Circuit Delay

1. Assume that the clock period is 20 ns, the inverter in the network below has a propagation delay of 5 ns and the AND gate has a propagation delay of 10 ns. Draw a timing diagram for the network showing X, Y, and Z. Assume that X is initially 0, Y is initially 1, X becomes 1 for 80 ns, and then X is 0 again. Fill out the timing diagram for the circuit below:

![Timing Diagram 1](image1.png)

State

1. Fill out the timing diagram for the circuit below:

```
+-----+     +-----+     +-----+
IN=|D Q|--s0=|D Q|--s1=|D Q|--Out
    |      |      |      |
---+-----+     |------|     +-----+
CLK=---------------------

clk  in  s0  s1  out
```

2. Fill out the timing diagram for the circuit below:

```
+-----+     +-----+
A=|D Q|->R1=|D Q|->R2=--
    |      |      |
---+-----+     +-----+     +-----+
CLK=----->o--+

clk  lclk  A  R1  R2
```
Logic Gates

1. Label the following logic gates:

   ![Logic Gates Diagram]

   **Solution:** not, and, or, xor, nand, nor, xnor

2. Convert the following to boolean expressions:
   
   (a) NAND
   
   **Solution:** \( \overline{A} \overline{B} + \overline{A}B + AB \)

   (b) XOR
   
   **Solution:** \( \overline{A}B + AB \)

   (c) XNOR
   
   **Solution:** \( \overline{AB} + AB \)

3. Create an AND gate using only NAND gates. (Can NAND gate implement ANY Boolean function by itself?)

   ![AND gate using NAND gates diagram]

   **Solution:**

4. How many different two-input logic gates can there be? How many n-input logic gates?

   **Solution:** A truth table with \( n \) inputs has \( 2^n \) rows. Each logic gate has a 0 or a 1 at each of these rows. Imagining a function as a \( 2^n \)-bit number, we count \( 2^{2^n} \) total functions, or 16 in the case of \( n = 2 \).
Boolean Logic

\[ 1 + A = 1 \quad A + \bar{A} = 1 \quad A + AB = A \quad (A + B)(A + C) = A + BC \]
\[ 0B = 0 \quad B\bar{B} = 0 \quad A + \bar{A}B = A + B \]
DeMorgan’s Law: \[ \bar{AB} = \bar{A} + \bar{B} \quad \bar{A} + \bar{B} = \bar{A}B \]

1. Minimize the following boolean expressions:
   
   (a) Standard: \((A + B)(A + \bar{B})C\)
   
   **Solution:**
   
   \[
   (AA + A\bar{B} + AB + B\bar{B})C = (A + A(\bar{B} + B))C = AC
   \]
   
   (b) Grouping & Extra Terms: \(\bar{A}\bar{B}\bar{C} + \bar{A}B\bar{C} + AB\bar{C} + AB\bar{C} + ABC + A\bar{B}C\)
   
   **Solution:**
   
   \[
   \bar{A}\bar{C}(\bar{B} + B) + A\bar{C}(B + \bar{B}) + AC(B + \bar{B})
   = \bar{A}\bar{C} + A\bar{C} + AC
   = \bar{A}\bar{C} + A\bar{C} + AC
   = (\bar{A} + A)\bar{C} + A(\bar{C} + C)
   = A + \bar{C}
   \]
   
   (c) DeMorgan’s: \(\bar{A}(BC + \bar{B})\)
   
   **Solution:**
   
   \[
   \overline{A(BC + \bar{B})} = \bar{A} + \overline{BC + \bar{B}} = \bar{A} + \overline{BCBC}
   = \bar{A} + (B + C)(\bar{B} + \bar{C})
   = \bar{A} + B\bar{C} + BC
   \]