كلية مدينة العلم الجامعة

قسم هندسة الحاسوب

# محاضرات المرحلة الاولى لمادة الهندسة الالكترونية

اعداد

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# المحاضرة الثالثة

# The Diode الثنائي

Electronic Devices and Circuit Theory

Eleventh Edition

Robert L. Boylestad and Louis Nashelsky

# Diode Parameters

1. **Bulk resistance** $r_B = (V_F - V_B)/I_F$
2. **It is the sum of the resistance values of the P-and N-type semiconductor materials of which the diode is made of.Usually, it is very small. It is given by**

$r_B = (V_F - V_B)/I_F$

**2. Junction resistance** $(r_j) = (V_T / I_F)$

**Its value for forward-biased junction depends on the magnitude of forward *dc* current.**

$r_j = 25\ (mV)/I_F (mA)$ **– for Ge**

$= 50\ (mV)/I_F (mA)$ **– for Si**

**Obviously, it is a variable resistance.**

**3. Dynamic or ac resistance**

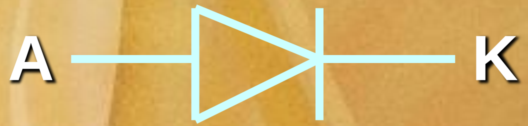
$r_{ac}$ or $r_d = r_B + r_j = (V_F - V_B)/I_F + \eta V_T / I_F$

**For large values of forward current, $r_j$ is negligible. Hence, $r_{ac} = r_B$. For small values of $I_F$, $r_B$ is negligible as compared to $r_j$. Hence $r_{ac} = r_j$.**

# Types of Diodes and Their Uses

**PN Junction Diodes:**

Are used to allow current to flow in one direction while blocking current flow in the opposite direction. The pn junction diode is the typical diode that has been used in the previous circuits.




Schematic Symbol for a PN Junction Diode


Representative Structure for a PN Junction Diode

**Zener Diodes:**

Are specifically designed to operate under reverse breakdown conditions. These diodes have a very accurate and specific reverse breakdown voltage.


Schematic Symbol for a Zener Diode

Kristin Ackerson, Virginia Tech EE
Spring 2002

# Types of Diodes and Their Uses

## Light-Emitting Diodes:

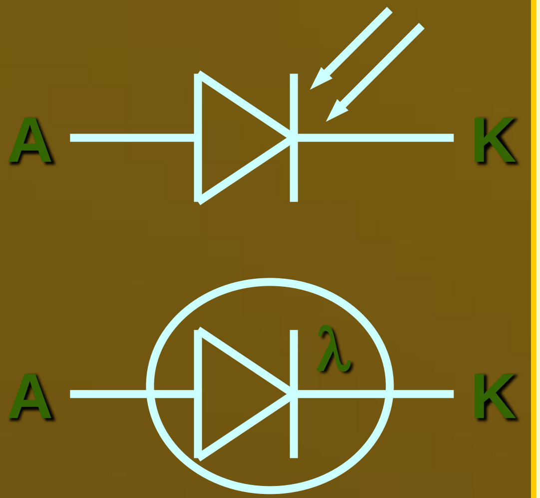
Light-emitting diodes are designed **with a very large band-gap so movement of carriers across their depletion region emits photons of light energy**. Lower band-gap LEDs (Light-Emitting Diodes) emit infrared radiation, while LEDs with higher band-gap energy emit visible light. Many stop lights are now starting to use LEDs because they are extremely bright and last longer than regular bulbs for a relatively low cost.


Schematic Symbol for a Light-Emitting Diode

The arrows in the LED representation indicate emitted light.

