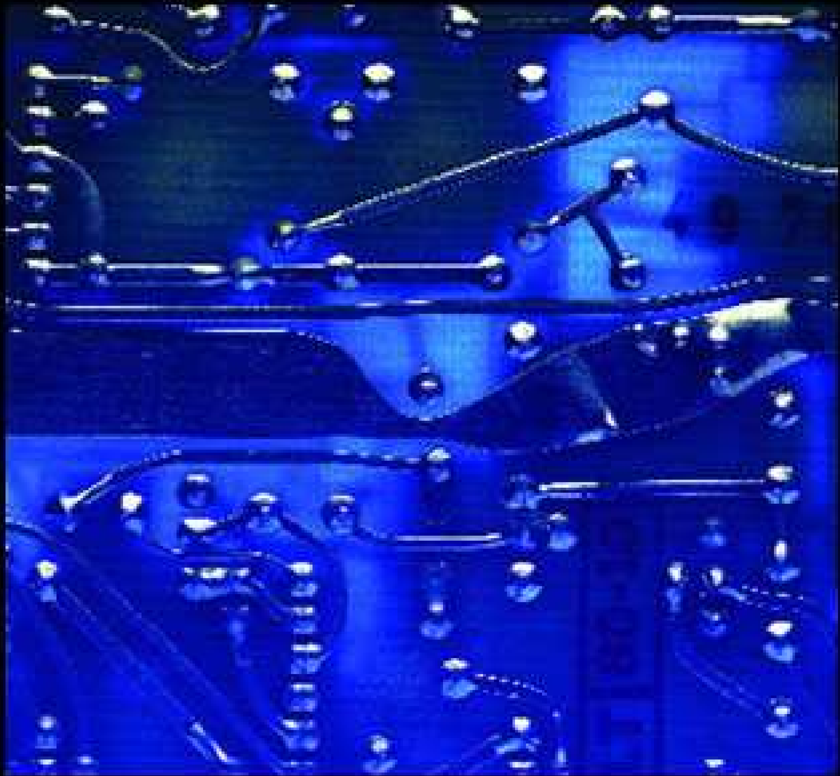
# ELECTRONIC DEVICES AND CIRCUIT THEORY

TENTH EDITION



BOYLESTAD

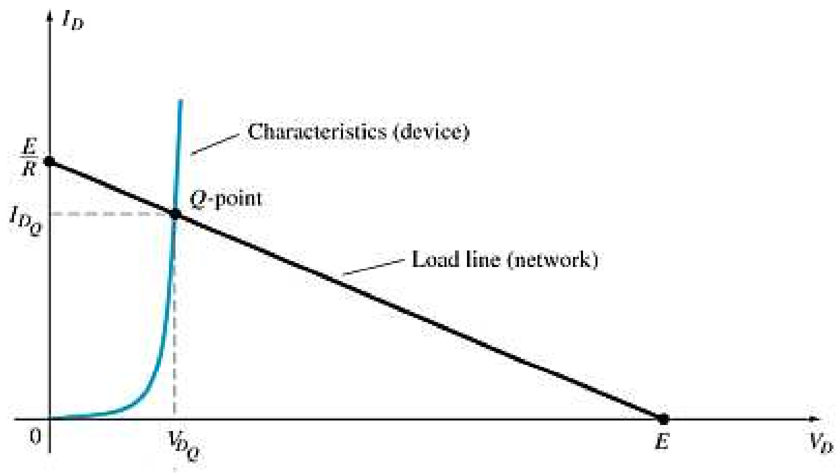
PEARSON

# Chapter 2:
# Diode Applications

# 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.







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# Series Diode Configurations

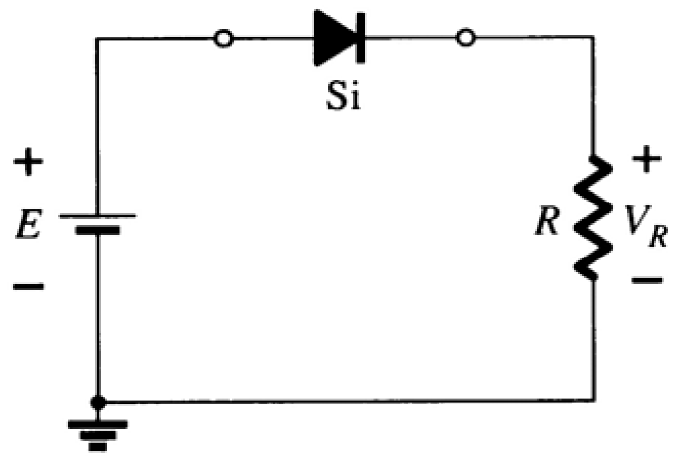
## Forward Bias

**Constants**

- **Silicon Diode:** $V_D = 0.7$ V
- **Germanium Diode:** $V_D = 0.3$ V

**Analysis (for silicon)**

- $V_D = 0.7$ V (or $V_D = E$ if $E < 0.7$ V)
- $V_R = E - V_D$
- $I_D = I_R = I_T = V_R / R$





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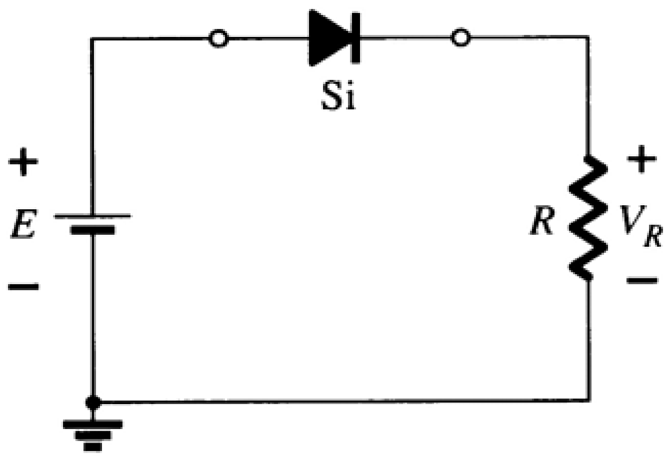
# Series Diode Configurations

