GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)
Semester-III

Course Title: Elements of Power Electronics
(Course Code: 4332404)

Diploma programmer in which this course is offered	Semester in which offered
Power Electronics	Third

1. RATIONALE

Power electronics is a subject that concerns the applications of electronic principles in to situation that are rated at higher power level rather than small signal level power. Many semiconductor devices such as SCR, DIAC, TRIAC, MOSFET and power transistors are available for such higher power applications. These contents of the course will create a general understanding of these power electronic semiconductor devices. Further, the course is intended to generate the requisite skills required in the industry for selecting and maintaining of various power electronic devices and related circuits.

2. COMPETENCY

The purpose of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Operate semiconductor switches for various power electronic applications**

3. COURSE OUTCOMES (COs)

The practical exercises, the underpinning knowledge and the relevant soft skills associated with this competency are to be developed in the student to display the following COs:

CO 1) Identify various power electronic switches.
CO 2) Select Thyristor switches for various operations.
CO 3) Select Transistor switches for various operations.
CO 4) Design various triggering circuits for semiconductor switches.
CO 5) Protect semiconductor switches by various protection circuits.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
3	-	2	4	30	70	25	25	150

(*): For this practical only course, 25 marks under the practical CA has two components i.e. the assessment of micro-project, which will be done out of 10 marks and the remaining 15 marks are for the assessment of practical. This is designed to facilitate attainment of COs holistically, as there is no theory ESE.

***Legends: L**-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** -Practical; **C** – Credit, **CA** - Continuous Assessment; **ESE** -End Semester Examination.*

5. SUGGESTED PRACTICAL EXERCISES

*Following practical outcomes (PrOs) that are the sub-components of the Course Outcomes (Cos). Some of the **PrOs** marked **'*'** are compulsory, as they are crucial for that particular CO at the 'Precision Level' of Dave's Taxonomy related to 'Psychomotor Domain'.*

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. required
1.	Study maximum ratings of various power semiconductor switches.	I	2
2.	Design SCR testing kit	I	2
3.	Understand VI characteristics of SCR	II	2*
4.	Understand VI characteristics of TRIAC	II	2*
5.	Understand VI characteristics of GTO	II	2*
6.	Understand VI characteristics of MCT	II	2*
7.	Understand VI characteristics of MOSFET	III	2*
8.	Understand VI characteristics of IGBT	III	2*
9.	Test the performance of BJT as a switch.	III	2
10.	Design DC gate triggering circuits (R and RC) for SCR.	IV	4*
11.	Design AC gate triggering circuits (R and RC) for SCR.	IV	4*
12.	Test the performance of ramp comparator triggering circuit using Uni-Junction Transistor (UJT).	IV	2*
13.	Test the performance of Gate-drive circuit by using BJT of a GTO to turn-on and turn-off.	IV	2*
14.	Evaluate the performance of single-phase AC voltage control circuit using TRIAC/DIAC combination. Record the waveforms of input supply voltage, output voltage, TRIAC voltage, DIAC voltage and capacitor voltage under different firing angles.	IV	2*
15.	Evaluate the performance of Triggering circuit for BJT/MOSFET/TRIAC using optoisolator (optocoupler).	IV	2*
16.	Evaluate the performance of a TCA-785 based triggering circuit used to trigger SCR/TRIAC/MOSFET.	IV	2
17.	Test the performance of snubber circuit for dv/dt protection of an SCR.	V	2*
18.	Test the performance of Gate triggering protection circuit by Zener diode of an SCR.	V	2
19.	Test the performance of overvoltage protection circuit for MOSFET.	V	2
	Minimum 14 Practical Exercises		**28 Hrs.**

Note

i. *More **Practical Exercises** can be designed and offered by the respective course teacher to develop the industry relevant skills/outcomes to match the COs. The above table is only a suggestive list.*

ii. *The following are some **sample** 'Process' and 'Product' related skills (more may be added/deleted depending on the course) that occur in the above listed **Practical Exercises** of this course required which are embedded in the COs and ultimately the competency.*

S. No.	Sample Performance Indicators for the PrOs	Weightage in %

S. No.	Sample Performance Indicators for the PrOs	Weightage in %
1	Prepare of experimental setup	20
2	Operate the equipment setup or circuit	20
3	Follow safe practices measures	10
4	Record observations correctly	20
5	Interpret the result and conclude	30
Total		**100**

6. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

These major equipments with broad specifications for the PrOs is a guide to procure them by the administrators to user in uniformity of practical's in all institutions across the state.

