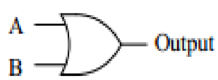
# IN1006 Systems Architecture 2018/19

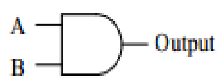
## Tutorial 3 Answers: Logic Gates and Circuits

### Exercises

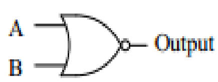
1. Identify each of these logic gates by name and complete their respective truth tables



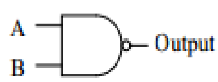

| A | B | Output |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |




| A | B | Output |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

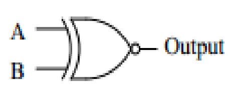



| A | B | Output |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |




| A | B | Output |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

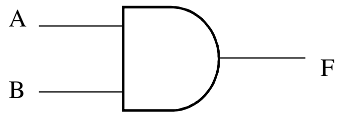

| A | B | Output |
|---|---|---|
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |




| A | B | Output |
|---|---|---|
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

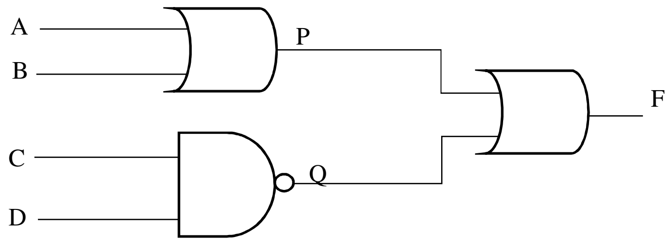
2. Convert the following circuits directly to Boolean expressions:

(a).




$F = A \cdot B$

(b).



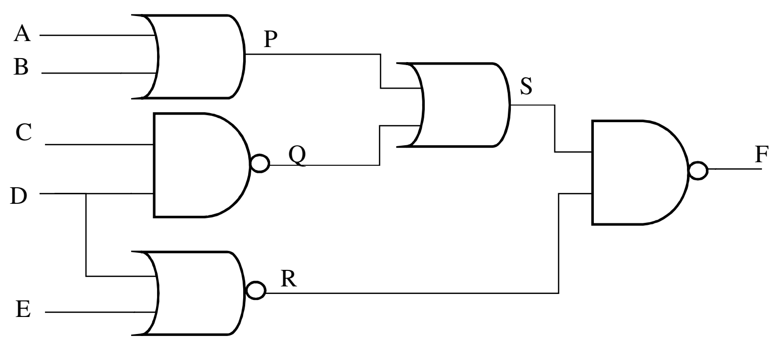

$P = A + B$

$Q = \overline{C \cdot D}$

$F = P + Q$

$F = (A + B) + (\overline{C \cdot D})$

(c).




$R = \overline{D + E}$

$S = P + Q$

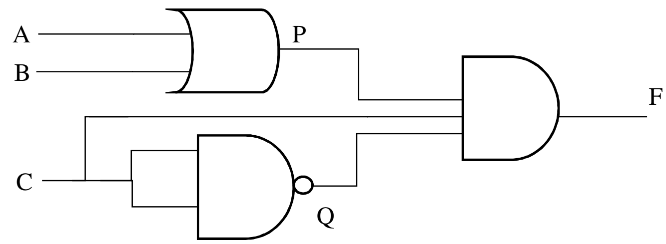
$P = A + B$

$Q = \overline{C \cdot D}$

$F = \overline{S \cdot R}$

$F = \overline{(((A + B) + (\overline{C \cdot D})) \cdot (\overline{D + E}))}$

(d).



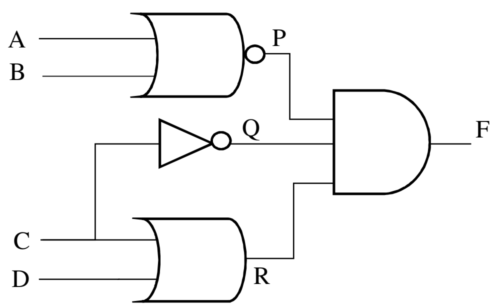

$P = A + B$

$Q = \overline{C \cdot C}$

$F = P \cdot C \cdot Q$

$F = (A + B) \cdot C \cdot (\overline{C \cdot C})$

(e).




