Diode Circuit Analysis, Lect 5

There are several methods for analyzing this circuit:
- graphical load line
- math
- ideal diode model
- CVD model

Graphical

Sometimes you only have a graph of the I-V characteristic, so if you have to use load line analysis.
\[
I_D = I_S \left( e^{\frac{V_B}{n U_T}} - 1 \right) = 10^{-13} \left( e^{40 V_B} - 1 \right)
\]

\[
10 V = 10^7 I_D + V_B
\]

\[
10 V = 10^7 \cdot 10^{-13} \left( e^{40 V_B} - 1 \right) + V_B
\]

This equation, however, is a transcendental equation. It does not have a closed form solution.

Turn to Matlab or Excel to find the solution.

\[
f = 10 V - 10^7 \cdot 10^{-13} \left( e^{40 V_B} - 1 \right) - V_B
\]

\[
f' = -4 \times 10^{-8} \left( e^{40 V_B} \right) - 1
\]

\[
V_B^{initial} = V_B - \frac{f(V_B)}{f'(V_B)}
\]

\[
I_D = 10^{-13} \left( e^{40 V_B} - 1 \right)
\]

Start with a guess for \( V_B \)

Then calculate \( f, f', V_B^{new}, \) and \( I_D \)

Iterate...
Ideal Diode

The ideal diode model is a non-continuous model.

It estimates the diode separately based on conditions. It is the simplest model (and the least accurate).

The model

\[ V_o < 0 \quad \Rightarrow \quad \text{modeled as an open} \]
\[ V_o > 0 \quad \Rightarrow \quad \text{modeled as a short} \]
**Constant Voltage Drop**

Notice that for almost any value of $I_D$ where the diode is conducting, $V_D \approx 0.7V$.

The ideal model neglects this voltage. The Constant Voltage Drop model adds it back in.

The book says that it uses a diode voltage of 0.6V. I learned it using 0.7V. Don't get confused if I bounce back and forth.

\[ I_D = \frac{10V - 0.6V}{10k} = 0.94mA \]
Comparison of Models

<table>
<thead>
<tr>
<th></th>
<th>Diode Current</th>
<th>Diode Voltage</th>
<th>% Error Cor</th>
<th>% Error V</th>
</tr>
</thead>
<tbody>
<tr>
<td>load line</td>
<td>0.94 mA</td>
<td>0.65 V</td>
<td>1.71%</td>
<td>9.69%</td>
</tr>
<tr>
<td>math</td>
<td>0.942 mA</td>
<td>0.547 V</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>ideal</td>
<td>1 mA</td>
<td>0 V</td>
<td>6.16%</td>
<td>10%</td>
</tr>
<tr>
<td>CVD</td>
<td>0.94 mA</td>
<td>0.6 V</td>
<td>1.21%</td>
<td>9.69%</td>
</tr>
</tbody>
</table>

Now we look at multiple diode circuits...

Load line → only works for single diode circuit
Math → becomes complex fast!
Ideal → Possible candidate
CVD → More likely candidate

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Assume ideal

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[Diagram of a circuit with diodes and text:

10k

15V

D1

D2

4 possible states

d1 off
off
on
off

d2 off
off
on
off

Assume ideal]
Assume they are both on

\[ I_1 = \frac{15V - 0V}{10k} = 1.5mA \]

\[ I_{D2} = 0 - (-10V) = 2mA \]

\[ I_1 = I_{D1} + I_{D2} \]

\[ 1.5mA + 2mA = 3.5mA \] which is not allowed

\[ 15V - I_1 (10k) - I_1 (5k) = -10V \]

\[ 25V = I_1 (15k) \]

\[ \frac{25V}{15k} = I_1 = 1.67mA \]

\[ V_{D1} = 15V - (1.67mA)(10k) = -1.67V \]
$C_{VD} = 0.6\,\text{V}$

$V_c = -0.6\,\text{V}$
$V_b = -0.6\,\text{V} + 0.6\,\text{V} = 0$
$V_A = 0 - 0.6 = -0.6\,\text{V}$

$I_1 = \frac{10 - 0}{10\,\text{k}} = 1\,\text{mA}$

$I_2 = \frac{-0.6\,\text{V} - (-20\,\text{V})}{10\,\text{k}} = 1.94\,\text{mA}$

$I_3 = \frac{-0.6\,\text{V} - (-10\,\text{V})}{10\,\text{k}} = 0.94\,\text{mA}$

$I_2 = I_{01}, \quad I_1 = I_{01} + I_{02}, \quad I_3 = I_{02} + I_{03}$

$I_{01} = 1.94\,\text{mA}$
$I_{02} = 1\,\text{mA} - 1.94\,\text{mA} = -0.94\,\text{mA}$ \leftarrow \text{problem}
$I_{03} = 0.94\,\text{mA} + 0.94\,\text{mA} = 1.88\,\text{mA}$
So, let's assume $D_1, D_3 \rightarrow \text{on}$  
$D_2 \rightarrow \text{off}$

![Circuit Diagram]

\[ 10V - I_{D1}(10K) - 0.6V - I_{D3}(10K) = -20V \]

\[ 29.4V = I_{D1}(20K) \]

\[ 29.4V = I_{D1} = 1.47mA > 0 \checkmark \]

\[ 0V - 0.6V - I_{D3}(10K) = -10V \]

\[ 9.4V = I_{D3}(10K) \]

\[ \frac{9.4V}{10K} = I_{D3} = 0.94mA \]

$V_{D2}$

\[ 10V - I_{D1}(10K) - V_{D2} + 0.6V = 0 \]

\[ 10 - 14.7V - V_{D2} + 0.6V = 0 \]

\[ -4.1V = V_{D2} \]