B.Sc (HONS.) in ECE Part-III, Sixth Semester Examination, 2022
Subject: Power Electronics
Subject Code: ECE-530825
Examination Code: 5626
Duration: 3 Hours
Full Marks: 80

Question 1 Answer
(a) What is power electronics? Write down the application of power electronics. (4 marks)
Power Electronics (2 marks):
Power electronics is the branch of electrical engineering that deals with the conversion, control, and conditioning of electric power using electronic devices. It involves the use of semiconductor devices like diodes, thyristors, and transistors to manage power flow efficiently.
Applications (2 marks):
- Industrial motor drives (e.g., variable speed drives)
- Power supplies for computers and communication systems
- Renewable energy systems (solar inverters, wind turbines)
- Electric vehicles and battery chargers
- HVDC transmission systems

(b) **What is piezoelectric transducer? Write down the advantages and disadvantages of thermocouple.** *(6 marks)*
Piezoelectric Transducer (2 marks):
A piezoelectric transducer converts mechanical pressure or vibration into electrical signals using the piezoelectric effect. Materials like quartz or certain ceramics generate voltage when subjected to mechanical stress.
Advantages of Thermocouple (2 marks):
- Wide temperature range
- Fast response time
- Simple and rugged construction
- Inexpensive and easily replaceable

Disadvantages of Thermocouple (2 marks):
- Non-linear output
- Requires cold junction compensation
- Lower accuracy compared to RTDs
- Susceptible to noise in long-distance transmission

(c) **Explain the operation principle of LVDT with necessary figures.** *(6 marks)*
LVDT Principle (4 marks):
The **Linear Variable Differential Transformer (LVDT)** is an electromechanical transducer that converts linear displacement into an electrical signal.
- It consists of a primary coil centered between two secondary coils.
- A movable ferromagnetic core changes the magnetic coupling between the coils.

- When the core is centered, the voltages induced in the secondary coils are equal and opposite, resulting in zero output.
- Displacement of the core causes imbalance, producing a differential AC output proportional to the movement.

Great! Here's a **mark-wise structured answer** for **Question 2**, tailored to help you score full marks with clarity and precision:

Question 2 Answer

(a) Define SCR. Write down the operation principle of SCR. ***(6 marks)***

Definition of SCR (2 marks):

A **Silicon Controlled Rectifier (SCR)** is a four-layer, three-terminal semiconductor device used to control high power. It acts as a switch that can turn on or off the flow of current in a circuit. Terminals: **Anode**, **Cathode**, and **Gate**.

Operation Principle (4 marks):

- When a positive voltage is applied to the **anode** with respect to the **cathode**, the SCR remains **off** until a gate pulse is applied.
- A small gate current triggers the SCR into conduction mode.
- Once turned on, it continues conducting even if the gate signal is removed, as long as the anode current remains above the **holding current**.
- It turns **off** only when the anode current drops below the holding current (natural or forced commutation).

(b) Write down about different turn ON methods for SCR. ***(4 marks)***

Turn ON Methods (1 mark each):

1. **Forward Voltage Triggering:**
   Apply forward voltage across anode and cathode; SCR turns on when breakdown occurs.
2. **Gate Triggering:**
   Apply a small positive pulse to the gate terminal while forward biased.
3. **dv/dt Triggering:**
   A rapid change in voltage across the SCR can cause it to turn on due to capacitive effects.
4. **Temperature Triggering:**
   Excessive junction temperature can cause leakage current and trigger the SCR.

(c) Define UJT. Explain the operation principle of UJT. ***(6 marks)***

Definition of UJT (2 marks):

A **Unijunction Transistor (UJT)** is a three-terminal semiconductor device used mainly for triggering and timing applications. Terminals: **Emitter (E)**, **Base 1 (B1)**, and **Base 2 (B2)**.

Operation Principle (4 marks):

- UJT has a single PN junction and a resistive silicon bar between B1 and B2.
- When emitter voltage is less than the **peak point voltage**, the device is **off**.
- As emitter voltage increases and reaches the **peak point**, the PN junction becomes forward biased.

