CHAPTER 2

2-1.*

a) $\overline{XYZ} = \bar{X} + \bar{Y} + \bar{Z}$

Verification of DeMorgan's Theorem

X	Y	Z	XYZ	$\overline{XYZ}$	$\bar{X}+\bar{Y}+\bar{Z}$
0	0	0	0	1	1
0	0	1	0	1	1
0	1	0	0	1	1
0	1	1	0	1	1
1	0	0	0	1	1
1	0	1	0	1	1
1	1	0	0	1	1
1	1	1	1	0	0

b) $X + YZ = (X + Y) \cdot (X + Z)$

The Second Distributive Law

X	Y	Z	YZ	$X+YZ$	$X+Y$	$X+Z$	$(X+Y)(X+Z)$
0	0	0	0	0	0	0	0
0	0	1	0	0	0	1	0
0	1	0	0	0	1	0	0
0	1	1	1	1	1	1	1
1	0	0	0	1	1	1	1
1	0	1	0	1	1	1	1
1	1	0	0	1	1	1	1
1	1	1	1	1	1	1	1

c) $\bar{X}Y + \bar{Y}Z + X\bar{Z} = X\bar{Y} + Y\bar{Z} + \bar{X}Z$

X	Y	Z	$\bar{X}Y$	$\bar{Y}Z$	$X\bar{Z}$	$\bar{X}Y+\bar{Y}Z+X\bar{Z}$	$X\bar{Y}$	$Y\bar{Z}$	$\bar{X}Z$	$X\bar{Y}+Y\bar{Z}+\bar{X}Z$
0	0	0	0	0	0	0	0	0	0	0
0	0	1	0	1	0	1	0	0	1	1
0	1	0	1	0	0	1	0	1	0	1
0	1	1	1	0	0	1	0	0	1	1
1	0	0	0	0	1	1	1	0	0	1
1	0	1	0	1	0	1	1	0	0	1
1	1	0	0	0	1	1	0	1	0	1
1	1	1	0	0	0	0	0	0	0	0

2-2.*

a) $\bar{X}\bar{Y} + \bar{X}Y + XY \quad = \quad \bar{X} + Y$

$= (\bar{X}Y + \bar{X}\bar{Y}) + (\bar{X}Y + XY)$

$= \bar{X}(Y + \bar{Y}) + Y(X + \bar{X})$

$= \bar{X} + Y$

b) $\bar{A}B + \bar{B}\bar{C} + AB + \bar{B}C \quad = \quad 1$

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

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

$$B + \overline{B} = 1$$

c) $Y + \overline{X}Z + X\overline{Y} \quad = \quad X + Y + Z$

$= Y + X\overline{Y} + \overline{X}Z$
$= (Y + X)(Y + \overline{Y}) + \overline{X}Z$
$= Y + X + \overline{X}Z$
$= Y + (X + \overline{X})(X + Z)$
$= X + Y + Z$

d) $\overline{X}\,\overline{Y} + \overline{Y}Z + XZ + XY + Y\overline{Z} \quad = \quad \overline{X}\,\overline{Y} + XZ + Y\overline{Z}$

$= \overline{X}\,\overline{Y} + \overline{Y}Z(X + \overline{X}) + XZ + XY + Y\overline{Z}$
$= \overline{X}\,\overline{Y} + X\overline{Y}Z + \overline{X}\,\overline{Y}Z + XZ + XY + Y\overline{Z}$
$= \overline{X}\,\overline{Y}(1 + Z) + X\overline{Y}Z + XZ + XY + Y\overline{Z}$
$= \overline{X}\,\overline{Y} + XZ(1 + \overline{Y}) + XY + Y\overline{Z}$
$= \overline{X}\,\overline{Y} + XZ + XY(Z + \overline{Z}) + Y\overline{Z}$
$= \overline{X}\,\overline{Y} + XZ + XYZ + Y\overline{Z}(1 + X)$
$= \overline{X}\,\overline{Y} + XZ(1 + Y) + Y\overline{Z}$
$= \overline{X}\,\overline{Y} + XZ + Y\overline{Z}$

