Electronic Circuits for Mechatronics (ELCT 609)

Spring 2021

Lecture 2: PN Junctions Applications

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PN-Junction Applications

Practical Circuits

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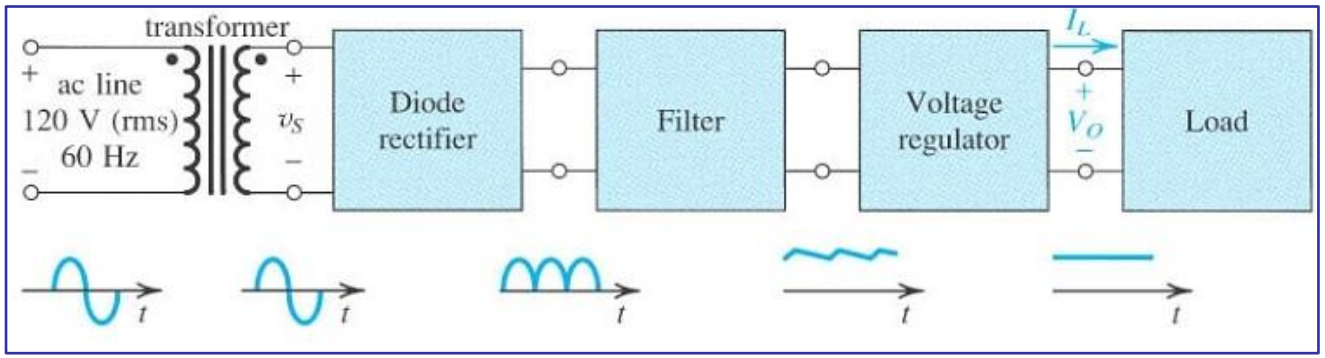
Power Supply Circuit using Diodes

- DC Power supply is implemented using diodes
  - Rectifiers are used to convert AC signal to DC signal