## Reverse Bias

**Diodes ideally behave as open circuits**




**Analysis**

- $V_D = E$
- $V_R = 0$ V
- $I_D = 0$ A

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# Parallel Configurations

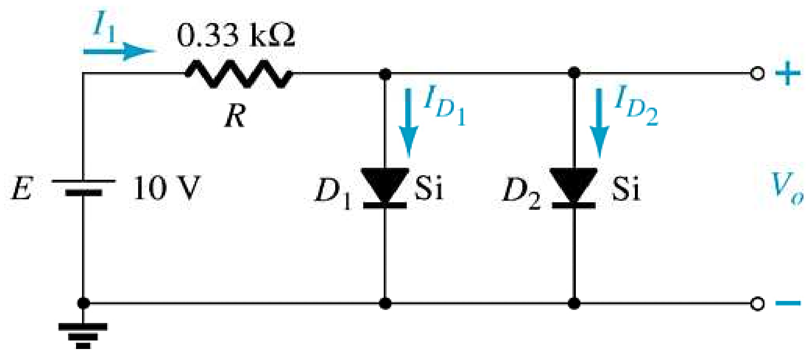
$$V_D = 0.7\text{ V}$$

$$V_{D1} = V_{D2} = V_O = 0.7\text{ V}$$

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

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

$$I_{D1} = I_{D2} = \frac{28\text{ mA}}{2} = 14\text{ mA}$$







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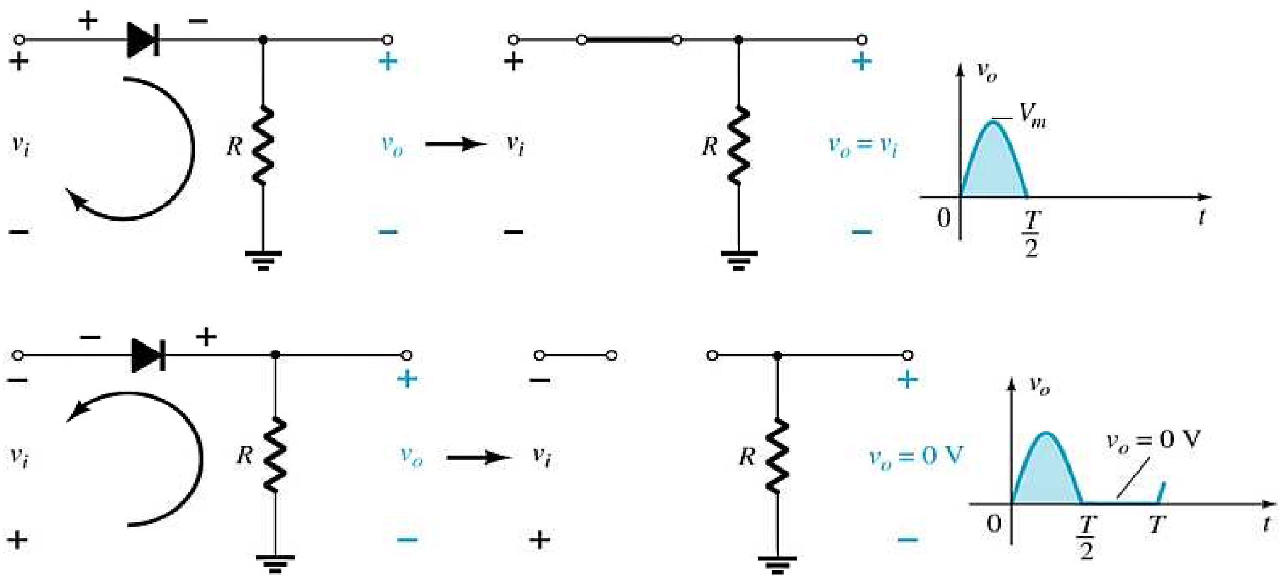
# Half-Wave Rectification

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




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

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# 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.**

$$\text{PIV (or PRV)} > V_m$$

- **PIV = Peak inverse voltage**
- **PRV = Peak reverse voltage**
- **$V_m$ = Peak AC voltage**


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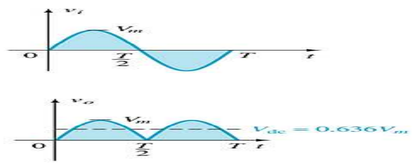
# Full-Wave Rectification

**The rectification process can be improved by using a full-wave rectifier circuit.**

**Full-wave rectification produces a greater DC output:**

- **Half-wave: $V_{dc} = 0.318V_m$**
- **Full-wave: $V_{dc} = 0.636V_m$**







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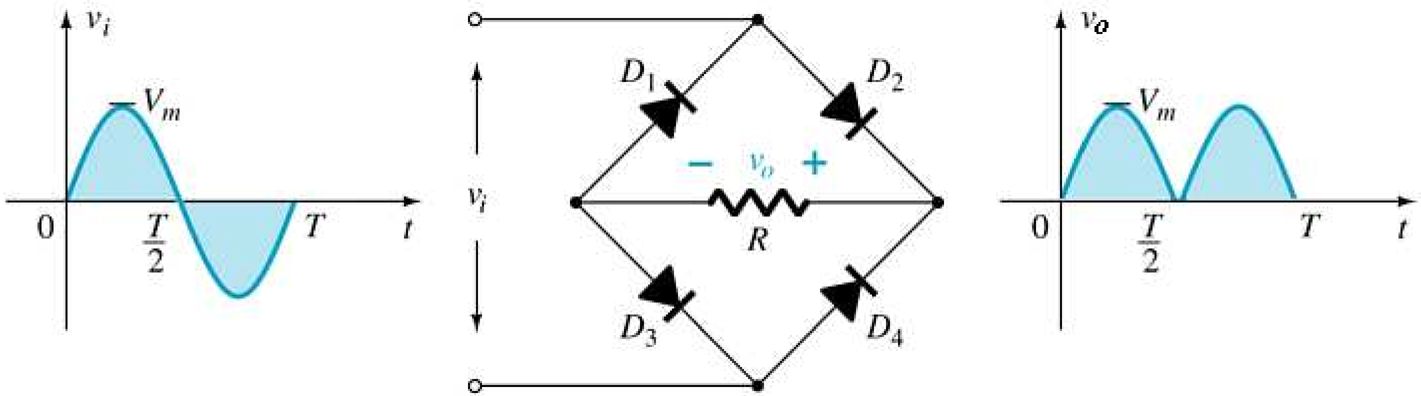
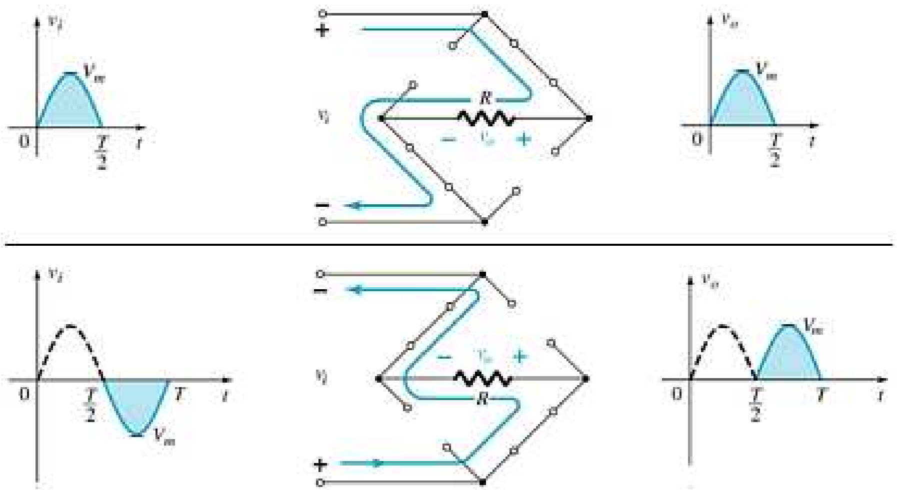
# Full-Wave Rectification




