Roll No.													

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

TEST 1

Sem & AY: Odd Sem 2019-20
Course Code: ECE 302
Course Name: POWER ELECTRONICS
Program & Sem: B.Tech. (ECE) & V

Date: 01.10.2019
Time: 2.30 to 3.30 PM
Max Marks: 40
Weightage: 20%

Instructions:

(i) *Read the question properly and answer accordingly.*
(ii) *Question paper consists of 3 parts.*
(iii) Scientific and Non-programmable calculators are permitted.

Part A [Memory Recall Questions]

Answer both the Questions. Each Question carries four marks. (2Qx4M=8M)

1. What is power electronics? Write the advantages and disadvantages of power electronics? (C.O.NO.1) [Knowledge]

2. Mention any four power semiconductor devices? (C.O.NO.1) [Knowledge]

Part B [Thought Provoking Questions]

Answer both the Questions. Each Question carries six marks. (2Qx6M=12M)

3. Justify how Snubber circuit will protect SCR against high dv/dt voltage? (C.O.NO.1) [Comprehension]
4. Why series connection of two or more SCRs is needed? What is the technical difficulty we encounter while connecting SCRs in series? How do you overcome this difficulty? (C.O.NO.1) [Comprehension]

Part C [Problem Solving Questions]

Answer both the Questions. Each Question carries ten marks. (2Qx10M=20M)

5. The switching characteristics of power BJT shown in Fig.1. The parameters are V_{CC}=200V, $V_{CE(sat)}$=2V, I_{CEO}=2.5mA, $I_{C(sat)}$=80A, $V_{BE(sat)}$=2.5V, I_B=8A, t_d=0.4μs, t_r=0.9μs, t_s=5μs, t_f=3.2μs, duty cycle (δ)=50% and switching frequency (f) is 10KHz. Sketch the instantaneous power curve due to collector current and determine average power loss (P_{AVIC}) due to collector current?

(C.O.NO.1) [Application]

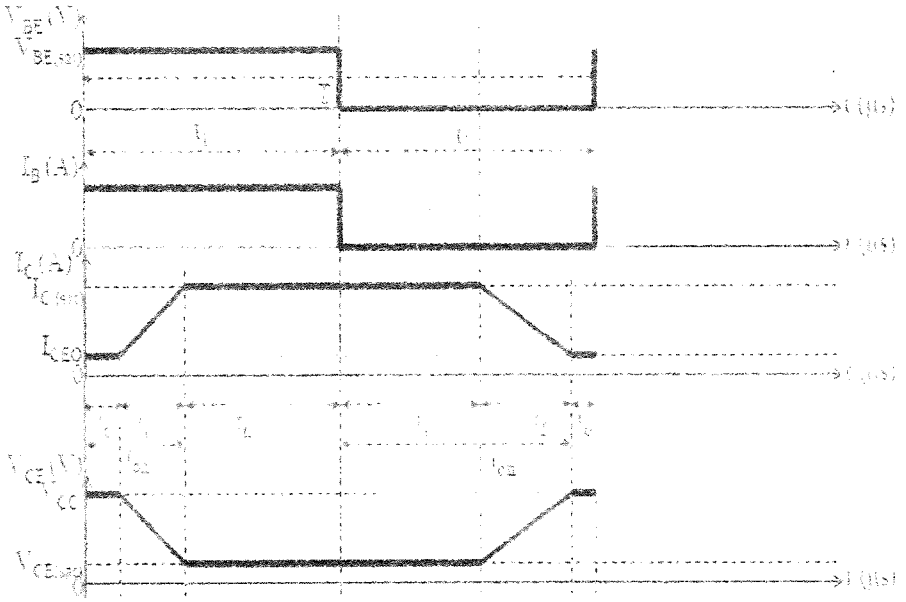


Fig. 1.

6. The power BJT circuit shown in Fig. 2. is specified to have β in the range 10 to 45, the load resistance R_C=10Ω, V_{CC}=200V, V_{BB}=10V. If $V_{CE(sat)}$=1V and $V_{BE(sat)}$=1.5V. Determine R_B that results in saturation with an ODF of 6?