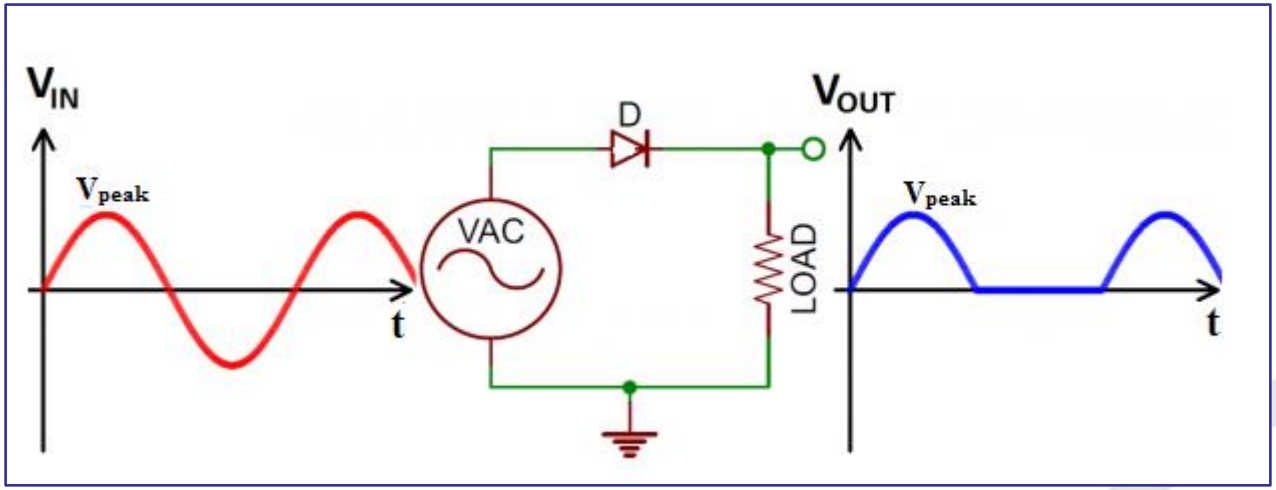


DC Power Supply Circuit Components

Rectifiers

- **Half-wave Rectifier**

$$V_{inAvg.} = 0 \qquad V_{outAvg.} = \frac{V_{Peak}}{\pi}$$

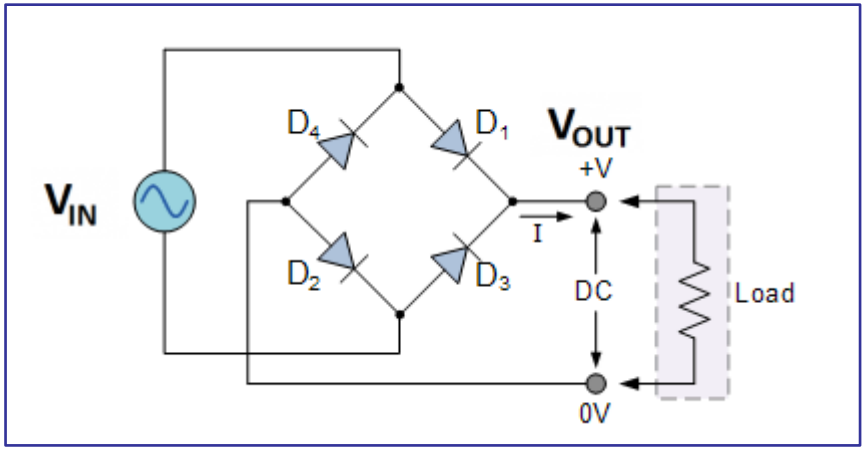


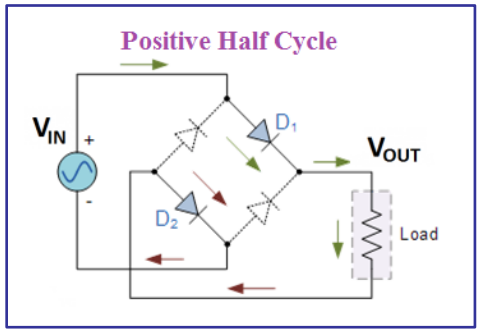
Rectifiers

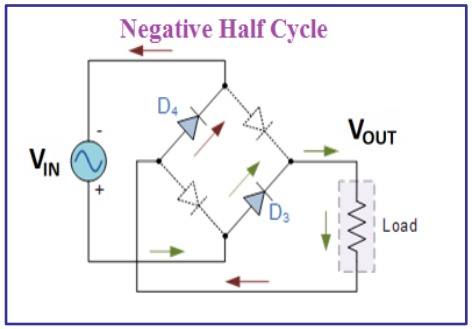
- **Full-wave Rectifier**

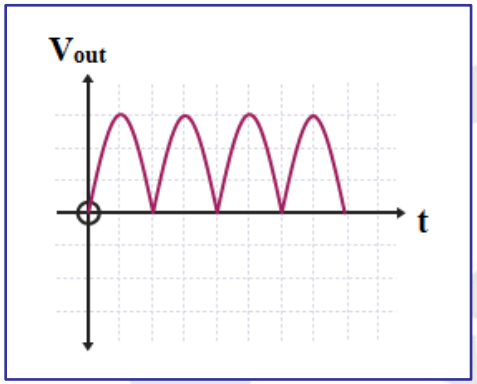
$$V_{inAvg.} = 0$$

$$V_{outAvg.} = \frac{2V_{Peak}}{\pi}$$









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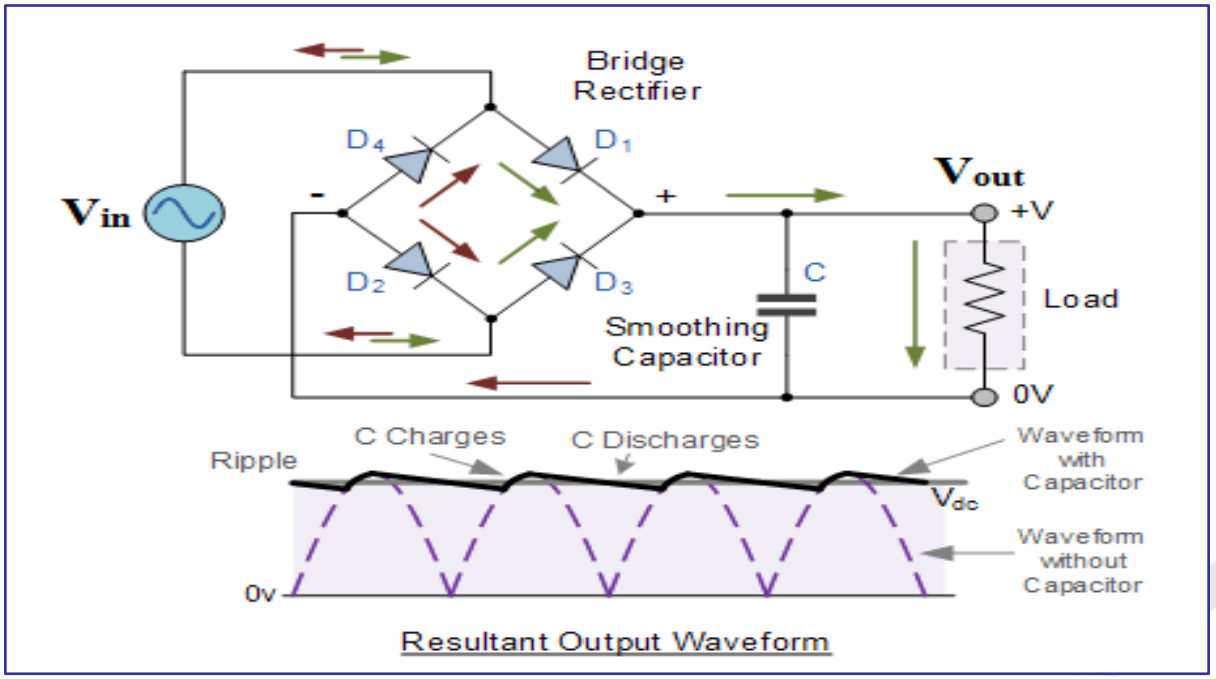
Rectifiers

- **Full-wave Rectifier**



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Limiters (Clippers)