# Types of Diodes and Their Uses

## Photodiodes:



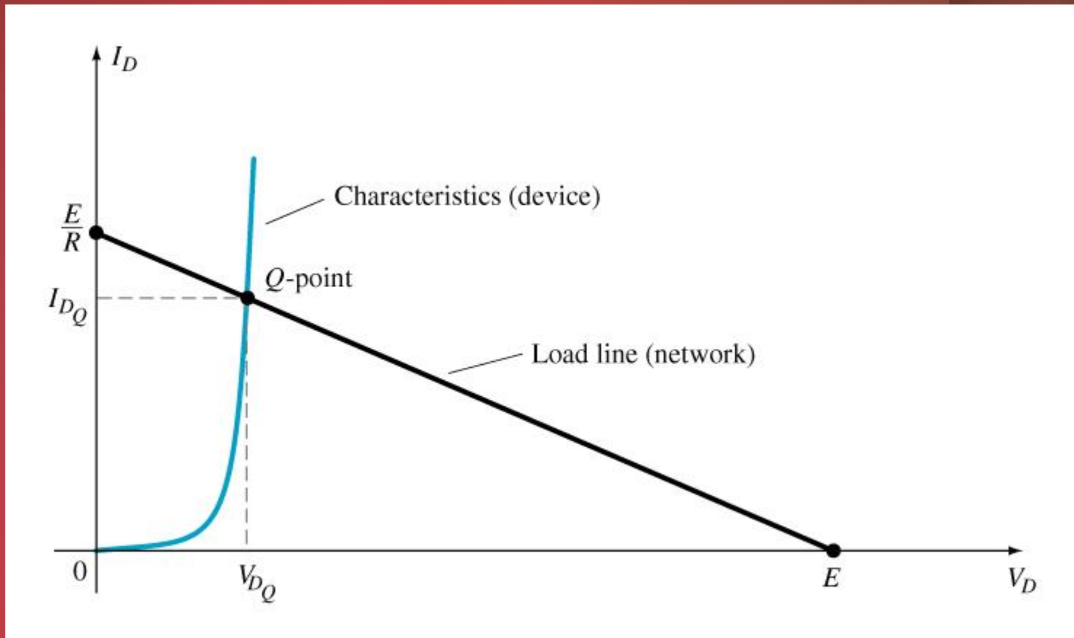

Schematic Symbols for Photodiodes

While LEDs emit light, **Photodiodes are sensitive to received light**. They are constructed so their pn junction can be exposed to the outside through a clear window or lens.

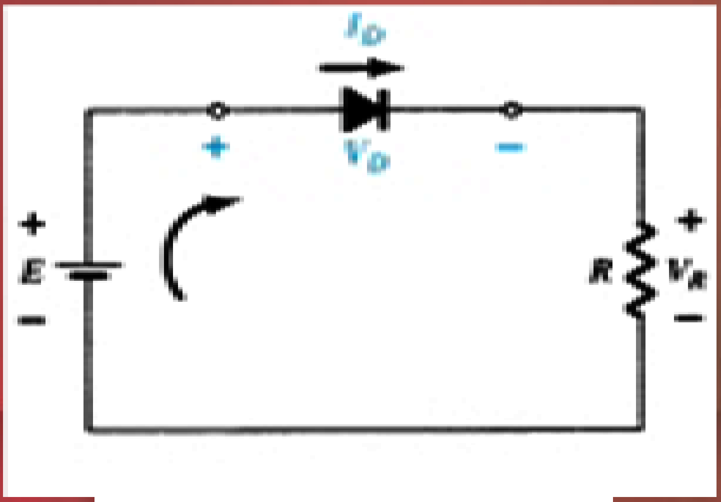
In Photovoltaic mode, when the pn junction is exposed to a certain wavelength of light, the diode generates voltage and can be used as an energy source. **This type of diode is used in the production of solar power.**

# Load-Line Analysis

The load line plots all possible combinations of diode current ($I_D$) and voltage ($V_D$) for a given circuit. The maximum $I_D$ equals $E/R$, and the maximum $V_D$ equals $E$.




The point where the load line and the characteristic curve intersect is the Q-point, which identifies $I_D$ and $V_D$ for a particular diode in a given circuit.



