Report

CHAPTER 1

Introduction

- A **tunnel diode** is a type of semiconductor diode characterized by its ability to operate at very high frequencies due to the quantum mechanical effect known as **tunneling**. Unlike regular diodes, tunnel diodes are **heavily doped** on both the p-type and n-type sides, which results in a very narrow **depletion region**. Because of this, electrons can "tunnel" through the junction even when the applied voltage is very low. This unique property allows the tunnel diode to conduct current almost instantaneously.

- One of the most important characteristics of a tunnel diode is the presence of **negative resistance** in its current-voltage (I-V) curve. In a specific voltage range, as the voltage increases, the current actually decreases — this is the region of negative resistance. This unusual behavior is what makes tunnel diodes useful in **oscillators, high-frequency amplifiers**, and **microwave circuits**. Their speed and low power consumption make them suitable for applications where conventional diodes and transistors might fall short.

- Although tunnel diodes are not as widely used today due to the rise of newer and more efficient semiconductor devices, they still find use in specialized fields that demand **ultra-fast response times** and **high-frequency performance**. Invented by **Leo Esaki** in 1957, the tunnel diode played an important role in the development of high-speed electronics and remains a significant milestone in semiconductor device history.

CHAPTER 2

Objectives

- The main objective of a tunnel diode is to utilize the principle of quantum tunneling to achieve extremely fast switching speeds and efficient operation at very high frequencies. Due to its heavily doped p-n junction, the depletion region becomes very narrow, allowing electrons to tunnel through the junction even at very low forward bias voltages. This tunneling effect results in a region of **negative resistance** in the current-voltage characteristic of the diode, which is not found in conventional diodes.

- This unique property enables the tunnel diode to function effectively in high-frequency applications such as microwave oscillators, high-speed amplifiers, and ultra-fast switching circuits. It is especially useful in electronic systems that require rapid response and low power consumption. Although its usage has declined with the development of advanced semiconductor technologies, the tunnel diode still plays a crucial role in niche areas where speed and frequency performance are critical

CHAPTER 3

FLOWCHART

CHAPTER 4

Theory

A **Junction Field Effect Transistor (JFET)** is a voltage-controlled device that regulates current by applying a voltage to the gate terminal. The **2N4416** is an **N- channel JFET** widely used in analog electronics.

Key Parameters of Tunnel Diode:

- **I (Current):** The flow of charge through the diode.
- **V (Voltage):** The voltage applied across the diode terminals.
- **V_{peak}:** Voltage at which the current is maximum.
- **I_{peak}:** Maximum current the diode conducts.
- **V_{valley}:** Voltage at which the current is minimum after the peak.
- **I_{valley}:** Minimum current in the negative resistance region.
- **Negative Resistance Region:** Region where current decreases as voltage increases.

V-I Characteristics:

The Tunnel Diode has a unique V-I characteristic with a region of **negative resistance** due to quantum tunneling.

1. **Forward Bias Characteristics (I vs V):**
   • Shows the variation of current (I) with increasing forward voltage (V).
   • The curve includes three key regions:
   ▪ **Forward Conduction Region:** Current increases with voltage up to a peak point (I_{peak}, V_{peak}).
   ▪ **Negative Resistance Region:** After the peak, current decreases with increasing voltage until the valley point (I_{valley}, V_{valley}).
   ▪ **Positive Resistance Region:** Beyond the valley, current increases again like a normal diode.

2. **Reverse Bias Characteristics:**
   • Under reverse bias, the diode conducts a small current similar to a regular diode until breakdown.
   • Due to heavy doping, the breakdown occurs at relatively low reverse voltage.

PSpice Simulation:

• PSpice is a circuit simulation tool used to analyze and visualize the behavior of electronic components.
• A tunnel diode model (e.g., 1N3716) can be used in the simulation to study its V-I characteristics.

• Simulation helps in observing the unique negative resistance region without the need for a physical circuit.

