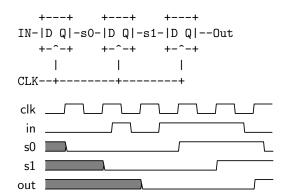
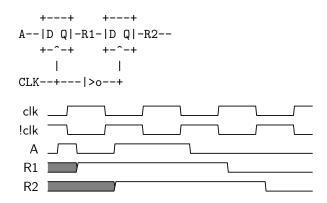
## State

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

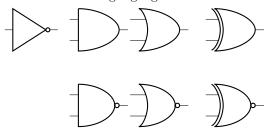


2. Fill out the timing diagram for the circuit below:



## Logic Gates

1. Label the following logic gates:



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

- 2. Convert the following to boolean expressions:
  - (a) NAND

Solution:  $\bar{A}\bar{B} + \bar{A}B + A\bar{B}$ 

(b) XOR

Solution:  $\bar{A}B + A\bar{B}$ 

(c) XNOR

Solution:  $\bar{A}\bar{B} + AB$ 

3. Create an AND gate using only NAND gates.

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**

$$\begin{array}{lll} 1+A=1 & A+\bar{A}=1 & A+AB=A & (A+B)(A+C)=A+BC \\ 0B=0 & B\bar{B}=0 & A+\bar{A}B=A+B \\ \text{DeMorgan's Law:} & \overline{AB}=\bar{A}+\bar{B} & \overline{A+B}=\bar{A}\bar{B} \end{array}$$

1. Minimize the following boolean expressions:

(a) Standard:  $(A+B)(A+\bar{B})C$ 

Solution: 
$$(AA+A\bar{B}+AB+B\bar{B})C=(A+A(\bar{B}+B))C=AC \tag{1}$$

(b) Grouping & Extra Terms:  $\bar{A}\bar{B}\bar{C} + \bar{A}B\bar{C} + AB\bar{C} + A\bar{B}\bar{C} + ABC + A\bar{B}C$ 

Solution:

$$\bar{A}\bar{C}(\bar{B}+B) + A\bar{C}(B+\bar{B}) + AC(B+\bar{B}) = \bar{A}\bar{C} + A\bar{C} + AC \qquad (2) 
= \bar{A}\bar{C} + A\bar{C} + A\bar{C} + AC \qquad (3) 
= (\bar{A}+A)\bar{C} + A(\bar{C}+C) \qquad (4) 
= A+\bar{C} \qquad (5)$$

(c) DeMorgan's:  $\overline{A(\bar{B}\bar{C} + BC)}$ 

Solution:

$$\overline{A(\bar{B}\bar{C} + BC)} = \bar{A} + \overline{\bar{B}\bar{C} + BC}$$

$$= \bar{A} + \overline{\bar{B}\bar{C}BC}$$

$$= \bar{A} + (B + C)(\bar{B} + \bar{C})$$

$$= \bar{A} + B\bar{C} + \bar{B}C$$
(6)
(7)
(8)
(9)