# Series Diode Configurations

## Forward Bias

**Constants**

**Silicon Diode:** $V_B = 0.7$ V

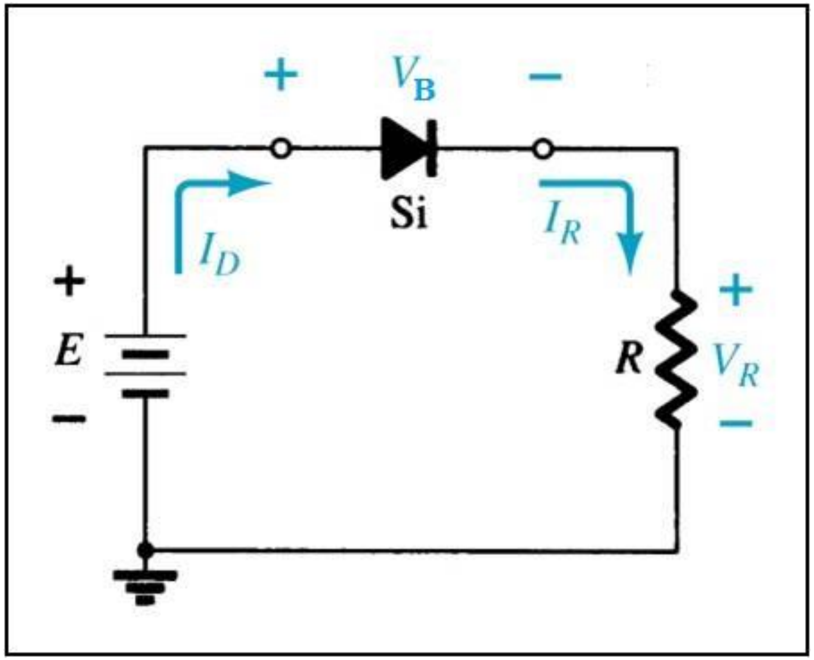
**Germanium Diode:** $V_B = 0.3$ V

**Analysis (for silicon)**

$V_D = 0.7$ V (or $V_B = E$ if $E < 0.7$ V)

$V_R = E - V_B$

$I_D = I_R = I_T = V_R / R$



# Series Diode Configurations

## Reverse Bias

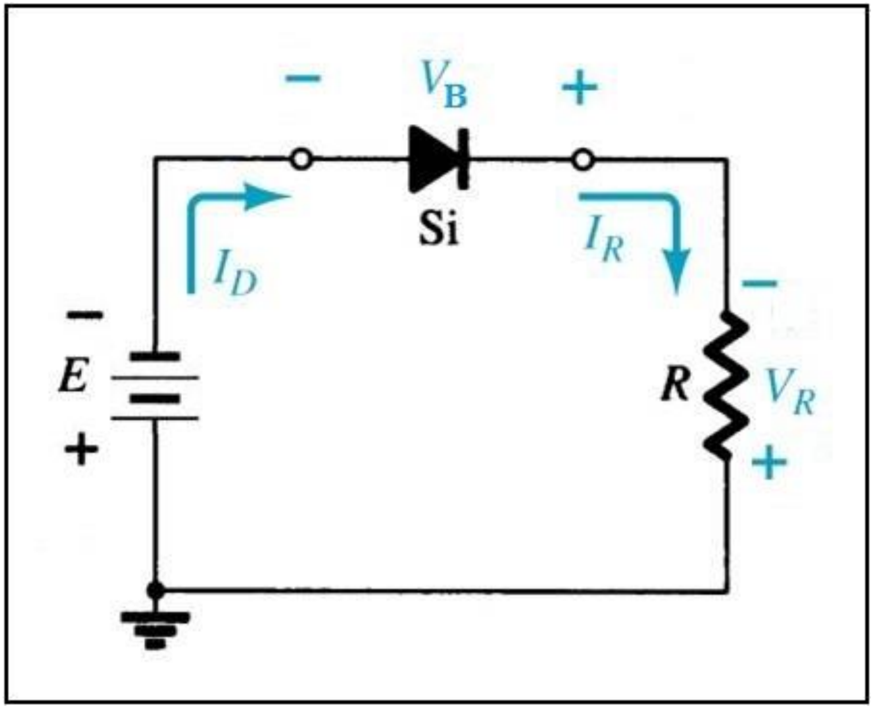
**Diodes ideally behave as open circuits**