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	SCR Characteristics Kit: Working voltage :(220-240)VAC, Anode Voltage :0-30VDC, Gate Voltage :0-30VDC, Output Voltage :0-30VDC, Output Current :1 Amps, 4. Digital Voltmeter DC 3½ Digit having Dual range of 20V/200V, Digital Current meter DC 3½ Digit having range of 0-1A	3
2	TRIAC Characteristics Kit: Kit Working voltage :(220-240)VAC, Anode Voltage :0-30VDC, Gate Voltage :0-30VDC, Output Voltage :0-30VDC, Output Current :1 Amps, VI characteristic of TRIAC Study Module, Patch cards, 6A power supply card, 3A Fuse.	4
3	SEMICONDUCTOR AND THYRISTOR CHARACTERISTICS TRAINER (ANALOG): Power Supplies: DC Power Supply 5V/15V at 150mA Switch Selectable , DC Power Supply 15V/30V at 150mA Switch Selectable , Operated on Mains power 230V, 50Hz +10% Analog Meters: Dual Range Voltmeter-5V/15V, Dual Range Voltmeter-25V/50V, Dual Range Ammeter 250uA/25mA, Dual Range Ammeter 5mA/50mA, Meter ranges are selectable with toggle switches. Components are mounted on the panels are: PN Junction Diode Germanium OA81, Zener Diode 6.2V,Led ,Diac DB3,IGBT IRGBC20S, TRANSISTOR CL100, TRANSISTOR SK100,SCR TYN604, TRIAC BT136,UJT 2N2646,Voltage Control through Potentiometer.	3,4,5,6,7,8
4	SCR triggering circuit: On board AC source : 0 V - 18 V On board firing circuits: R Triggering Circuit RC Half Wave Triggering Circuit RC Full Wave Triggering Circuit Interconnections : 2 mm sockets Firing angle variation : Gradually variation using firing control (2MW) SCR : 1 SCRs 2P4M, 400 V/2A Test points : 8 nos Product Tutorial : Online on www.ScientechLearning.com Dimensions (mm) : W 420 x D 255 x H 100 Power Supply (Mains) : 110V - 260V AC, 50/60Hz.	10,11
5	UJT triggering circuit: On board AC source : 18 V - 0 V - 18 V On board DC Supply : +5 V, +12 V On board triggering circuits : 555 IC triggering circuit UJT triggering circuit Interconnection : 2 mm socket SCR : SCRs TYN616, 600V/16 A Test points : 4 nos.	12
6	Power Electronics Lab: Size of Breadboard : 172.5 mm × 128.5 mm DC Power Supply : +5 V, -5 V 500 mA, +12V, -12 V 500 mA +15 V, 250 mA +35V, -35V, 250 mA AC Power Supply : 18V-0V-18V 0V-15V On board Firing Circuits Frequency range : 30Hz to 900Hz variable Amplitude : 12V PWM control of G1, G2, G3 and G4 Duty cycle control of "Gate" Signal is	3,4,5,6,7,8,9,10,11,12,13

S. No.	Equipment Name with Broad Specifications	PrO. No.
	0 to 100% SCR Assembly : 4 SCRs 2P4M, 400V/2A Power Devices : IGBT-G4BC20S, MOSFETIRFZ44N, UJT-2N2646, DIACDB3, TRIAC-BT136, PUT2N6027 Pulse transformer on board : 2 nos. PT4502 1:1 and one is PT4503 1:1:1 Circuit Components on board: Electrolytic Capacitor 1uF, 63V Metalized Capacitor 0.1uF, 63V Metalized Capacitor 0.33uF, 63V Diode 1N4007, Inductor 68mH, Inductor 68mH, Inductor 10mH Load selector : 6 load resistances- 47E/7W, 120E/5W, 270E/5W, 2K2/2W, 1K/1W, 1K/10W Test points : 10 nos Power Supply (Mains) : 220V/110V, 50Hz/60Hz Included Accessories : Bread boards : 2 nos. Connecting wires : 20 nos. 2mm to 1mm Patch cords : 15 nos. 2mm Patch cords (Red) 16" : 4 nos. 2mm Patch cords (Black)16'' : 4 nos. 2mm Patch cords (Blue) 16'' : 12 nos. Mains cord : 1 no.	
7	Single Phase Converter Firing Techniques using TCA 785: On board AC source : 0 V - 15 V, 18 V - 0 V - 18V On board firing circuits : TCA785 firing scheme Triangular comparator firing scheme Interconnections : 2mm sockets SCR assembly : 4 SCRs 2P4 M, 400V/2A Mains Supply : 220V/110V, 50 Hz / 60 Hz Test Points : 9 nos Product Tutorial : Online on www.ScientechLearning.com Dimensions (mm) : W 420 x D 255 x H 100 Weight : 2 Kg. (approximately) o Operating Conditions : 0-40 C, 85% RH Included Accessories : 2mm Patch cord (Red) 16"-6 nos. 2mm Patch cord (Black) 16"-6 nos. 2mm Patch cord (Blue) 16"-6 nos. Mains cord-1 no.	16
8	Lamp Dimmer: DIAC TRIAC firing circuit, UJT firing circuit SCR & TRIAC: 1 SCRs TYN 616, 600V/16A and, TRIAC BT136, Load : Lamp 100W Mains Supply (mains) : 220V/110V, 50 Hz/60 Hz	14