2-3.+

a) $AB\overline{C} + B\overline{C}\,\overline{D} + BC + \overline{C}D \quad = \quad B + \overline{C}D$

$= AB\overline{C} + ABC + BC + B\overline{C}\,\overline{D} + B\overline{C}D + \overline{C}D$
$= AB(\overline{C} + C) + B\overline{C}(\overline{D} + D) + BC + \overline{C}D$
$= AB + B\overline{C} + BC + \overline{C}D$
$= B + AB + \overline{C}D$
$= B + \overline{C}D$

b) $WY + \overline{W}Y\overline{Z} + WXZ + \overline{W}X\overline{Y} \quad = \quad WY + \overline{W}X\overline{Z} + \overline{X}Y\overline{Z} + X\overline{Y}Z$

$= (WY + W\overline{X}Y\overline{Z}) + (\overline{W}XY\overline{Z} + \overline{W}\,\overline{X}Y\overline{Z}) + (WXYZ + WX\overline{Y}Z) + (\overline{W}X\overline{Y}Z + \overline{W}X\overline{Y}\,\overline{Z})$
$= (WY + WXYZ) + (\overline{W}XY\overline{Z} + \overline{W}X\overline{Y}\,\overline{Z}) + (\overline{W}\,\overline{X}Y\overline{Z} + W\overline{X}Y\overline{Z}) + (WX\overline{Y}Z + \overline{W}X\overline{Y}Z)$
$= WY + \overline{W}X\overline{Z}(Y + \overline{Y}) + \overline{X}Y\overline{Z}(\overline{W} + W) + X\overline{Y}Z(W + \overline{W})$
$= WY + \overline{W}X\overline{Z} + \overline{X}Y\overline{Z} + X\overline{Y}Z$

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

$= \overline{\overline{A\overline{D} + \overline{A}B + \overline{C}D + \overline{B}C}}$
$= \overline{(\overline{A} + D)(A + \overline{B})(C + \overline{D})(B + \overline{C})}$
$= \overline{(\overline{A}\,\overline{B} + AD + \overline{B}D)(BC + B\overline{D} + \overline{C}\,\overline{D})}$
$= \overline{\overline{A}\,\overline{B}\,\overline{C}\,\overline{D} + ABCD}$
$= (A + B + C + D)(\overline{A} + \overline{B} + \overline{C} + \overline{D}) = (\overline{A} + \overline{B} + \overline{C} + \overline{D})(A + B + C + D)$

2-4.+

Given: $A \cdot B = 0, A + B = 1$

Prove: $(A + C)(\overline{A} + B)(B + C) \quad = \quad BC$

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

$$= 0 + C(\overline{A} + B)$$
$$= C(\overline{A} + B)(0)$$
$$= C(\overline{A} + B)(A + B)$$
$$= C(AB + \overline{A}B + B)$$
$$= BC$$

2-5.+

Step 1: Define all elements of the algebra as four bit vectors such as A, B and C:

$A = (A_3, A_2, A_1, A_0)$

$B = (B_3, B_2, B_1, B_0)$

$C = (C_3, C_2, C_1, C_0)$

Step 2: Define OR_1, AND_1 and NOT_1 so that they conform to the definitions of AND, OR and NOT presented in Table 2-1.

a) $A + B = C$ is defined such that for all i, $i = 0, ... ,3$, C_i equals the OR_1 of A_i and B_i.

b) $A\ B = C$ is defined such that for all i, $i = 0, ... ,3$, C_i equals the AND_1 of A_i and B_i.

c) The element 0 is defined such that for A = “0”, for all i, $i = 0, ... ,3$, A_i equals logical 0.

d) The element 1 is defined such that for A = “1”, for all i, $i = 0, ... ,3$, A_i equals logical 1.

e) For any element A, $\overline{A}$ is defined such that for all i, $i = 0, ... ,3$, $\overline{A_i}$ equals the NOT_1 of A_i.

2-6.