$R = C + D$

$Q = \overline{C}$

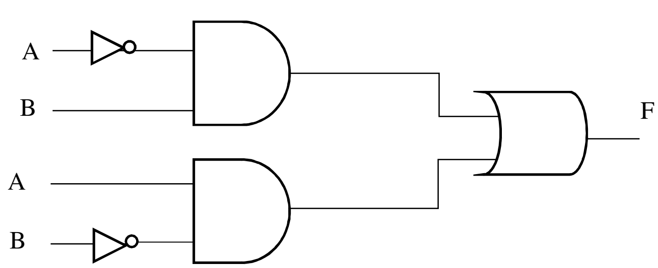
$P = \overline{A + B}$

$F = P \cdot Q \cdot R$

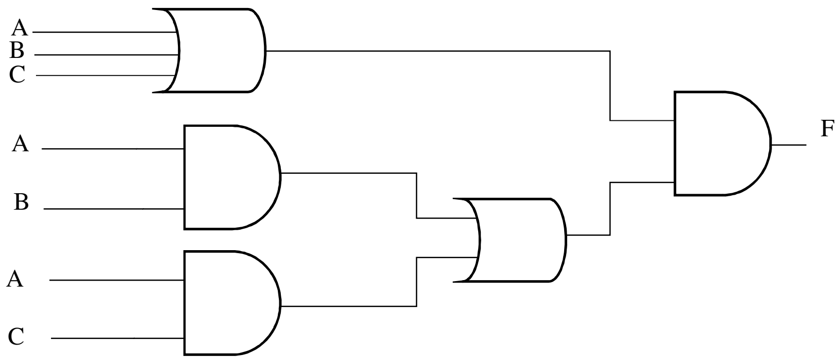
$F = (\overline{A + B}) \cdot \overline{C} \cdot (C + D)$

3. Draw logic diagrams using only AND, OR, and NOT gates to implement the following Boolean expressions. In each case draw the diagrams directly from the expressions and do not attempt to simplify them first.

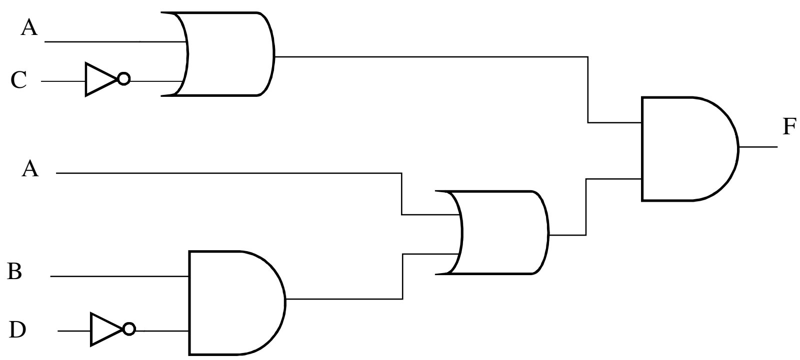
   (a) $F = \overline{A} \cdot B + A \cdot \overline{B}$



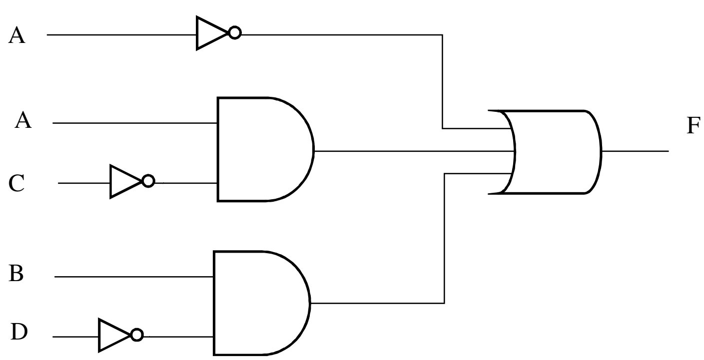
(b) $F = (A + B + C)(A \cdot B + A \cdot C)$