7. AFFECTIVE DOMAIN OUTCOMES

The following ***sample*** Affective Domain Outcomes (ADOs) are embedded in many of the above mentioned COs and PrOs. More could be added to fulfill the development of this competency.

a) Work as a leader/a team member.
b) Follow safety practices while using power semiconductor devices.
c) Practice environmentally friendly methods and processes.(Environment related)

The ADOs are best developed through the laboratory/field based exercises. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

i. 'Valuing Level' in 1st year
ii. 'Organization Level' in 2nd year.
iii. 'Characterization Level' in 3rd year.

8. UNDERPINNING THEORY

Only the major Underpinning Theory is formulated as higher level UOs of *Revised Bloom's taxonomy* in order development of the COs and competency is not missed out by the students and teachers. If required, more such higher level UOs could be included by the course teacher to focus on attainment of COs and competency.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at Application and above level)	Topics and Sub-topics
Unit – I Basics of Power semiconductor Devices	1a. Describe the significance of power electronics with applications.	1.1 Introduction to power electronics, History of Power Electronics Development. Applications of power electronics: Power electronics in Information technology, robotics and flexible production, role of power electronics in providing sustainable electric energy- Energy conversation, Electric-Motor Driven Systems, Lighting, Transportation, Renewable Energy and Utility Applications of Power Electronics
	1b. Explain Power semiconductor switches with their symbol, and maximum ratings briefly.	1.2 Semiconductor devices: Diode, Thyristor family (DIAC,SCR,LASCR,ASCR,RCT, GTO,SITH,MCT,TRIAC,SCS,SUS,SBS), Transistor family (BJT, MOSFET, IGBT, SIT, PUT, UJT)- symbol, maximum ratings.
	1c. Explain recent and potential advancements in the field of power semiconductor device.	1.3 Recent and potential advancements in power electronics devices.
	1d. Classify Power electronic converters.	1.4 Power electronic converters: AC-DC, DC-DC, DC-AC, AC-AC converters with their applications.
Unit– II Thyristor Family	2a. Describe construction and characteristics of SCR. 2b. List advantages disadvantages and applications of an SCR.	2.1 SCR: Construction, Principle of operation, characteristics (V-I, & gate). 2.2 SCR: advantages, disadvantages applications.
	2c. Describe Structure, principle of operation and characteristics of GTO. 2d. List advantages disadvantages and applications of an GTO.	2.3 GTO: Structure, turn on and turn off process, I-V characteristics. 2.4 GTO: advantages, disadvantages applications.
	2e. Describe characteristics of and applications of DIAC.	2.5 DIAC: Schematic diagram, characteristics and applications.
	2f. Describe construction, characteristics and turn on	2.6 TRIAC: Structure, SCR Equivalent ckt, characteristics (V-I), mode of turn on

