandgap semiconductor technology with focus on silicon carbide and gallium nitride devices. Loss modeling covering conduction loss, dynamic switching loss calculations, and semiconductor device selection criteria.	
5	19.10.2026	Non-Isolated DC–DC Converters (Choppers) & PWM Control Fundamental energy transfer principles based on volt-second and ampere-second balance conditions. Core non-isolated converter topologies including Buck, Boost, and Buck-Boost circuits. Transition boundaries between continuous conduction mode and discontinuous conduction mode. Analysis of inductor current ripple, output capacitor voltage ripple, critical inductance thresholds, and pulse-width modulation duty cycle regulation.	[1] chapter 6 p. 196–264 [2] chapter 2 p. 118–147 [3] chapter 13 p. 220–233 [4] chapter 2, 6 p. 15–41, 163–211
6	26.10.2026	LAB 2 — Closed-Loop Hardware Build: Buck Converter Pre-lab design task for step-down DC-DC conversion specifying component sizing and current parameters. Practical hardware implementation involving power MOSFET, diode, inductor, capacitor bank, load, and gate drive control circuitry. Waveform acquisition and performance evaluation by monitoring switching node behavior, inductor ripple, conversion efficiency, and practical system losses.	[1] chapter 6 p. 196–264 [2] chapter 2 p. 118–147 [3] chapter 13 p. 220–233 [4] chapter 2, 6, 9 p. 15–41, 163–211, 347–405
7	02.11.2026	Isolated DC–DC Converters & High-Frequency Magnetics Design Galvanic isolation requirements and the functional role of high-frequency transformers in modern power conversion. Isolated converter topologies including Flyback, Forward, Push-Pull, Half-Bridge, and Full-Bridge configurations. Advanced magnetic design considerations using area-product and core-geometry	[1] chapter 7 p. 265–330 [2] chapter 22 p. 595–602 [3] chapter 13 p. 220–233 [4] chapter 10–12 p. 409–505

		methods, permeance, core saturation limits, power loss density, skin and proximity effects, and Litz wire selection.	
8	09.11.2026	Single-Phase & Three-Phase DC–AC Inverters & Modulation Techniques Single-phase and Three-phase Voltage Source Inverters (VSI) utilizing half-bridge and full-bridge topologies under 180-degree and 120-degree conduction modes. Operational principles of square-wave modulation, Sinusoidal Pulse-Width Modulation (SPWM), Unipolar/Bipolar switching, and Space Vector PWM (SVPWM). Detailed evaluation of modulation index, carrier frequency ratio, harmonic elimination, and Total Harmonic Distortion (THD) filtering.	[1] chapter 8 p. 331–386 [2] chapter 5, 7 p. 193–281, 305–339 [3] chapter 14 p. 234–278 [4] chapter 6 p. 163–211
9	16.11.2026	LAB 3 — Single-Phase & Three-Phase Inverter Analysis & Modulation Pre-lab theoretical calculations for output AC voltage, modulation index, and LC filter sizing under DC input. Hardware assembly or simulation of single-phase and three-phase Voltage Source Inverters (VSI) using SPWM and SVPWM modulation techniques. Waveform acquisition and performance evaluation by monitoring AC output harmonics, Total Harmonic Distortion (THD), filter effectiveness, and switching losses.	[1] chapter 8 p. 331–386 [2] chapter 5, 7 p. 193–281, 305–339 [3] chapter 14 p. 234–278 [4] chapter 6 p. 163–211
	TBA	Midterm exam	
10	23.11.2026	Open-Loop / Closed-Loop Control & Thermal Management Small-signal modeling of converters using state-space averaging, control-to-output transfer functions, voltage-mode vs. current-mode control, slope compensation, and PID controller design. Thermal management networks, junction-to-ambient thermal resistance modeling, conduction and switching loss calculations, heatsink design, and thermal modeling.	[1] chapter 10 p. 431–460 [2] chapter 8 p. 340–362 [3] chapter 19 p. 437–492 [4] chapter 7–9 p. 215–405

11	30.11.2026	AC-AC Conversion & Power Factor Correction (PFC) AC Voltage Controllers: Single-phase and three-phase phase-angle control, cycloconverters, and matrix converters. Passive vs. Active Power Factor Correction. Boost PFC converter: Average current mode control, continuous vs. critical conduction mode (CRM/CCM). Active power filters (Shunt and Series APF) for harmonic suppression.	[1] chapter 5 p. 171–195 [2] chapter 3 p. 148–151 [3] chapter 16, 33 p. 314–330, 826–848 [4] chapter 20–21 p. 849–930
12	07.12.2026	LAB 4— Inverter Modulation, SPWM/SVPWM & Harmonic Testing Pre-lab calculation of switching sequences, modulation indices, and pulse-width modulation timing for single-phase and three-phase inverters. Hardware and simulation setup connecting a direct current supply to an inverter stage powering balanced R-L loads. Waveform verification analyzing phase voltages, line currents, switching losses, and harmonic spectrum alignment in Multisim/hardware.	[1] chapter 8 p. 331–386 [2] chapter 5, 7 p. 193–281, 305–339 [3] chapter 14 p. 234–278 [4] chapter 6, 20 p. 163–211, 849–865
13	14.12.2026	Power Electronics for Electric Vehicles (EVs) and Renewable Energy Systems Electric vehicle drivetrain architectures tracing energy flow from energy storage through bidirectional conversion to traction drives. Auxiliary converter modules including on-board chargers, low-voltage supplies, and fast direct current charging interfaces. Motor drive control principles across permanent magnet and induction motor configurations. Regenerative braking power flow and vehicle-to-grid integration concepts. Laboratory module analyzing PWM synthesis, torque-speed response, and regenerative power flow. Solar photovoltaic conversion stages covering current-voltage characteristics, maximum power point tracking principles, boost stages, and grid-tied inverters. Wind energy conversion chains involving variable-speed generation, rectification, intermediate direct current links, and grid-interface inverters. Energy storage interfacing utilizing battery banks, supercapacitors, and bidirectional power flow controllers.	[2] chapter 21 p. 583–594 [3] chapter 31 p. 788–813 [2] chapter 18 p. 533–542 [3] chapter 23 p. 544–570

14	21.12.2026	Power Electronics for Electrical Grids & Smart Grid Integration&Lab5 Grid synchronization techniques using phase-locked loops, active and reactive power flow management, and power factor regulation. Grid support capabilities including voltage stabilization, frequency response, and active harmonic mitigation. Advanced grid-connected concepts covering grid-following vs. grid-forming control, static synchronous compensators, high-voltage direct current transmission, and flexible alternating current transmission systems. Graduate-level analysis on the operational impacts of inverter-based resources on power grid rotational inertia	[2] chapter 17, 19–20 p. 470–581 [3] chapter 32 p. 814–825
15	28.12.2026	Project Presentations & Course Finalization Presentation of final student design projects covering high-efficiency converter modeling, control system validation, and thermal design. Comprehensive course review and final examination preparation.	Student-led research; Independent literature review by students
	TBA	Final exam	