## Bridge Rectifier

- **Four diodes are connected in a bridge configuration**
- $V_{DC} = 0.636V_m$



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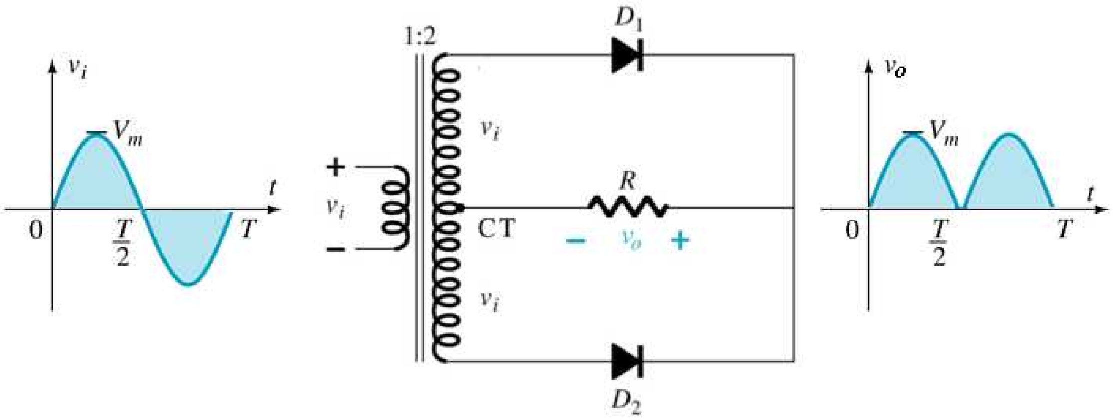
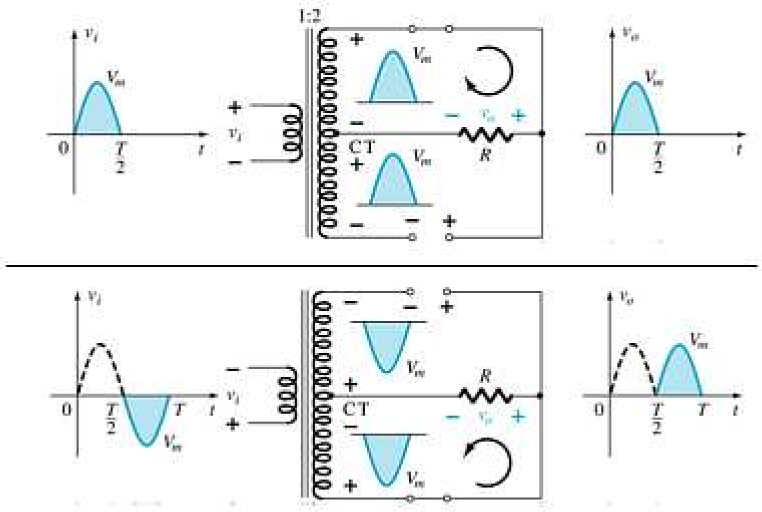
# Full-Wave Rectification




## Center-Tapped Transformer Rectifier




**Requires**

- **Two diodes**
- **Center-tapped transformer**

$$V_{DC} = 0.636V_m$$

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# Summary of Rectifier Circuits

| Rectifier | Ideal $V_{DC}$ | Realistic $V_{DC}$ |
|---|---|---|
| Half Wave Rectifier | $V_{DC} = 0.318V_m$ | $V_{DC} = 0.318V_m - 0.7$ |
| Bridge Rectifier | $V_{DC} = 0.636V_m$ | $V_{DC} = 0.636V_m - 2(0.7\text{ V})$ |
| Center-Tapped Transformer Rectifier | $V_{DC} = 0.636V_m$ | $V_{DC} = 0.636V_m - 0.7\text{ V}$ |

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

**In the center tapped transformer rectifier circuit, the peak AC voltage is the transformer secondary voltage to the tap.**