**Analysis**

$V_D = E$

$V_R = 0$ V

$I_D = 0$ A



# Parallel Diode Configurations

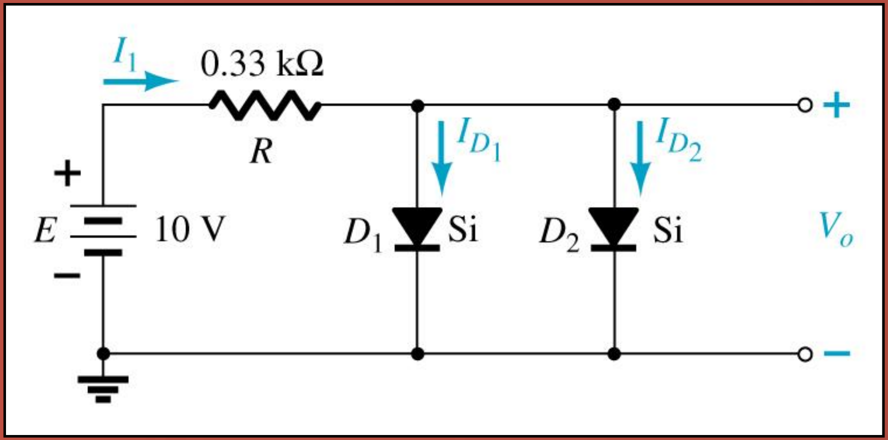
$$V_B = 0.7\,\text{V}$$

$$V_{B1} = V_{B2} = V_o = 0.7\,\text{V}$$

$$V_R = 9.3\,\text{V}$$

$$I_R = \frac{E - V_B}{R} = \frac{10\,\text{V} - .7\,\text{V}}{.33\,\text{k}\Omega} = 28\,\text{mA}$$

$$I_{B1} = I_{B2} = \frac{28\,\text{mA}}{2} = 14\,\text{mA}$$



# Peak-to-Peak / Average / RMS

- The peak-to-peak value of a sine wave is the voltage or current from the positive peak to the negative peak.
- The peak-to-peak values are represented as:

$$V_{pp} \text{ and } I_{pp}$$

Where: $V_{pp} = 2V_p$ and $I_{pp} = 2I_p$

- The rms (root mean square) value of a sinusoidal voltage is equal to the dc voltage that produces the same amount of heat in a resistance as does the sinusoidal voltage.

$$V_{rms} = 0.707V_p$$

$$I_{rms} = 0.707I_p$$

# THE DC OUTPUT CURRENT OR VOLTAGE IN HWR

average current has to be found out.

* Average value $= \frac{\text{Area under the curve over a cycle}}{\text{Base}} = \frac{\int_0^{\pi} i\, d\theta}{2\pi}$

** It may be remembered that the *area of one-half cycle of a simusoidal wave* is twice the peak value. Thus in this case, peak value is $I_m$ and, therefore, area of one-half cycle is $2\, I_m$.

$$\therefore \qquad I_{av} = I_{dc} = \frac{2\, I_m}{2\pi} = \frac{I_m}{\pi}$$

$$I_{dc} = \frac{1}{2\pi}\int_0^{\pi} i\, d\theta = \frac{1}{2\pi}\int_0^{\pi} \frac{V_m \sin\theta}{r_f + R_L}\, d\theta$$

$$= \frac{I_m}{\pi}$$

**$1/\pi$ =0.318**

**$2/\pi = 0.636$**

**So the DC output current or voltage is 0.318 $V_m$,**

**where $V_m$ = the peak AC voltage.**

**For a half-wave rectified wave, $I_{rms} = I_m / 2$**

# PIV (PRV)

**Because the diode is only forward biased for one-half of the AC cycle, it is also reverse biased for one-half cycle.**

**It is important that the reverse breakdown voltage rating of the diode be high enough to withstand the peak, reverse-biasing AC voltage.**