1. Tunnel Diode Basics Recap:

• A tunnel diode is a heavily doped p-n junction device that shows negative resistance due to quantum tunneling.
• It conducts current at very low voltages and is useful in high-speed and microwave applications.
• The key feature of a tunnel diode is its ability to operate in the negative resistance region, which can be seen clearly in the simulated V-I curve.

---

1. Types of Characteristics Studied

A. **Forward V-I Characteristics:**

- Shows the current flow as the forward voltage increases.
- Includes the peak point, negative resistance region, and valley point.

B.**Negative Resistance Region:**

- A unique region where current decreases as voltage increases.
- Important for applications like oscillators and amplifiers.

C. **Reverse Characteristics:**

- Displays the current behavior under reverse bias.
- Shows low reverse breakdown voltage due to heavy doping.

D.**Dynamic Resistance:**

- The slope of the V-I curve at any point (dV/dI).
- Can be positive or negative depending on the region.

E.**Conductance Characteristics:**

- Indicates how well the diode conducts in different voltage regions.

---

2. PSpice Simulation Setup

1. Write SPICE Code:
    a. Define the circuit components (resistors, sources, etc.).
    b. Set up the simulation (e.g., transient, DC sweep).
    c. Use the .plot command to specify the variables (voltage and current) you want to graph.
2. Save SPICE Netlist:
    a. Save the code with a .cir extension (e.g., circuit.cir).
3. Run the Simulation:
    a. Open the SPICE software (e.g., PSpice).
    b. Load the .cir file.

c. Run the simulation.

4. Generate V-I Graph:
   a. The graph will be generated automatically based on the .plot command in the SPICE code.
   b. View the results in the simulation output window.
5. Interpret the Graph:
   a. The V-I graph will display the voltage and current relationship based on the simulation

---

3. Expected Results

1. **Output Characteristics (V-I Curve):**
   - N-shaped curve.
   - Current increases to a peak (Ip), then decreases (negative resistance), then rises again.
   - Negative differential resistance between peak and valley.
2. **Transfer Characteristics:**
   - Sharp current rise at low voltage.
   - Peak at Vp, minimum at Vv.
   - Shows negative resistance region between Vp and Vv.

---

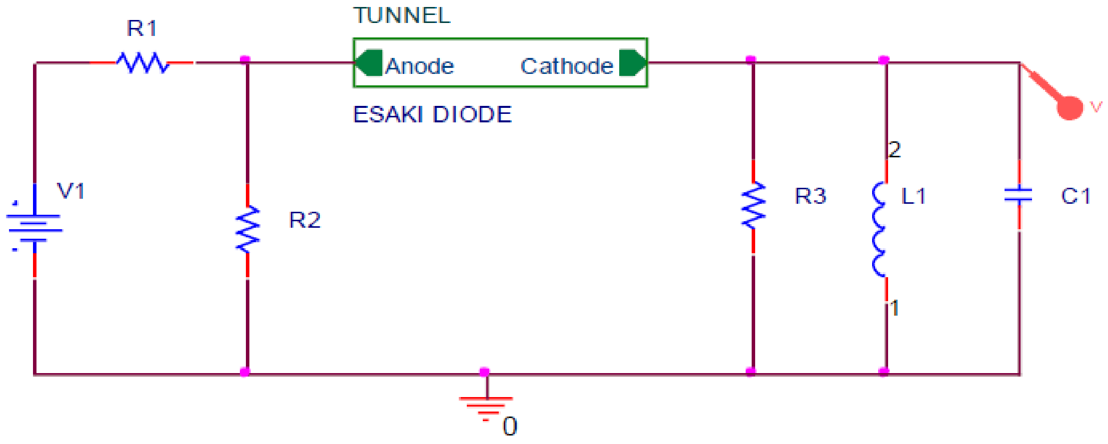
4. Applications of V/I Characterization

- Designing **high-speed oscillators** and **microwave frequency circuits**.
- Utilizing the **negative resistance region** for amplifiers and switching.
- Understanding **peak and valley points** for proper biasing.
- Verifying tunnel diode behavior before practical implementation.