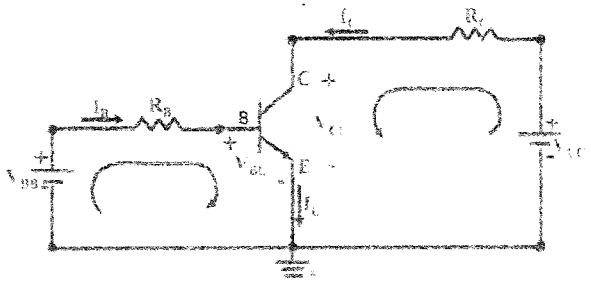


Fig. 2.

(C.O.NO.1) [Application]

SCHOOL OF ENGINEERING

SET A

Semester: V
Course Code: ECE 302
Course Name: Power Electronics
Branch & Sem: ECE & V

Date: 01-10-2019
Time: 2.30-3.30 PM
Max Marks: 40
Weightage: 20%

Extract of question distribution [outcome wise & level wise]

Q.NO.	C.O.NO	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels		Thought provoking type [Marks allotted] Bloom's Levels		Problem Solving type [Marks allotted]		Total Marks
			K		C		A		
1	1	Module1/ Introduction, Power BJT and SCR	04	L2					04
2	1	Module1/ Introduction, Power BJT and SCR	04	L2					04
3	1	Module1/ Introduction, Power BJT and SCR			06	L2			06
4	1	Module1/ Introduction,			06	L2			06

		Power BJT and SCR									
5	1	Module1/ Introduction, Power BJT and SCR							10	L2	10
6	1	Module1/ Introduction, Power BJT and SCR							10	L2	10
	Total Marks	40		08			12		20		

K =Knowledge Level C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

[I hereby certify that All the questions are set as per the above guide lines. DR. Sreenivasappa B V]

Reviewers' Comments

Everything O.K. except uneven distribution of time in part 'C' when compared to marks.

Annexure- II: Format of Answer Scheme

SCHOOL OF ENGINEERING

SOLUTION

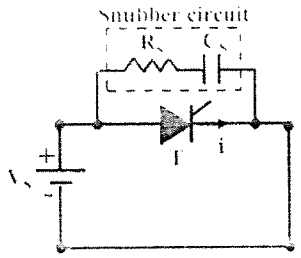
Semester: V
Course Code: ECE 302
Course Name: Power Electronics
Branch & Sem: ECE & V

Date: 01-10-2019
Time: 2.30-3.30 PM
Max Marks: 40
Weightage: 20%

Part A (2Q x 4M = 8 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
1	**Power electronics is an application of solid state electronics for the control and conversion of electric energy.** **Advantages: High reliable, efficiency, low losses, compact** **Disadvantages: Introduces harmonics into the source as well as load, electromagnetic interference**	02 01 01	02 min 02 min
2	SCR, Power BJT, MOSFET, GTO	Each 01 mark (04)	02 min

Part B (2Q x 6M = 12 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
3	**If the rate of rise of forward voltage $\frac{dV_S}{dt}$ is high then resultant high charging current can turn-on the SCR even when gate voltage is zero. This can be avoided by using a Snubber circuit connected in parallel with the device as shown in Fig. 1.**  Fig. 1. **The Snubber circuit is a series combination of resistance Rs and capacitance Cs. When SCR is off Cs charges to a voltage**	01+01+01 02 01	10 min

	equal to Vs. When SCR is on Cs discharges through SCR and sends current equal to $\frac{V_S}{R_S}$.		
4	When the input voltage is large and if it is not possible to block this voltage with one SCR, then it is essential to connect two or more SCRs in series. Due to variation in the leakage current in each SCR, the voltage blocking will not be equal by each SCR. To overcome this problem it is necessary to connect a resistor of value *R* parallel to each SCR	02 02 02	10 min