Unit	Unit Outcomes (UOs) (4 to 6 UOs at Application and above level)	Topics and Sub-topics
	process of TRIAC. 2g. List advantages disadvantages and applications of a TRIAC.	process. 2.7 TRIAC: advantages, disadvantages applications.
	2h. Explain main features and basic structure, characteristics advantages and disadvantages of MCT 2i. List advantages disadvantages and applications of a MCT.	2.8 MCT: features, Basic structure characteristic, advantages-disadvantages. 2.9 MCT: advantages, disadvantages applications.
	2j. Compare Thyristors.	2.10 Compare various Thyristors.
Unit – III Power Transistor Family	3a Explain Power BJT as a switch	3.1 Power BJT: function as a switch – cut off mode and saturation mode.
	3b Explain basic structure, types, and characteristics of Power MOSFET. 3c List advantages disadvantages and applications of a MOSFET.	3.2 Power MOSFET: Types (enhancement mode- P-channel, N-channel), basic structure, characteristics (I-V and transfer) as an ideal and real switch. 3.3 MOSFET: advantages, disadvantages applications.
	3d Explain basic structure and characteristics of IGBT. 3e List advantages disadvantages and applications of a IGBT	3.4 IGBT: Basic structure, characteristics (I-V and transfer) as an ideal and real switch. 3.5 IGBT: advantages, disadvantages applications.
	3f Compare transistors.	3.6 Compare various transistors.
Unit– IV Drive circuits for Power semiconductor devices.	4a. Explain pulse transformer connections. 4b. Explain optoisolators used in triggering circuit. 4c. Explain working principle and applications of UJT. 4d. Explain working principle and applications of PUT.	4.1 Pulse transformer connections for two SCRs 4.2 Commonly used optoisolators; working, advantages and applications. 4.3 UJT: structure, equivalent circuit, normal UJT biasing, applications.. 4.4 PUT: structure, PUT in on and off state, PUT oscillator.
	4e. Design Gate triggering circuit to turn on an SCR.	4.5 Turn on methods: • Gate triggering:-Resistive, RC, Pulse triggering: using UJT(ramp triggering)
	4f. Design Gate triggering circuit to turn on an GTO.	4.6 Gate-drive circuit of a GTO for turn-on and turn-off using BJT.
	4g. Design TRIAC gate triggering circuit.	4.7 TRIAC gate circuit using DIAC.
	4h. Design a triggering circuit of TRANSISISTOR/MOSFET/TRIAC using optocoupler.	4.8 Triggering circuit for BJT/MOSFET/TRIAC using optoisolator (optocoupler).
	4i. Design a triggering circuit of TRANSISISTOR/MOSFET/TRIAC	4.9 Triggering circuit for BJT/MOSFET/TRIAC using TCA 785 IC.

Unit	Unit Outcomes (UOs) (4 to 6 UOs at Application and above level)	Topics and Sub-topics
	using IC TCA 785.	
Unit– V Power semiconductor switches protection and ratings.	5a Explain different types of SCR protection.	5.1 SCR Protection: • Main power circuit: di/dt, dv/dt, over current, over voltage, snubber circuit. • Gate circuit: Gate circuit protection using Zener diode.
	5b Explain different types of MOSFET protection.	5.2 MOSFET Protection: overvoltage, over current, Gate protection.
	5c Describe Thyristor ratings.	5.3 Thyristor ratings: • Voltage ratings: Peak working forward-blocking voltage (V_{DWM}), Peak repetitive forward blocking voltage (V_{DRM}), Peak working reverse voltage (V_{RWM}), Peak repetitive reverse voltage (V_{RRM}), Voltage safety factor, finger voltage, on state voltage drop. • Current ratings: Average On-State current, RMS On-State current, holding and lathing current.
	5d Describe MOSFET ratings.	5.4 MOSFET ratings: • Breakdown voltage, maximum on state voltage, Maximum Gate voltage, maximum continuous current, switching time and average power dissipation, on state resistance.

***Note**: The UOs need to be formulated at an 'Application Level' and above of Revised Bloom's Taxonomy' to accelerate the attainment of the COs and the competency.*

9. SUGGESTED SPECIFICATION TABLE FOR QUESTIONPAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I.	**Basics of Power semiconductor Devices**	**04**	**4**	**4**	**0**	**08**
II.	**Thyristor Family**	**10**	**4**	**10**	**0**	**14**
III.	**Power Transistor Family**	**08**	**4**	**8**	**0**	**12**
IV.	**Drive circuits for Power semiconductor devices.**	**12**	**0**	**6**	**16**	**22**
V.	**Power semiconductor switches protection and ratings**	**08**	**0**	**6**	**8**	**14**
Total		**42**	**12**	**34**	**24**	**70**

