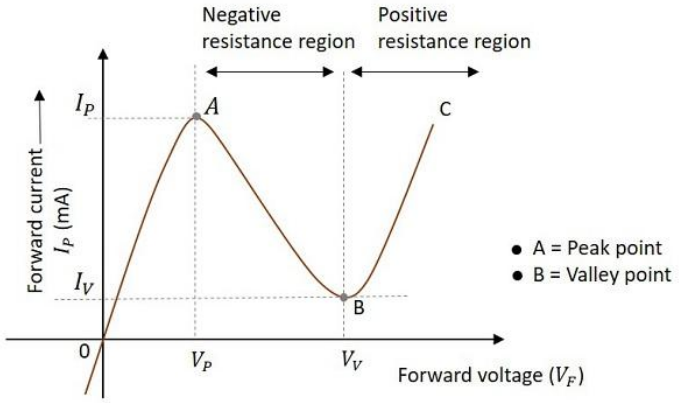
TRANSFERED ELECTRON DEVICES: GUNN DIODES

EEEN 566 – MICROWAVE ENGINEERING

Friday, March 13, 2026

POSITIVE & NEGATIVE RESISTANCE

1. **All active two-terminal solid-state devices have negative resistance**. The real part of their impedance is negative over a range of frequencies.
2. **Positive Resistance:** The current through the resistance and the voltage across it are in phase. Voltage drop across it is positive and a power (I^2 R) is dissipated.
3. **Negative Resistance:** Current and voltage are out of phase by 180°. Voltage drop across it is negative, and a power (I^2 R) is generated.



Summary:

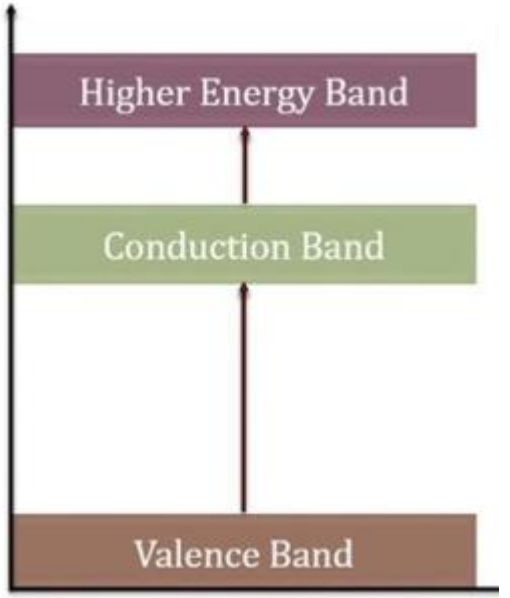
Positive resistances absorb power (passive devices)

Negative resistances generate power (active devices).

Further Reading: Negative resistance: meaning and measurement

WHAT IS TRANSFERRED ELECTRON DEVICE (TED)?

- **Transferred electron devices (TEDs)** are semiconductor devices that utilize the "Gunn effect" to generate microwaves, based on the **principle of electrons transferring between energy levels within the semiconductor material.**



(a) Energy levels in a TED

WHAT ARE THE DIFFERENCES BETWEEN TEDs & TRANSISTORS?

	TRANSISTORS	TEDS
JUNCTIONS & GATES	Transistors operate with either junctions or gates.	TEDs are bulk devices having no junctions or gates.
MATERIALS USED	Most transistors are fabricated from elemental semiconductors, such as silicon or germanium.	TEDs are fabricated from compound semiconductors, such as gallium arsenide (GaAs), indium phosphide (InP), or cadmium telluride (CdTe).
ENERGY LEVELS	Transistors operate with electrons whose energy is not much greater than the thermal energy (0.026 eV at room temperature) of electrons in the semiconductor..	TEDs operate with "hot" electrons whose energy is very much greater than the thermal energy

WHAT IS GUNN DIODE?

1. **Gunn diode is a two-terminal semiconductor component that generates microwave frequencies** by exploiting the "Gunn effect" and exhibits negative differential resistance.
2. **A Gunn diode is a semiconductor device formed by only N-type material.**
3. **Gunn diode is made of n-type material** where electrons acts as majority carriers which are transferred from one valley to another.
4. **Gunn diodes can generate continuous power in the range of several milliwatts** in the frequency range 1 to 200 GHz.
5. **Gunn diode has efficiency of 5 to 15%.**