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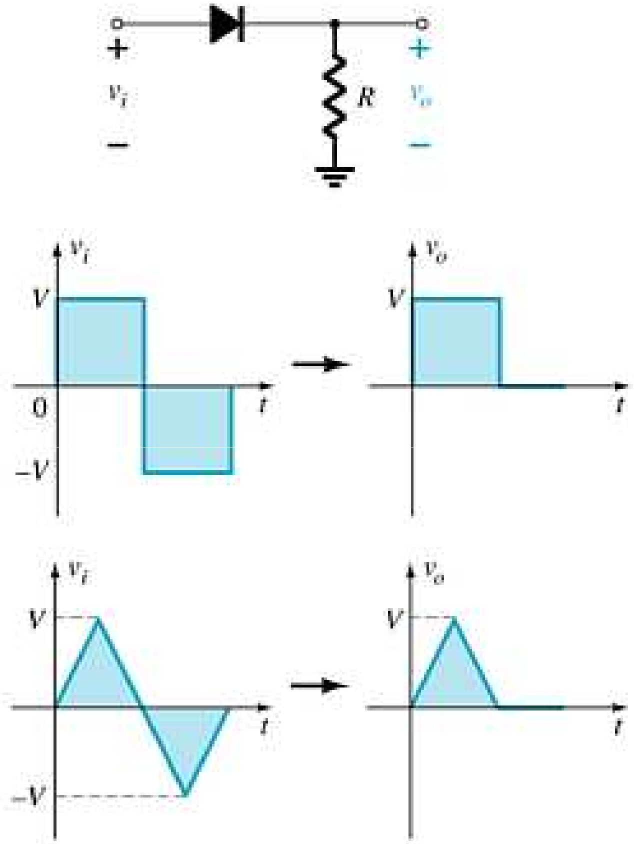
# Diode Clippers

**The diode in a series clipper "clips" any voltage that does not forward bias it:**

- **•A reverse-biasing polarity**
  **•A forward-biasing polarity less than 0.7 V (for a silicon diode)**



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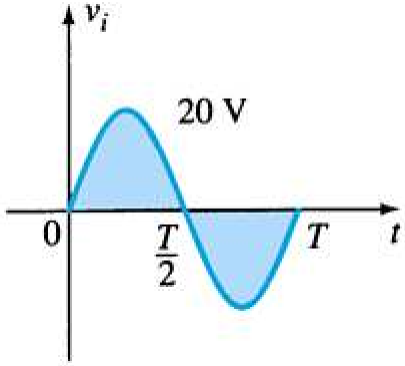
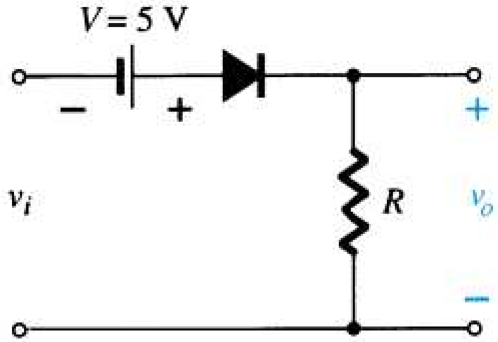
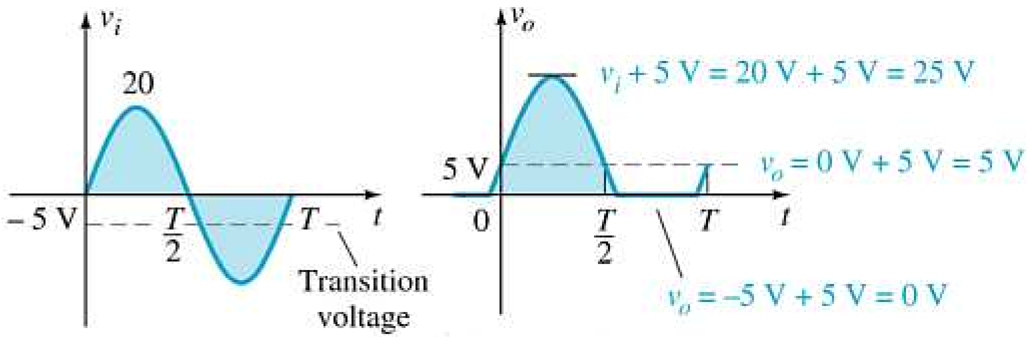
# Biased Clippers

**Adding a DC source in series with the clipping diode changes the effective forward bias of the diode.**







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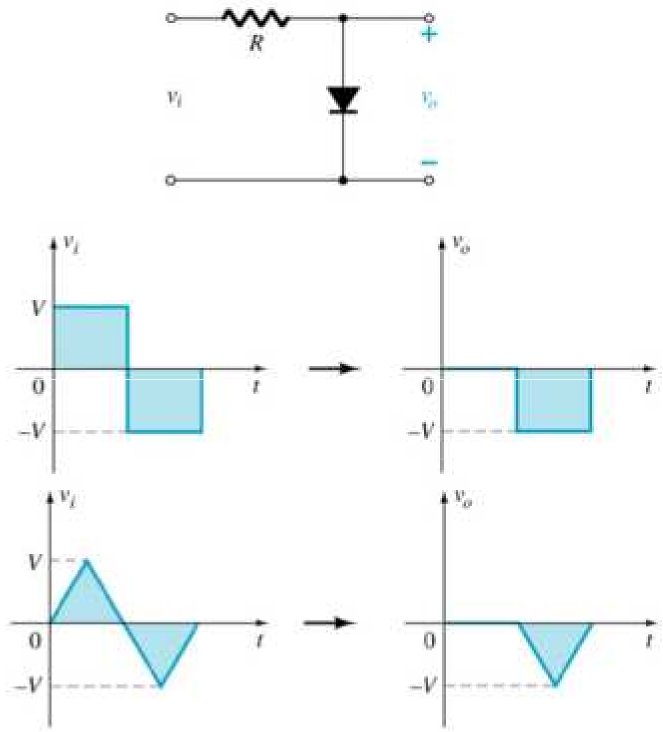
# Parallel Clippers