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

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

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

b) $\overline{(A + B + C)}\,\overline{(ABC)}$

$= \overline{A}\,\overline{A}\,\overline{B}\,\overline{C} + \overline{A}\,\overline{B}\,\overline{B}\,\overline{C} + \overline{A}\,\overline{B}\,\overline{C}\,\overline{C}$

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

$= \overline{A}\,\overline{B}\,\overline{C} + \overline{A}\,\overline{B}\,\overline{C} + \overline{A}\,\overline{B}\,\overline{C} = \overline{A}\,\overline{B}\,\overline{C}$

c) $AB\overline{C} + AC = A(B\overline{C} + C) = A(B + C)$

d) $\overline{A}\,\overline{B}D + \overline{A}\,\overline{C}D + BD$

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

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

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

e) $\overline{(\overline{A} + B)}\,\overline{(\overline{A} + \overline{C})}\,\overline{(A\overline{B}C)}$

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

$= 0$

2-7.*

a) $\overline{X}\,\overline{Y} + XYZ + \overline{X}Y = \overline{X} + XYZ = (\overline{X} + XY)(\overline{X} + Z) = (\overline{X} + X)(\overline{X} + Y)(\overline{X} + Z)$

$= (\overline{X} + Y)(\overline{X} + Z) = \overline{X} + YZ$

b) $X + Y(Z + \overline{X + Z}) = X + Y(Z + \overline{X}\,\overline{Z}) = X + Y(Z + \overline{X})(Z + \overline{Z}) = X + YZ + \overline{X}Y$

$= (X + \overline{X})(X + Y) + YZ = X + Y + YZ = X + Y$

c) $\overline{W}X(\overline{Z} + \overline{Y}Z) + X(W + \overline{W}YZ) = \overline{W}X\overline{Z} + \overline{W}X\overline{Y}Z + WX + \overline{W}XYZ$

$= \overline{W}X\overline{Z} + \overline{W}XZ + WX = \overline{W}X + WX = X$

d) $(AB + \overline{A}\,\overline{B})(\overline{C}\,\overline{D} + CD) + \overline{AC} = AB\overline{C}\,\overline{D} + ABCD + \overline{A}\,\overline{B}CD + \overline{A}\,\overline{B}\,\overline{C}\,\overline{D} + \overline{A} + \overline{C}$

$= ABCD + \overline{A} + \overline{C} = \overline{A} + \overline{C} + A(BCD) = \overline{A} + \overline{C} + C(BD) = \overline{A} + \overline{C} + BD$

2-8.

a) $F = A\overline{B}C + \overline{A}\,\overline{C} + AB$

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

b) $\overline{\overline{F}} = \overline{\overline{A\overline{B}C + \overline{A}\,\overline{C} + AB}}$

$= \overline{\overline{(A\overline{B}C)}\,\overline{(\overline{A}\,\overline{C})}\,\overline{(AB)}}$

2-9.*

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

b) $\overline{F} = ((V + \overline{W})\overline{X} + \overline{Y})Z$

c) $\overline{F} = [\overline{W} + \overline{X} + (Y + \overline{Z})(\overline{Y} + Z)][W + X + Y\overline{Z} + \overline{Y}Z]$

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

2-10.*

Truth Tables a, b, c

X	Y	Z	a
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1

A	B	C	b
0	0	0	1
0	0	1	1
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	0
1	1	0	0
1	1	1	1

W	X	Y	Z	c
0	0	0	0	0
0	0	0	1	0
0	0	1	0	1
0	0	1	1	0
0	1	0	0	0
0	1	0	1	0
0	1	1	0	1
0	1	1	1	0
1	0	0	0	0
1	0	0	1	0
1	0	1	0	1
1	0	1	1	0
1	1	0	0	1
1	1	0	1	1
1	1	1	0	1
1	1	1	1	1

a) Sum of Minterms: $\overline{X}YZ + X\overline{Y}Z + XY\overline{Z} + XYZ$

Product of Maxterms: $(X + Y + Z)(X + Y + \overline{Z})(X + \overline{Y} + Z)(\overline{X} + Y + Z)$

b) Sum of Minterms: $\overline{A}\,\overline{B}\,\overline{C} + \overline{A}\,\overline{B}C + \overline{A}BC + ABC$