- **Limiters (Clippers)**
  - It is a Linear Circuit used for signal conditioning
  - The circuit limits the output voltage to a predefined value
  - Any connections with diodes can be employed (parallel!)

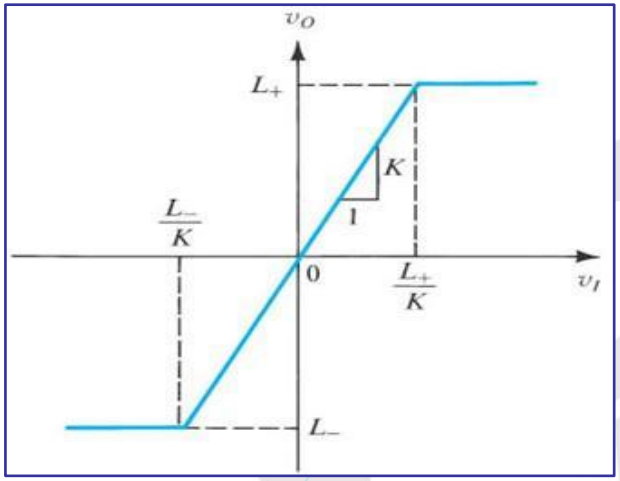
$V_{out} = L_-$ $\quad V_{in} < \frac{L_-}{K}$

$V_{out} = KV_{in}$ $\quad \frac{L_-}{K} < V_{in} < \frac{L_+}{K}$

$V_{out} = L_+$ $\quad V_{in} > \frac{L_+}{K}$

K is the proportionality Constant

General Transfer Function of a Limiter



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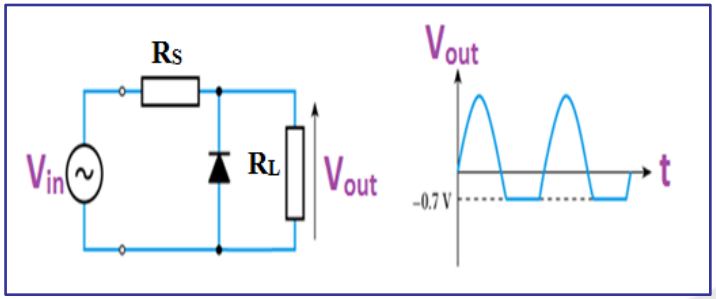
Limiters (Clippers)

