REF. NO. : EX/PE/PC/B/T/225/2025

NAME OF THE EXAMINATION: B.E. POWER ENGINEERING SECOND YEAR SECOND SEMESTER - 2025

SUBJECT: DIGITAL AND POWER ELECTRONICS

TIME: 3 HOURS FULL MARKS: 100

COURSE OUTCOMES (CO)

CO1: Explain Number Systems-Binary, Hexadecimal and Decimal, 1's and 2's Complement Representations, Binary Arithmetic, Boolean Logic and Logic Gates, Simplification using K-Maps
CO2: Describe Sequential Logic and Flip Flops; Registers and Counters; Logic Family Characteristics and their Interfacing; 555 Timers in Different Modes
CO3: Describe the Working Principle of Semiconductor Devices Such as Thyristor, BJT, JFET, MOSFET etc.
CO4: Illustrate the Operation of Uncontrolled Rectifiers: Single-Phase, 3-Phase Bridge Rectifiers, Controlled Rectifiers: Single-Phase, 3-Phase Half Wave, Full Wave Bridge Circuits, Dual Converters, AC Voltage Controllers
CO5: Illustrate the Principle of Operation of Cycloconverter, DC Choppers, 1-Ph, 3-Ph Inverters

Attempt **ALL** questions

[1] Answer (a) and any TWO (2) questions from (b) – (e) **[4 + 2@8 = 20]** **[CO1]**

(a) *Choose the correct option(s)*

(i) The 12-bit 2's complement form of $(-65.5)_{10}$ is
a) 10111110.1000
b) 01000001.1000
c) 10111110.0111
d) 10111111.0

(ii) Convert the $(AB6)_{16}$ to decimal
a) 1166 b) 2572 c) 2742 d) 2992

(iii) An XOR gate produces an output only when its two inputs are
a) High b) Low c) Same d) Different

(iv) The Boolean equation for a NAND gate is
a) $\overline{AB} = C$
b) $\overline{A + B} = C$
c) $A + B = C$
d) $\bar{A} + \bar{B} = C$

(b) Convert $(92.35)_{10}$ to its binary equivalent using successive multiplication/division as the case may be. Write answer up to 4 decimal places.

(c) Subtract $(46)_{10}$ from $(19)_{10}$ using the 12-bit 2's complement arithmetic. Give final answer in decimal form.

(d) Simplify the Boolean expression $(A + \bar{B} + \bar{C})(A + \bar{B} + C)(A + B + \bar{C})$ using laws of Boolean algebra. Draw the simplified logic circuit.

(e) Express the Boolean function $F = XY + \bar{X}Z + Y\bar{Z}$ in a sum of min-terms form. Also find the max-terms in POS form of the same function.

[2] Answer (a) and any TWO (2) questions from (b) – (e) **[4 + 2@8 = 20]** **[CO2]**

(a) *Choose the correct option(s)*

(i) A J-K flip-flop is in the toggle mode when
a) J = 1, K = 0
b) J = 1, K = 1
c) J = 0, K = 1
d) J = 0, K = 0

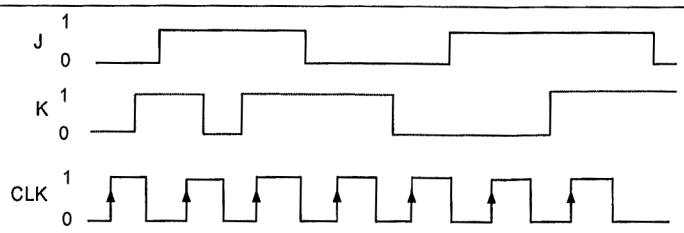
(ii) A 4-bit shift-left register is storing the nibble 1110. The nibble 0111 is waiting to be entered on the serial data-input line. After two clock pulses, the shift register is storing _____
a) 1111 b) 1101 c) 1001 d) 0011

