GUJARAT TECHNOLOGICAL UNIVERSITY

BRANCH NAME: POWER ELECTRONICS (24)
SUBJECT NAME: Power Electronics Design
Subject Code: 2172410
BE SEMESTER VII

Type of Course: Engineering Science (Power Electronics)

Prerequisite: **1) 2132404: Principles of Power Electronics**
2) 2142405: Analog Electronics & its Applications
3) 2142406: Digital Electronics & its Applications
4) 2152407: Power Electronics Circuits-I
5) 2162409: Power Electronics Circuits-II

Rationale: This is an era of control of electricity with the help of power semiconductor devices in order to achieve desired control with better power quality. With an aim to enable the students to understand the concept of design and learn the designing of such power electronics converters, this subject focuses on the study of design considerations and design of various essential circuits of power converters like Isolated and Non-isolated driver circuits for switches, Magnetics design, Measurement and Protection Circuits, Voltage and Current Sensing Circuits, Delay Circuits, PCB designing for High Power Circuits and High Frequency Applications.

Teaching and Examination Scheme:

<table>
<tr><td colspan="3">Teaching Scheme</td><td>Credits</td><td colspan="6">Examination Marks</td><td rowspan="4">Total Marks</td></tr>
<tr><td rowspan="3">L</td><td rowspan="3">T</td><td rowspan="3">P</td><td rowspan="3">C</td><td colspan="3">Theory Marks</td><td colspan="3">Practical Marks</td></tr>
<tr><td rowspan="2">ESE (E)</td><td colspan="2">PA (M)</td><td colspan="2">PA (V)</td><td rowspan="2">PA (I)</td></tr>
<tr><td>PA</td><td>ALA</td><td>ESE</td><td>OEP</td></tr>
<tr><td>4</td><td>0</td><td>2</td><td>6</td><td>70</td><td>20</td><td>10</td><td>20</td><td>10</td><td>20</td><td>150</td></tr>
</table>

L- Lectures; T- Tutorial/Teacher Guided Student Activity; P- Practical; E- Exam; M- Mid Semester; V- Viva; I- Internal; C- Credit; ESE- End Semester Examination; PA- Progressive Assessment; OEP- Open Ended Problems; ALA- Active Learning Assignments.

Learning Objectives:

- Review of various power converters.
- To understand engineering design process.
- To study the design of non-isolated driver circuits for various power circuits.
- To study the design of isolated driver circuits for various power circuits.
- To study the design of Magnetics in power electronics.
- To study the design of various measurement and protection circuits for Power Devices.
- To study the design of voltage and current sensing circuits.
- To study the design of PCB designing for high power and high frequency applications.

Content:

Sr. No.	Topic With Details	Teaching Hours	% Weight age
1	**Introduction to Engineering Design Process:** • Design: Definition – Steps of Engineering Design – Considerations for Engineering Design w.r.t. Power Electronics (Calculation of Component Values, Ratings, Material, Tolerance, etc.; Component Selection, Electrical Noise, PCB Design)	6	10% - 15%
2	**Non-Isolated Driver Circuits Design:** • Design of Non-Isolated Driver Circuits for Various Power Devices (Power BJT, MOSFET, IGBT, SCR, TRIAC) – Grounding Considerations for Driver Circuits	6	10% - 15%
3	**Isolated Driver Circuits Design:** • Requirement & Importance of Isolation – Design of Isolated Driver Circuits for Various Power Devices (Power BJT, MOSFET, IGBT, SCR, TRIAC) using Opto-Coupler & Pulse Transformer – Floating Ground Considerations for Isolated Driver Circuits	6	15% - 20%
4	**Line Frequency Magnetics Design:** • Transformer and Inductor Design for Line Frequency	4	10% - 15%
5	**High Frequency Magnetics Design:** • Transformer Design for Bridge, Forward, Flyback and Push-Pull Converters – Transformer Design for Driver Circuits • Inductor Design for Power Converters	6	15% - 20%
6	**Design of Measurement & Protection Circuits:** • Power Switch Protection Circuits – Control Terminal (Gate/Base) Protection Circuit – Short Circuit Protection – Over Voltage & Over Current Protection Circuits – di/dt & dv/dt Protection Circuits – Thermal Protection • V, I, f Measurement – Measurement of Analog Quantities	8	20% - 25%
7	**Thermal Design:** • Thermal Resistance & its Consideration – Heat Sink Calculations and Design – Forced (Concept of Cooling Fan, Water and Oil for Cooling of Heat Sink) and Natural Cooling of Heat Sinks	6	10% - 15%
8	**PCB Design:** • Concept of PCB – Terminology – Types (Paper, Glass Epoxy, Aluminium Clad, Single Layer, Double Layer, Multi Layered, Flexible) • Design Consideration for Voltage Isolation and Current Capacity, Noise Reduction Through PCB Layout, High and Low Power Circuit on Single PCB, Component & I/O Placement – PCB Design for Mixed Signal (Analog and Digital) Circuits	6	10% - 15%

