Electronic Circuits

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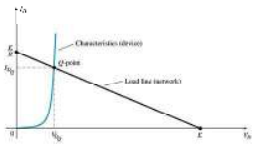
Load-Line Analysis

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

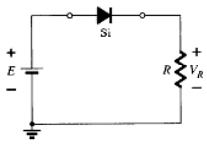
Forward Bias

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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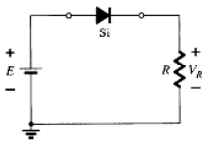
Series Diode Configurations

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

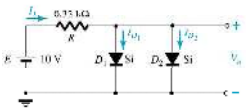
$$V_D = 0.7\text{ V}$$

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

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

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

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



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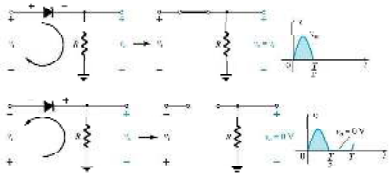
Half-Wave Rectification

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.

PIV (or PRV) > V_m

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

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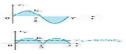
Full-Wave Rectification

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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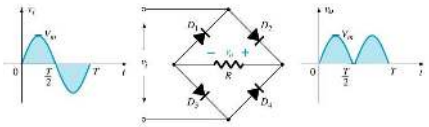
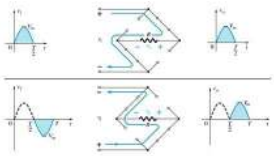
Full-Wave Rectification



Bridge Rectifier

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



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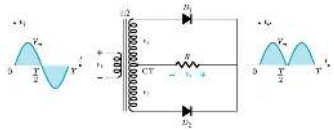
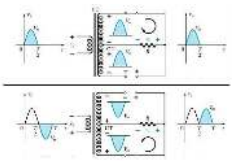
Full-Wave Rectification



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	$V_{DC} = 0.636V_m$	$V_{DC} = 0.636V_m - 2(0.7\ V)$
Center-Tapped Transformer Rectifier	$V_{DC} = 0.636V_m$	$V_{DC} = 0.636V_m - 0.7\ V$

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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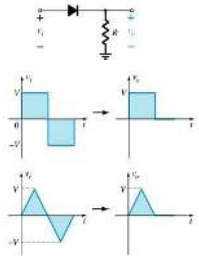
Diode Clippers

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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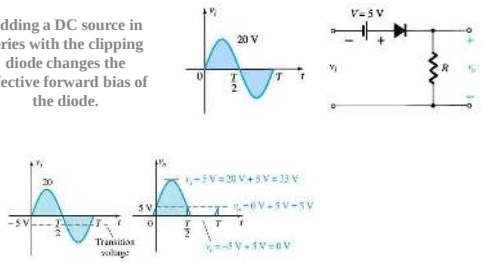
Biased Clippers

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



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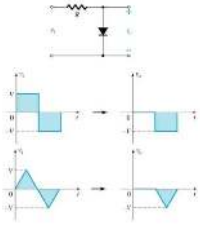
Parallel Clippers

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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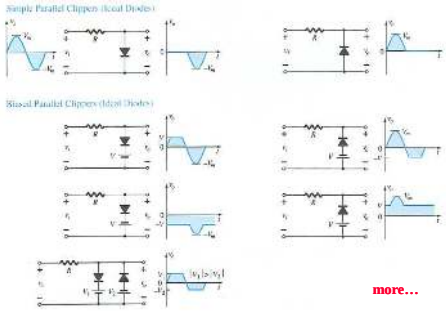
Summary of Clipper Circuits



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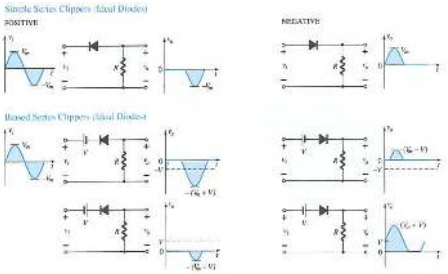
Summary of Clipper Circuits



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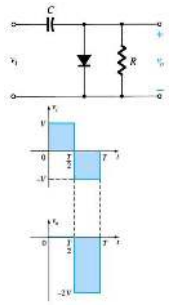
Clampers

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



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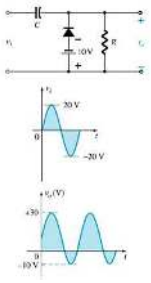
Biased Clamper Circuits

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

The DC source lets you adjust the DC clamping level.



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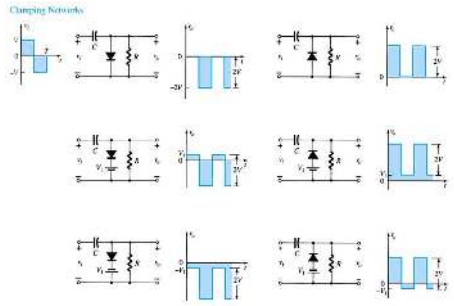
Summary of Clamper Circuits



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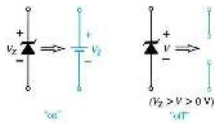
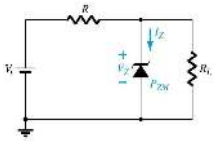
Zener Diodes

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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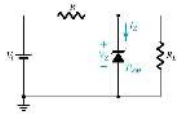
Zener Resistor Values

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:

$$I_{Lmin} = I_R - I_{ZK}$$



The *maximum* value of resistance is:

$$R_{Lmax} = \frac{V_Z}{I_{Lmin}}$$

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

$$I_{Lmax} = \frac{V_L}{R_L} = \frac{V_Z}{R_{Lmin}}$$

The *minimum* value of resistance is:

$$R_{Lmin} = \frac{RV_Z}{V_i - V_Z}$$

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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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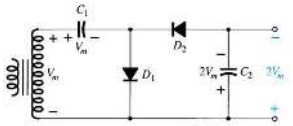
Voltage Doubler



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

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

where V_m = peak secondary voltage of the transformer

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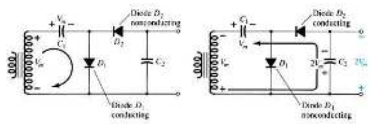
Voltage Doubler

- **Positive Half-Cycle**
  - D_1 conducts
  - D_2 is switched off
  - Capacitor C_1 charges to V_m
- **Negative Half-Cycle**
  - D_1 is switched off
  - D_2 conducts
  - Capacitor C_2 charges to V_m



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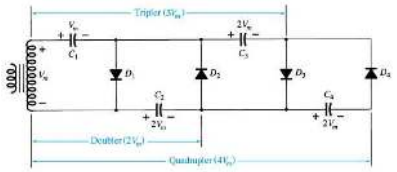
Voltage Tripler and Quadrupler



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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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