Solutions #6: ECL

Note on drawing from PSPICE: if a node is not indicated, the lines do not touch.

Question #1: FAN OUT for an ECL Inverter:

a. \( \beta = 20, I_E = (-5+.7+.9)/1240 = 2.74mA \)
   \( I_B = I_E/(\beta+1) = 130\mu A \)
   \( I_{RE} = (-5+0.9)/2k\Omega = 2.05mA; I_{B8} = 0.2/300 = 0.667 mA \)
   \( I_E' = 14.01mA \)
   \( I_{oAvailable} = 14.01-2.05 = 11.96mA \)
   \( N = 11.96/0.130 = 92 \)

b. \( I_{B'}, I_C \) and \( I_{oAvailable} \) all are the same. \( I_{B'} = \frac{1}{2} I_E'/(\beta+1) = 65\mu A \)
   \( N = 11.96/0.065 = 184 \)

c. Repeat with -0.9V in part A replaced with 0.8V

d. Repeat with -0.9V in part A replaced with -1.0V

Question #2: ECL Inverter

a. \( Q_2 \) is off, \( Q_1 \) is on, \( I_{C1} = I_{E1} * \beta/(\beta+1) \)
   \( I_{C1} = 1.82mA, I_{B3} = I_{E3}/(\beta+1) = 2mA/11 = 0.18mA \)
   \( I_{RC1} = I_{C1} + I_{B3} = 2mA \)
   \( V_{C1} = 0 - 2mA*500\Omega = -1V \)
   \( V_{oL} = V_{E3} = V_{C1} - 0.8V = -1.8V \)

b. \( Q_1 \) is off, \( I_o = 0, I_{E3} = 2mA, I_{B3} = 0.18mA \)
   \( V_{B3} = 0 - V_{R1} = -500\Omega*(0.18mA) = -0.09V \)
   \( V_{oH} = V_{E3} = -0.09V - 0.8V = -0.89V \)

c. \( V_{REF} = (-1.8V + -0.89V)/2 = -1.35V \)
   \( V_{R3} = -( -1.35V +0.8V) = 0.55V \)
   \( R_3 = 0.55V/2mA = 275\Omega \)

d. Power:
   \( P(R_2) = 0 \)
   \( P(Q_2) = 0 \)
   \( V_{E1} = -0.8V - 0.8V = -1.6V \)
   \( V_{C1} = -1V; V_{CE} = 0.6V; I = 2mA \)
   \( P(Q_1) = 0.6V*2mA = 1.2mW \)
   \( P(R_1) = 1V*2mA = 2mW \)
   \( P(R_3) = 2mA*(1.2V - 0.8V) = 0.8mW \)
   \( P(D) = 0.8V*2mA = 1.6mW \)
   \( P(Q_3) = 2mA * -1.8V = 3.6mW \)
   \( P(R_4) = 1k\Omega * 2mA^2 = 4mW \)

Total = 13.2mW
Question #3: ECL Gate
a. \( V_{OH} = 0V \) (Q4 is off)
b. Q4 is on, Q3 is off
   \[ E = -1.2V - 0.8V = -2V \]
   \[ I_e = (-2V - (-5V))/1k\Omega = 3mA \]
   \[ V_{OL} = -3mA * 400\Omega = -1.2V \]
c. Q1 & Q4 are off, Q2 & Q3 are on
   \[ V_{B3} = 0 - 0.8V = -0.8V \]
   \[ V_o = V_{OH} = 0V \]
d. Q4 is off, Q1 & Q2 & Q3 are on
   \[ V_{B3} = 0 - 0.8V = -0.8V \]
   \[ V_o = V_{OH} = 0V \]
e. Q1 & Q2 & Q3 are off, & Q4 is on
   \[ E = -1.2V - 0.8V = -2V \]
   \[ V_o = V_{OL} = -1.2V \]

Question #4: ECL Gate
a. \( Q_4 = \text{Off} \)
   \[ V_{OH} = 0 - 500\mu A * 400\Omega = -0.2V \]
b. Q3 is off, Q4 is on
   \[ E = -1.2V - 0.8V = -2V; \]
   \[ I_{E4} = (5 - 2)/1k\Omega = 3mA \]
   \[ I_{RC4} = 3mA\beta/((\beta + 1)) + 0.5mA = 3.2mA \]
   \[ V_{OL} = 3.2mA * 400\Omega = -1.3V \]
c. \( V_{IL} = -1.2V - 0.8V + 0.7V + 0.8V = -0.5V \)
d. Worst Case: one input high, one input low
   \[ E = -1.7V \]
   \[ I_{E3} = (5 - 1.7V)/1k\Omega = 3.3mA \]
   \[ I_{B3} = 3.3mA/11 = 0.3mA; \]
   \[ I_R = (5 - 1 - 0.8V)/10k\Omega = 0.41mA \]
   \[ I_{E1} = 0.41mA + 0.3mA = 0.71mA \]
   \[ I_{B1} = I_{IH} = 7.1/(\beta + 1) = 64\mu A \]

Question #5:
 a. This is a NOR gate.
 b. \( V_{IL} = -1.3V + 0.2V = -1.1V \)
 c. \( V_{IH} = -1.1V + 0.2V = -0.9V \)
 d. \( V_{E12} = -0.9V - 0.2V - 0.8V = -1.9V \)
   \[ I_{E1} = (5 - 1.9V)/1k\Omega = 3.1mA \]
   \[ I_{IH} = I_{B1} = 3.1mA/11 = 0.28mA \]
e. Q2 is off, Q1 & Q3 are on; \( V_o = -0.9V, V_{B3} = -0.1V, I_{B3} = I_{R1} = .1/400 = 250\mu A \)
   \[ I_e = (\beta + 1)*250\mu A = 2.75mA; \]
   \[ I_{R3} = (5 - 0.9V)/5k\Omega = 0.82mA \]
   \[ I_o = 1.93mA \]
   \[ \text{Fan Out} = \frac{I_o}{I_{IH}} = 1.93/0.28 = 6 \]
Answers are provided here for 38, 43, 44 and 45 of Chapter 14 of Sedra & Smith. If solutions are desired, please email Rebecca.

Question #38:
\[
\begin{align*}
V_{oH} &= -0.75V \\
V_{oL} &= -1.44V \\
V_{iL} &= -1.22V \\
V_{iH} &= -0.98V \\
V_R &= -1.095V
\end{align*}
\]

Question #43:
\[
\begin{align*}
\text{Part A:} & \quad V_{iL} = -1.375V \quad V_{iH} = -1.265V \\
\text{Part B:} & \quad V_{iL} = -1.493V \quad V_{iH} = -1.147V
\end{align*}
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Question #44:
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P_{D(\text{Total})} = 74.8mA
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Question #45:
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\beta = 21.2
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