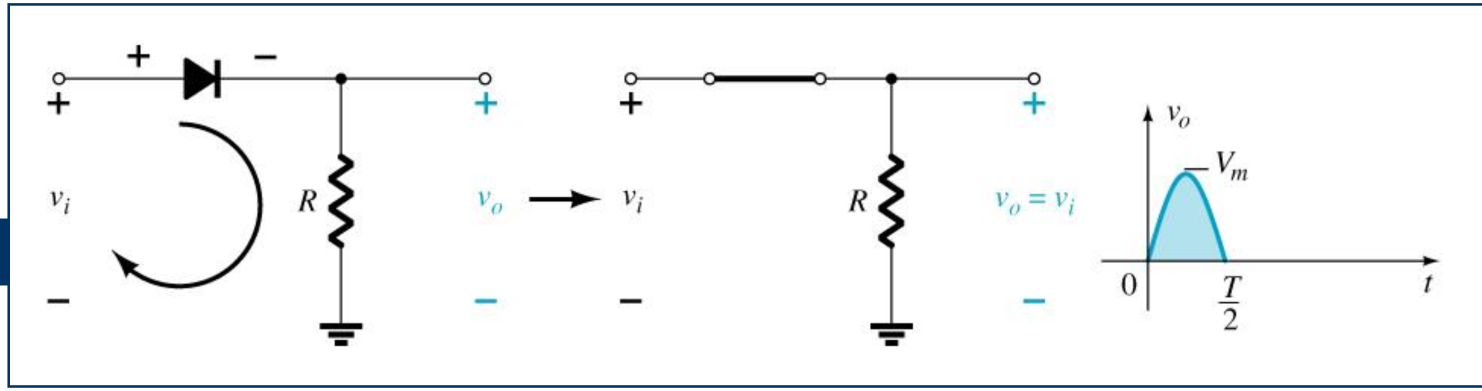
$$\text{PIV} > V_m$$

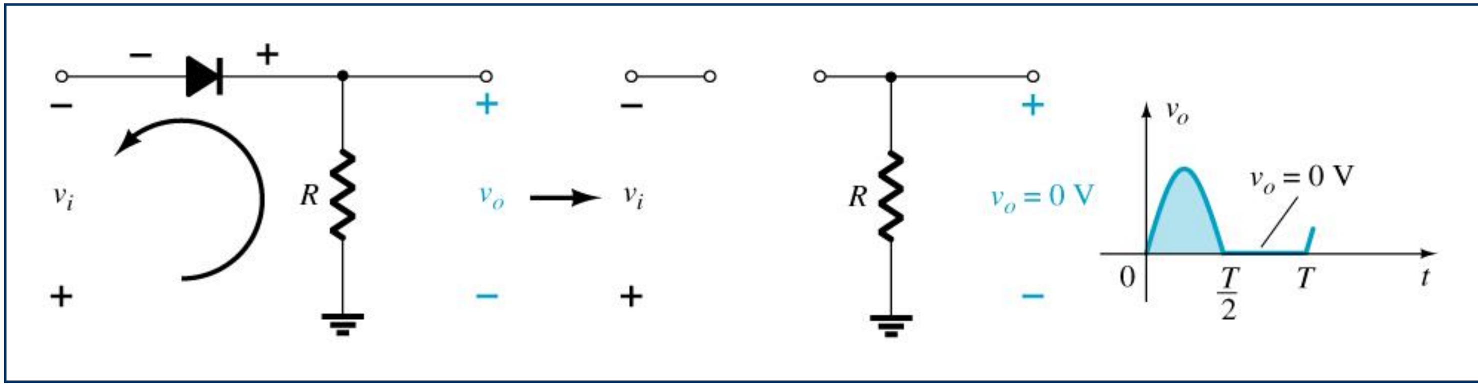
**Where PIV = Peak inverse voltage**

**$V_m$ = Peak AC voltage**

# Half-Wave Rectification

**The diode conducts only when it is forward biased, therefore only half of the AC cycle passes through the diode to the output.**

