GUJARAT TECHNOLOGICAL UNIVERSITY

BE-1 SEMESTER– PAPER SOLUTION – WINTER 2024

Subject Name & Code:
Basic Electronics Engineering- BE01000111

Marks

Q.1 **(a)** Explain working of Zener break down. **03**

Answer:
Working of Zener Breakdown
Zener breakdown occurs in a **heavily doped p-n junction diode** when it is **reverse biased**. Because of heavy doping, the **depletion region is very narrow**, and a **strong electric field** is developed across the junction even at low reverse voltages.
When the **reverse voltage reaches a critical value** known as the **Zener breakdown voltage (Vz)**, the electric field becomes strong enough to **break covalent bonds** and **release electrons**. These electrons tunnel from the valence band to the conduction band, a process known as **quantum mechanical tunneling**.
This results in a **sudden increase in reverse current**, while the voltage across the diode remains almost **constant** at Vz. This property is used in **Zener diodes** for **voltage regulation** in electronic circuits.

Important Points to Mention in the Answer:

- Occurs in reverse-biased, heavily doped p-n junction.
- Strong electric field across thin depletion layer.
- Electrons tunnel due to quantum effect (tunneling).
- Sharp increase in current, voltage remains constant (Vz).
- Used in Zener diodes for voltage regulation.

(b) Explain forward bias PN junction diode with diagram. **04**

Answer:

(c) Write a short note: V-I characteristic of P-N junction diode. **07**

Answer:
Short Note: V-I Characteristic of P-N Junction Diode
The **V-I (Voltage-Current) characteristic** of a **P-N junction diode** shows the relationship between the voltage applied across the diode and the current flowing through it. It is studied under two conditions: **Forward Bias** and **Reverse Bias**.
1. Forward Bias Condition:

- In forward bias, the **positive terminal** of the battery is connected to the **P-side** and the negative terminal to the **N-side**.
- As the forward voltage increases and crosses a certain threshold (called **cut-in or knee voltage**), the diode starts conducting.
- For **silicon diode**, this threshold voltage is approximately **0.7 V**, and for **germanium diode**, it is about **0.3 V**.
- After the knee voltage, the current increases rapidly with a small increase in

voltage.

2. Reverse Bias Condition:

- In reverse bias, the **positive terminal** is connected to the **N-side** and the negative terminal to the **P-side**.
- Only a very small leakage current (due to minority carriers) flows, which is almost constant.
- This continues until the reverse voltage reaches a certain high value known as **breakdown voltage**. Beyond this, the diode breaks down and conducts heavily, which may damage the diode if not protected.

4. Important Points:

- **Threshold voltage (V_k):** Minimum voltage to conduct in forward bias.
- **Reverse saturation current (I_0):** Small constant current in reverse bias.
- **Breakdown voltage:** Reverse voltage at which large current flows.

Q.2 (a) Why Zener diode can be used as voltage regulator? **03**

Answer:

A **Zener diode** is specially designed to operate in the **reverse breakdown region**. When connected in reverse bias and the applied voltage reaches the **Zener breakdown voltage (Vz)**, the diode starts conducting current while maintaining a **constant voltage** across its terminals.

This property of maintaining a nearly **constant output voltage** despite changes in input voltage or load current makes the Zener diode suitable for **voltage regulation**.

In a typical Zener voltage regulator circuit, the Zener diode is connected in parallel with the load. It **absorbs excess current** when the input voltage rises and **maintains voltage stability** across the load.

Key Points to Include:

- Zener operates in reverse breakdown region.
- Maintains constant voltage across load (Vz).
- Ideal for protecting circuits from voltage fluctuations.
- Commonly used in DC power supply regulation.

(b) Explain advantage and disadvantage of bridge rectifier over full wave rectifier. **04**

Answer:

🔹 **Bridge Rectifier:**

A bridge rectifier uses **four diodes** arranged in a bridge configuration to convert **AC to DC** using both halves of the input cycle.