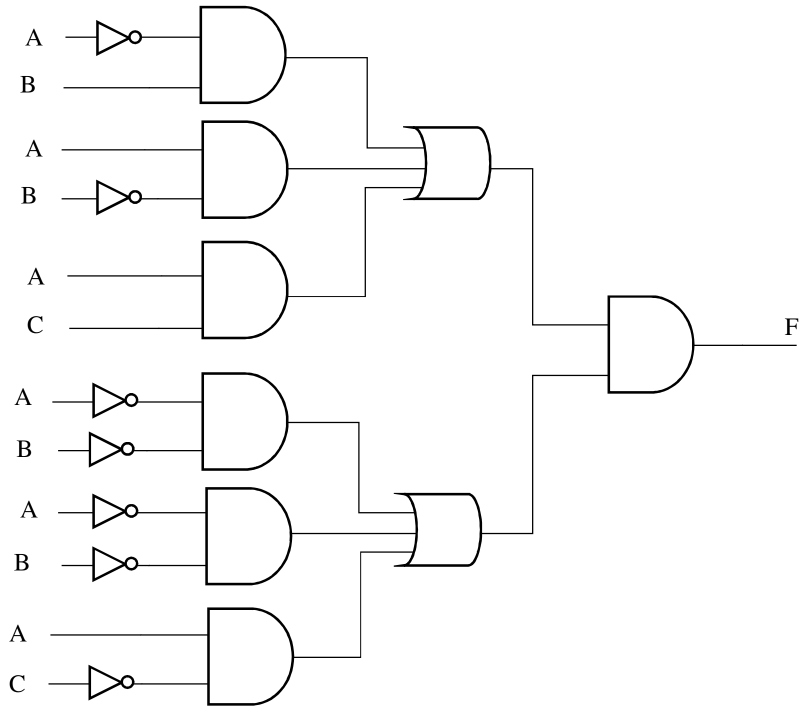

(c) $F = (A + \overline{C})(A + B \cdot \overline{D})$




(d) $F = \overline{A} + \overline{C} \cdot A + B \cdot \overline{D}$




(e) $F = (A \cdot \overline{B} + \overline{A} \cdot B + A \cdot C)(\overline{A} \cdot \overline{B} + \overline{A} \cdot \overline{B} + A \cdot \overline{C})$




4. Which of the expressions above are in sum-of-products form? How would you obtain a sum-of-products expression from a truth table?

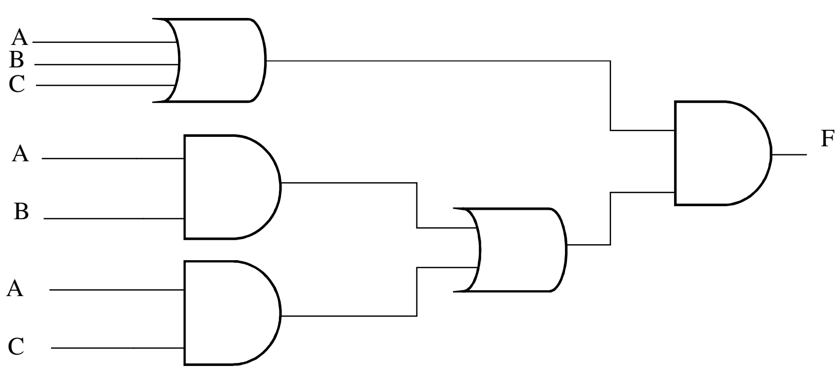
   *The sum of products form takes each set of conditions that return true and represents them as the value of each variable (0 is NOT) AND-ed together (product). Since if one set of conditions allow true to be return, these conditions are joined by ORs (sum).*

   *The expressions (a) and (d) are in sum-of-products form.*

   *It can be obtained from a truth table by writing a product (and) for each input set that returns true (negating where a variable's input is zero) and then adding them (or) together.*

5. Translate this Boolean expressions into its equivalent logic gate circuit:

   $$F = (A + B + C)(A \cdot B + A \cdot C)$$



6. Create the truth tables out of the following expressions:

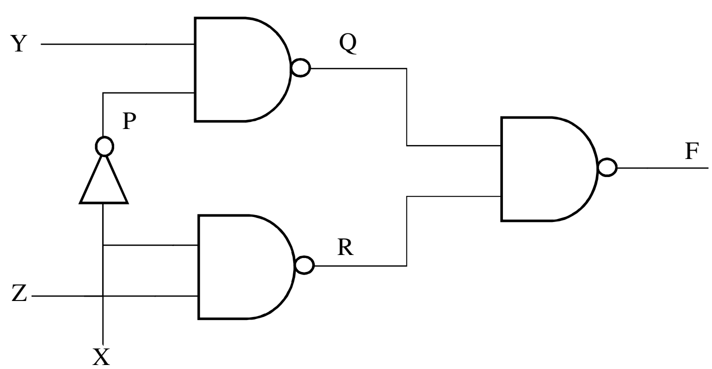
(a) $F = \overline{A} \cdot B + A \cdot \overline{B}$

| A | B | $\bar{A} \cdot B$ | $A \cdot \bar{B}$ | F |
|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 0 | 1 |
| 1 | 0 | 0 | 1 | 1 |
| 1 | 1 | 0 | 0 | 0 |