- This causes a sudden drop in emitter resistance, leading to **negative resistance** region and triggering conduction.
- Used in **relaxation oscillators**, **SCR triggering**, and **pulse generation**.

✅ Question 3 Answer

(a) What is DIAC? Explain the operation principle of DIAC with necessary diagrams. ***(5 marks)***

Definition of DIAC (2 marks)::A **DIAC (Diode for Alternating Current)** is a two-terminal, bidirectional semiconductor device that conducts current only after its **breakover voltage** is reached in either direction. It's commonly used to trigger TRIACs in AC circuits.

Operation Principle (2 marks):

- DIAC remains **non-conductive** until the applied voltage exceeds the breakover voltage.
- Once triggered, it conducts and allows current to flow.
- It turns off when the current drops below the **holding current**.

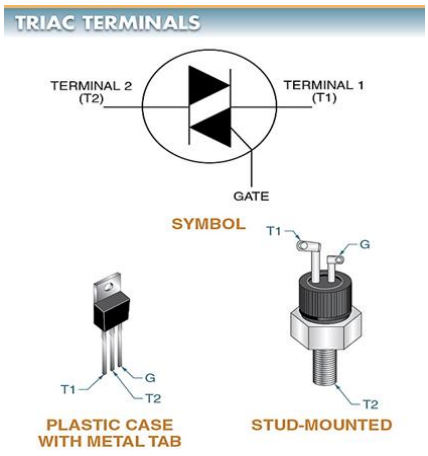
(b) What is PUT? What is the difference between SCR and TRIAC. ***(5 marks)***

Definition of PUT (2 marks):

A **Programmable Unijunction Transistor (PUT)** is a four-layer, three-terminal device similar to UJT but with programmable characteristics. Terminals: **Anode**, **Cathode**, and **Gate**. It's used in timing and triggering applications.

Difference between SCR and TRIAC (3 marks):

Feature	SCR	TRIAC
Terminals	Anode, Cathode, Gate	MT1, MT2, Gate
Conduction	Unidirectional	Bidirectional
Application	DC and controlled AC	AC control (both halves)
Triggering	Triggered in one direction	Triggered in both directions



(c) Explain the operation principle of TRIAC. ***(4 marks)***

TRIAC Operation Principle:

- TRIAC is a **bidirectional** device that conducts current in both directions when triggered.
- It consists of two SCRs connected in inverse parallel internally.
- Triggering is done by applying a gate pulse, regardless of polarity.
- Used in **AC power control**, such as dimmers, fan speed controllers, etc.

(d) Define GTO. ***(2 marks)***

GTO (Gate Turn-Off Thyristor):

A **GTO** is a type of thyristor that can be **turned on** by a gate pulse and **turned off** by applying a **negative gate signal**.

Unlike SCRs, GTOs don't need external commutation circuits for turn-off, making them useful in high-power switching applications.

✅ Question 4 Answer

(a) Single Phase Centre Tapped Step-Up Cycloconverter & Proof of (f_0 = 6f_s) *(6 marks)*

Operation Principle (4 marks):

- A **cycloconverter** converts AC power at one frequency to AC power at a lower or higher frequency without an intermediate DC stage.
- In a **single-phase center-tapped step-up cycloconverter**, two sets of controlled rectifiers are used to generate segments of the output waveform.
- The center-tapped transformer allows alternating conduction paths, producing multiple pulses per input cycle.
- By controlling the firing angles of the thyristors, segments of the input waveform are selected to synthesize a higher-frequency output.

Proof of (f_0 = 6f_s) (2 marks):

- For each input cycle, the cycloconverter can generate **6 output pulses** using controlled switching.
- Hence, the output frequency is:
  [f_0 = 6f_s]
  where (f_s) is the input frequency and (f_0) is the synthesized output frequency.