CHAPTER 5

Circuit Diagram & Simulation Procedure

Circuit Diagram :



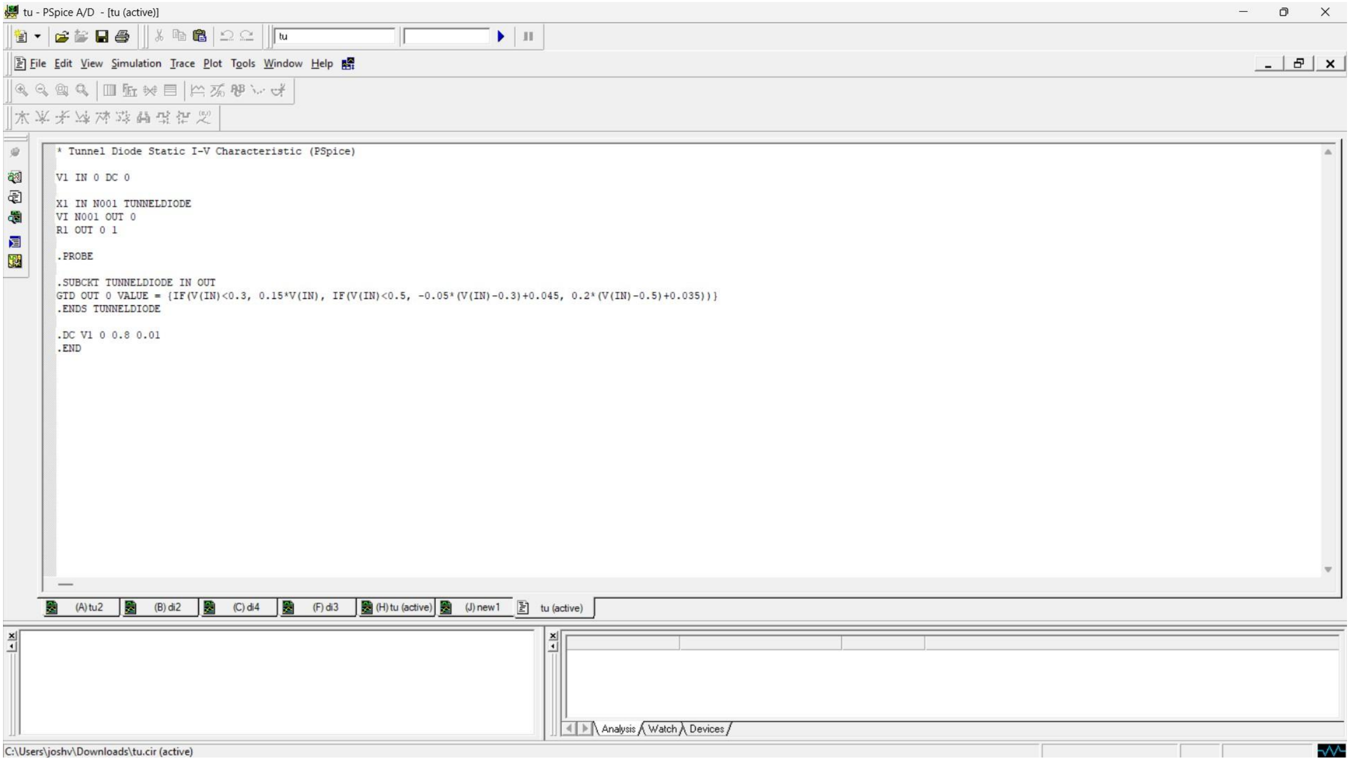
Simulation Procedure :

1. Launch PSpice and create a new project.
2. Place a tunnel diode model (use a custom model if not in library).
3. Connect a voltage source (V) in series with the tunnel diode.
4. Place a small series resistor (e.g., 1Ω) to measure current.
5. Ground the negative terminal of the voltage source.
6. Insert a DC sweep for the voltage source (e.g., 0V to 1V) to observe I-V behavior.
7. Use a .model statement for the tunnel diode if required (e.g., .model TUNNEL D(IS=1n, N=1, Rs=0.1, BV=1.5)).
8. Run the simulation and plot the I-V curve (current through diode vs voltage across diode).