✅ **Advantages of Bridge Rectifier over Full-Wave Rectifier:**

1. **No Center Tap Required:**
   - A bridge rectifier does **not require a center-tapped transformer**, making it more economical and simpler to construct.
2. **Better Transformer Utilization:**
   - In a bridge rectifier, the entire transformer secondary winding is used during both half cycles, improving **transformer efficiency**.
3. **Higher Output Voltage:**
   - Since both halves of the AC waveform are fully utilized, the **DC output is higher** than that of a center-tap full-wave rectifier with

the same input.

✅ **Disadvantages of Bridge Rectifier over Full-Wave Rectifier:**

1. **More Power Losses:**
    - The bridge rectifier uses **two diodes in each half-cycle**, resulting in **greater voltage drop** and **power loss** (due to two diode drops instead of one).
2. **Complex Design:**
    - Requires **four diodes** instead of two, making the circuit **slightly more complex and costlier** than a center-tap full-wave rectifier.

✅ **Conclusion:**
While a bridge rectifier offers **higher efficiency** and does not require a center-tap transformer, it comes at the cost of **higher diode losses**. Its compactness and practicality make it widely used in modern power supply circuits.

(c) Explain half wave rectifier with neat diagram and also draw the output waveform. **07**

Answer:
Half Wave Rectifier
A **half wave rectifier** is an electronic circuit that converts **alternating current (AC)** into **direct current (DC)** using a **single P-N junction diode**.

Working Principle:

- A **transformer** steps down the AC supply to the desired level.
- The **diode** is connected in series with the **load resistor (R_L)**.
- The AC supply is applied to the input terminals.

Working During Positive Half Cycle:

- During the **positive half cycle** of AC input, the **diode is forward biased** and conducts current.
- The **current flows through the load resistor**, and we get **output voltage** across R_L which follows the shape of the input.

Working During Negative Half Cycle:

- During the **negative half cycle**, the **diode becomes reverse biased** and does **not conduct**.
- So, **no current flows** through the load, and **output voltage is zero**.

Circuit Diagram of Half Wave Rectifier:

Input and Output Waveform:

Output Waveform

OR

(c) Explain the shunt and series clipping circuits with diagram. **07**

Answer:
Clipping Circuits:
Clipping circuits are used to **clip off (cut) a portion of the input signal** without distorting the remaining part of the waveform. They are also known as **limiters**.

Clipping circuits are broadly classified into:
1. **Series Clipping Circuits**
2. **Shunt Clipping Circuits**

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1. Series Clipping Circuit:
In a **series clipper**, the **diode is connected in series** with the load resistor. Depending on the orientation of the diode, it clips either the **positive** or **negative** half of the input waveform.
(a) Positive Series Clipper (Negative Clipping):
Circuit Diagram:

Operation:
- **Positive half-cycle**: Diode is **reverse biased**, acts as open circuit → Output = Input
- **Negative half-cycle**: Diode is **forward biased**, acts as short → Output = 0

Waveform:
- Output waveform will have the **negative half clipped**.

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2. Shunt Clipping Circuit:
In a **shunt clipper**, the **diode is connected parallel (shunt)** to the load resistor.
(b) Positive Shunt Clipper (Negative Clipping):
Circuit Diagram:

Operation:
- **Positive half-cycle**: Diode is **reverse biased** → No conduction → Output = Input
- **Negative half-cycle**: Diode is **forward biased** → Shorted to ground → Output = 0

Waveform:
- Output waveform has **negative part clipped** off.

Feature	Series Clipper	Shunt Clipper
Diode Position	In series with load	In parallel with load
Clipping Action	Depends on diode direction	Depends on diode direction
Output Clipping	One half-cycle is blocked	One half-cycle is shorted

Q.3 **(a)** Draw the symbol of PNP transistor and NPN transistor and explain why it is called ″Bipolar Transistor″? **03**

Answer:
Why it is Called a Bipolar Transistor:
It is called a **Bipolar Junction Transistor (BJT)** because **both types of charge carriers—electrons** and **holes**—are involved in its operation.
- In **NPN transistors**, electrons are the majority carriers.
- In **PNP transistors**, holes are the majority carriers.

