3.1 The Ideal Diode (pp.139-141)

A. The Ideal Diode Symbol

B. Ideal Diode Behavior
**HO: Linear Device Behavior**

C. Diode Bias Regions

1) Forward Biased
2) Reverse Biased

**HO The Ideal Diode**

**HO Diode Mechanical Analogy**
D. Ideal Diode Circuit Analysis

\[ V_{D1}^i = \begin{cases} + & \text{if } i_{D1}^i > 0 \\ - & \text{if } i_{D1}^i < 0 \end{cases} \]

\[ V_{D2}^i = \begin{cases} + & \text{if } i_{D2}^i > 0 \\ - & \text{if } i_{D2}^i < 0 \end{cases} \]
HO: The Ideal Diode Circuit Analysis Guide

HO: Example: A Simple Ideal Diode Circuit

HO: Example: Analysis of a Complex Diode Circuit
Linear Device Behavior

1) Recall the circuit behavior of a resistor:

\[ i = \frac{v}{R} \]

2) If \( R=0 \), then we have a short circuit:

\[ v = 0 \]
3) If $R = \infty$, then we have a **open** circuit:

![Open Circuit Diagram]

$$i = 0$$

4) We can also plot the behavior of both current and voltage sources:

![Current and Voltage Source Diagrams]
The Ideal Diode

An ideal diode—the circuit device with a split personality!

→ Is it a short? Or is it an open?

\[ + V_D^i - \]

\[ i_D^i \]

<table>
<thead>
<tr>
<th>( V_D^i )</th>
<th>( i_D^i )</th>
<th>( V_D^i )</th>
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<tbody>
<tr>
<td>(&lt; 0)</td>
<td>(&gt; 0)</td>
<td>(&gt; 0)</td>
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<tr>
<td>invalid</td>
<td>forward biased</td>
<td>invalid</td>
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<tr>
<td>(= 0)</td>
<td>reverse biased</td>
<td>no bias</td>
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The Diode
Mechanical Analogy

An ideal diode is sort of like a mechanical valve!

Case 1: Valve allows liquid to flow in pipe from side A to side C.

There is no drop in pressure (P) from side A to side C.

\[ P_A - P_C = 0 \]
Case 2: Valve prevents liquid from flowing back from side C to side A.

No flow occurs when pressure $P_C$ is greater than pressure $P_A$

$\Rightarrow \quad P_A - P_C < 0$

Note the analogies with an ideal diode:

**Valve**  
Pressure  
Liquid Flow  
Side A  
Side C  
Case 1  
Case 2

**Diode**  
Voltage  
Current  
Anode  
Cathode  
Forward Bias  
Reverse Bias
The Ideal Diode Circuit Analysis Guide

Follow these easy steps to successfully analyze a circuit containing one or more ideal diodes!

Step 1: Assume a bias state for each ideal diode.

⇒ In other words, GUESS!!

Either,

a) Assume an ideal diode is forward biased, or

b) Assume it is reversed biased.

Step 2: Enforce the equality condition consistent with your assumption.

a) If you assume an ideal diode is f.b., then ENFORCE the equality:

\[ v_D = 0 \]

HOW? ⇒ By replacing the ideal diode with a short circuit!
b) If you assumed an ideal diode was r.b., then ENFORCE the condition that:

\[ i_D^i = 0 \]

HOW? ⇒ By replacing the ideal diode with an open circuit.

IMPORTANT !!! Retain the same current and voltage definitions when you replace the ideal diode!

If, then, or

\[ i_d^i \]
\[ v_d^i \]
\[ i_d^i = 0 \]
\[ v_d^i \]
\[ i_d^i \]
\[ v_d^i = 0 \]

Step 3: ANALYZE the circuit.

After the all ideal diodes have been replaced with either shorts or opens:

a) Determine all desired (required) circuit values.

b) Determine \( i_d^i \) through each short circuit and \( v_d^i \) across each open circuit.
**Step 4:** **CHECK** the inequality consistent with your assumption to see if this assumption is correct.

**HOW??**

a) An **ideal** diode cannot have negative current flowing through it. If you **ASSUMED** the ideal diode was **forward biased**, **CHECK** to see if the **short** circuit current is positive, i.e.:

\[ i_D^i > 0 \]

If true, you **ASSUMED** correctly! If not, your **f.b.** assumption is wrong.

b) An **ideal** diode cannot have positive voltage across it. If you **ASSUMED** the ideal diode was **reversed biased**, **CHECK** to see if the **open** circuit voltage is negative, i.e.:

\[ v_D^i < 0 \]

If true, you **ASSUMED** correctly! If not, your **r.b.** assumption is wrong.