**The diode in a parallel clipper circuit "clips" any voltage that forward bias it.**

**DC biasing can be added in series with the diode to change the clipping level.**







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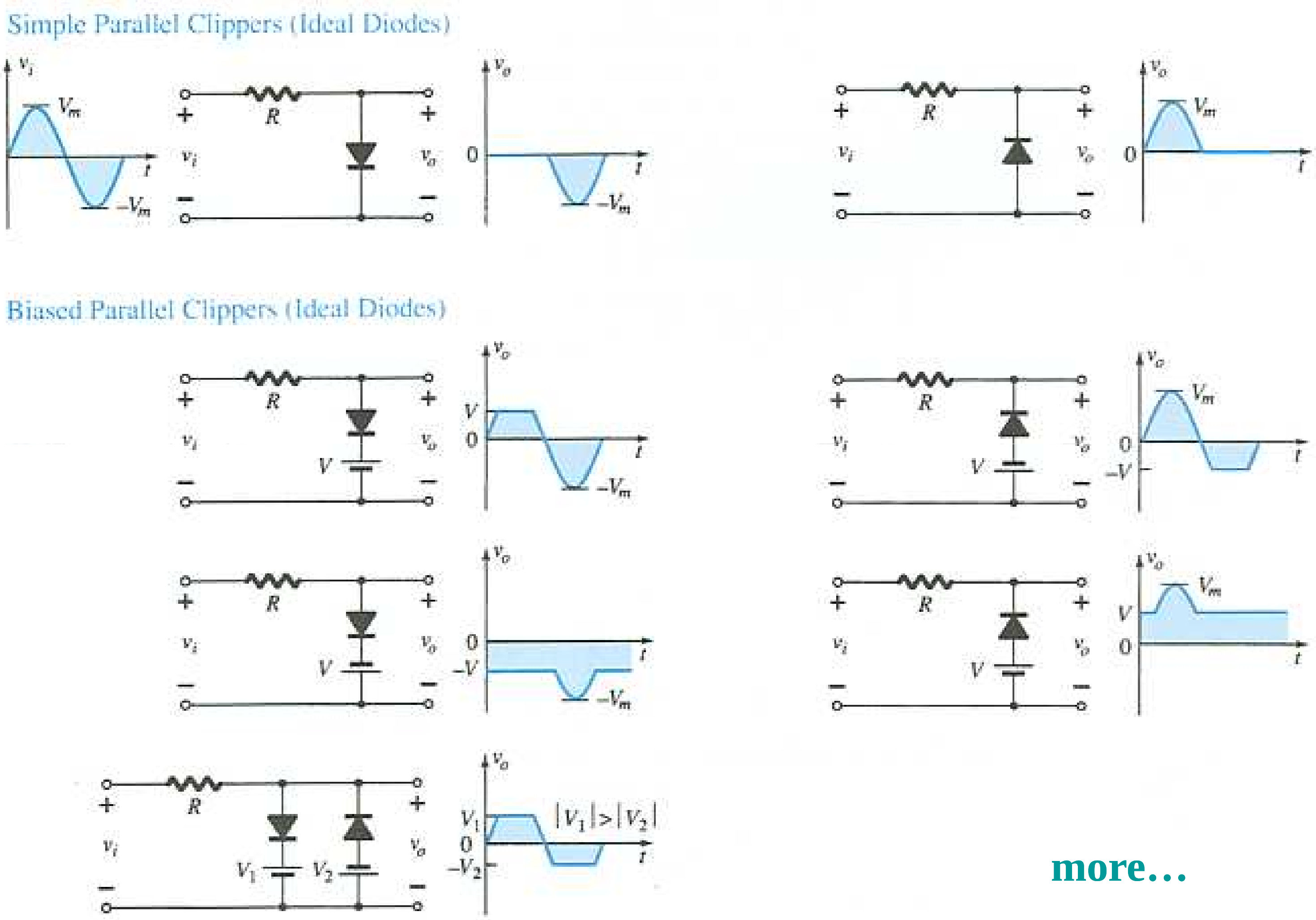
# Summary of Clipper Circuits

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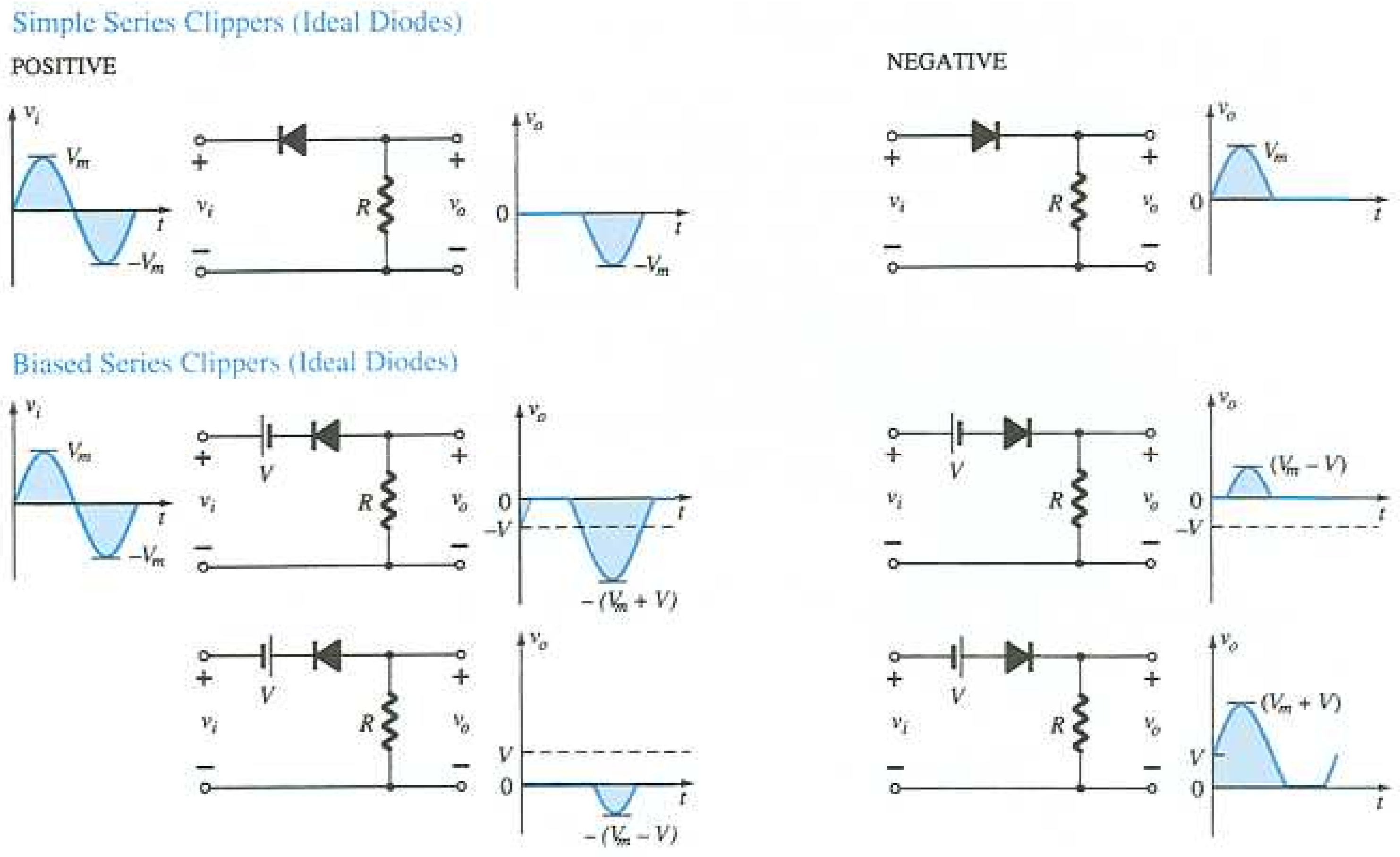
# Summary of Clipper Circuits