CHAPTER 6

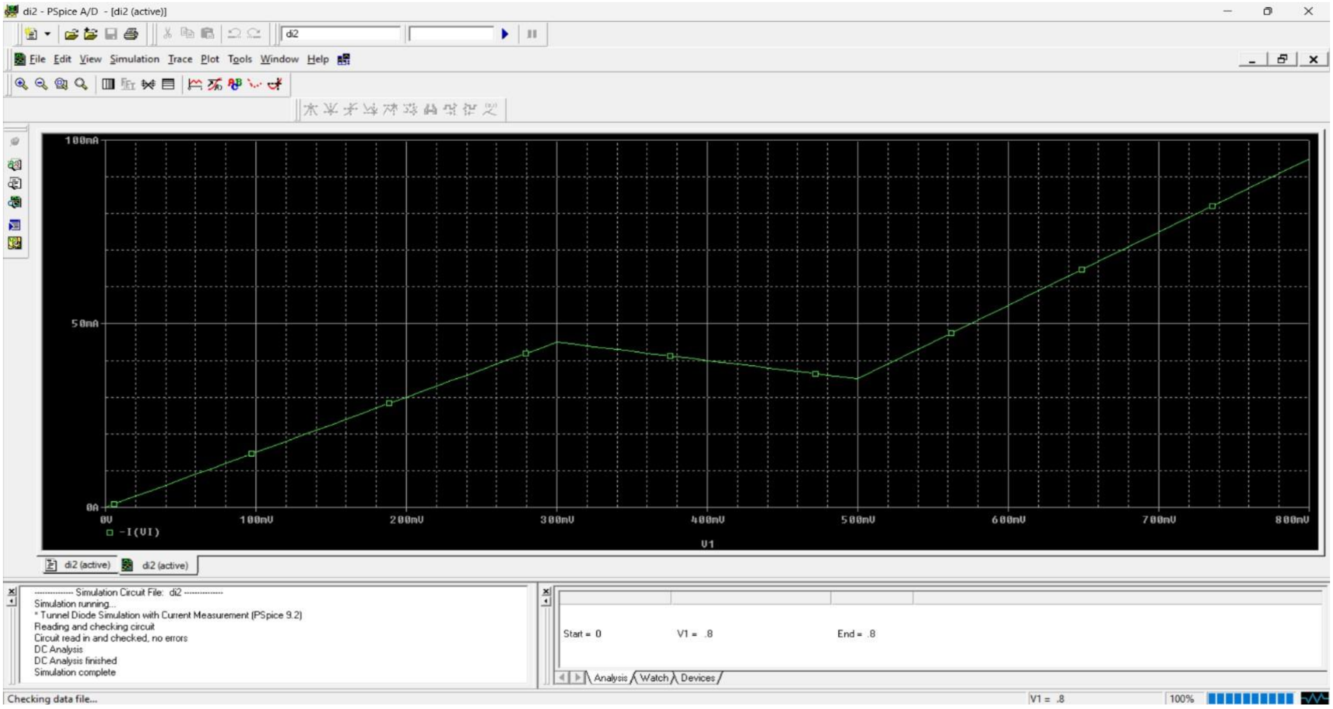
Pspice Coding & Diagram

Simulation Program 1 :