**Step 5:** If you **ASSUMED** incorrectly, then change your assumptions and return to step 1!
Notes on ideal diode circuit analysis:

1) You **must** check all assumptions in this form:

\[ i_D^i = 2 \text{ mA} > 0 \checkmark \quad \text{or} \quad v_D^i = 2.2 > 0 \times \]

2) Do **not** check the condition that you enforced!

3) For *every* circuit, one and only one assumption will be valid.
Example: A Simple Ideal Diode Circuit

Consider this simple circuit that includes an ideal diode:

```
  5.0 V
   +---
      |
      |
   2 K
   +---
      |
      |
  i_D^i
   +---
      |
      |
  v_D^i
```

Q: What are $i_D^i$ and $v_D^i$?

A: Follow the five easy analysis steps!

**Step 1:** Let’s **ASSUME** the ideal diode is reverse biased (we’re just guessing!).

**Step 2:** We therefore **ENFORCE** $i_D^i = 0$ by replacing the ideal diode with an **open** circuit.

**Step 3:** Now we **ANALYZE** the circuit; finding the value of $v_D^i$. 
Step 4: Now let’s CHECK our result. ⇒ Is $v_D^i < 0$?

$v_D^i = \ldots$

We must change our assumption, and then start over (Doh!).

1) Now ASSUME the ideal diode is forward biased (what’s left?).

2) We therefore ENFORCE $v_D^i = 0$ by replacing the ideal diode with an short circuit.

3) Now we ANALYZE the circuit; finding the value of $i_D^i$. 
4) Now, let's CHECK our result. \[ \Rightarrow \text{Is } i_D^i > 0 \? \]

\[ i_D^i = \]

Our assumption is correct!

Therefore, in this circuit, we now know that:

\[ v_D^i = 0 \text{ and } i_D^i = \]
Example: Analysis of a Complex Diode Circuit

Consider this circuit with two ideal diodes:

Let's analyze this circuit and find $V_{D1}^i$, $i_{D1}^i$, $V_{D2}^i$, and $i_{D2}^i$!

Remember, we must accomplish each of the five steps:

Step 1: \textit{Assume} that both D1 and D2 are “on” (might as well!).

Step 2: \textit{Enforce} the equalities $V_{D1}^i = 0 = V_{D2}^i$, by replacing each ideal diode with a short circuit.
Step 3: **ANALYZE** the resulting circuit, and find $i_{D1}'$ and $i_{D2}'$.

![Circuit Diagram]

Begin with **KCL**:

$$i = i_{D1}' + i_{D2}'$$

where $i = \ldots$

and $i_{D2}' = \ldots$

Therefore, $i_{D1}' = \ldots$
Step 4: Now we must CHECK inequalities to see if our assumptions are correct!

\[ i_{D1}^i = \]

\[ i_{D2}^i = \]

One assumption is therefore INCORRECT. We must proceed to step 5—change our assumptions and completely start again!

Q: Wait a second! We don’t have to completely start from the beginning, do we? After all, our assumption about diode \( D_2 \) turned out to be true—so we already know that \( i_{D2}^i = \) and \( v_{D2}^i = 0 \), right?

A: NO! The solution for diode \( D_2 \) is dependent on the state of both diodes \( D_1 \) and \( D_2 \). If the assumption of just one diode turns out to be incorrect, then the solutions for all diodes are wrong!

So, let’s change our assumption and start all over again!
Step 1: Now **ASSUME** that $D_1$ is "off" and $D_2$ is "on".

Step 2: **ENFORCE** $i_{D1}^i = 0$ (D1 open) and $v_{D2}^i = 0$ (D2 short).

Step 3: **ANALYZE** resulting circuit, and find $v_{D1}^i$ and $i_{D2}^i$.

Note $i = i_{D2}^i =$

and from KVL:
4) CHECK our assumptions.

\[ i_{D2}^i = \]

\[ v_{D1}^i = \]

\[ v_{D2}^i = \quad i_{D2}^i = \]

\[ v_{D1}^i = \quad i_{D1}^i = 0 \]

\[ v_{D2}^i = 0 \]

\[ i_{D2}^i = \]

\[ \therefore \text{Assumptions are correct! We are finished!} \]