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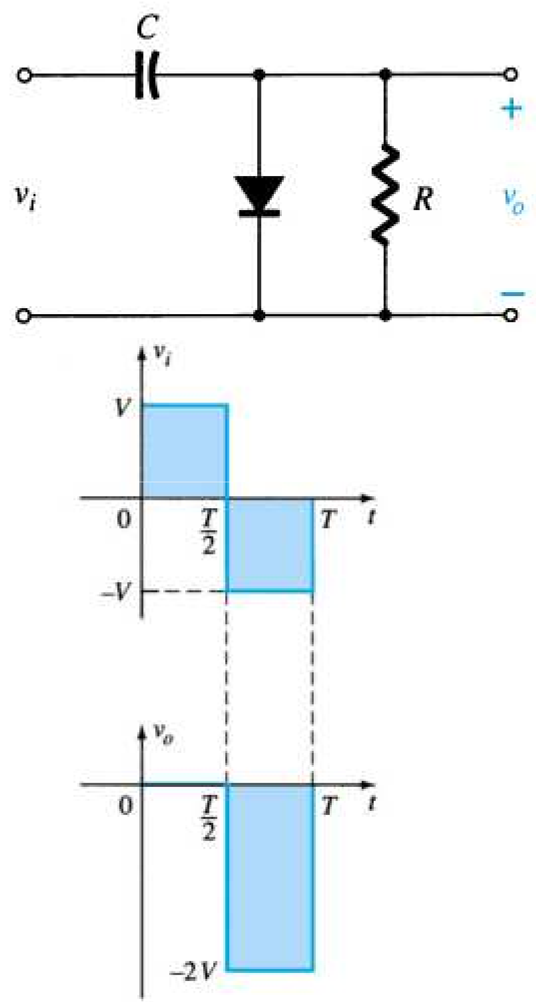
# Clampers

**A diode and capacitor can be combined to “clamp” an AC signal to a specific DC level.**







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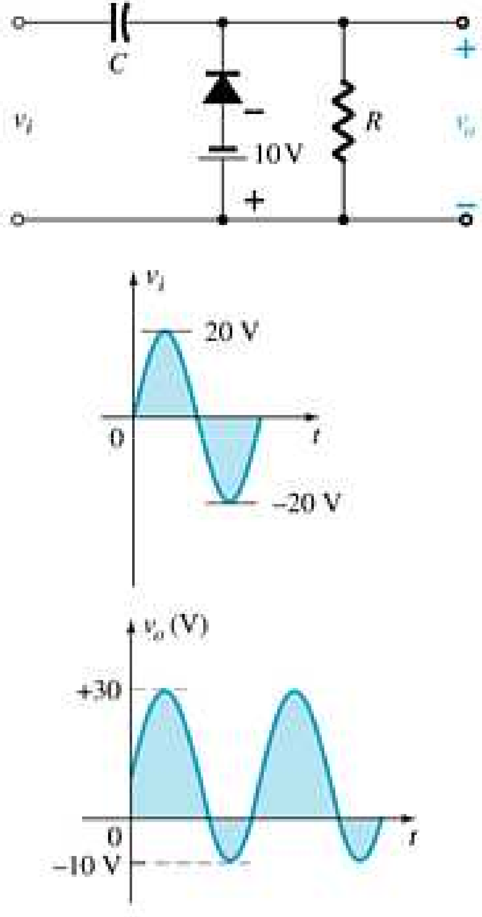
# Biased Clamper Circuits