Product of Maxterms: $(A + \overline{B} + C)(\overline{A} + B + C)(\overline{A} + B + \overline{C})(\overline{A} + \overline{B} + C)$

c) Sum of Minterms: $\overline{W}\,\overline{X}Y\overline{Z} + \overline{W}XY\overline{Z} + W\overline{X}Y\overline{Z} + WX\overline{Y}\,\overline{Z} + WX\overline{Y}Z + WXY\overline{Z}$

$+ WXYZ$

Product of Maxterms: $(W + X + Y + Z)(W + X + Y + \overline{Z})(W + X + \overline{Y} + \overline{Z})$

$(W + \overline{X} + Y + Z)(W + \overline{X} + Y + \overline{Z})(W + \overline{X} + \overline{Y} + \overline{Z})$

$(\overline{W} + X + Y + Z)(\overline{W} + X + Y + \overline{Z})(\overline{W} + X + \overline{Y} + \overline{Z})$

2-11.

a) $E = \Sigma m(1, 2, 4, 6) = \Pi M(0, 3, 5, 7)$, $F = \Sigma m(0, 2, 4, 7) = \Pi M(1, 3, 5, 6)$

b) $\overline{E} = \Sigma m(0, 3, 5, 7)$, $\overline{F} = \Sigma m(1, 3, 5, 6)$

c) $E + F = \Sigma m(0, 1, 2, 4, 6, 7)$, $\quad E \cdot F = \Sigma m(2, 4)$

d) $E = \overline{X}\overline{Y}Z + \overline{X}Y\overline{Z} + X\overline{Y}\overline{Z} + XY\overline{Z}$, $\quad F = \overline{X}\overline{Y}\overline{Z} + \overline{X}Y\overline{Z} + X\overline{Y}\overline{Z} + XYZ$

e) $E = \overline{Z}(X + Y) + \overline{X}\overline{Y}Z$, $\quad F = \overline{Z}(\overline{X} + \overline{Y}) + XYZ$

2-12.*

a) $(AB + C)(B + \overline{C}D) = AB + AB\overline{C}D + BC = AB + BC$ s.o.p.

$= B(A + C)$ p.o.s.

b) $\overline{X} + X(X + \overline{Y})(Y + \overline{Z}) = (\overline{X} + X)(\overline{X} + (X + \overline{Y})(Y + \overline{Z}))$

$= (\overline{X} + X + \overline{Y})(\overline{X} + Y + \overline{Z})$ p.o.s.

$= (1 + \overline{Y})(\overline{X} + Y + \overline{Z}) = \overline{X} + Y + \overline{Z}$ s.o.p.

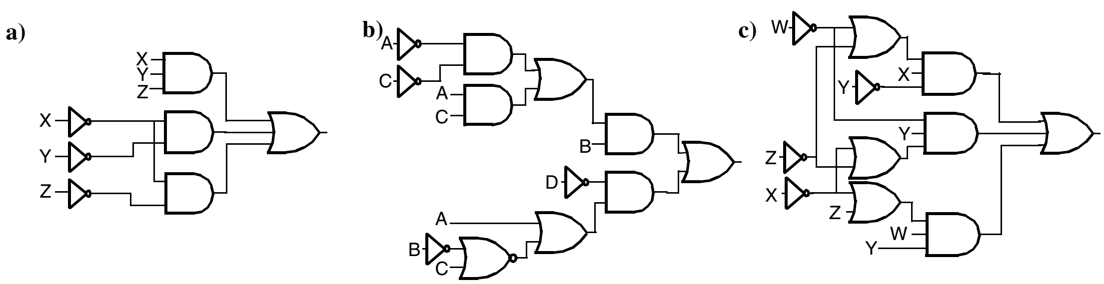
c) $(A + B\overline{C} + CD)(\overline{B} + EF) = (A + B + C)(A + B + D)(A + \overline{C} + D)(\overline{B} + EF)$

$= (A + B + C)(A + B + D)(A + \overline{C} + D)(\overline{B} + E)(\overline{B} + F)$ p.o.s.