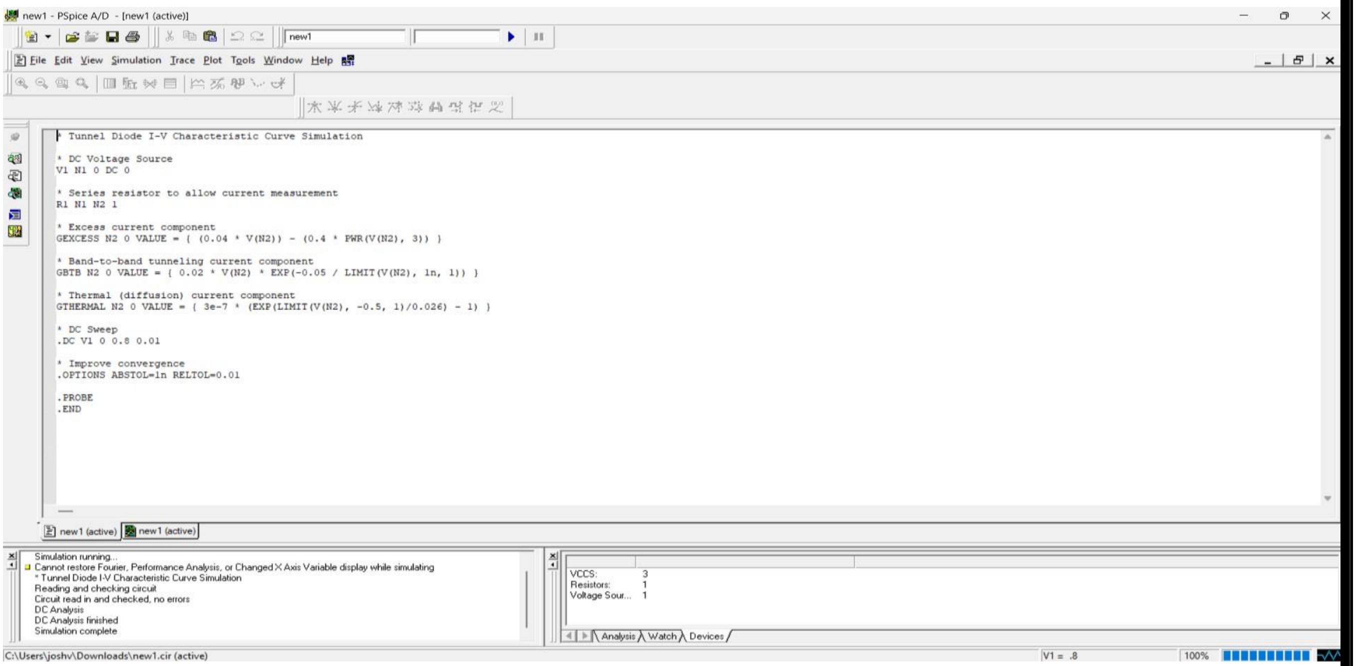


```
* Tunnel Diode Static I-V Characteristic (PSpice)

V1 IN 0 DC 0

X1 IN N001 TUNNELDIODE
VI N001 OUT 0
R1 OUT 0 1

.PROBE

.SUBCKT TUNNELDIODE IN OUT
GTD OUT 0 VALUE = {IF(V(IN)<0.3, 0.15*V(IN), IF(V(IN)<0.5, -0.05*(V(IN)-0.3)+0.045, 0.2*(V(IN)-0.5)+0.035))}
.ENDS TUNNELDIODE

.DC V1 0 0.8 0.01
.END
```

