Lab 2: Resistors and Diodes

ENGR 2420 | Olin College

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Postlab

1. (a) We derive the equation as follows.

$$-V_{on} + \frac{V_{in}}{U_T} = e^{\frac{V - V_{on}}{U_T}} + \frac{V}{U_T} - V_{on}$$

This can also be simplified to:

$$V_{in} = e^{\frac{V - V_{on}}{U_T}} + V$$

(b) When $V < V_{on}$ by more than a few U_T, we can approximate the equation as:

$$V_{in} = V$$

(c) When $V > V_{on}$ by more than a few U_T, we can approximate the equation as:

$$V_{in} = e^{\frac{V}{U_T}} + V$$

2. (a) $V \approx V_1$ if $V_1 < V_2$ by more than a few U_T because if term $e^{\frac{V_1 - V_2}{U_T}}$ will effectively go to zero, allowing the second given equation simplify to $V = V_1$.
Additionally, $V \approx V_2$ if $V_1 > V_2$ by more than a few U_T because if V_1 in the term $e^{\frac{-V_1}{U_T}}$ in the first given equation is big, that whole term will go to zero and the equation will simplify as shown:

$$V = -U_T \log e^{\frac{-V_2}{U_T}} = -U_T \frac{-V_2}{U_T} = V_2$$

(b) We can equate V_1 to V_{in} and V_2 to V_{on}, giving us the equation:

$$V = V_{in} - U_T \log(1 + e^{(V_{in} - V_{on})/U_T})$$

This means that the voltage across the transistor is about equal to V_{in} when it is less than V_{on}, which matches the behavior of the transistor we measured above.

(c) We can obtain an express for I in terms of V_{in} as follows:

$$I = \frac{V_{in} - V}{R}$$

$$I \cdot R = V_{in} - V$$

$$I \cdot R = V_{in} - (V_{in} - U_T \log(1 + e^{\frac{V_{in} - V_{on}}{U_T}}))$$

We can further simplify $\frac{U_T}{R}$ as I_{on}:

$$I = I_{on} \log(1 + e^{\frac{V_{in} - V_{on}}{U_T}})$$

When $V_{in} < V_{on}$ by more than a few U_T, we can approximate the whole term as

When $V_{in} > V_{on}$ by more than a few U_T, the 1 term in the log is near meaningless and we can approximate the whole equation as $I \approx I_{on} \frac{V_{in} - V_{on}}{U_T}$, which simplifies to $I \approx \frac{V_{in} - V_{on}}{R}$

This fits the behavior observed in our measured data.

(d) We need to find an equation that gives I in terms of V_{in}. To find the current, we can start with the approximation of the ideal diode equation, given earlier as

$$I = I_s e^{V/U_T}$$

We got V and dealt with V_{in} in part b, so we can sub in that equation for V as shown.

$$I = I_s e^{V_{in} - U_T \log(1 + e^{(V_{in} - V_{on})/U_T})/U_T}$$

By plotting this, we see that when $V_{in} < V_{on}$ by more than a few U_T, the equation follows a logistic curve as we see in our data. Conversely, When $V_{in} > V_{on}$ by more than a few U_T, the equation levels off at a value (I'm guessing this should be I_{on}?).