Part C (2Q x 10M 20 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
5	f=10KHz T=1/f=1/10KHz=100μs, $t_1 = \delta T = 50\mu s = t_2$		20 min
	Power loss due to Ic	01	
	Power loss due to t_d (P_{td}): $P_{td} = 0.5(t_d/T) = 0.002W$	01	
	Power loss due to t_r (P_{tr}): $P_{tr} = (2/3)4000(t_r/T) = 24W$	01	
	Power loss due to t_n (P_{tn}): $P_{tn} = 160(t_n/T) = 77.92W$, $t_n = t_1 - (t_d + t_r) = 50\mu s - (1.3\mu s) = 48.7\mu s$	01 01	
	Power loss due to t_s (P_{ts}): $P_{ts} = 160(t_s/T) = 8W$	01	
	Power loss due to t_f (P_{tf}): $P_{tf} = (2/3)4000(t_f/T) = 85.33W$	01	
	Power loss due to t_o (P_{to}): $P_{to} = 0.5(t_o/T) = 0.209W$, $t_o = t_2 - (t_s + t_f) = 50\mu s - (8.2\mu s) = 41.8\mu s$	01	
	$P_{AVIC} = P_{td} + P_{tr} + P_{tn} + P_{ts} + P_{tf} + P_{to} = 195.461W$	02	
6	We have $R_B = \frac{V_{BB} - V_{BE(sat)}}{I_B}$	02	12 min
	$= \frac{10-1.5}{I_B} = \frac{10-1.5}{I_B} = \frac{8.5}{11.94} = 0.7118\Omega$	02	
	$ODF = \frac{I_B}{I_{B(sat)}}$	02	
	From this $I_B = I_{B(sat)} X\ ODF$	02	
	$I_B = 1.99X6 = 11.94A$	02	

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GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

TEST 2

Sem & AY: Odd Sem 2019-20
Course Code: ECE 302
Course Name: POWER ELECTRONICS
Program & Sem: B.Tech.(ECE) & V

Date: 19.11.2019
Time: 2.30 PM to 3.30 PM
Max Marks: 40
Weightage: 20%

Instructions:

(i) Read the question properly and answer accordingly.
(ii) Question paper consists of 3 parts.
(iii) Scientific and Non-programmable calculators are permitted.

Part A [Memory Recall Questions]

Answer both the Questions. Each Question carries four marks. (2Qx4M=8M)

1. What is AC voltage controller? Give the classification of AC voltage controllers?
[4M] (C.O.NO. 1) [Bloom's level-L2]

2. What is the difference between semiconverter and full converter?
[4M] (C.O.NO. 1) [Bloom's level-L2]

Part B [Thought Provoking Questions]

Answer both the Questions. Each Question carries six marks. (2Qx6M=12M)

3. A 1-Φ half wave AC voltage controller has a resistive load of R=6Ω and input voltage V_s=230V, 50Hz. The thyristor switch is triggered at an angle of α=π/2. Determine (i) RMS output voltage (ii) Input power factor (iii) Average input current?
[6M] (C.O.NO. 1) [Bloom's level-L2]

4. A 2kW heater is connected across a 1-Φ$230V, 50Hz$, supply through an SCR. If the delay angle $\alpha = \frac{\pi}{4}$. Calculate the power observed by the heater element?
[6M] (C.O.NO. 1) [Bloom's level-L2]

Part C [Problem Solving Questions]

Answer both the Questions. Each Question carries ten marks. (2Qx10M=20M)

5. The step down chopper has resistive load of $R = 10\Omega$, the dc input voltage $V_s = 200V$ and voltage across the chopper when it is ON $V_{ch} = 2V$. If the chopping frequency $f = 1kHz$ and duty cycle is 70% determine (i) Average output voltage (ii) RMS output voltage (iii) Chopper efficiency (iv) Effective input resistance (v) RMS value of the fundamental component of the output voltage? [10M] (C.O.NO. 1) [Bloom's level-L2]

6. A 1-Φ ON-OFF AC voltage controller has a resistive load of R=10Ω and input voltage V_s=120V, 50Hz. The thyristor switch is ON for 25 cycles and OFF for 75 cycles. Determine (i) RMS output voltage (ii) Input power factor (iii) Average current of thyristor (iv) RMS currents of thyristor? [10M] (C.O.NO. 1) [Bloom's level-L2]

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

Semester: V
Course Code: ECE 302
Course Name: Power Electronics
Branch & Sem: ECE & V

Date: 19-11-2019
Time: 2.30-3.30 PM
Max Marks: 40
Weightage: 20%

Extract of question distribution [outcome wise & level wise]

Q.NO.	C.O.NO	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels			Thought provoking type [Marks allotted] Bloom's Levels			Problem Solving type [Marks allotted]			Total Marks
			K			C			A			
1	2	Module2/ AC voltage controllers		04	L2							04
2	2	Module2/ Controlled rectifiers		04	L2							04
3	2	Module2/ AC voltage controllers					06	L2				06
4	2	Module2/ Controlled rectifiers					06	L2				06
5	3	Module3/ DC choppers								10	L2	10

6	2	Module2/ AC voltage controllers								10	L2	10
	Total Marks	40		08			12			20		

K =Knowledge Level C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

Remarks.

