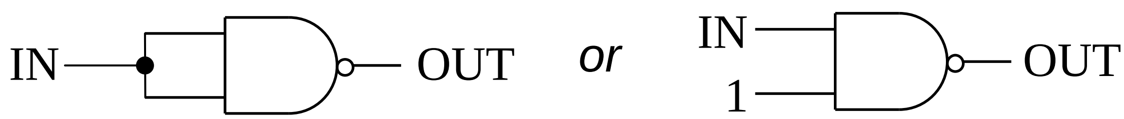
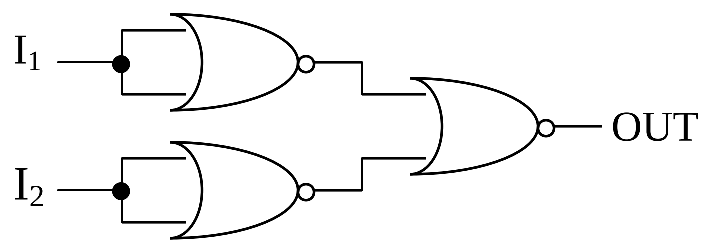
ECEn/CS 224
Chapter 4 Homework Solutions

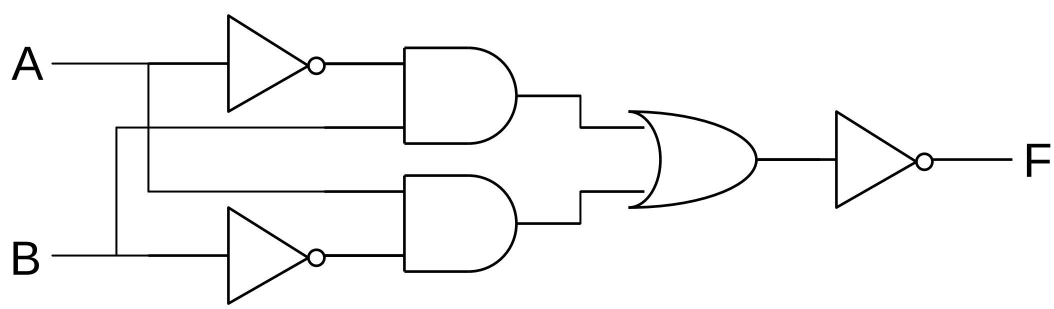
4.1 Create an inverter (NOT gate) using a single 2-input NAND gate.



4.4 Create and AND gate using only NOR gates.



4.5 Draw the gate-level schematic for this equation: $F = (AB' + A'B)'$. Use only AND, OR, and NOT gates.



4.6 Write the boolean equation for the circuit shown in Figure 4.27. Write it using parentheses so that the structure of the equation exactly matches the structure of the circuit.

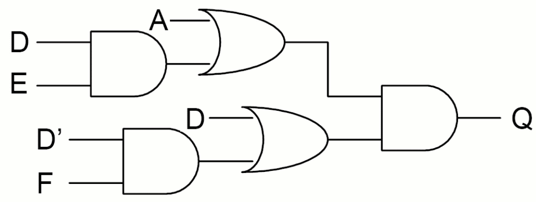
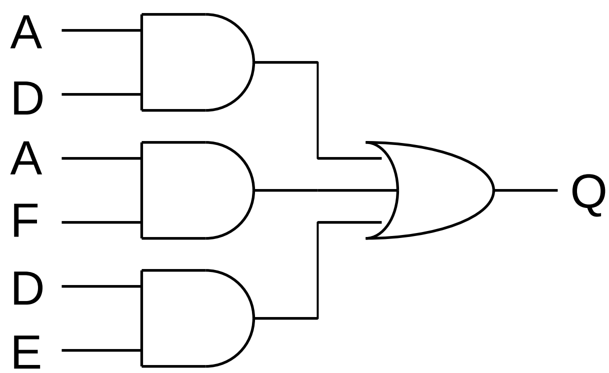


Figure 4.27: Circuit A

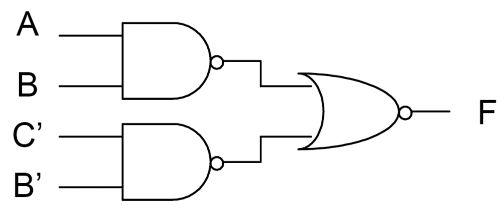
$$Q = (A+DE)(D+D'F)$$

4.8 Write a 2-level AND-OR equation for the circuit shown in Figure 4.27. This will require that you do some algebraic manipulations first. Draw the resulting circuit.

$$\begin{aligned} Q &= (A+DE)(D+D'F) \\ &= (A+DE)(D+F) \\ &= AD + AF + DDE + DEF \\ &= AD + AF + DE + DEF \\ &= AD + AF + DE(1+F) \\ &= AD + AF + DE \end{aligned}$$



4.11 Write the truth table for the circuit shown in Figure 4.28(c).



(c) Circuit D

Figure 4.28: More Circuits

A	B	C	F
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	0
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	0

4.15 Evaluate the circuit of Figure 4.27 using the metrics of Table 4.1 (see text book). Do this by summarizing its levels of logic, delay, etc.