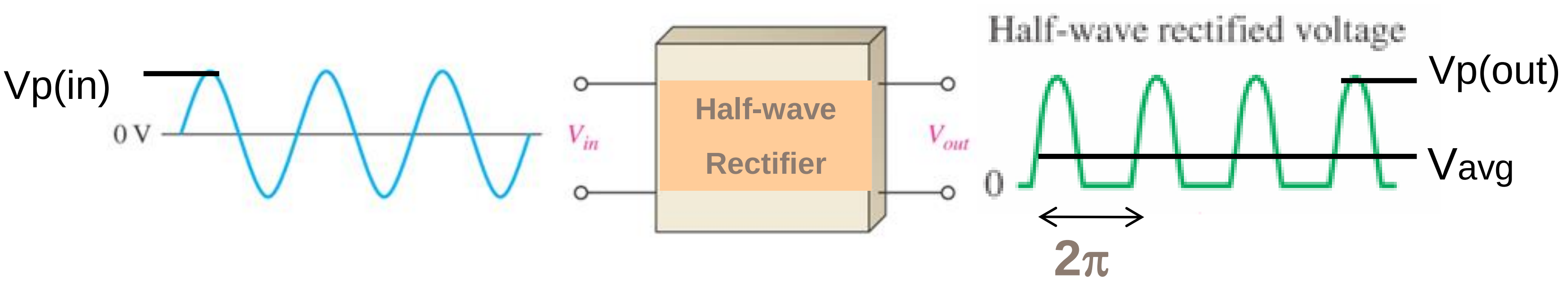



**The DC output voltage is 0.318 $V_m$, where $V_m$ = the peak AC voltage.**

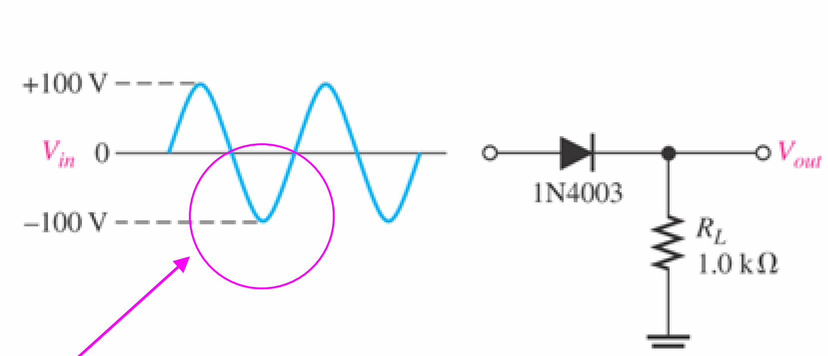
# Half-wave Rectifier

- Note that the frequency stays the same
- Strength of the signal is reduced
- $V_{avg} = V_{p(out)}/\pi = 0.318 \times V_{p(out)}$ [31.8 % of Vp]
- $V_{p(out)} = V_{p(in)} - V_B$
- For Silicon $V_B = 0.7$ V

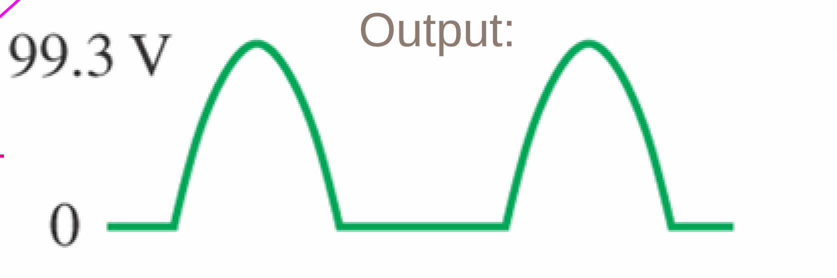


# Half-wave Rectifier - Example

- Draw the output signal
  - Vp(out) = Vp(in) – 0.7
  - Vavg = 99.3/π
  - What happens to the frequency?