1. All the questions are set for C.O. 1 only what about other C. Os?
2. In Thought provoking questions more problems are given. It should provoke the thought rather than like mathematical problems.
3. All the question are set for Bloom Level 2 only.

Annexure- II: Format of Answer Scheme

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE REACH GREATER HEIGHTS

SOLUTION

Semester: V
Course Code: ECE 302
Course Name: Power Electronics
Branch & Sem: ECE & V

Date: 19-11-2019
Time: 2.30-3.30 PM
Max Marks: 40
Weightage: 20%

Part A (2Q x 4M =8 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
1	AC voltage controllers (ACVC) are power electronic converters that convert fixed AC to variable AC without changing frequency. There are two types in ACVC (i) ON-OFF ACVC (Integral grade ACVC) (ii) Phase angle ACVC – (ii.a) 1-Φ ACVC (ii.a.1) Unidirectional ACVC (Half wave ACVC) (ii.a.2) Bidirectional ACVC (Full wave ACVC) (ii.b) 3-Φ ACVC (ii.b.1) Unidirectional ACVC (Half wave ACVC) (ii.b.2) Bidirectional ACVC (Full wave ACVC)	02 02	02 min 02 min
2	Semiconverter operates in first quadrant where output voltage and current are positive and hence output power is positive. Full converter operates in first and fourth quadrants. In first quadrant output voltage and current are positive and hence output power is positive and in fourth quadrant output current is positive but output voltage is negative, hence output power is negative	02 02	02 min

Part B (2Q x 6M = 12 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
3	$V_m = \sqrt{2}V_s = 325V$ (i) $V_{orms} = \frac{V_s}{\sqrt{2\pi}}\sqrt{2\pi - \alpha + \frac{\sin 2\alpha}{2}} = 199.18V$ (ii) $PF = PF = \frac{V_{orms}}{V_s} = 0.86$	01 02 01	10 min

	(iii) $V_{odc} = \frac{V_m}{2\pi}(\cos\alpha - 1)$, $I_{odc} = \frac{V_{odc}}{R} = -8.62A$	02	
4	$V_m = \sqrt{2} \cdot 230 = 325V$	01	10 min
	Heater resistance is $R = \frac{V_S}{I_O} = \frac{V_S}{\left(\frac{P_O}{V_S}\right)} = \frac{V_S^2}{P_O} = \frac{230^2}{2000} = 26.45\Omega$	02	
	The power absorbed by the heater is $P_h = \frac{V_{orms}^2}{R} = \frac{(154.94)^2}{26.45} = 907.65W$	01	
	Where $V_{orms} = \frac{V_m}{2\sqrt{\pi}}\sqrt{\pi - \alpha + \frac{sin2\alpha}{2}} = 154.94V$	02	

Part C (2Q x 10M =20 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
5	$k = 0.7$		20 min
	(i) $V_{odc} = k(V_s - V_{ch}) = 138.6V$	01	
	(ii) $V_{orms} = \sqrt{k}(V_s - V_{ch}) = 165.65V$	01	
	(iii) $P_L = \frac{k(V_s - V_{ch})^2}{R} = 2744.28W$ $P_S = \frac{V_s k(V_s - V_{ch})}{R} = 2772W$ $\eta = \frac{P_L}{P_s} = 0.99$	02 01	
	(iv) $R_i = \frac{V_s}{I_s} = \frac{V_s}{I_{odc}} = \frac{V_s}{\frac{V_{odc}}{R}} = \frac{V_s R}{k(V_s - V_{ch})} = 14.43\Omega$	02	
	(v) The compact trigonometric Fourier series expansion for the output voltage waveform is given by $v_o(t) = \frac{a_o}{2} + \sum_{n=1}^{\infty} v_{on}\sin(nwt + \varphi_n)$	01	
	Where $v_{on} = \sqrt{\frac{a_n^2 + b_n^2}{2}}$ = RMS value of the n[th] harmonic component of the output voltage.		
	$a_o = \frac{2}{T}\int_0^T v_o(t)dt$		