The **current conduction** in a BJT takes place due to the **movement of electrons and holes**, making it a **bipolar** (two-pole) device, unlike **unipolar** devices like FETs, which use only one type of charge carrier.

(b) Explain solar cell with diagram. **04**

Answer:

◆ **Solar Cell (Photovoltaic Cell):**

A **solar cell** is a **semiconductor device** that **converts light energy (sunlight)** directly into **electrical energy** through the **photovoltaic effect**.

✅ **Construction:**

- Made from **semiconductor materials** like **silicon (Si)**.
- Consists of a **PN junction** formed between **p-type** and **n-type** silicon.
- A **transparent glass cover** protects the cell.
- **Metallic contacts** collect the current.

✅ **Working Principle:**

1. When **sunlight (photons)** strikes the **PN junction**, it **excites electrons** in the semiconductor.
2. **Electron-hole pairs** are generated.
3. The electric field at the **depletion region** drives electrons toward the **n-side** and holes toward the **p-side**.
4. This creates a **potential difference**, generating **DC voltage** and current when the circuit is closed.

Diagram of a Solar Cell:

Applications:

- Calculators, street lighting, satellites, solar panels in homes and industries.

✅ **Conclusion:**

A **solar cell** is an eco-friendly, renewable source of electricity. It is a key component in **solar energy systems** used for sustainable power generation.

(c) Draw the circuit of CB configuration of transistor and explain Input and output characteristics of CB configuration of transistor. **07**

Answer:

CB Configuration of Transistor (Common Base Configuration)

In the **common base (CB)** configuration, the **base terminal is common** to both input and output.

- **Input** is applied between **emitter and base**.
- **Output** is taken between **collector and base**.

Circuit Diagram of CB Configuration:

1. Input Characteristics (IE vs VEB at constant VCB):

- **Definition**: It is the graph plotted between **Emitter current (IE)** and **Emitter-Base voltage (VEB)**, keeping **Collector-Base voltage (VCB) constant**.

Observation:

- The input characteristics are similar to a **forward-biased diode**.
- For a small increase in VEB, emitter current IE increases rapidly.
- The input resistance is **low**.

Graph:

2. Output Characteristics (IC vs VCB at constant IE):

- **Definition**: It is the graph plotted between **Collector current (IC)** and **Collector-Base voltage (VCB)**, keeping **Emitter current (IE) constant**.

Observation:

- Collector current increases slightly with V_{CB} initially, then becomes **almost constant**.
- The output resistance is **very high**.
- The CB configuration has **current gain less than 1**, but **voltage gain is high**.

Graph:

Important Points:

- **Current gain (α) = IC / IE**, typically 0.95 to 0.99
- **Used in** high-frequency applications
- **Base is grounded** (common), hence the name *common base*

OR

Q.3 (a) Derive relationship between α dc and β dc of a transistor. **03**

Answer:

In a transistor:

- **A dc** is the **common-base current gain**, defined as:

αdc=IC/IE

- **β dc** is the **common-emitter current gain**, defined as:

$$\beta_{dc} = \frac{I_C}{I_B}$$

Now, we know that:

$$I_E = I_C + I_B \Rightarrow I_B = I_E - I_C$$

Substitute this in the expression of β_{dc}:

$$\beta_{dc} = \frac{I_C}{I_E - I_C}$$

Divide numerator and denominator by I_E:

$$\beta_{dc} = \frac{\frac{I_C}{I_E}}{1 - \frac{I_C}{I_E}} = \frac{\alpha_{dc}}{1 - \alpha_{dc}}$$

Final Relationship:

βdc=αdc/1−αdc

And conversely,

αdc=βdc/1+βdc

(b) Explain fixed bias and self bias in a transistor. **04**

Answer:

1. Fixed Bias (Base Bias):

◆ **Definition:**

In this method, a resistor is connected between the **base** of the transistor and the **positive supply (Vcc)** to provide the necessary base current.