- **Limiters Example 1:**
  - Assume that the Diodes have V_{th}=0.7V
  - Draw 'V_{out}', if 'V_{in}' is a sinusoidal signal with 10kHz and 10Vpp

$$For\ V_{in} > -\frac{V_D}{K} \qquad V_{out} = KV_{in}$$

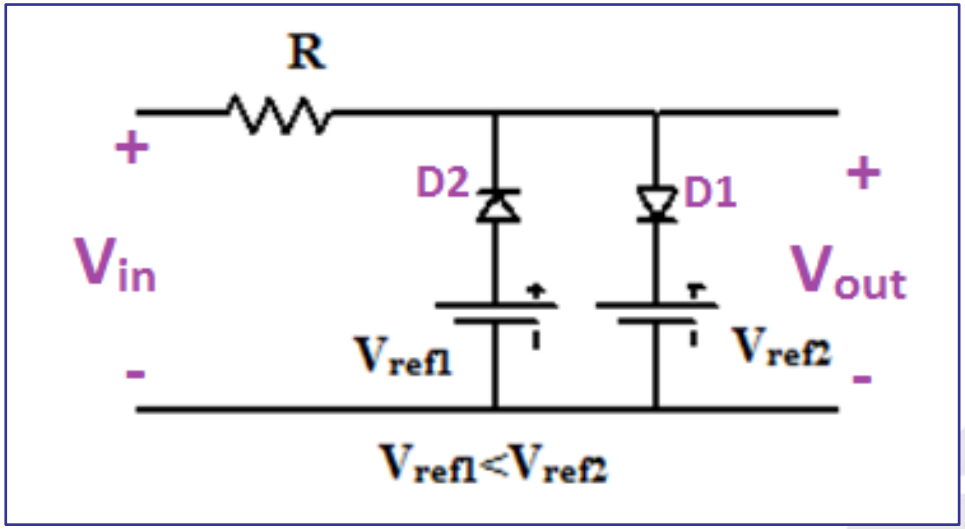


$$For\ V_{in} < -\frac{V_D}{K} \qquad V_{out} = -V_D$$

$$K = \frac{R_L}{R_S + R_L}$$

Limiters (Clippers)

- **Limiter Example 2:**
  - Assume that the Diodes are ideal, Draw 'V_{out}' vs. 'V_{in}'
  - Draw 'V_{out}', if 'V_{in}' is a sinusoidal signal with 10kHz and 10Vpp



Zener Diodes

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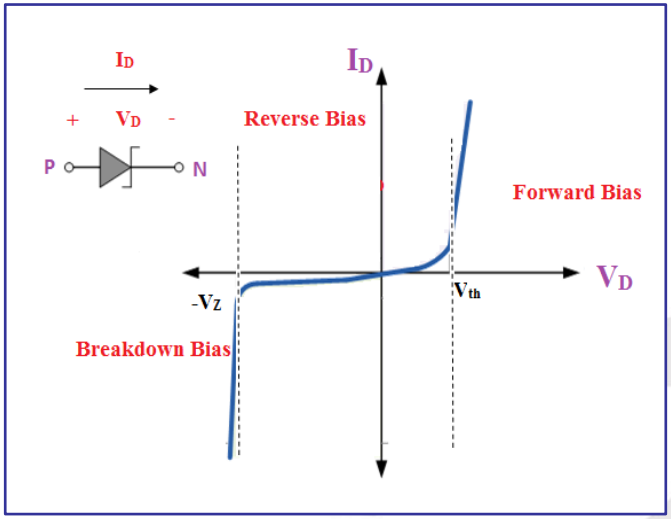
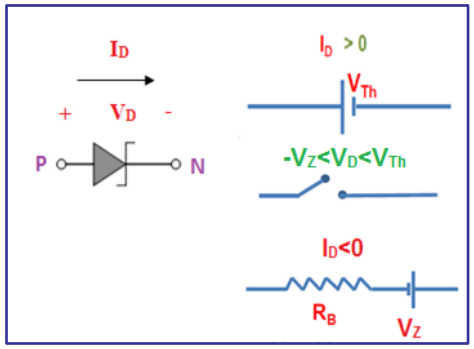
Zener Diode