	$$a_n = \frac{2}{T}\int_0^T v_o(t)\cos(nwt)dt$$ $$b_n = \frac{2}{T}\int_0^T v_o(t)\sin(nwt)dt$$ **To find out RMS value of the fundamental component of the output voltage put n=1 in v_{on}** $$v_{o1} = \sqrt{\frac{a_1^2 + b_1^2}{2}} = \sqrt{\frac{(-29.97)^2 + (41.25)^2}{2}} = \sqrt{1299.8817}$$ $$= 36.05V$$	02	
6	$V_m = \sqrt{2}V_s = 169.7V$, $k = \frac{m}{m+n} = \frac{25}{25+75} = 0.25$ (i) $V_{orms} = V_s\sqrt{k} = 60V$ (ii) $PF = \sqrt{k} = 0.5$ (iii) $I_{AT1} = \frac{kV_m}{\pi R} = 1.35A$ (iv) $I_{RT1} = \frac{\sqrt{k}V_m}{2R} = 4.24A$	01+02 02 01 02 02	12 min

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GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

END TERM FINAL EXAMINATION

Semester: Odd Sem. 2019 - 20
Course Code: ECE 302
Course Name: POWER ELECTRONICS
Program & Sem: B.Tech (ECE) & V (DE–II)

Date: 23 December 2019
Time: 9.30 AM to12.30 PM
Max Marks: 80
Weightage: 40%

Instructions:
(i) Read the all questions carefully and answer accordingly.
(ii) Question paper consists of 3 parts.
(iii) Scientific and Non-programmable calculators are permitted.

Part A [Memory Recall Questions]

Answer all the Questions. Each Question carries 2 marks. **(10Qx2M=20M)**

1. What are the applications of power electronics? (C.O.No.1) [Knowledge]
2. Mention various types of power converters? (C.O.No.1) [Knowledge]
3. What is the role of Snubber circuit in SCR? (C.O.No.1) [Knowledge]
4. What is inverter? (C.O.No.4) [Knowledge]
5. What is the range of output voltage in step-up chopper? (C.O.No.3) [Knowledge]
6. Classify control rectifiers? (C.O.No.2) [Knowledge]
7. What is the advantage of single phase full converter over semiconverter? (C.O.No.2) [Knowledge]
8. Write the output voltage equation for 1-Φ half bridge inverter? (C.O.No.4) [Knowledge]
9. Specify the reverse blocking voltage across each device in half bridge inverter? (C.O.No.4) [Knowledge]
10. Mention the applications of AC voltage controller? (C.O.No.2) [Knowledge]

Part B [Thought Provoking Questions]

Answer all the Questions. Each Question carries 6 marks. **(5Qx6M=30M)**

11. If two bulbs of 100 W and 150 W are connected in series across a 230V AC power supply. Specify which bulb glow brighter and why? (C.O.No.2) [Comprehension]

12. Explain how 1-Φ full bridge inverter can be used as step down chopper?
(C.O.No.4) [Comprehension]

13. How do you generate two pulses per half cycle in single pulse width modulation?
(C.O.No.4) [Comprehension]

14. Explain how power flow can be controlled in both direction in chopper?
(C.O.No.3) [Knowledge]

15. In power electronics, explain how low power circuit is isolated from high power circuit?
(C.O.No.1) [Knowledge]

Part C [Problem Solving Questions]

Answer all the Questions. Each Question carries 10 marks. (3Qx10M=30M)

16. A step up chopper has an input voltage of 220V and an output voltage of 600V. if the non-conducting time of the chopper is $100\mu s$. Calculate the pulse width. In case the pulse width is divided into two equal parts for constant frequency operation. Find the new output voltage.
(C.O.No.3) [Comprehension]

17. The half wave controlled rectifier has a purely resistive load of R and the delay angle is $\alpha = \pi/3$. Determine (i) η (ii) *FF* (iii) *RF* (iv) *TUF* (v) *PIV* (C.O.No.1) [Comprehension]

18. The 1- Φ half bridge inverter has a resistive load of 10Ω and the DC input voltage is 24V. Calculate (i) RMS output voltage (ii) Fundamental component of the output voltage (iii) First five harmonics of the output voltage (iv) Fundamental power consumed by the load (v) RMS power consumed by the load. (C.O.No.4) [Comprehension]

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

SCHOOL OF ENGINEERING

END TERM FINAL EXAMINATION

Extract of question distribution [outcome wise & level wise]