- **Circuit Diagram:**

- **Characteristics:**

- **Base current (Ib)** is constant, determined by:

$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

- **Simple** in design and easy to understand.

- **Limitations:**

- Not stable with **temperature or β variations**.
- Not suitable for amplifier circuits.

✅ **2. Self Bias (Emitter Bias or Voltage Divider Bias):**

- **Definition:**

In this method, a **voltage divider network** is used to provide base bias. An **emitter resistor** adds stability by introducing negative feedback.

- **Circuit Diagram**

- **Characteristics:**

- Base voltage is obtained from **voltage divider (R1 and R2)**.
- The **emitter resistor (Re)** adds **stability** against temperature and β changes.

- **Advantages:**

- **Highly stable** operating point.
- Commonly used in **amplifier circuits**.

(c) Derive h parameters for transistor CE amplifier. Also Draw and explain h parameter equivalent model for CE amplifier. **07**

Answer:

Introduction to h-parameters:

h-parameters (hybrid parameters) are a set of four parameters used to describe the behavior of a **two-port linear network**, such as a transistor amplifier. For the **Common Emitter (CE) configuration**, these parameters relate input and output voltages and currents using a linear model.

General Form of h-parameter Equations (for CE):

In a two-port network, the **input voltage (V_1)** and **output current (I_2)** are expressed in terms of **input current (I_1)** and **output voltage (V_2)** as:

V1=h11I1+h12V2

I2=h21I1+h22V2

Where for **CE configuration**:

- V1=VBE: Input voltage (base-emitter)
- I1=IB: Input current (base current)
- V2=VCE: Output voltage (collector-emitter)
- I2=IC: Output current (collector current)

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h-parameters for CE configuration:

h-Parameter	**Symbol**	**Name**
Input Impedance	hie	Short-circuit input impedance
Reverse Voltage Gain	Hre	Reverse voltage transfer ratio
Forward Current Gain	Hfe	Current gain with shorted output

Output Admittance	Hoe	Output admittance

h-Parameter Equivalent Circuit for CE Amplifier:

Explanation of the Model:

- **Input side**:
  - The input is applied between **base and emitter**.
  - A resistor hie represents the **input impedance**.
  - A **dependent voltage source** or **current source** models the effect of the output on the input.
- **Output side**:
  - The output is taken from **collector to emitter**.
  - The current source hfeIB represents the **controlled current gain**.
  - A resistor (or admittance hoe) is connected across the output to represent **output conductance**.

Conclusion:

- The **h-parameter model** simplifies the small-signal analysis of the **CE amplifier**.
- It uses four parameters to represent input impedance, output admittance, and gains.
- It is widely used for **AC analysis** and designing amplifier circuits in electronics.

Q.4 (a) Draw voltage multiplier circuit. **03**

Answer:
Voltage Multiplier Circuit
A **voltage multiplier** is an electronic circuit that converts **AC voltage to a higher DC voltage** using a combination of **diodes and capacitors**. Common types include **doublers**, **triplers**, and **quadruplers**.
Below is the circuit diagram of a **Voltage Doubler** (the simplest and most commonly asked voltage multiplier):

Circuit Diagram of Voltage Doubler:

Explanation:

- During the positive half cycle, **C1 charges** through **D1** up to the peak AC voltage.
- During the negative half cycle, the AC source and C1 together **charge C2** through **D2**, adding their voltages.
- Thus, **C2 charges to nearly twice the peak voltage** of the AC input.

Conclusion:
This circuit multiplies the input AC voltage, providing a higher DC output without a transformer. It is called a **voltage multiplier** because it uses **diodes and capacitors** to **multiply the voltage level**.

(b) Explain FET as an Amplifier **04**

Answer:

- **FET (Field Effect Transistor) as an Amplifier:**

A **Field Effect Transistor (FET)** can be used as a **voltage amplifier** because it has **high input impedance** and **low output impedance**, making it ideal for amplifying weak signals.