(b) $F = (A + B + C)(A \cdot B + A \cdot C)$

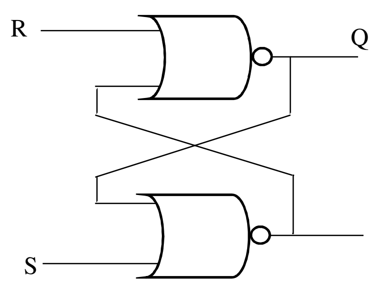
| A | B | C | A · B | A · C | (A · B + A · C) | A + B + C | F |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 |
| 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 |
| 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

7. Draw the truth table for this logic circuit



| X | Y | Z | P | Q | R | F |
|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| 0 | 1 | 0 | 1 | 0 | 1 | 1 |
| 0 | 1 | 1 | 1 | 0 | 1 | 1 |
| 1 | 0 | 0 | 0 | 1 | 1 | 0 |
| 1 | 0 | 1 | 0 | 1 | 0 | 1 |
| 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 1 | 1 | 1 | 0 | 1 | 0 | 1 |

8. Draw the truth table for the following R-S flip flop

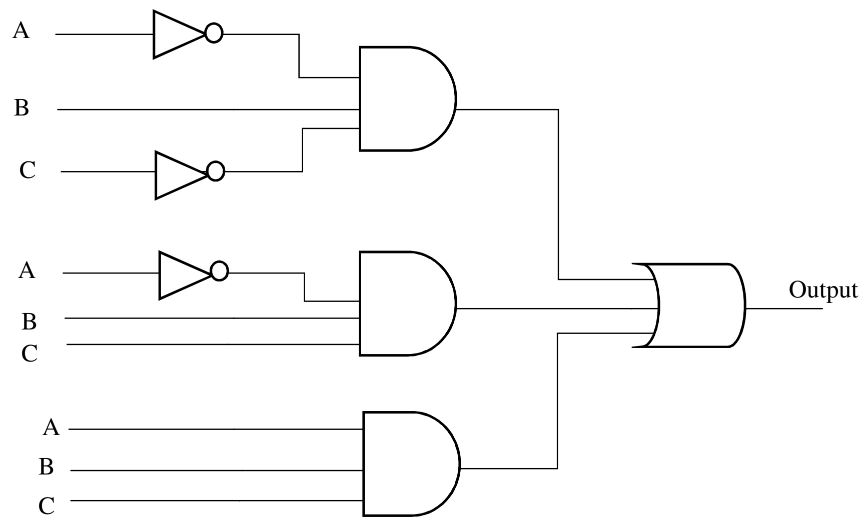



| S | R | Q(t) | Q(t + 1) |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | undefined |
| 1 | 1 | 1 | undefined |

9. Write an SOP expression for this truth table and then draw a gate circuit diagram corresponding to that SOP expression

| A | B | C | Output |
|---|---|---|---|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 1 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 1 |

Output = $\bar{A} \cdot B \cdot \bar{C} + \bar{A} \cdot B \cdot C + A \cdot B \cdot C$




10. Explain in plain English, what a sequential circuit is, and how it differs from a combinational circuit?

    *A sequential circuit is one where the output depends not only on its current inputs but also its previous inputs. In contrast, the combinational circuits that we have looked at up until now do not remember their previous inputs and so their outputs are always a function of their current inputs.*

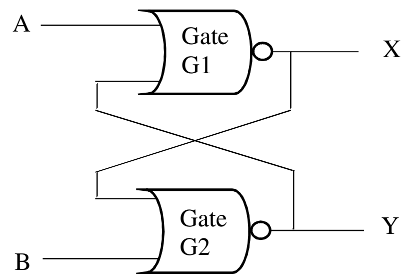
11. Draw a clocked SR flip-flop, its truth table, and explain what is meant by 'clocked'

*Figures c and d from the slide "The clocked SR flip-flop" in lecture. A clocked SR flip flop is attached to a "clock".*

12. Draw and explain the workings of a 4-bit register made of D flip-flops.

    *As in slide "D Flip-Flops Create Registers" from the lecture.*

13. Assume you are given the following R-S flip flop with inputs A and B and outputs X and Y.




a. Assume its initial state is A=0, B=0, X=0 and Y=1. What is the effect of setting input B to 1?

   *X is set to 1 and Y to 0*

b. Assume its initial state is A=0, B=1, X=1 and Y=0. What is the effect of setting input B to 0?

   *No change to X or Y*

c. Assume its initial state is A=0, B=0, X=1 and Y=0. What is the effect of setting input A to 1?

   *X is set to 0 and Y to 1*

d. Assume its initial state is A=1, B=0, X=0 and Y=1. What is the effect of setting input A to 0?

   *No change to X or Y*