Monday, 10 February 2025

Design of Power Electronics Converters

Design of Power Electronics Converters - Course Syllabus

- Prof. Sergio Vidal Garcia Oliveira, Dr.
- Power Electronics Researcher
- www.linkedin.com/in/sergio-vidal-garcia-oliveira
- https://orcid.org/0000-0002-2862-3870
- e-mail: sergio_vidal@ieee.org

- Total Hours: 72 lectures (50 minutes/each)
- Course Level: Advanced Undergraduate
- Room: Sala 6-I-SD
- Prerequisites:
  - Basic Circuit Analysis
  - Power Electronics Fundamentals
  - Control Systems

- Course Objectives
  - This course provides students with a solid foundation in the design, analysis, and simulation of Switched-Mode Power Supplies (SMPS). By the end of the course, students will:
    - Understand the principles and operation of SMPS topologies.
    - Develop mathematical models for static and dynamic analysis.
    - Learn to design magnetic components and implement proper control strategies.
    - Perform simulations using **LTSPICE, PSIM, or PLECS** (student's choice).
    - Apply their knowledge to real-world applications in power electronics.

- Course Outline
  - The course is divided into four main modules, integrating theory, simulation, and hands-on projects.
  - Module 1: Fundamentals of Switched-Mode Power Supplies (SMPS) [Weeks 1-3]
    - 1. Introduction to Power Conversion
    - 2. Review of Linear vs. Switched-Mode Power Supplies

- 3. Essential Components: Semiconductors, Inductors, Capacitors, Transformers
- 4. Losses in Power Converters and Efficiency Considerations
- 5. Basic SMPS Topologies: Buck, Boost, Buck-Boost Converters
- 6. Hands-on: Simulation of basic SMPS topologies (Student chooses: LTSPICE, PSIM, or PLECS)

- Module 2: Advanced Topologies and Modeling [Weeks 4-8]
  - 7. Isolated Converters: Flyback, Forward, Push-Pull, Half-Bridge, Full-Bridge
  - 8. Resonant Converters: LLC and ZVS/ZCS Techniques
  - 9. Small-Signal Modeling and Transfer Functions of SMPS
  - 10. Stability Analysis and Compensation Design
  - 11. Practical Aspects: Gate Driving, PCB Layout, Parasitics, EMI Considerations
  - 12. **Hands-on: Simulation of isolated topologies (LTSPICE, PSIM, or PLECS)
- Module 3: Magnetic Design and Control Strategies [Weeks 9-12]
  - 13. Design of Transformers and Inductors for SMPS
  - 14. Magnetic Core Materials and Winding Techniques
  - 15. Introduction to Digital and Analog Control for SMPS
  - 16. PID Controllers and Compensation Techniques
  - 17. Hands-on:** Simulation of closed-loop control strategies (LTSPICE, PSIM, or PLECS)
- Module 4: Applications and Advanced Topics [Weeks 13-18]
  - 18. High-Efficiency SMPS for Renewable Energy Systems
  - 19. Battery Chargers and Power Factor Correction (PFC)
  - 20. GaN and SiC in High-Frequency Power Conversion
  - 21. Industry Standards and Safety Considerations
  - 22. **Final Project:** **Design, simulation, and report on a custom SMPS (Software choice: LTSPICE, PSIM, or PLECS)**
  - 23. Case Studies and Future Trends in Power Electronics

- Teaching Methodology
  - Lectures (60%): Theory, problem-solving, and design discussions.
  - Simulations (30%): Hands-on exercises using LTSPICE, PSIM, or PLECS (student choice).
  - Projects (10%): Final project where students design a real-world SMPS assisted by dilation tools.

- Evaluation Methods
- Grading is designed to balance theoretical knowledge, simulations, and practical design skills, following **top international university standards**.
- Assessment Method
  - Midterm Exam (Theory + Simulation) | 30% |
  - Final Exam (Theory + Design) | 30% |
  - Lab Reports & Simulation Assignments | 20% |
  - Final Project & Presentation | 20% |
- Midterm Exam: Analytical and simulation-based questions covering fundamental topics.
- Final Exam: In-depth design-oriented problems with simulation validation.
- Lab Reports: Evaluation of circuit simulations, explanation of waveforms, and comparison with theoretical models.
- Final Project: Students design, simulate, and document a custom high-efficiency SMPS, selecting their preferred simulation tool (LTSPICE, PSIM, or PLECS).

- Recommended Textbooks
  - 1. Pulse-width modulated DC–DC power converters - Marian K. Kazimierczuk. Second edition.
  - 2. Fundamentals of Power Electronics" – Robert W. Erickson & Dragan Maksimović
  - 3. Power Electronics: Converters, Applications, and Design – Ned Mohan, Tore Undeland, William Robbins
  - 4. Switch-Mode Power Supplies: SPICE Simulations and Practical Designs – Christophe Basso

- Software Tools (Student Choice)
  - Students will **choose one** or combine the following tools for their assignments and project:
    - LTSPICE (Free) – Widely used for SMPS circuit simulation.
    - PSIM – Specialized in power electronics modeling.
    - PLECS – Advanced real-time control simulation for power systems.

- Final Remarks
  - This syllabus aligns with the rigorous academic standards of MIT (USA), ETH Zurich (Switzerland), TU Munich (Germany), and Imperial College London (UK). It offers a blend of theoretical depth, practical application, and flexible simulation choices, ensuring students develop industry-ready skills.