ECE121: Electronics (1)

Lecture 7: Tunnel Diodes
Diode AC Resistance

Dr. Haitham El-Hussieny

Electronics and Communications Engineering
Faculty of Engineering (Shoubra)
Benha University

Spring 2017

Lecture Outline:

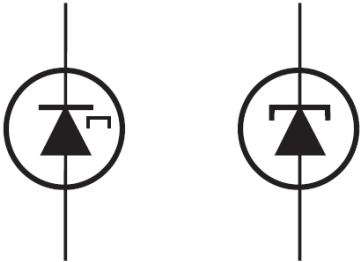
1. Tunnel Diodes.

2. Networks with AC and DC Sources.

Table of Contents

Introduction:

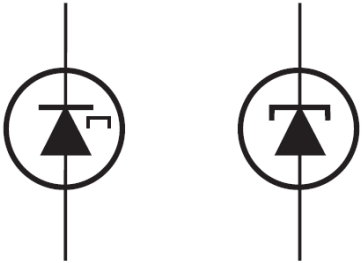
- The tunnel diode was first introduced by *Leo Esaki* in 1958. It is mainly used in **low voltage high frequency applications**.



Tunnel diode Symbols

Introduction:

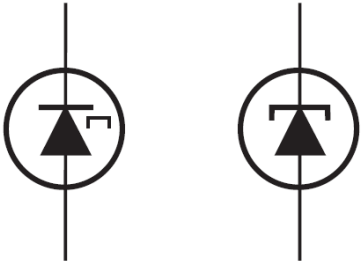
- The tunnel diode was first introduced by *Leo Esaki* in 1958. It is mainly used in **low voltage high frequency applications**.
- It is fabricated by doping the semiconductor materials a level **100 to several thousand times** that of a typical semiconductor diode.



Tunnel diode Symbols

Introduction:

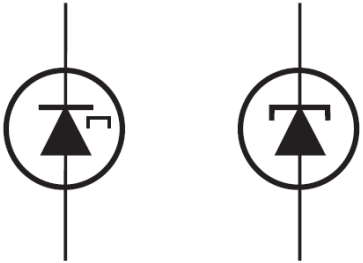
- The tunnel diode was first introduced by *Leo Esaki* in 1958. It is mainly used in **low voltage high frequency applications**.
- It is fabricated by doping the semiconductor materials a level **100 to several thousand times** that of a typical semiconductor diode.
- This results a thin depletion region which many carriers can "**tunnel**" at low forward-bias potentials



Tunnel diode Symbols

Introduction:

- The tunnel diode was first introduced by *Leo Esaki* in 1958. It is mainly used in **low voltage high frequency applications**.
- It is fabricated by doping the semiconductor materials a level **100 to several thousand times** that of a typical semiconductor diode.
- This results a thin depletion region which many carriers can "**tunnel**" at low forward-bias potentials



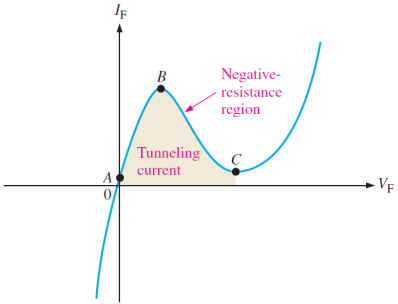
Tunnel diode Symbols

Negative Resistance:

Tunnel diodes are different from any ordinary diode in that it has a negative-resistance region. In this region, an **increase in terminal voltage results in a reduction in diode current**.

Tunnel Diode Characteristic:

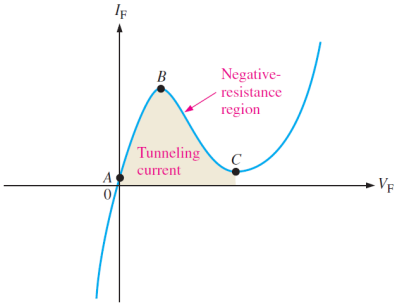
- Tunnel diodes are constructed with **germanium or gallium arsenide** by doping the p and n regions **much more heavily** than in a conventional diode.