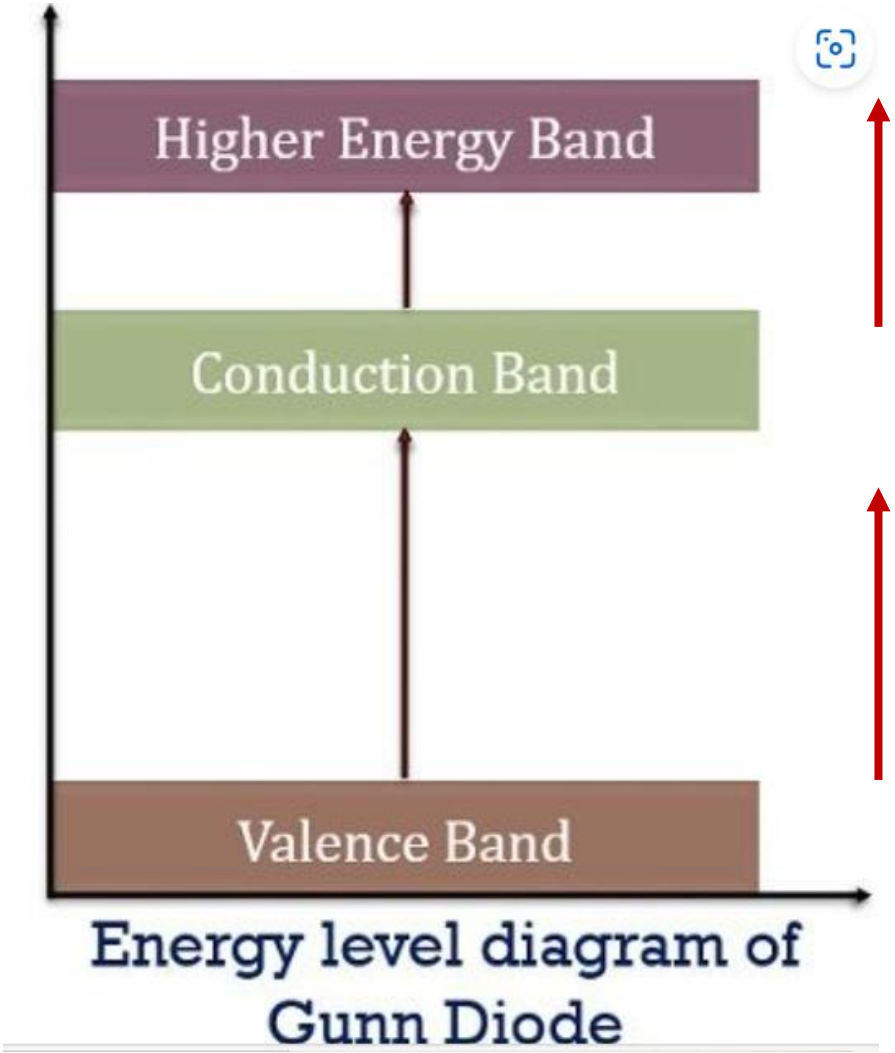
Symbol of Gunn Diode

WHAT IS GUNN EFFECT?

- **Gunn effect is the high-frequency oscillation of electric current through certain semiconducting materials (e.g. GaAs) when a strong electric field is applied**, leading to the generation of microwaves.
- Gunn effect was discovered by J.B. Gunn in 1962.

OPERATING PRINCIPLE OF GUNN DIODE

3. When the applied voltage increases further, the electrons in the higher energy state gains sufficient energy and moves back to the lower energy state.