(b) Principle of Operation of Step-Down DC Chopper *(4 marks)*

Step-Down DC Chopper (Buck Converter):

- Converts a higher DC input voltage to a lower DC output voltage.
- Uses a **power semiconductor switch** (like a transistor or thyristor), a **diode**, and an **inductor**.
- When the switch is **ON**, energy is stored in the inductor.
- When the switch is **OFF**, the inductor releases energy to the load through the diode.
- Output voltage is controlled by adjusting the **duty cycle (D)**:
  [Vout = D \c.V_{in}]

(c) Single Phase Half-Wave Converter with Resistive Load and Delay Angle (\alpha = \frac{\pi}{2}) *(6 marks)*

Let's calculate the following:

(i) Efficiency (2 marks)

Efficiency (\eta) is the ratio of DC output power to input power.
For resistive load and (\alpha = \frac{\pi}{2}), conduction occurs for half the cycle.
[\eta = \frac{V_{dc}^2}{V_{rms}^2}]
Using derived values (approximate):
[\eta \approx 40.5%]

(ii) Form Factor (2 marks)

Form Factor = (\frac{V_{rms}}{V_{dc}})
For (\alpha = \frac{\pi}{2}):
[\text{Form Factor} \approx 1.56]
(iii) Ripple Factor (2 marks)
Ripple Factor =
[\sqrt{\left(\frac{V_{rms}}{V_{dc}} \right)^2 - 1}]
[\text{Ripple Factor} \approx 1.15]

Here's a **well-structured answer** for **Question 5**, broken down by subpart and mark allocation to help you maximize your score:

✅ **Question 5 Answer**
(a) PWM Inverter and Its Operation *(8 marks)*
Definition (2 marks):

- A **PWM (Pulse Width Modulation) inverter** is a type of inverter that converts DC to AC using high-frequency switching techniques to control the output voltage and frequency.
- It generates a **sinusoidal output** by modulating the width of pulses in the output waveform.

Working Principle (6 marks):

- The inverter uses **power semiconductor switches** (e.g., IGBTs or MOSFETs) to chop the DC input into a series of pulses.
- The **width of each pulse** is varied according to the amplitude of a reference sine wave.
- A **carrier wave** (usually triangular) is compared with the reference sine wave to generate switching signals.
- The output waveform is a **PWM signal**, which is filtered to approximate a sinusoidal AC output.
- **Advantages:**
    - Better harmonic performance
    - Precise control of output voltage and frequency
    - High efficiency and reduced losses

(b) Single Phase Full-Wave Controlled Rectifier *(6 marks)*

Operation Principle (3 marks):

- Uses **two thyristors** in a bridge configuration to convert AC to DC.
- Both halves of the AC cycle are used, with controlled firing angles (\alpha).
- Conduction occurs from (\alpha) to (\pi) in the positive half and (\pi + \alpha) to (2\pi) in the negative half.
- Output is a **pulsating DC** with controllable average voltage.

Average Output Voltage (2 marks):
For a purely resistive load: [V_avg = \frac{2V_m}{\pi} \cos(\alpha)]
where (V_m) is the peak input voltage and (\alpha) is the firing angle.
RMS Output Voltage (1 mark):
[V_{rms} = V_m \sqrt{\frac{1}{\pi} \left(\pi - \alpha + \frac{\sin(2\alpha)}{2} \right)}]

(c) Step-Up DC Chopper (Boost Converter) ***(5 marks)***
Operation Principle:

- Converts a **low DC input voltage** to a **higher DC output voltage**.
- Key components: **switch (transistor), diode, inductor, and capacitor**.

Working Steps:

1. **Switch ON:**
    - Current flows through the inductor, storing energy.
    - Diode is reverse-biased, load is supplied by the capacitor.
2. **Switch OFF:**
    - Inductor releases energy through the diode to the load.
    - Output voltage increases due to inductor's back EMF.

Output Voltage Equation:
[V_{out} = \frac{V_{in}}{1 - D}]
where (D) is the duty cycle ($0 < D < 1$).

Here's a clear and concise answer for **Question 6**, organized by subpart and mark allocation to help you score full marks:

✅ **Question 6 Answer**

(a) Difference Between DC and AC Motor ***(5 marks)***

Feature	**DC Motor**	**AC Motor**
Power Source	Direct Current (DC)	Alternating Current (AC)
Construction	Brushes and commutator required	Brushless (uses stator and rotor)
Speed Control	Easy via voltage variation	More complex (requires frequency control)
Maintenance	Higher due to brushes	Lower due to fewer moving parts
Applications	Used in variable speed drives, robotics	Used in fans, pumps, industrial machinery

(b) Phase Locked Loop (PLL) Control of DC Drives ***(5 marks)***
Principle of Operation:

- A **Phase Locked Loop (PLL)** is a control system that locks the phase of an output signal to a reference signal.
- In DC drives, PLL is used to **synchronize motor speed** with a reference frequency.