**The input signal can be any type of waveform such as sine, square, and triangle waves.**

**The DC source lets you adjust the DC camping level.**



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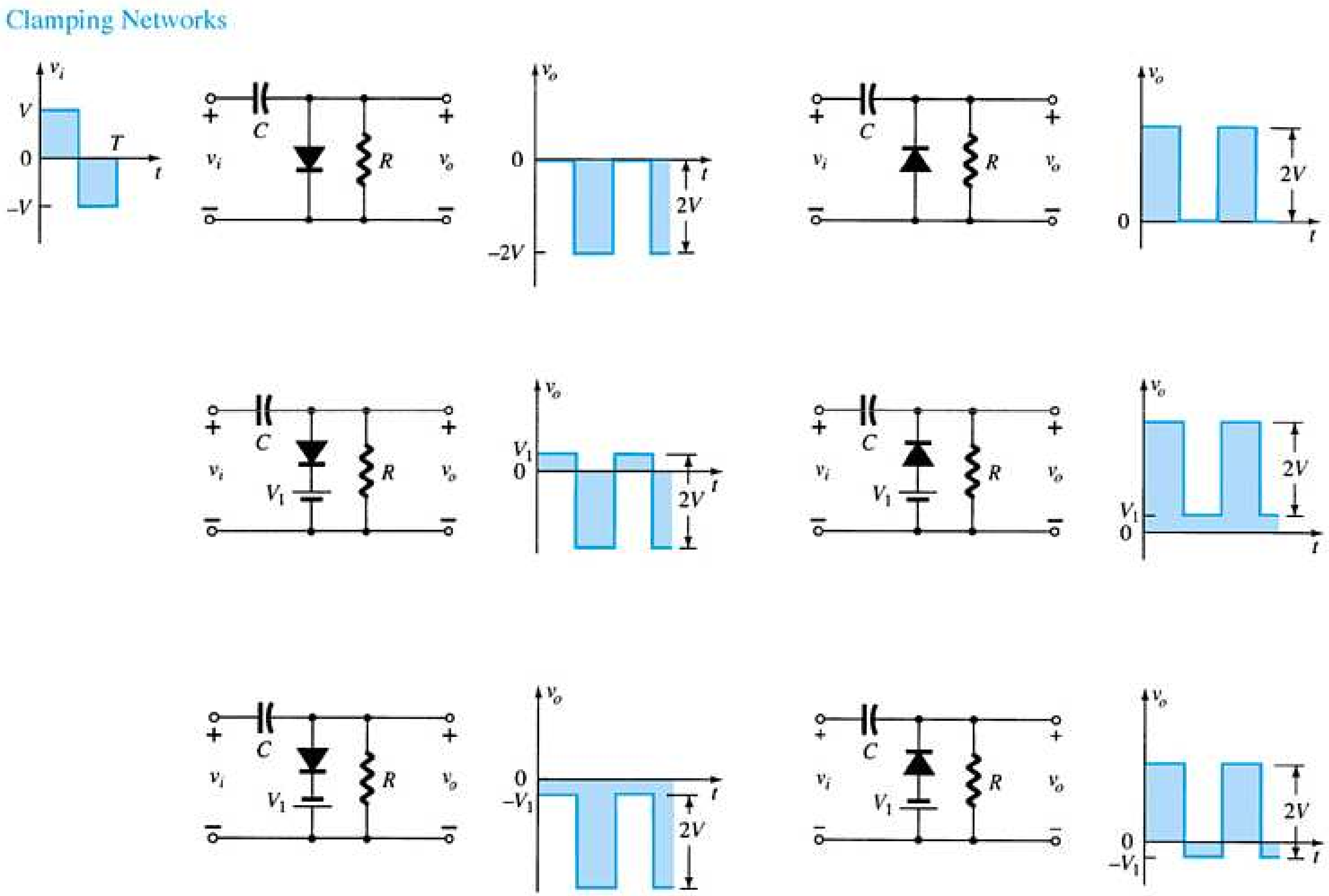
# Summary of Clamper Circuits



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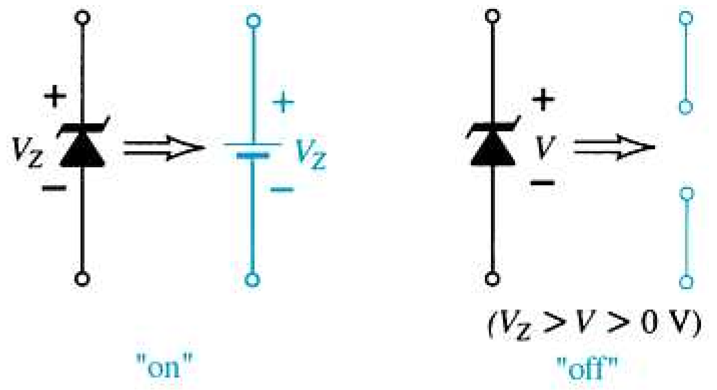
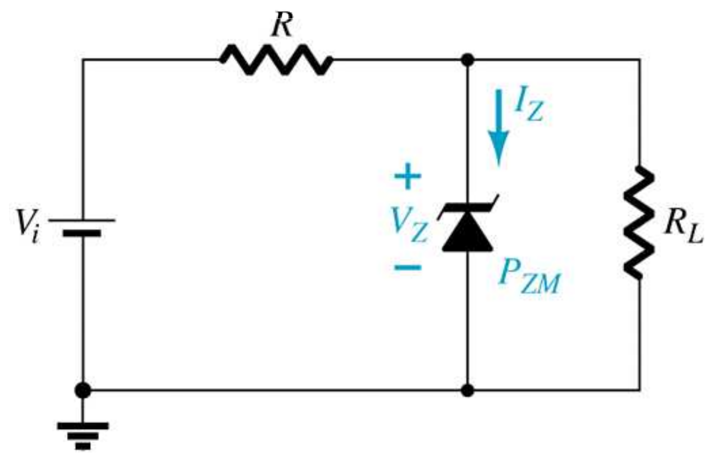
# Zener Diodes




The Zener is a diode operated in reverse bias at the Zener Voltage ($V_z$).

- When $V_i \geq V_Z$
  - The Zener is on
  - Voltage across the Zener is $V_Z$
  - Zener current: $I_Z = I_R - I_{RL}$
  - The Zener Power: $P_Z = V_Z I_Z$
- When $V_i < V_Z$
  - The Zener is off
  - The Zener acts as an open circuit







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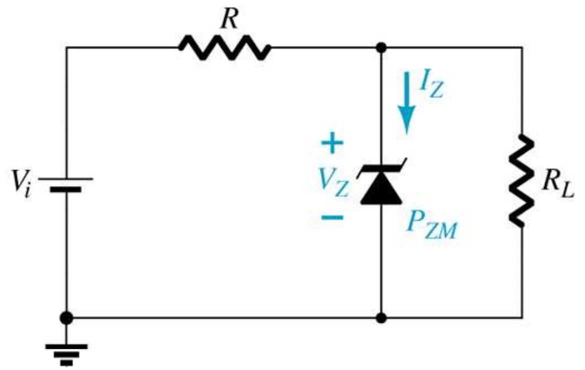
# Zener Resistor Values

**If *R* is too large, the Zener diode cannot conduct because the available amount of current is less than the minimum current rating, $I_{ZK}$. The minimum current is given by:**

$$I_{L\min} = I_R - I_{ZK}$$




**The *maximum* value of resistance is:**

$$R_{L\max} = \frac{V_Z}{I_{L\min}}$$

**If *R* is too small, the Zener current exceeds the maximum current rating, $I_{ZM}$. The maximum current for the circuit is given by:**

$$I_{L\max} = \frac{V_L}{R_L} = \frac{V_Z}{R_{L\min}}$$

**The *minimum* value of resistance is:**

$$R_{L\min} = \frac{RV_Z}{V_i - V_Z}$$

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# Voltage-Multiplier Circuits

**Voltage multiplier circuits use a combination of diodes and capacitors to step up the output voltage of rectifier circuits.**