Q.NO	C.O.NO (% age of CO)	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels	Thought provoking type [Marks allotted] Bloom's Levels	Problem Solving type [Marks allotted]	Total Marks
			K	C	A	
1	1	1	2			2
2	1	1	2			2
3	1	1	2			2
4	4	4	2			2
5	3	3	2			2
6	2	2	2			2
7	2	2	2			2
8	3	3	2			2
9	4	4	2			2
10	2	2	2			2
11	1	1		6		6
12	4	4		6		6
13	4	4		6		6
14	2	2	6			6
15	1	1	6			6
16	3	3		10		10
17	1	1		10		10

18	4	4		10		10
	Total Marks		32	48		80

K =Knowledge Level C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

I hereby certify that all the questions are set as per the above guidelines.

Faculty Signature:

Reviewer Commend: Dr. LEVY. M

(1) Faculty Not signed
(2) Distribution of Mark. —,
(3) Thought provoking questions —— ?
(4) Step Mark — ?
(5) Question Numbering 1— 18 — ?

SCHOOL OF ENGINEERING

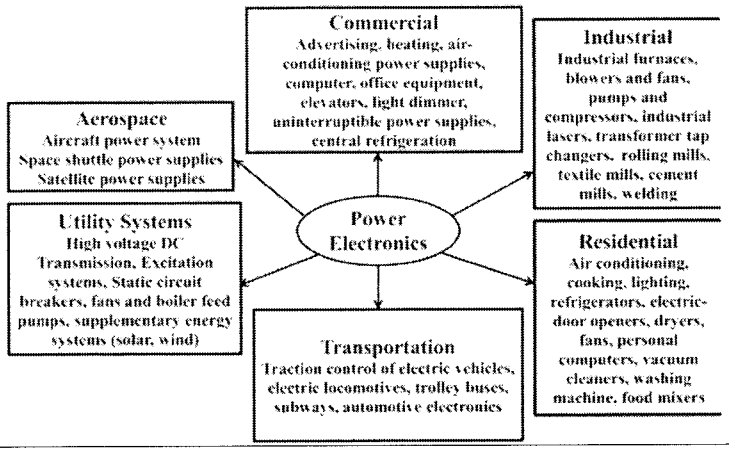
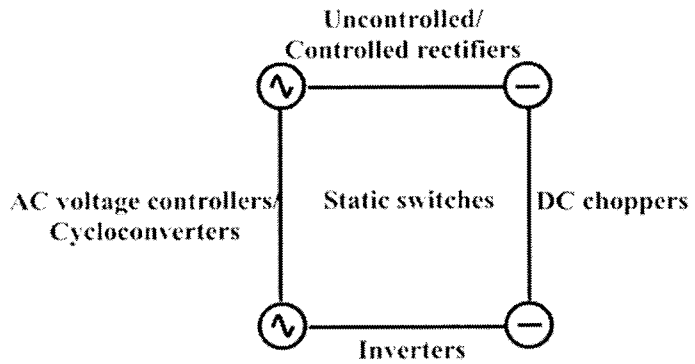
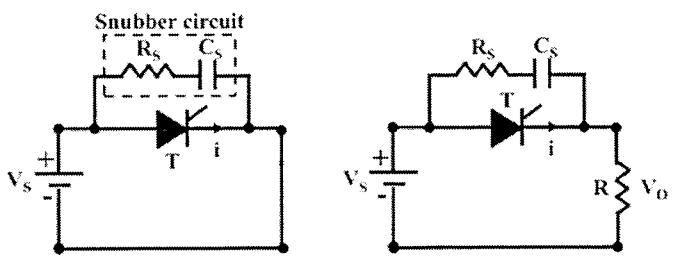
SOLUTION

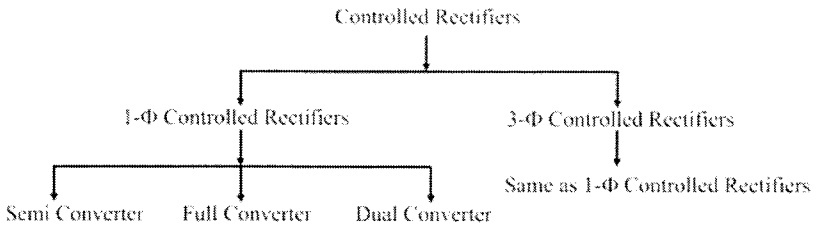
Semester: Odd Sem. 2019-20
Course Code: ECE 302
Course Name: POWER ELECTRONICS
Program & Sem: B.TECH & V