(iii) A Mod-6 asynchronous counter can be designed with _____ number of T-Flip Flops. When the input clock frequency to such a counter is 30 Khz, its output frequency is _____ Hz.
a) 3, 10 b) 6, 500 c) 3, 5000 d) 2, 10000

(iv) The most obvious identifying feature of a TTL gate is its
a) Large fan-out
b) High power dissipation
c) Interconnected transistors
d) Multi-emitter input transistor

(b) What is the basic difference between a latch and an edge-triggered flip-flop?
Write the truth table for a positive edge-triggered J-K Flip-Flop. The following timing diagram shows the sequence of inputs in the terminals J, K, and CLK of a positive edge triggered JK Flip-Flop. Complete the diagram with corresponding output sequence Q in the same timing diagram.

[Turn over



(c) Draw and explain the operation of a 3-bit bidirectional SISO shift register using D flip flops while inputting the data **011** from left to right (MSB first) and then outputting it from right to left (LSB first).

(d) Design a Mod-5 Asynchronous counter using negative edge-triggered T-FFs. Explain its operation with the help of timing diagram, and write the corresponding truth table.

(e) Name and explain the three different pulse generating modes of an IC 555 timer.
You need to design a clock pulse generating circuit producing nearly 1.6 kHz frequency and nearly 60% duty cycle. The components available are: 555 IC, 12 V DC power supply, 0.1 μF, 0.01 μF, 0.02 μF, 1 μF, 10 kΩ, 15 kΩ, 18 kΩ, 25 kΩ, 30 kΩ, 36 kΩ, 48 kΩ, 60 kΩ . Choose proper components to design the circuit. Show proper calculation steps and draw the circuit (external connections only).
[Hint: $t_1 = 0.695(R_A + R_B)C_T$, $t_2 = 0.695R_BC_T$]

[3] Answer (a) and any TWO (2) questions from (b) – (e) **[4 + 2@8 = 20]** **[CO3]**

(a) *Choose the correct option(s)*

(i) In the forward blocking mode, the middle junction (J2) of a SCR has the characteristics of that of a:
a) Inductor b) capacitor
c) Diode d) transistor

ii) A TRIAC is basically a
a) 2-terminal switch
b) 2-terminal bilateral switch
c) 3 terminal unilateral switch
d) 3 terminal bidirectional switch

iii) In a thyristor di/dt protection is achieved through the use of
a) L in series with the thyristor b) R across thyristor
c) RC across thyristor d) RL across thyristor

iv) The two-transistor model of a SCR can be obtained by:
b) Bisecting the SCR vertically
c) Bisecting the SCR's middle two layers
d) Bisecting the SCR horizontally
e) Bisecting the SCR's two outer layers

(b) Why an SCR does not start to conduct immediately even when a positive voltage is applied to it? Explain how a gate pulse can make it conducting. Mark latching current, holding current, forward breakover voltage, and reverse breakdown voltage positions on the static V-I characteristics of a SCR.

(c) Explain with two transistor analogy of an SCR, how positive feedback action takes place during turn-on of an SCR.

(d) Why a SCR may get damaged due to high rate of change of voltage and current in it?
How di/dt and dv/dt protections are achieved in SCR? Explain with relevant circuit diagrams.

(e) What is commutation? Where are forced commutation circuits implemented?
Describe the Class C – Complementary commutation process for turning off a SCR.

[4] Answer (a) and any TWO (2) questions from (b) – (e) **[4 + 2@8 = 20]** **[CO4]**

(a) *Choose the correct option(s)*

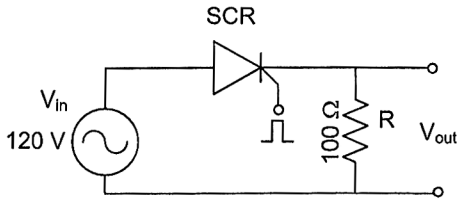
(i) If the firing angle in a SCR rectifier is reduced, average value of the output voltage is:
a) Increased b) decreased
b) remain unaffected
c) proportionately increased