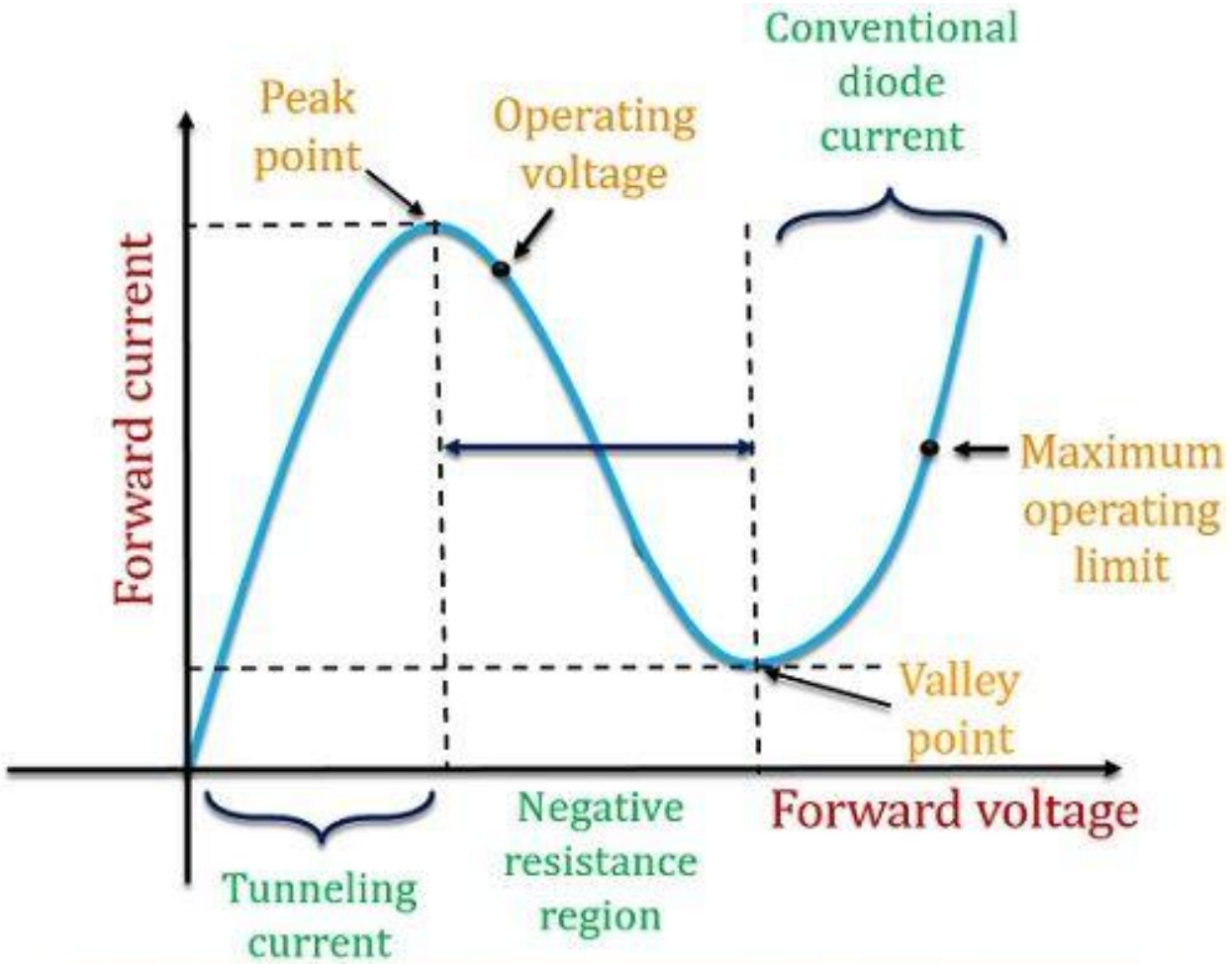
Energy level diagram of Gunn Diode

2. When the voltage further increases then, instead of allowing a large flow of current the electrons in the conduction band, electrons **move towards the energy band where electrons are less mobile hence current decreases with the increase in voltage**.

1. When voltage is applied to the device, electrons in the valence band starts moving towards the conduction band thereby allowing the flow of current.

CHARACTERISTIC CURVE OF A GUNN DIODE

Peak Point: Increasing the voltage the current through the device starts decreasing.



ADVANTAGES OF GUNN DIODE

ADVANTAGES

- Lower manufacturing cost.
- High reliability
- Lower operating voltage than normal diodes.
- Easy installation.

DISADVANTAGES

- Lower stability
- Lower efficiency
- More noise

APPLICATIONS OF GUNN DIODES

1. **Microwave Signal Generation:** Used to generate microwave frequencies, particularly in the gigahertz range, for various applications.
2. **Radar Systems:** Employed in radar systems for applications like collision avoidance in aircraft, anti-lock braking systems, and traffic flow monitoring.
3. **Communication Systems:** Used in microwave transmitters for radio communication and satellite communication.

Further Reading:
microwave-devices-and-circuits-samuel-liao.pdf pages 269 - 280

WORKED EXAMPLE – GUNN DIODE

A typical *n*-type GaAs Gunn diode has the following parameters:

Threshold field: E_h = 2800 V/cm
Applied field: E = 3200 V/cm
Device length: L = 10 μm
Doping concentration: no = 2 x 10^{14} cm^{-3}
Operating frequency: f = 10 GHz

(a) Compute the electron drift velocity.
(b) Calculate the current density.
(c) Estimate the negative electron mobility

Further Reading:
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WORKED EXAMPLE – GUNN DIODE (ANS)

(a) The electron drift velocity, V_d is

$V_d = f \times l =$ 10 x 10^9 x 10 x 10^{-6} = 10^5 m/sec = 10^7 cm/sec

(b) Current density, j is given by

$J = qnv$ = 1.6 X 10^{-19} X 2 X 10^{20} X 10 X 10^9 X 10^{-5}

= 3.2 x 10^6 A/m2

= 320 A/cm^2

(c) The negative electron mobility μ_n is

$$\mu_n = -\frac{v_d}{E} = \frac{10^7}{3200} = -3100 \text{ cm}^2/\text{V.sec}$$

Further Reading:

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