- Peak Inverse Voltage (PIV)
  - The peak voltage at which the diode is reverse biased
  - In this example PIV = Vp(in)-
  - Hence, the diode must be rated for PIV = 100 V

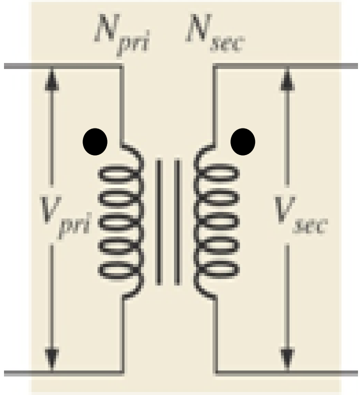


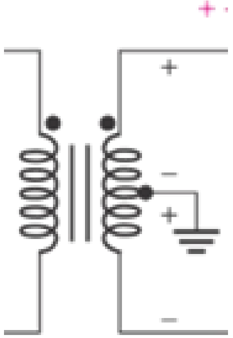
# Transformers (Review)

- Transformer: Two inductors coupled together – separated by a dielectric
  - When the input magnetic field is changing voltage is induced on the second inductor
  - The dot represents the + (voltage direction)
- Applications:
  - Step-up/down
  - Isolate sources
- Turns ratio (n)
  - n = Sec. turns / Pri. turns = Nsec/ Npri
- Vsec = n. Vpri

  depending on value of n : step-up or step-down

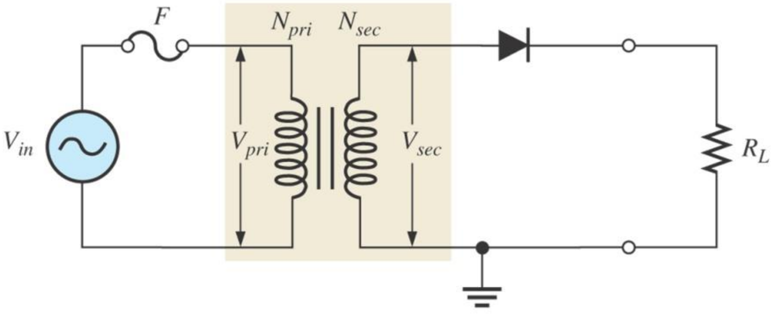
- Center-tapped transformer
  - Voltage on each side is Vsec/2

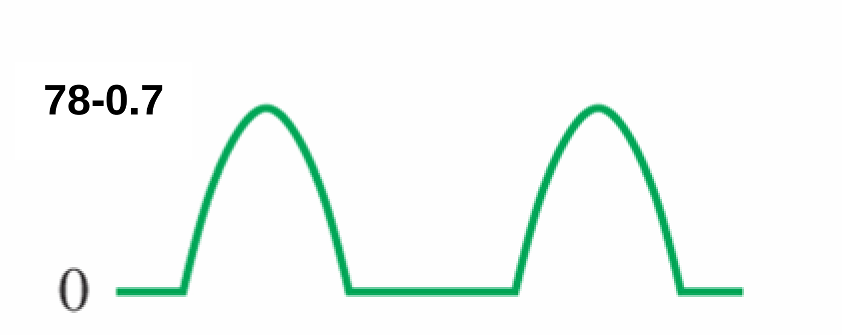


# Half-wave Rectifier - Example

- **Example:**
  - Assume that the input is a sinusoidal signal with Vp=156 V & T = 2 msec; assume Nsec:Npri = 1:2
  - Draw the signal
  - Find turns ratio;
  - Find Vsec;
  - Find $V_{out}$.