(ii) In a single-phase full-wave controlled bridge rectifier, minimum and maximum output voltages are obtained at which firing angles?
a) 0^0, 180^0 respectively
b) 0^0, 90^0 respectively
c) 180^0, 0^0 respectively
d) 90^0, 180^0 respectively

(iii) A single-phase half wave AC line voltage controller consists of
a) one SCR in anti-parallel with one diode
b) one SCR is parallel with one diode
c) two SCRs in anti-parallel
d) two SCRs in parallel

(iv) At the output terminals of an AC line voltage controller:
a) variable ac with variable frequency is obtained
b) variable dc with fixed frequency is obtained
c) variable dc with variable frequency is obtained
d) variable ac with fixed frequency is obtained

(b) For the circuit shown below, if firing angle is 60^0, calculate the average voltage across the resistor R, and also calculate the average power at the output. Derive the necessary formula.



(c) What is the problem of current chopping in controlled rectifiers? How can it be avoided by the use of free-wheeling diodes?
Explain with proper waveforms, the operating principle of such a freewheeling diode for single-phase controlled half-wave rectifier circuit (assume that the nature of load is R-L and supply voltage is $V_m sin\omega t$).

(d) A single-phase AC-AC half-controller has a resistive load of R = 10 ohm and the input voltage is Vs = 120 V, 60 Hz. The delay angle of thyristor is $\alpha=\pi/2$.
Determine:
(a)The RMS value of output voltage
(b) The average input power factor
(c) The average input current
{Hint: $V_0 = \frac{V_m}{2}\sqrt{\frac{2\pi-\alpha+\frac{sin2\alpha}{2}}{\pi}}$, $V_{DC}= \frac{V_m}{2\pi}[cos\alpha - 1]$ }

(e) Draw the circuit diagram of a single-phase AC-AC full-wave controller.
Derive an expression for the average output voltage of such a controller circuit with firing angle α in the positive half cycle and firing angle β in the negative half cycle.

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[5] Answer (a) and any TWO (2) questions from (b) - (e) **[4 + 2@8 = 20]** **[CO5]**

(a) *Choose the correct option(s)*

(i) A single-phase center-tap transformer type cycloconverter uses _____
a) 2 SCRs
b) 2 SCRs + 2 Diodes
c) 4 SCRs
d) 3 SCRs + 3 Diodes

(ii) A In DC chopper, the waveform for input and output voltages are respectively
a) constant, variable
b) discontinuous, continuous
c) variable, constant
d) continuous, discontinuous

(iii) If T is the time period for a chopper circuit and D is its duty cycle, then the chopping frequency is
a) D/Ton
b) D/Toff
c) Ton/D
d) Toff/D

(iv) In a single-phase half-bridge VSI, _____ SCR(s)/SCR are/is gated at a time.:
a) 1
b) 2
c) 3
d) 4

(b) What is cycloconverter? Mention the applications of a cycloconverter.
With the help of circuit diagram and relevant waveforms explain the operation of a single-phase center-tapped transformer type cycloconverter.

(c) Explain with the help of circuit diagram, the principle of operation of step-up boost chopper.
Derive the expression of output voltage of such a chopper as a function of its duty cycle. What value of duty cycle can make the chopper to make output voltage to be double of the input voltage?

(d) A step-down buck chopper has a resistive load of R = 10Ω, and the input voltage is 200V. When the chopper is turned on, the voltage drop across the switch is 10 V. The chopping frequency is f = 1 kHz. If the duty cycle is 40%, determine (a) the average output voltage of the chopper (b) the average output current through the load, (c) ON time of the chopper switch, (d) OFF time of the chopper switch. Draw the relevant circuit diagram.

(e) What is an inverter? What are its application areas?
Explain how the voltage of a single-phase inverter can be controlled by different PWM techniques.

End of Question paper