✅ **Circuit Description:**

- The **input signal** is applied between **gate and source**.
- The **output** is taken between **drain and source**.
- A suitable **biasing arrangement** ensures the FET operates in the **active region**.

✅ **Working Principle:**

1. When a small **AC input signal** is applied to the gate, it modulates the **channel width** of the FET.
2. This causes a **change in drain current (Id)**.
3. The varying drain current produces a **proportional voltage drop** across the **drain resistor (Rd)**.
4. This gives an **amplified output signal** across Rd.

✅ **Diagram: Common Source FET Amplifier Circuit**

Key Features:

- High **input impedance** → does not load the previous stage.
- Used in **audio**, **RF**, and **instrumentation amplifiers**.
- Provides **voltage gain** without drawing much input current.

✅ **Conclusion:**

An FET acts as an efficient **voltage amplifier** due to its **voltage-controlled** nature and high input impedance. It is widely used in **low-noise and high-frequency applications**.

(c) Compare CE, CB and CC configuration with respect to different transistor. **07**

Answer:

Introduction:

Transistor can be connected in **three basic configurations**:

1. **Common Emitter (CE)**
2. **Common Base (CB)**
3. **Common Collector (CC)**

Each configuration has different characteristics in terms of input/output resistance, voltage/current gain, and phase relation.

📊 **Comparison Table:**

Parameter	**Common Emitter (CE)**	**Common Base (CB)**	**Common Collector (CC)**
Input Impedance	Medium (1 kΩ to 5 kΩ)	Low (50 Ω to 500 Ω)	High (greater than 100 kΩ)
Output Impedance	Medium	High	Low
Current Gain (β or α)	High (20 to 500)	Less than 1 (α ≈ 0.98)	High (≈ same as CE)
Voltage Gain	High	High	Less than 1
Power Gain	High	Medium	Medium
Phase Shift	180° (inverted output)	0° (no phase shift)	0° (no phase shift)
Application	General purpose	High frequency applications	Impedance matching

	amplifiers		(buffer stage)
Input Between	Base and Emitter	Emitter and Base	Base and Collector
Output Between	Collector and Emitter	Collector and Base	Emitter and Collector
Feedback Type	Negative	Positive	Negative

✅ **Conclusion:**

- **CE configuration**: Most widely used due to high **voltage gain**, **current gain**, and **power gain**.
- **CB configuration**: Used for **high-frequency** applications due to low input capacitance.
- **CC configuration**: Also known as **emitter follower**; mainly used for **impedance matching** because of high input and low output impedance.

OR

Q.4 (a) Explain in brief applications of JFET. **03**

Answer:

Applications of JFET (Junction Field Effect Transistor)

JFET is a **voltage-controlled device** with **high input impedance** and **low noise**, making it useful in many analog applications. Some important applications are:

1. **Amplifiers:**
    - JFETs are used in **small-signal amplifiers**, especially in **radio frequency (RF)** and **audio frequency (AF)** applications due to their low noise and high input impedance.
2. **Buffer or Impedance Matching:**
    - Due to high input and low output impedance, JFETs are used as **buffer amplifiers** to match impedances between high-resistance sources and low-resistance loads.
3. **Analog Switches:**
    - JFETs can be used as **electronic switches** in analog signal paths because of their ability to control current with a voltage.
4. **Voltage-Controlled Resistors:**
    - In the ohmic region, a JFET acts like a **voltage-controlled resistor**, useful in **automatic gain control (AGC)** circuits.
5. **Oscillator Circuits:**
    - JFETs are often used in oscillator circuits due to their **stable gain** and **low distortion** properties.

Summary of Key Points:

- Used in amplifiers (RF/AF).
- Acts as buffer due to impedance properties.
- Used in analog switching circuits.
- Behaves as voltage-controlled resistor.
- Suitable for oscillator and AGC circuits.