Date: 23.12.2019
Time: 3 HRS
Max Marks: 80
Weightage: 40%

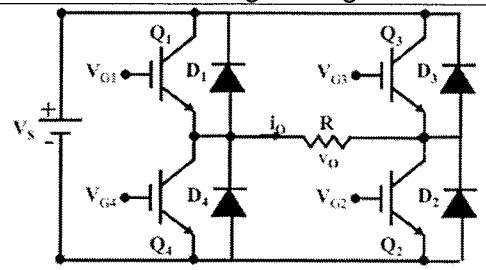
Part A

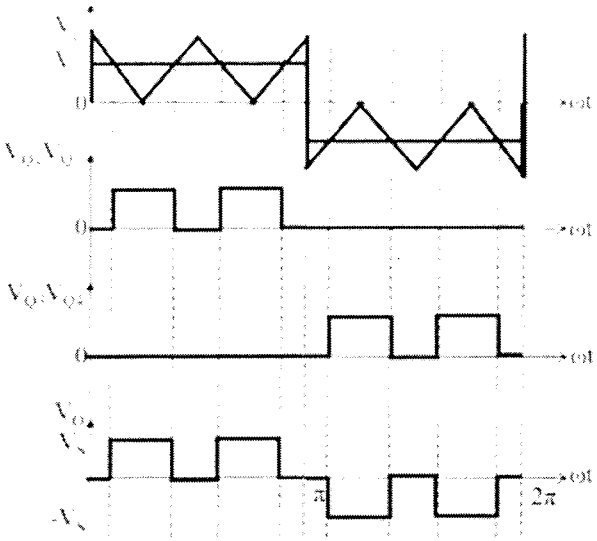
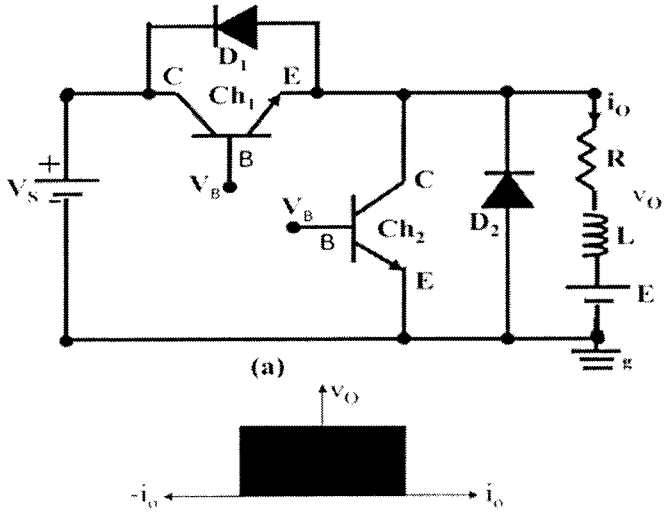
(10Q x 2M = 20Marks)

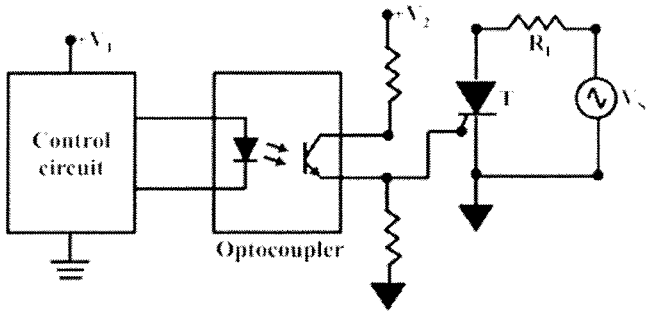
Q No	Solution	Scheme of Marking	Max. Time required for each Question
1		2	3min
2		2	3min
3	This can be avoided by using a Snubber circuit connected in parallel with the device as shown in Figure 	2	3min