- **Breakdown Phenomena (Breakdown Biased)**
  - Reverse biasing can cause the diodes to conduct in opposite direction under large reverse voltage value
    - Zener Effect
    - Avalanche Effect
  - Breakdown is non-destructive
  - **Applications:**
    - Shunt Regulator
    - Limiters



Zener Diode

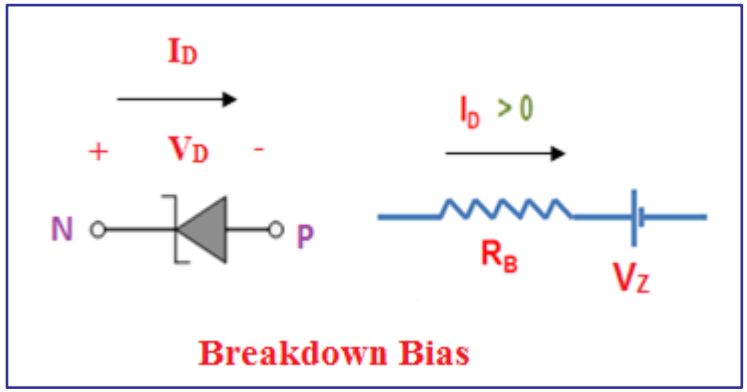
- **I-V Characteristics modeling for Zener Diode**



Forward Biased	Reverse Biased	Breakdown Biased
Assume	Assume	Assume
$V_D = V_{Th}$	$I_D = 0$	$V_D = -V_Z - I_D R_B$
Verify	Verify	Verify
$I_D > 0$	$-V_Z < V_D < V_{Th}$	$I_D < 0$

Zener Diode I-V Characteristics

- **I-V Characteristics modeling for Zener Diodes**
  - Note: You can reverse the diode polarity in Breakdown



Breakdown Biased

Assume

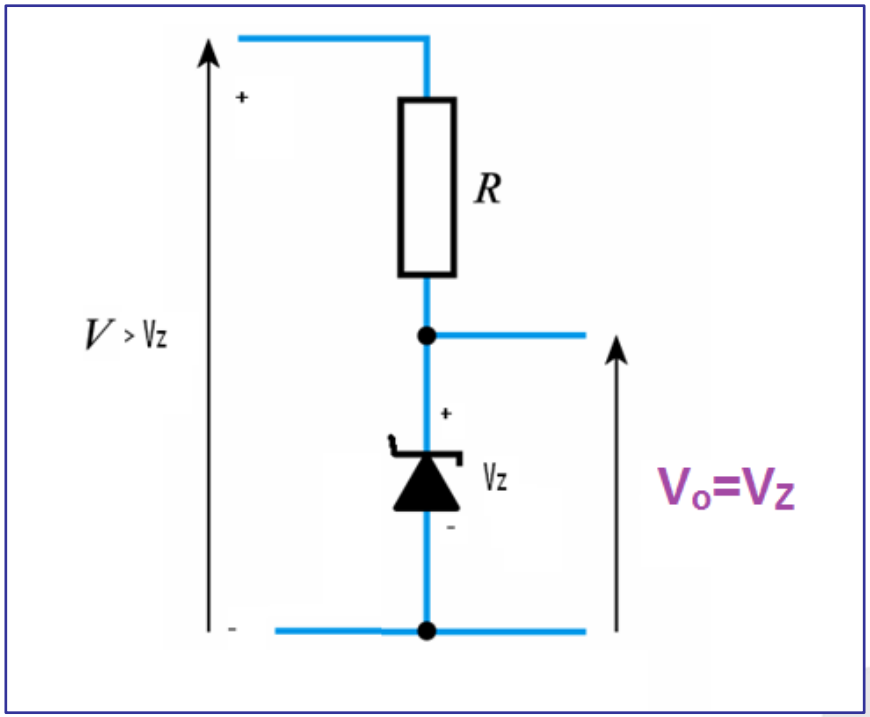
$$V_D = V_Z + I_D R_B \cong V_Z$$

Verify

$$I_D > 0$$

Zener Diode Application

- **Voltage Regulator**



Zener Diode Example

- **Draw the output voltage vs. the input voltage**
  - Voltage limiter using Zener