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.
Series Diode Configurations

Forward Bias

Constants
- Silicon Diode: $V_D = 0.7 \text{ V}$
- Germanium Diode: $V_D = 0.3 \text{ V}$

Analysis (for silicon)
- $V_D = 0.7 \text{ V}$ (or $V_D = E$ if $E < 0.7 \text{ V}$)
- $V_R = E - V_D$
- $I_D = I_R = I_T = V_R / R$
Series Diode Configurations

**Reverse Bias**
Diodes ideally behave as open circuits

**Analysis**
- $V_D = E$
- $V_R = 0 \text{ V}$
- $I_D = 0 \text{ A}$
Parallel Configurations

\[ V_D = 0.7 \text{ V} \]
\[ V_{D1} = V_{D2} = V_O = 0.7 \text{ V} \]
\[ V_R = 9.3 \text{ V} \]
\[ I_R = \frac{E - V_D}{R} = \frac{10 \text{ V} - 0.7 \text{ V}}{0.33 \text{ k}\Omega} = 28 \text{ mA} \]
\[ I_{D1} = I_{D2} = \frac{28 \text{ mA}}{2} = 14 \text{ mA} \]
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.
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.

\[
PIV \text{ (or PRV)} > V_m
\]

- \( PIV \) = Peak inverse voltage
- \( PRV \) = Peak reverse voltage
- \( V_m \) = Peak AC voltage
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: $V_{dc} = 0.636V_m$
Full-Wave Rectification

Bridge Rectifier

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

Center-Tapped Transformer Rectifier

Requires
- Two diodes
- Center-tapped transformer

\[ V_{DC} = 0.636V_m \]
## Summary of Rectifier Circuits

<table>
<thead>
<tr>
<th>Rectifier</th>
<th>Ideal $V_{DC}$</th>
<th>Realistic $V_{DC}$</th>
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<td>Half Wave Rectifier</td>
<td>$V_{DC} = 0.318V_m$</td>
<td>$V_{DC} = 0.318V_m - 0.7$</td>
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<tr>
<td>Bridge Rectifier</td>
<td>$V_{DC} = 0.636V_m$</td>
<td>$V_{DC} = 0.636V_m - 2(0.7 \text{ V})$</td>
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<td>Center-Tapped Transformer Rectifier</td>
<td>$V_{DC} = 0.636V_m$</td>
<td>$V_{DC} = 0.636V_m - 0.7 \text{ V}$</td>
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$V_m = \text{peak of the AC voltage.}$

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

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

\[ v_i = \begin{cases} 
20 \text{ V} & \text{for} \ 0 \leq t < \frac{T}{2} \\
5 \text{ V} & \text{for} \ \frac{T}{2} \leq t < T 
\end{cases} \]

\[ v_o = \begin{cases} 
0 \text{ V} + 5 \text{ V} = 5 \text{ V} & \text{for} \ \frac{T}{2} \leq t < T \\
-5 \text{ V} + 5 \text{ V} = 0 \text{ V} & \text{for} \ 0 \leq t < \frac{T}{2} 
\end{cases} \]
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.
Summary of Clipper Circuits

Simple Parallel Clippers (Ideal Diodes)

Biased Parallel Clippers (Ideal Diodes)

more…
Summary of Clipper Circuits

Simple Series Clippers (Ideal Diodes)

**POSITIVE**

**NEGATIVE**

Biased Series Clippers (Ideal Diodes)
Clampers

A diode and capacitor can be combined to “clamp” an AC signal to a specific DC level.
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.
Summary of Clamper Circuits

Clamping Networks

- Diagrams showing different clamper circuit configurations with voltage waveforms.

- Various component configurations including resistors (R), capacitors (C), diodes, and voltage levels (V).

- Illustrations depict the behavior of the clamper circuits under different input conditions.

- The diagrams highlight the response of the circuits to input signals, showing how they clamp or limit the voltage levels.
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
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:

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

The maximum value of resistance is:

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

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

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

The minimum value of resistance is:

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

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

\[ V_{\text{out}} = V_{C2} = 2V_m \]

where \( V_m \) = peak secondary voltage of the transformer
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 $V_m$

$$V_{out} = V_{C2} = 2V_m$$
Voltage Tripler and Quadrupler

\[ V_{m} \]

\[ C_{1} \]

\[ D_{1} \cdot D_{2} \cdot D_{3} \cdot D_{4} \]

\[ C_{2} \]

\[ C_{3} \]

\[ C_{4} \]

\[ V_{m} \]

\[ 3V_{m} \]

\[ 2V_{m} \]

\[ 2V_{m} \]

\[ 4V_{m} \]

Tripler (3Vₘ)
Doubler (2Vₘ)
Quadrupler (4Vₘ)
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