(b) Explain Transconductance and switching in FET. **04**

Answer:

1. Transconductance (g_m) in FET:

🔹 **Definition:**

Transconductance is the **measure of how effectively the gate voltage (Vgs)**

controls the drain current (Id) in a Field Effect Transistor (FET).

🔹 **Formula:**

$$gm=dId/dVgs$$

Where:

- gm = Transconductance (siemens or mho)
- Id = Drain current
- Vgs = Gate-to-source voltage

🔹 **Explanation:**

- It represents the **rate of change of drain current** with respect to **gate voltage**.
- Higher transconductance means **better amplification capability** of the FET.
- Depends on the **type and dimensions of the FET** and its **biasing conditions**.

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2. Switching in FET:

🔹 **Explanation:**

FETs can act as **electronic switches** by using **gate voltage** to control the **flow of current** between drain and source.

🔹 **Operation:**

- **ON State:** When a suitable gate voltage (V_{gs}) is applied, the channel **conducts**, and current flows between drain and source.
- **OFF State:** When gate voltage is removed or reverse-biased, the channel becomes **non-conductive**, and no current flows.

🔹 **Applications:**

- FETs are widely used as **switching devices** in:
  - Digital circuits (logic gates)
  - Analog signal processing
  - Power electronics (MOSFETs)

✅ **Conclusion:**

- **Transconductance (gm)** is a key parameter for the **amplification behavior** of FETs

(c) Compare the different characteristics of the following semiconductor devices: bipolar junction transistor, field-effect transistor. **07**

Answer:
Introduction:
A **Bipolar Junction Transistor (BJT)** and a **Field Effect Transistor (FET)** are both three-terminal semiconductor devices used for **amplification** and **switching** applications. However, they operate on different principles and have different electrical characteristics.

📊 **Comparison Between BJT and FET:**

Characteristic	BJT	FET
Full Form	Bipolar Junction Transistor	Field Effect Transistor
Type of Device	Current-controlled device	Voltage-controlled device
Charge Carriers	Both electrons and holes (bipolar)	Either electrons (n-channel) or holes (p-channel)
Input Impedance	Low (approx. 1 kΩ)	Very high (approx. >100 kΩ to MΩ)
Output Impedance	Medium	High
Control Terminal	Base	Gate

Main Current Flow	Between collector and emitter	Between drain and source
Input Current	Requires continuous input current (I_B)	No input current (ideal gate current ≈ 0 A)
Power Consumption	Higher	Lower
Thermal Stability	Less stable	More thermally stable
Switching Speed	Slower compared to FET	Faster switching
Noise Performance	Higher noise	Low noise
Size and Fabrication	Bulkier, less suitable for VLSI	Smaller, better suited for integrated circuits
Applications	Low-frequency amplifiers, switching, analog circuits	RF amplifiers, buffer amplifiers, digital circuits

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✅ **Conclusion:**

- **BJT** is preferred where **high gain** and **linear amplification** are required.
- **FET** is widely used in modern electronic circuits due to its **high input impedance**, **low power consumption**, and **suitability for integration** in ICs.

Q.5 (a) Explain the AC load line of transistor. **03**

Answer:
AC Load Line of Transistor
The **AC load line** represents the behavior of a transistor amplifier when an **AC signal** is applied. It shows how the **collector current (IC)** and **collector-emitter voltage (VCE)** vary due to the **AC input signal**, superimposed on the **DC operating point** (Q-point).

Definition:
The **AC load line** is a straight line drawn on the output characteristics of a transistor, showing all possible instantaneous values of **IC** and **VCE** when both **AC and DC signals** are present.

Equation of AC Load Line:

$$VCE=VCC-IC\cdot RAC$$

Where:

- VCE: Collector-emitter voltage
- VCC: Supply voltage
- IC: Collector current
- RAC: Total AC load (includes collector resistor and load connected to the output)

Explanation:

- The **AC load line** is steeper than the **DC load line** if additional load is connected.
- It passes through the **Q-point** (quiescent point).
- It helps determine the **maximum undistorted output swing** of the amplifier.

