Postlab 2

① $I_R = I_T = I_{in}$ where $I_R = \frac{V_{in}-V}{R}$ and $I_T = I_s e^{V/U_T}$

a) so $\frac{V_{in}-V}{R} = I_s e^{V/U_T}$ → $\boxed{V_{in} = I_s e^{V/U_T} R + V \quad \text{eq. 1}}$

and we know $V_{on} = U_T \ln(I_{on}/I_s)$ and $I_{on} = \frac{U_T}{R}$

so $V_{on} = U_T \ln\left(\frac{U_T}{RI_s}\right)$

$e^{\left(\frac{V_{on}}{U_T}\right)} = \frac{U_T}{RI_s}$ → $\boxed{RI_s = U_T e^{-V_{on}/U_T} \quad \text{eq. 2.}}$

plugging eq. 2 into eq. 1:

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

b) when $V < V_{on}$ by a few U_T, $e^{(V-V_{on})/U_T} \approx 0$, so

$V_{in} \approx V$

and $I = I_s e^{V/U_T}$ where $V = V_{in}$

so $\boxed{I = I_s e^{V_{in}/U_T}}$

c) when $V > V_{on}$ ... e-term becomes very large

so

$V_{in} \approx U_T e^{V-V_{on}/U_T}$

and $\boxed{I = \frac{V_{in}}{R}}$ b/c V is negibible compared to V_{in}

Postlab 2

Ruby Spring 2/11/15

②

a) if $V_1 < V_2$ by several U_T:

using the second equation

$V = V_1 - U_T \log(1 + e^{(V_1-V_2)/U_T})$

$e^{(-V_2)/U_T} \approx 0$ and $\log(1+0) = 0$

therefore

$V = V_1 - U_T(0) = V_1$

$\boxed{V = V_1}$

if $V_1 > V_2$ by several U_T:

using the first equation

$V = -U_T \log(e^{-V_1/U_T} + e^{-V_2/U_T})$

$e^{-V_1/U_T} \approx 0$

therefor

$V = -U_T \log(e^{-V_2/U_T}) = -U_T \cdot \frac{-V_2}{U_T} = V_2$

$\boxed{V = V_2}$

b) $V_{in} = U_T e^{(V-V_{on}/U_T)} + V$ from problem 1a

solve for V:

$V = V_{in} - U_T e^{(V-V_{on}/U_T)}$

which is very similar to the SMF (soft min function)

so $V = V$, $V_1 = V_{in}$, $V_2 = V_{on}$ } so when $V_{in} < V_{on}$, $V \approx V_{in}$; when $V_{in} > V_{on}$, $V \approx V_{on}$;

or, precisely → $V = -U_T \ln(e^{-V_{in}/U_T} + e^{-V_{on}/U_T})$

c) $I = \frac{V}{R}$

so

$I = \frac{V_{in}-V}{R} = \frac{\cancel{V_{in}} - \cancel{V_{in}} - U_T \ln(1 + e^{(V_{in}-V_{on}/U_T)})}{R}$

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

when $V_{in} < V_{on}$ → $\boxed{I = 0}$

when $V_{in} > V_{on}$ then $\ln(1 + e^{(V_{in}-V_{on})/U_T}) \approx \ln(e^{\frac{V_{in}}{U_T}})$

$\ln(e^{V_{in}/U_T}) = \frac{V_{in}}{U_T}$ → $\boxed{I = \frac{-V_{in}}{R}}$

d) $V = \cancel{U_T} \ln\left(\frac{I}{I_s}\right) = -\cancel{U_T} \ln(e^{-V_{in}/U_T} + e^{-V_{on}/U_T})$

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

when $V_{in} < V_{on}$ → $\boxed{I = I_s e^{V_{on}/U_T}}$

when $V_{in} > V_{on}$ → $\boxed{I = I_s e^{V_{in}/U_T}}$