Suggested Specification table with Marks (Theory):

Distribution of Theory Marks				
Remembrance R Level	**Understanding U Level**	**Application A Level**	**Analyse N Level**	**Evaluate E Level**
10%	30%	25%	25%	20%

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. Datasheets and Application Notes of Various ICs.
2. Transformer and Inductor Design Handbook by Mclyman
3. Designing Magnetic Components for High Frequency DC-DC Converters by Mclyman, Kg Magnetics Inc.
4. Transformer and Inductor Design Handbook, 3ed by Mclyman, Marcel Dekker, Inc.
5. Power Electronics: Essentials & Applications by L. Umanand, Wiley.
6. Operational Amplifiers: Applications and Design by Jerald G. Graeme & Gene E. Tobey, McGraw Hill.
7. Op-Amps Design: Application & Troubleshooting, 2ed by David L. Terrell, Butterworth-Heinemann (Elsevier).
8. Power Electroncis Design: A Practitioner's Guide by Keith H Sueker, Newnes (Elsevier).
9. Switchmode Power Supply Handbook, 3ed by Keith Billings & Taylor Morey.
10. Power Switching Converters, 2ed by Simon Ang and Alejandro Oliva, Yesdee.
11. The Art of Electronics by Paul Horowitz, Cambridge University Press.
12. Power Supply Cookbook by Marty Brown, Newnes.
13. The J & P Transformer Book, 12ed by Martin J. Heathcote, Newnes.
14. Power Electronics: Converters, Applications and Design by Mohan, Undeland and Robbins, Wiley India.
15. PCB Design Tutorial by David L. Jones. (http://alternatezone.com/electronics/files/PCBDesignTutorialRevA.pdf)
16. The Essence of Power Electronics by Ross, Prentice Hall
17. Practical Electronics for Inventors by Paul Scherz, McGraw Hill
18. Advanced DC to DC Converters by Fang Lin Luo & Hong Ye, CRC Press
19. The Power Electronics Handbook by T L Skvarenina, CRC Press

Course Outcome:

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

1. Understand the concept of engineering design and compare different power semiconductor switches and be able to select appropriate power switch for different applications.
2. Understand and design various isolated and non-isolated basic driver circuits for power switches.
3. Understand and design transformers and inductors for line and high frequency applications.
4. Understand and be able to select, design and implement protection circuits for power switches and circuits.
5. Understand and design circuits for measurement of various quantities like voltage, current, etc.
6. Understand different types of thermal considerations and be able to select and design proper heat sinks for various applications.
7. Understand different types of PCBs and its design w.r.t. various considerations.

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.

- Study and design of transformer and inductor for line and high frequency applications.
- Study and design isolated and non-isolated driver circuits for various power semiconductor devices.
- Study and design protection circuits for various power semiconductor devices.
- Study and design circuits for measurement of various analog quantities.
- Study and design PCB for various circuits.
- Study, design and select proper Heat Sink for power switches in various applications.

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.

List of Experiments and 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 (Magnetics Design):

1. To study engineering design process.
2. To study and design magnetics (transformer and inductor) design for line frequency applications.
3. To study and design magnetics (transformer and inductor) design for high frequency applications.

Group B (Device Driver Circuits):

4. To study and design non-isolated driver circuit for various power devices.
5. To study and design non-isolated driver circuit for various power devices.

Group C (Measurement & Protection Circuits):

6. To study and design various protection (OV, OC, SC, di/dt, dv/dt, Gate/Base) circuits for power switches.
7. To study and design circuits for measurement of voltage and current.
8. To study measurement of various analog quantities like temperature, speed, etc.

Group D (PCB & Thermal Considerations):

9. To study and design PCBs for various applications.
10. To study and design heat sinks for thermal protection of power switches.

Major Equipment:

- GP PCB Board, Function Generator, AC & DC Power Supply, Oscilloscope, Power Electronics Trainer Kits, Multimeter, Various Kits for Experimental Setup, Soldering Station, Power Scope, Voltage and Current Probes, etc.
- Consumable Items: Various Power Semiconductor Switches, Various Control, Driver and Measurement ICs, Heat Sinks, PCBs, 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.smps.us/smpsdesign.html
- http://www.poweresim.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 websites:

- http://www.datasheetcatalog.com
- http://nptel.iitm.ac.in/courses.php
- http://ocw.mit.edu
- http://www.smpstech.com
- Websites of various electronic components and semiconductor manufacturers.