Importance:

- It helps in analyzing the **dynamic (AC) response** of a transistor amplifier.
- Ensures that the transistor remains in the **active region** during signal amplification.
- Aids in proper **biasing and signal design** for amplifiers.

(b) Explain E-type MOSFET with neat diagram. **04**

Answer:
E-Type MOSFET (Enhancement-Type MOSFET):
An **Enhancement-type MOSFET (E-MOSFET)** is a type of Metal-Oxide-Semiconductor Field Effect Transistor that **does not conduct** at zero gate voltage. It requires a **positive gate-to-source voltage (VGS)** for an **n-channel** type (or negative for p-channel) to induce a channel and allow current flow.

✅ **Construction:**
- Made using **silicon substrate** (p-type for n-channel).
- No physical channel exists initially.
- A **thin oxide layer** is grown over the substrate, and a **metal gate** is deposited over it.
- **Source and drain terminals** are heavily doped **n+** regions for n-channel type.

✅ **Working Principle:**
1. **At VGS = 0:**
   - No channel exists; the MOSFET is **OFF**.
   - No current flows between drain and source.
2. **When VGS > Vth (threshold voltage):**
   - An **inversion layer** (n-type channel) is formed beneath the gate.
   - Current starts flowing from **drain to source** through the induced channel.
   - The **drain current (ID)** increases with increase in VGS.

Symbol of n-channel E-MOSFET:

Applications:
- Used in **digital switching**, **CMOS logic circuits**, **amplifiers**, and **power electronics** due to high input impedance and fast switching.

(c) Write a short note on Tunnel diode. **07**

Answer:
Introduction:
A **tunnel diode** is a special type of **highly doped P-N junction diode** that exhibits **negative resistance** due to a quantum mechanical effect called **tunneling**. It was invented by **Leo Esaki** in 1958 and is also known as the **Esaki diode**.

✅ **Construction:**
- Tunnel diode is made by **heavily doping** both the **P-type and N-type** regions (about 1000 times more than a regular diode).
- Due to heavy doping, the **depletion layer is very narrow**, typically less than **10^{-6} cm**.

✅ **Working Principle:**
- The **operation** of the tunnel diode is based on **quantum tunneling**.
- Under **small forward bias**, electrons **tunnel** through the narrow depletion region, resulting in a sudden increase in current.

- As voltage increases further, the **current decreases**, creating a region of **negative resistance**.
- After that, normal forward conduction resumes.

✅ **V-I Characteristics:**

- The V-I curve has three regions:
    1. **Forward bias region** with **positive resistance**.
    2. **Negative resistance region** (most important and unique).
    3. **Forward conduction region** similar to a normal diode.

- **Peak Current (I-P)**: Maximum current before negative resistance.
- **Valley Current (I-V)**: Minimum current after which normal conduction begins.
- **Negative Resistance Region**: Useful in high-speed and microwave applications.

✅ **Applications:**

- **High-frequency oscillators**
- **Microwave amplifiers**
- **Fast switching circuits**
- **Logic memory storage**
- **Pulse and oscillator circuits**

✅ **Advantages:**

- Very **fast switching speed**
- Can operate at **GHz frequency range**
- **Low power consumption**

✅ **Disadvantages:**

- **Low output power**
- **Limited current and voltage handling**
- Complex to fabricate

✅ **Conclusion:**

A **tunnel diode** is a unique device with **negative resistance characteristics**. Though not commonly used in general-purpose electronics, it plays a vital role in **microwave and high-speed digital applications** due to its **quantum tunneling behavior** and **fast response**.

OR

Q.5 **(a)** What is DC load line? Explain with necessary diagram. **03**

Answer:
What is DC Load Line?
The **DC load line** is a straight line drawn on the **output characteristics** of a transistor, which shows all possible combinations of **collector current (IC)** and **collector-emitter voltage (VCE)** for a given **DC bias condition** when no input signal is applied.