Working Steps:

1. A **tachogenerator** or encoder provides feedback on motor speed.
2. The PLL compares this feedback with a reference signal.
3. The **phase detector** generates an error signal based on phase difference.
4. This error is processed by a **loop filter** and used to adjust the motor control signal.
5. The motor speed is continuously adjusted to match the reference, ensuring **precise speed control**.

(c) Microprocessor-Based Motor Drive ***(3 marks)***

- A **microprocessor-based motor drive** uses a microprocessor or microcontroller to control motor operation.
- It handles tasks like **speed regulation, fault detection, PWM generation**, and **feedback processing**.
- Offers **programmability, flexibility**, and **intelligent control** for complex motor applications.

(d) Four Quadrant Converter ***(3 marks)*****:**A **four quadrant converter** allows control of motor in **all four quadrants** of operation:

1. **Forward motoring**
2. **Forward braking**
3. **Reverse motoring**
4. **Reverse braking**

- It enables both **directional control** and **regenerative braking**, making it ideal for applications like electric vehicles and robotics.

Question 6:**(i) Relaxation Oscillator:**A relaxation oscillator is a type of electronic oscillator that produces a **non-sinusoidal waveform**, such as a square wave or sawtooth wave.

- It works by **charging and discharging a capacitor** through a resistor, which causes periodic switching of a device like a transistor or op-amp.
- The timing of the waveform depends on the **RC time constant**.
- These oscillators are simple, low-cost, and commonly used in **timing circuits**, **flashing lights**, and **waveform generators**.

(ii) Temperature Transducer:A temperature transducer is a device that **senses temperature** and converts it into an **electrical signal**.

- It allows temperature measurement and control in electronic systems.
- Common types include:

    - **Thermocouples**: generate voltage based on temperature difference.
    - **RTDs (Resistance Temperature Detectors)**: change resistance with temperature.
    - **Thermistors**: have high sensitivity to temperature changes.
- Used in **industrial automation**, **HVAC systems**, **medical devices**, and **consumer electronics**.

(iii) IGBT (Insulated Gate Bipolar Transistor): An IGBT is a **power semiconductor device** that combines the advantages of a **MOSFET** and a **BJT**.

- It has **high input impedance** like a MOSFET and **high current handling** like a BJT.
- Controlled by a voltage signal at the gate terminal.
- Widely used in **motor drives**, **inverters**, **electric vehicles**, and **power supplies** due to its **high efficiency**, **fast switching**, and **low conduction losses**.

(iv) Freewheel Diode:A freewheel diode is used in circuits with **inductive loads** (like motors or coils) to provide a **path for current** when the main switch turns off.

- Prevents sudden voltage spikes caused by the collapsing magnetic field in the inductor.
- Protects switching devices like transistors or thyristors from damage.
- Essential in **DC chopper circuits**, **relay drivers**, and **motor control systems**.

(v) Optical Transducer: An optical transducer converts **light energy into electrical signals** or vice versa.

- Examples include:
    - **Photodiodes**: convert light into current.
    - **LEDs**: emit light when current flows.
    - **LDRs (Light Dependent Resistors)**: change resistance based on light intensity.
    - **Optocouplers**: isolate circuits using light transmission.
- Used in **automatic lighting**, **optical communication**, **barcode scanners**, and **safety systems**.

(vi) Schottky Diode:A Schottky diode is a special type of diode made using a **metal-semiconductor junction** instead of a p-n junction.

- It has a **low forward voltage drop** (typically 0.2–0.4 V) and **very fast switching speed**.
- Ideal for **high-frequency applications**, **power rectifiers**, and **clamping circuits**.
- Reduces power loss and improves efficiency in **switching power supplies**, **RF circuits**, and **solar inverters**.