***Legends:** R=Remember, U=Understand, A=Apply and above (Revised Bloom's taxonomy)*

***Note**: This specification table provides general guidelines to assist student for their learning and to teachers to teach and question paper designers/setters to formulate test items/questions assess the attainment of the UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary slightly from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a) Interpret various ratings given in thyristor datasheets.
b) Interpret various ratings given in thyristor datasheets.
c) Make a chart of Classification of power semiconductor switches with their maximum ratings.
d) Undertake a market survey for thyristor switches.
e) Undertake a market survey for transistor switches.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a) Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b) Guide student(s) in undertaking micro-projects.
c) ***'L' in section No. 4***means different types of teaching methods that are to be employed by teachers to develop the outcomes.
d) About ***20% of the topics/sub-topics*** which are relatively simpler or descriptive in nature is to be given to the students for ***self-learning***, but to be assessed using different assessment methods.
e) With respect to ***section No.11***, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
f) Guide students for selecting a proper Thyristor switches for specific applications.
g) Guide students for selecting a proper Transistor switches for specific applications.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project is group-based (group of 3 to 5). However, **in the fifth and sixth semesters**, the number of students in the group should **not exceed three**.

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The duration of the micro-project should be about **14-16 (fourteen to sixteen) student engagement hours**

during the course. The students ought to submit micro-project by the end of the semester to develop the industry-oriented COs.

A suggestive list of micro-projects is given here. This has to match the competency and the COs. Similar micro-projects could be added by the concerned course teacher:

a) Make a Presentation a various types of Thyristor and transistor switches used in relevant industries.
b) Prepare a report of maximum rating of semiconductor switches available in practice.
c) Prepare a report of advance power electronic switches/ module available for power electronic converters.

13. SUGGESTED LEARNING RESOURCES:

S. No.	Title of Book	Author	Publication with place, year and ISBN
1	Power Electronics	Singh M. D.; Khanchandani K.B.	McGraw Hill Education,2020 ISBN: 978-0070583894
2	Power Electronics Semiconductor Switches	Ramshaw R.S.	Springer, 2010 ISBN 978-0412288708
3	Power electronics	Bimbhra P.S.	Khanna Publishers,2021 ISBN: 9788174092793
4	Power electronics	Muhammad Rashid	Pearson Education, 2017 ISBN: 978-8120345317
5	Power Electronics: Devices, Circuits and Industrial Applications	Moorthi. V.R.	Oxford University Press, 2005 ISBN : 978-0195670929
6	Power Electronics, Converters, Applications and Design	Ned Mohan, Undeland , Robbins	Wiley , 2022 ISBN: 978-9354640278

14. SOFTWARE/LEARNING WEBSITES

a) https://www.vlab.co.in
b) https://nptel.ac.in
c) https://www.classcentral.com
d) https://swayam.gov.in/
e) https://shodhganga.inflibnet.ac.in/
f) https://www.coursera.org/specializations/semiconductor-devices
g) https://www.edx.org/learn/semiconductors

15. PO-COMPETENCY-CO MAPPING

Semester II	Elements of power electronics Course Code: .....)						
	POs and PSOs						
Competency & Course Outcomes	PO 1 Basic & Discipline specific knowledge	PO 2 Problem Analysis	PO 3 Design/ development of solutions	PO 4 Engineering Tools, Experimentation &Testing	PO 5 Engineering practices for society, sustainability & environment	PO 6 Project Management	PO 7 Life-long learning
Competency	Operate semiconductor switches for various power electronic applications						
CO 1) Identify various power electronic switches.	2	-	-	-	1	1	1
CO 2) Select Thyristor switches for various	3	1	1	2	1	2	2

	operations.						
CO 3)	Select Transistor switches for various operations.	3	1	1	2	1	2	2
CO 4)	Design various triggering circuits for semiconductor switches.	3	1	3	2	2	2	3
CO 5)	Protect semiconductor switches by various protection circuits.	3	2	3	2	2	2	3

Legend: '**3'** for high, '**2**' for medium, **'1'** for low or **'-'** for the relevant correlation of each competency, CO, with PO/ PSO

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16. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

S. No.	Name and Designation	Institute	Contact No.	Email
1.	Mr. Kalpaj Dhimar HOD(I/C) – Power Electronics Department.	Dr. S. & S. S. Ghandhy college of engineering & Technology, Surat	7990186322	powssg@gmail.com
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