Tunnel diode Characteristics

Tunnel Diode Characteristic:

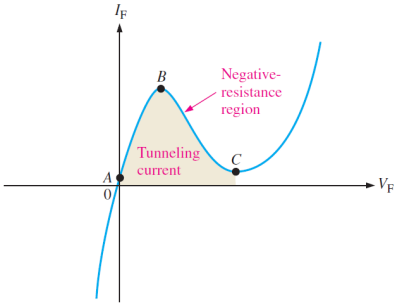
- Tunnel diodes are constructed with **germanium or gallium arsenide** by doping the p and n regions **much more heavily** than in a conventional diode.
- The heavy doping results in an extremely narrow depletion region.



Tunnel diode Characteristics

Tunnel Diode Characteristic:

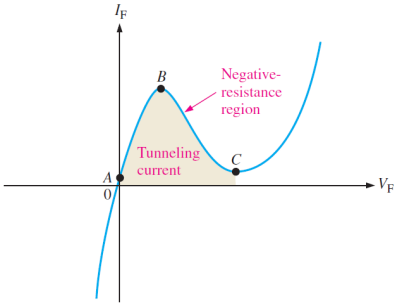
- Tunnel diodes are constructed with **germanium or gallium arsenide** by doping the p and n regions **much more heavily** than in a conventional diode.
- The heavy doping results in an extremely narrow depletion region.
- It allows conduction for all reverse voltages.



Tunnel diode Characteristics

Tunnel Diode Characteristic:

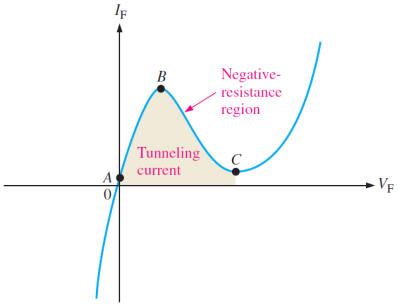
- Tunnel diodes are constructed with **germanium or gallium arsenide** by doping the p and n regions **much more heavily** than in a conventional diode.
- The heavy doping results in an extremely narrow depletion region.
- It allows conduction for all reverse voltages.
- Also, the extremely narrow depletion region allows electrons to "tunnel" through the pn junction at very low forward-bias voltages (point A to B)



Tunnel diode Characteristics

Tunnel Diode Characteristic:

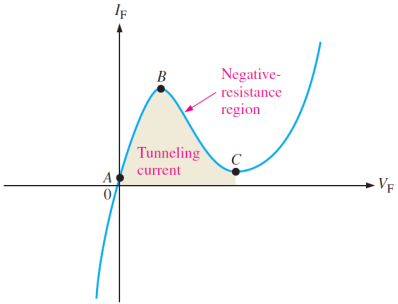
- Tunnel diodes are constructed with **germanium or gallium arsenide** by doping the p and n regions **much more heavily** than in a conventional diode.
- The heavy doping results in an extremely narrow depletion region.
- It allows conduction for all reverse voltages.
- Also, the extremely narrow depletion region allows electrons to "tunnel" through the pn junction at very low forward-bias voltages (point A to B)
- At point B, the forward voltage begins to decrease as the forward voltage continues to increase.



Tunnel diode Characteristics

Tunnel Diode Characteristic:

- Tunnel diodes are constructed with **germanium or gallium arsenide** by doping the p and n regions **much more heavily** than in a conventional diode.
- The heavy doping results in an extremely narrow depletion region.
- It allows conduction for all reverse voltages.
- Also, the extremely narrow depletion region allows electrons to "tunnel" through the pn junction at very low forward-bias voltages (point A to B)
- At point B, the forward voltage begins to decrease as the forward voltage continues to increase.
- At point C, the diode begins to act as a conventional forward biased diode.

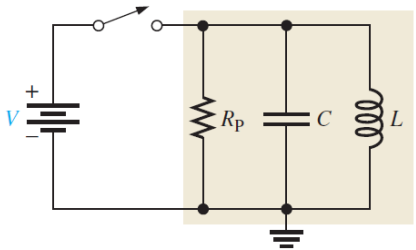


Tunnel diode Characteristics

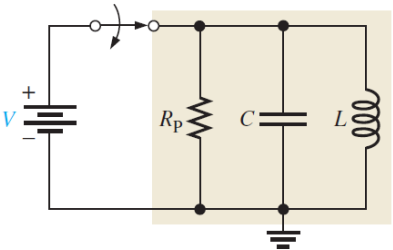
Tunnel Diode Application:

A tunnel diode can be used to **generate a sinusoidal voltage using simply a dc supply** and a resonant circuit.