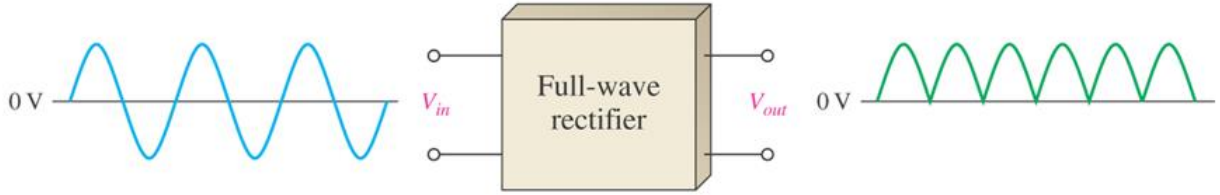

n = ½ = 0.5

Vsec = n ×Vpri = 78 V

Vout = Vsec – 0.7 = 77.3 V

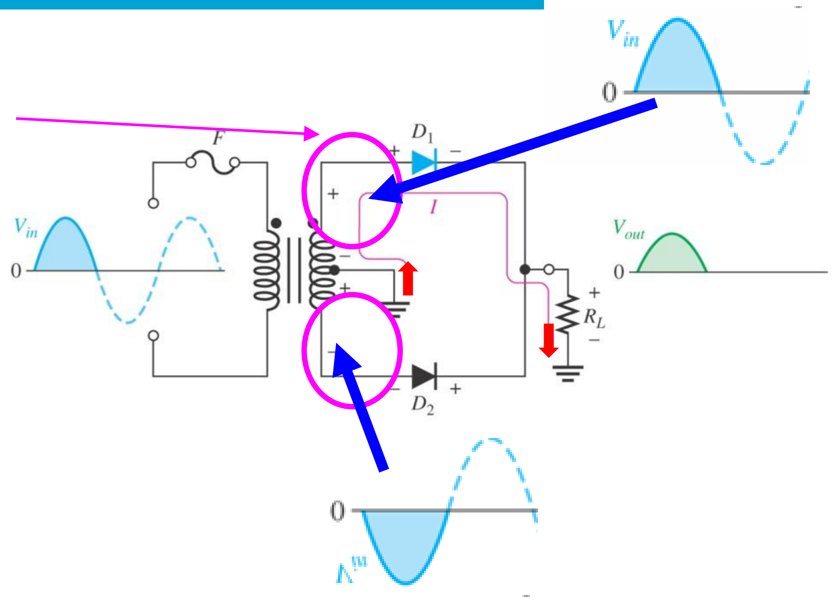
# Full-wave Rectifier

- Note that the frequency is doubled
- Vavg = 2Vp(out)/π = 0.637 x Vp(out)



# Full-wave Rectifier Circuit

- Center-tapped full-wave rectifier
  - Each half has a voltage = Vsec/2
- Only one diode is forward biased at a time
- The voltages at different halves are opposite of each other



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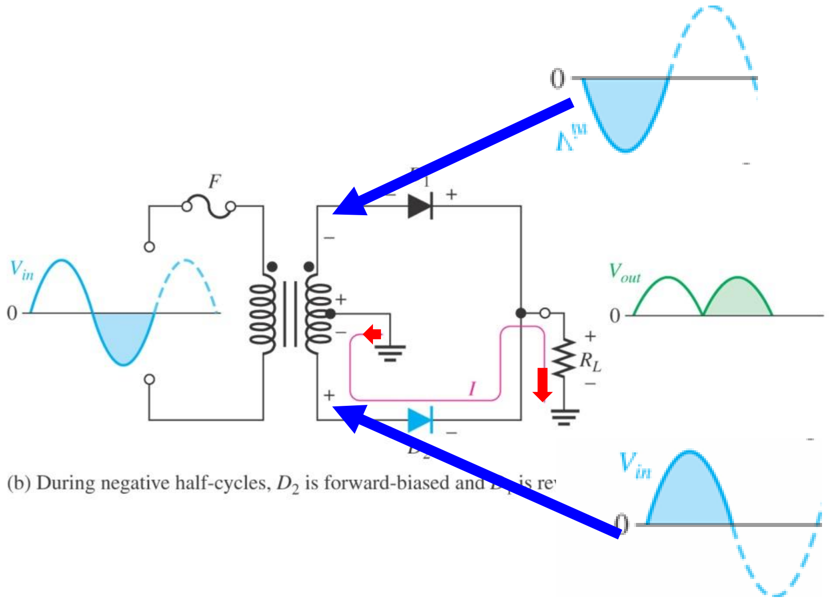

# Full-wave Rectifier Circuit

- Vout = Vsec /2 – 0.7
- Peak Inverse Voltage (PIV)
  - PIV = (Vsec/2 – 0.7)- (-Vsec/2) = Vsec – 0.7
- Vout = Vsec/2 – 0.7

Assuming D2 is reverse-biased → No current through D2