	The Snubber circuit is a series combination of resistance R_S and capacitance C_S. When SCR is off C_S charges to a voltage equal to V_S. When SCR is on C_S discharges through SCR and sends current equal to $\frac{V_S}{R_S}$.		
4	Inverter is a power electronic converter that converts fixed DC input voltage to a symmetrical AC output voltage of desired magnitude and frequency. Inverters are also known as DC-AC converters.	**2**	**2min**
5	Vo=Vs/(1-K), if K=0 Vo=Vs If if K=1 Vo= □	**2**	**4min**
6		**2**	**4min**
7	Power flow is in both the direction i.e. from source to load and load to source	**2**	**2min**
8	Vo(average) = 0 and Vo(rms) = Vs/2	**2**	**1min**
9	reverse blocking voltage across each device in half bridge inverter is Vs/2	**2**	**2min**
10	These are used in (i) Transformer tap changer (ii) Induction heating (iii) Light intensity control (iv) Speed control of induction motor.	**2**	**1min**

Part B (5Q x 6M = 30 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
11	$P_{100W}=V^2/R_{100W}$, R_{100W}=529 Ω and R_{150W}=352.66 Ω I = 230/(881.66)=0.26 Power loss due to 100 W and 150 W $P_{100W}= I^2 R_{100W}$ = 36W $P_{150W}= I^2 R_{150W}$ = 23.83W Hence 100 W bulb glow brighter than 150 W bulb	2 2 1 1	**15min**
12	 In the above figure to operate single phase full bridge inverter turn-on both Q1 and Q2 at a time and	4 2	**15min**

	turn-off both Q3 and Q4 and vary the duty cycle		
13		2 1 1 2	**15min**
14	Power flow in both direction in chopper is done using class C chopper 	1 3 2	**20min**
15	In power electronics the control circuit works at lower voltages and currents (low power) and the power converter works at higher voltages and currents (high power). The control circuits are easily damaged if exposed to high power. Hence, isolation is necessary between control circuit and power converter to protect control circuit from high power. There are two ways of isolation (i) Pulse transformers (ii) Optocouplers	2 1	**15min**

		3	

Part C (3Q x 10M = 30Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
16	The relation between input and output voltage for step up chopper is $$V_o = V_s\left[\frac{1}{1-k}\right]$$ $$k = 0.63$$ But $k = \frac{t_1}{T}$ The pulse width of the o/p voltage is $t_1 = kT = kt_1 + kt_2 = \frac{kt_2}{1-k} = \frac{0.63\,X100X10^{-6}}{1-0.63} = 170\mu s$ $$T = t_1 + t_2 = 170\mu s + 100\mu s = 270\mu s$$ If the pulse width is divided into two equal parts $t_1' = \frac{t_1}{2} = 85\mu s$ For constant frequency chopper T remains constant and hence $T = t_1' + t_2'$ $$t_2' = T - t_1' = 270\mu s - 85\mu s = 185\mu s$$ New duty cycle $k' = \frac{t_1'}{T} = \frac{85\mu s}{270\mu s} = 0.3148$ The new output voltage is $$V_o' = V_s\left[\frac{1}{1-k'}\right] = 220\left[\frac{1}{1-0.3148}\right] = 321.07V$$	02 02 02 02 02	**20min**
17	(i) $\eta = \frac{P_{odc}}{P_{oac}} = \frac{P_{odc}}{P_{orms}} = \left(\frac{V_{odc}}{V_{orms}}\right)^2 = \left(\frac{\frac{V_m}{2\pi}(1+\cos\alpha)}{\frac{V_m}{2\sqrt{\pi}}\sqrt{\pi-\alpha+\frac{\sin 2\alpha}{2}}}\right)^2 =$	02	**20min**

	0.2833 (ii) $FF = \frac{V_{orms}}{V_{odc}} = 1.87$ (iii) $RF = 1.21$ (i) $TUF = 0.1432$ (ii) $PIV = V_m$	02 02 02 02	
18	$V_S = 24V$, $R = 10\Omega$ (i) $V_{orms} = \frac{V_S}{2} = 12V$ (ii) $v_{o1} = 0.45V_S = 10.8V$ (iii) We have $v_{on} = \frac{1}{\sqrt{2}}\frac{2V_S}{n\pi}$ $v_{o3} = 3.6V$, $v_{o5} = 2.16V$, $v_{o7} = 1.54V$, $v_{o9} = 1.2V$, $v_{o11} = 0.98V$ (iv) $P_{o1} = \frac{v_{o1}^2}{R} = 11.664W$ (v) $P_{orms} = \frac{V_{orms}^2}{R} = 14.4W$	 01 01 06 01 01	**20min**