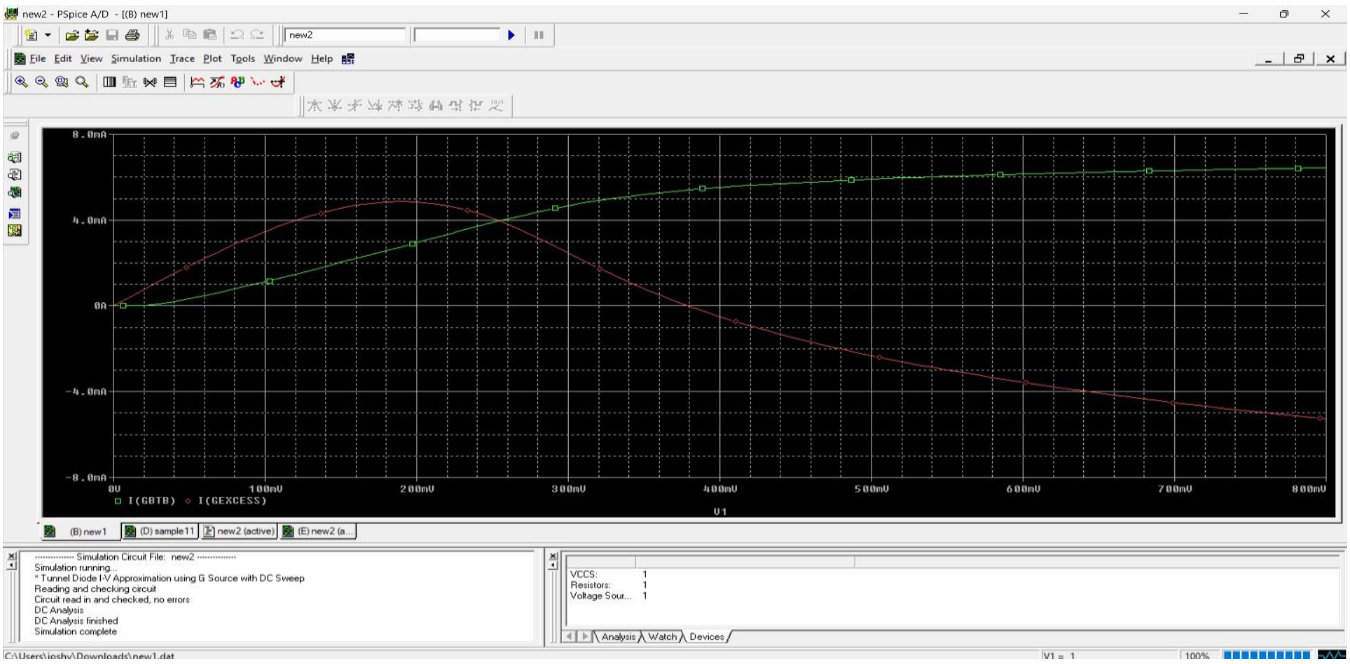
Simulation Graph 1 :



Simulation Program 2 :



Simulation Graph 2 :



CHAPTER 7

Result & Conclusion

Result :

The simulation of the **Tunnel Diode** was successfully carried out using **PSpice**. The following observations were made:

Output Characteristics (I vs V at varying voltage levels):

- **As voltage increased, current rose rapidly to a peak value (Ip), then decreased (negative resistance region), and finally increased again beyond the valley voltage (Vv).**
- **The negative differential resistance region was clearly observed between the peak and valley points.**
- **The behavior confirmed the unique nonlinear conduction of the tunnel diode.**

Transfer Characteristics:

- **The I-V curve showed a sharp increase in current at low forward voltages.**
- **A distinct peak current (Ip) was followed by a dip (valley current Iv), then a gradual rise as the diode entered the normal conduction region.**
- **This validated the quantum tunneling effect that defines tunnel diode operation**

Conclusion :

1. In this experiment, the **V/I characteristics of a Tunnel Diode** were successfully simulated using **PSpice**. The **output (I vs V)** and **transfer characteristics** were obtained and analyzed.
2. The results confirmed the unique behavior of a tunnel diode:
    1. The current increased to a **peak (Ip)**, then decreased in the **negative resistance region**, and increased again after the **valley point (Vv)**.
    2. The diode's **nonlinear I-V response** is due to **quantum tunneling**, characteristic of this device.
    3. The presence of a **negative differential resistance** region makes the tunnel diode suitable for high-frequency and fast-switching applications.
3. The simulation provided insight into the **working principles** of tunnel diodes and validated the accuracy of PSpice in analyzing **nonlinear semiconductor behavior**, all without requiring physical hardware.