- **Voltage Doubler**
- **Voltage Tripler**
- **Voltage Quadrupler**



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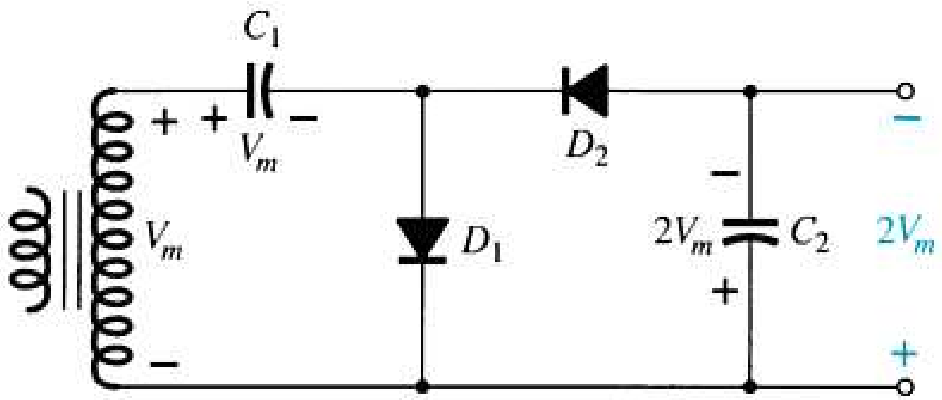
# Voltage Doubler




**This half-wave voltage doubler's output can be calculated by:**

$$\mathbf{V_{out} = V_{C2} = 2V_m}$$

**where $V_m$ = peak secondary voltage of the transformer**

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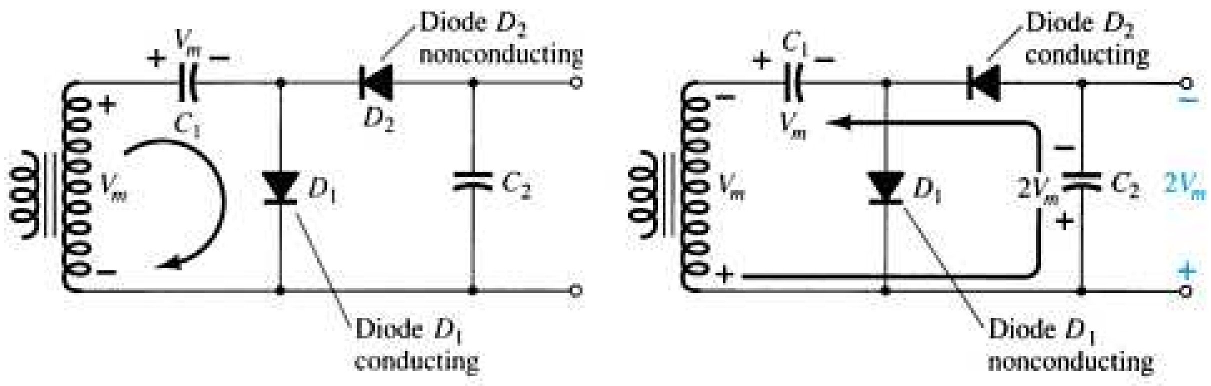
# Voltage Doubler

- **Positive Half-Cycle**
  - o **$D_1$ conducts**
  - o **$D_2$ is switched off**
  - o **Capacitor $C_1$ charges to $V_m$**

- **Negative Half-Cycle**
  - o **$D_1$ is switched off**
  - o **$D_2$ conducts**
  - o **Capacitor $C_2$ charges to $V_m$**

$$V_{out} = V_{C2} = 2V_m$$







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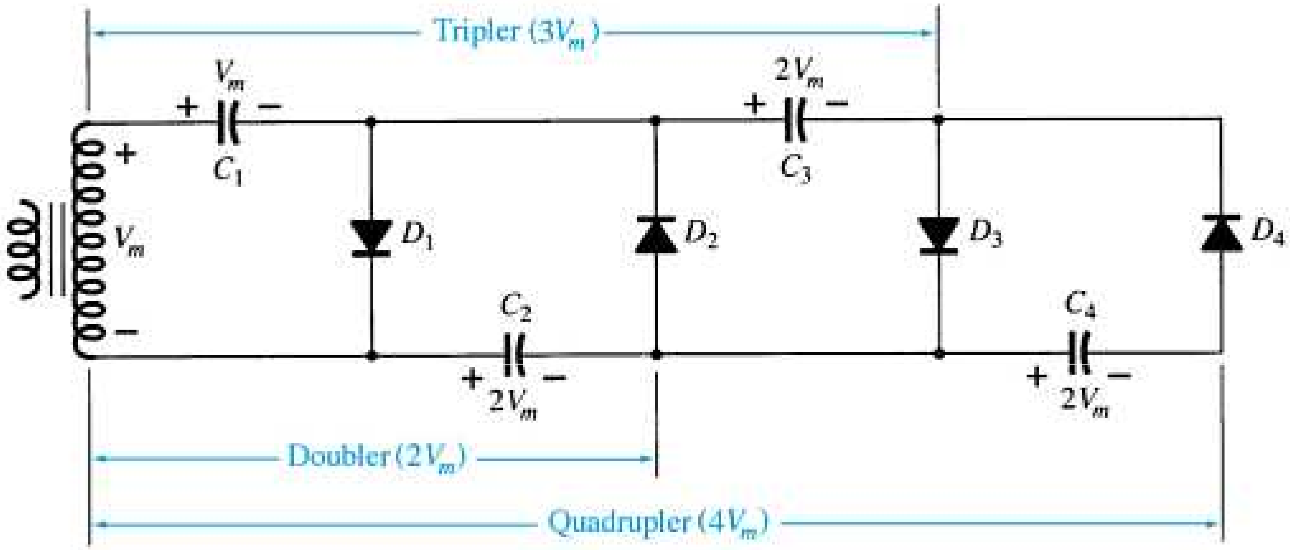
# Voltage Tripler and Quadrupler







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# Practical Applications

- Rectifier Circuits
  - Conversions of AC to DC for DC operated circuits
  - Battery Charging Circuits

- Simple Diode Circuits
  - Protective Circuits against
  - Overcurrent
  - Polarity Reversal
  - Currents caused by an inductive kick in a relay circuit

- Zener Circuits
  - Overvoltage Protection
  - Setting Reference Voltages



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