Logic Levels	3
Delay	$2 \bullet t_{AND2} + t_{OR2}$ †
Gate Count	5
Gate Inputs	10
Largest Gate	2 inputs

† Inclusion of t_{INV} in the delay calculation depends on whether you need to generate D’ or whether it is already available.

4.21 Prove or disprove the following proposed boolean theorem:

$$A(B \oplus C) = AB \oplus AC$$

A	**B**	**C**	**B ⊕ C**	**AB**	**AC**	**A(B ⊕ C)**	**AB ⊕ AC**
0	0	0	0	0	0	**0**	**0**
0	0	1	1	0	0	**0**	**0**
0	1	0	1	0	0	**0**	**0**
0	1	1	0	0	0	**0**	**0**
1	0	0	0	0	0	**0**	**0**
1	0	1	1	0	1	**1**	**1**
1	1	0	1	1	0	**1**	**1**
1	1	1	0	1	1	**0**	**0**

The last two columns show that $A(B \oplus C)$ is equal to $AB \oplus AC$.

Based on the knowledge of Figure 4.19, that $(XY)' = (X'+Y')$, we can also show equivalence algebraically:

$$\begin{aligned}
AB \oplus AC &= AB(AC)' + AC(AB)' && \textit{by the definition of XOR} \\
&= AB(A'+C') + AC(A'+B') && \textit{since } (XY)' = (X'+Y') \\
&= ABA' + ABC' + ACA' + AB'C \\
&= 0 + ABC' + 0 + AB'C \\
&= ABC' + AB'C \\
&= A(BC' + B'C) \\
&= A(B \oplus C) && \textit{by the definition of XOR}
\end{aligned}$$

Thus, they are equivalent. The relationship $(XY)' = (X'+Y')$ is called DeMorgan's law in will be covered in a later chapter.

ECEn/CS 224
Chapter 5 Homework Solutions

5.1 Write the minterm expansion for the function shown in Figure 5.10.

A	B	C	F
0	0	0	1
0	0	1	1
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	0

Figure 5.10: Sample Truth Table

For the minterm expansion, look at where the ones appear in the table and list the terms:

$F(A,B,C) = \Sigma m(0,1,3,5,6)$

5.2 Write the maxterm expansion for the function in the previous problem.

For the maxterm expansion, look at where the zeros appear in the truth table and list those terms, or simply list the terms that are missing from the minterm expansion of the previous problem.

$F(A,B,C) = \Pi M(2,4,7)$

5.3 Take the inverse of following expression (do not further minimize):
$[(AB+C'+0)(A'+B'(D+C))]$

$[(AB+C'+0)(A'+B'(D+C))]' = (AB+C'+0)'+(A'+B'(D+C))'$ *by DeMorgan's*
$= (AB)'\bullet C\bullet 1 + A\bullet(B'\bullet (D+C))'$ *by DeMorgan's*
$= (A'+B')\bullet C\bullet 1 + A\bullet (B+D'\bullet C')$ *by DeMorgan's*

Since the four expressions above are equal (by DeMorgan's laws), they are all the inverse of the original expression. By repeatedly applying DeMorgan's laws, we can arrive at the final expression shown above.

5.5 Convert the following minterm expansion to an equivalent maxterm expansion: $F = \Sigma m(0,1,4,7)$

First, assume that the function has three inputs, which allows for minterms 0 through 7. Since we have the minterm expansion, the maxterm expansion simply consists of the terms that are missing from the minterm expansion. That is:

$$F(A,B,C) = \Pi M(2,3,5,6)$$

5.7 Write the maxterm expansion for the following function: F = A + A'B' + BC'

One approach is to begin by drawing the truth table:

A	**B**	**C**	**F**
0	0	0	1
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

From the truth table we see that the only zero is in position ABC = 011 = 3. Therefore:

$$F(A,B,C) = \Pi M(3)$$

Another approach is to note that the term A corresponds to minterms 4, 5, 6, and 7; term A'B' corresponds to minterms 0 and 1; and term BC' corresponds to minterms 2 and 6. Therefore:

$$F(A,B,C) = \Sigma m(0,1,2,4,5,6,7)$$

The maxterm expansion consists of the terms missing from the minterm expansion. Therefore:

$$F(A,B,C) = \Pi M(3)$$

5.8 Minimize the expression of problem 5.1 using boolean theorems.

$F(A,B,C) = \Sigma m(0,1,3,5,6)$

$F = A'B'C' + A'B'C + A'BC + AB'C + ABC'$

$X = X + X$

$= A'B'C' + A'B'C + A'B'C + A'B'C + A'BC + AB'C + ABC'$

$X + X' = 1$

$= A'B'(C'+C) + A'C(B'+B) + B'C(A+A') + ABC'$

$= A'B' + A'C + B'C + ABC'$