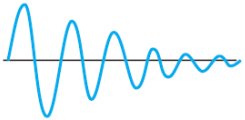
[1] Resonant circuit without tunnel diode:



(a)



(b)

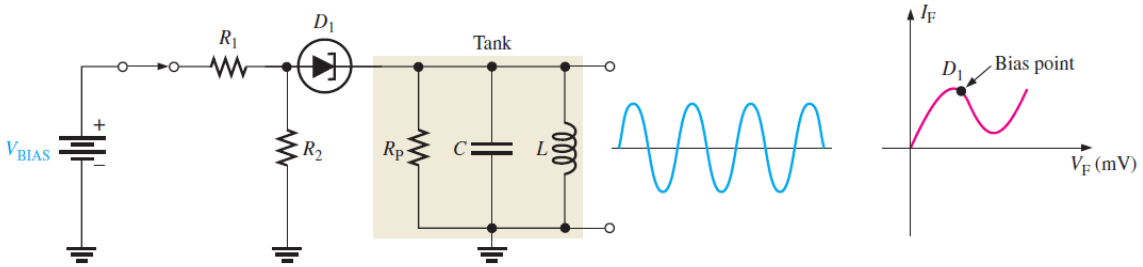


A damped sinusoidal output results

Tunnel Diode Application:

A tunnel diode can be used to **generate a sinusoidal voltage using simply a dc supply** and a resonant circuit.

[2] Resonant circuit with a tunnel diode:

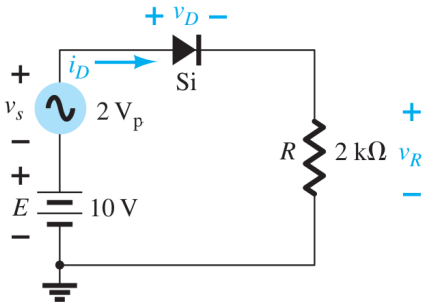


A non-damped sinusoidal output results if the diode is biased **to work at the middle of the negative resistance region**.

Table of Contents

Networks with AC and DC Sources:

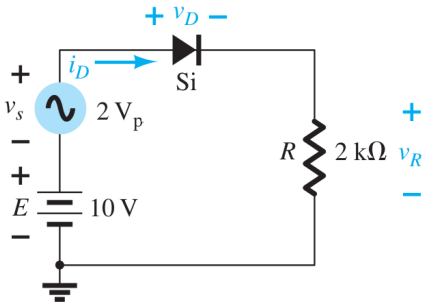
- We need to analyze diode circuits in case of both a dc and an ac input source.
- We can solve for the two sources by using the **Superposition Theorem**.



Network with a dc and ac supply

Networks with AC and DC Sources:

- We need to analyze diode circuits in case of both a dc and an ac input source.
- We can solve for the two sources by using the **Superposition Theorem**.



Network with a dc and ac supply

Superposition Theorem:

The response of any network with both an AC and a DC source can be found by finding the response to **each source independently** and then **combining the results**.

Networks with AC and DC Sources:

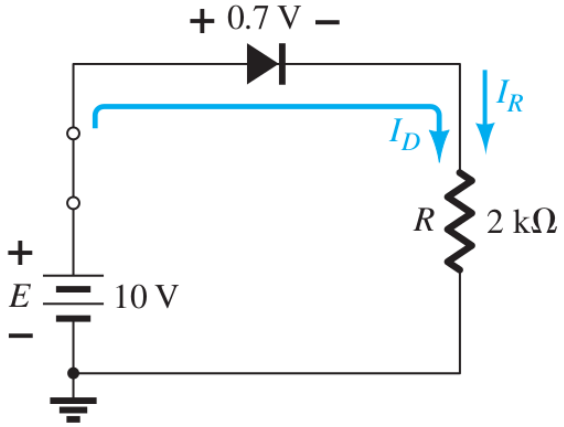
[1] DC Source Only:

- The **DC source is only applied** while the **AC source is removed** by replacing it with a **short-circuit**.
- Voltage across the R:

$$V_R = E - V_D = 10\ V - 0.7\ V = 9.3\ V$$

- Current I_D:

$$I_D = I_R = \frac{V_R}{R} = \frac{9.3\ V}{2\ k\Omega} = 4.65\ mA$$

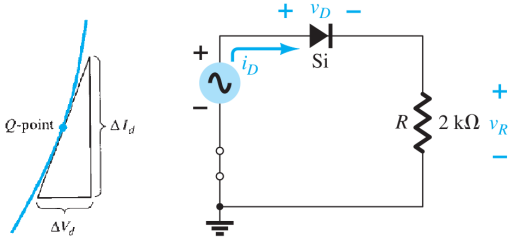


Network with a DC source only

Networks with AC and DC Sources:

[2] AC Source Only:

- The **AC source is only applied** while the **DC source is removed** by replacing it with a **short-circuit**.
- If a **sinusoidal rather than a DC input** is applied, the Q-Point will move up and down in a region of the characteristics.
- The change in current and voltage is specified by the **AC resistance,** r_D.
- The diode will be replaced by the **ac resistance,** r_D:



Network with an AC source only

$$r_D = \frac{\Delta V_d}{\Delta I_d}; \qquad r_D = \frac{26\ mV}{I_D} = \frac{26\ mV}{4.65\ mA} = 5.59\,\Omega$$

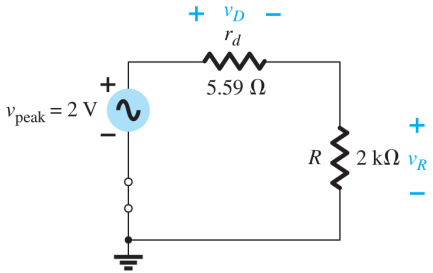
Networks with AC and DC Sources:

[2] AC Source Only:

- The Voltage V_{Rpeak} across the resistance R is:

$$V_{Rpeak} = \frac{2\ k\Omega\ 2\ V}{2\ k\Omega + 5.59\Omega} \approx 1.99\ V$$

$$V_{Dpeak} = V_s - V_{Dpeak} = 2\ V - 1.99\ V = 10\ mV$$

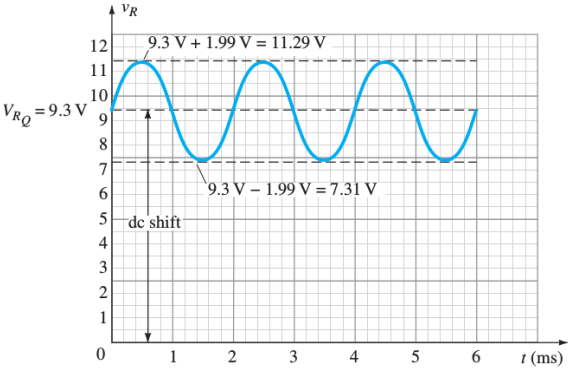


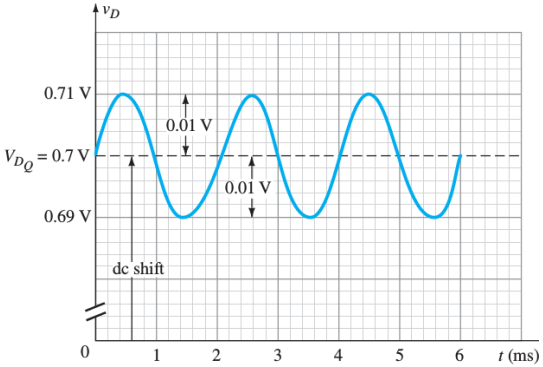
Network with an AC source only

Networks with AC and DC Sources:

[3] Combining both the AC and DC:

Combining the results of the DC and AC analysis will result in the waveforms for V_R and V_D:





End of Lecture

Best Wishes

haitham.elhussieny@gmail.com