Explanation:
For a transistor amplifier, applying **Kirchhoff's Voltage Law (KVL)** to the collector circuit:

$$VCC=IC\cdot RC+VCE$$

Rewriting:

$$VCE = VCC - IC \cdot RC$$

This is the equation of a straight line and is called the **DC load line**.

- It intersects the **VCE axis** when $IC = 0 \Rightarrow VCE = VCC$
- It intersects the **IC axis** when $VCE = 0 \Rightarrow IC = VCC/RC$

These two points are used to draw the line on the output characteristic curves.

DC Load Line Diagram:

Importance of DC Load Line:

- It helps determine the **Q-point** (quiescent or operating point) of the transistor.
- Ensures the transistor works in the **active region** for amplification.

(b) Explain D-type MOSFET with neat diagram. **04**

Answer:

◆ **D-Type MOSFET (Depletion-Type MOSFET):**

A **Depletion-type MOSFET (D-MOSFET)** is a type of MOSFET that **conducts even when the gate-to-source voltage (V GS) is zero**. It has a **physical channel** already present between the source and drain terminals.

It operates in **two modes**:

- **Depletion Mode** (negative V GS) → reduces current
- **Enhancement Mode** (positive V GS) → increases current

✅ **Construction:**

- Built on a **p-type substrate** for **n-channel D-MOSFET**.
- An **n-type channel** is already diffused between source and drain.
- A **thin insulating SiO_2 layer** is placed between the **metal gate** and the channel.
- Source and drain are heavily doped **n⁺** regions.

✅ **Working Principle:**

- **At V GS = 0 V**: The MOSFET is **ON**, and current flows through the n-type channel.
- **If V GS is negative**: The channel becomes **depleted** of carriers, and **drain current (I D) decreases**.
- **If V GS is positive**: More carriers are induced into the channel, and **I D increases**.

✅ **Symbol of n-channel D-MOSFET:**

Applications:

- Used in **analog switches**, **amplifiers**, **RF circuits**, and **oscillators**.
- Suitable for **low-noise and high-frequency applications**.

(c) Write a short note on seven segment display with diagram. **07**

Answer:

Introduction:

A **seven-segment display** is an electronic display device used to display **decimal numerals (0 to 9)** and some **alphabetic characters**. It is commonly used in **digital clocks**, **calculators**, **measuring instruments**, and other electronic display systems.

✅ **Construction:**

- A seven-segment display consists of **seven LED segments** arranged in the shape of the number **"8"**.
- Each segment is labeled as **a, b, c, d, e, f, g**.
- An **additional 8th segment**, called the **decimal point (dp)**, may also be present.

✅ **Diagram**

Types of Seven Segment Display:

1. **Common Anode (CA):**
   - All **anodes** of LEDs are connected together.
   - To glow a segment, the **cathode** is connected to **LOW (0V)**.
2. **Common Cathode (CC):**
   - All **cathodes** of LEDs are connected together.
   - To glow a segment, the **anode** is connected to **HIGH (5V)**.

✅ **Working:**

- Each segment is an individual **LED**.
- To display a number, specific segments are **turned ON or OFF**.
- Example: To display digit **2**, segments **a, b, g, e, d** are turned ON.

✅ **Example: Digit Representation**

Digit	Segments ON
0	a, b, c, d, e, f
1	b, c
2	a, b, g, e, d
3	a, b, c, d, g
4	f, g, b, c
5	a, f, g, c, d
6	a, f, e, d, c, g
7	a, b, c
8	a, b, c, d, e, f, g
9	a, b, c, d, f, g

✅ **Applications:**

- Digital clocks
- Calculators
- Electronic meters
- Instrument panels
- Timers and counters

✅ **Conclusion:**

A **seven-segment display** is a simple and efficient way to **visually represent numbers** in electronic circuits. It is easy to use, low in power consumption, and ideal for **digital display systems**.

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