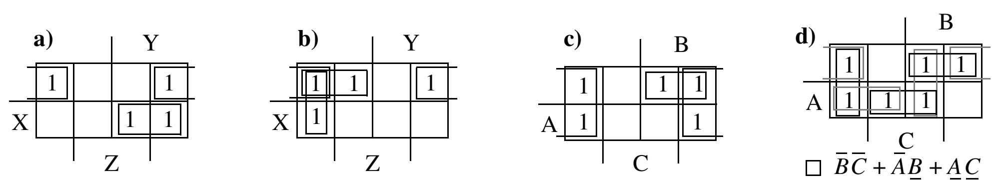
$(A + B\overline{C} + CD)(\overline{B} + EF) = A(\overline{B} + EF) + B\overline{C}(\overline{B} + EF) + CD(\overline{B} + EF)$

$= A\overline{B} + AEF + B\overline{C}EF + \overline{B}CD + CDEF$ s.o.p.

2-13.

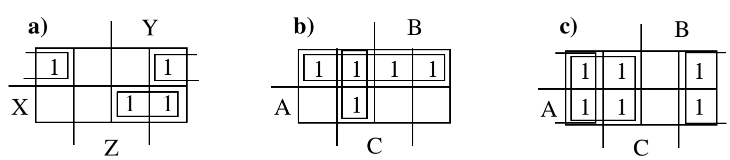


2-14.



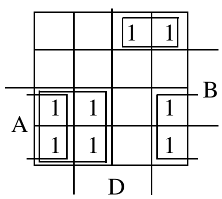
a) $\overline{X}\overline{Z} + XY$ b) $\overline{X}\overline{Y} + \overline{X}\overline{Z} + \overline{Y}\overline{Z}$ c) $\overline{C} + \overline{A}B$ d) □ $\overline{B}\overline{C} + \overline{A}B + AC$ or □ $BC + A\overline{B} + \overline{A}\overline{C}$

2-15. *

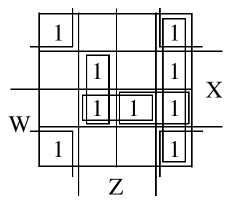


a) $\overline{X}\overline{Z} + XY$ b) $\overline{A} + C\overline{B}$ c) $\overline{B} + \overline{C}$

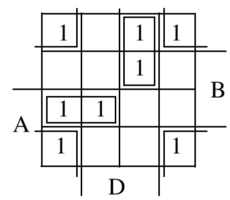
2-16.



$A\overline{C} + A\overline{D} + \overline{A}\overline{B}C$



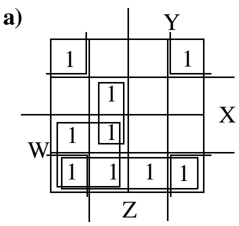
$Y\overline{Z} + \overline{X}\overline{Z} + X\overline{Y}Z + (WXZ \text{ or } WXY)$



$\overline{B}\overline{D} + AB\overline{C} + \overline{A}CD$

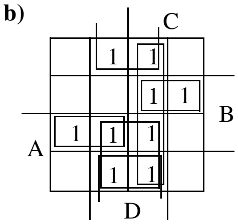
2-17.

a)



$F = \overline{X}\overline{Z} + W\overline{Y} + W\overline{X} + X\overline{Y}Z$

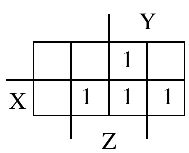
b)



$F = \overline{B}D + \overline{A}BC + AB\overline{C} + (AD \text{ or } CD)$

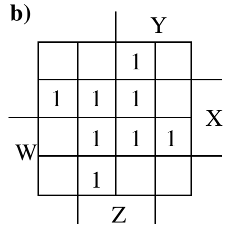
2-18. *

a)



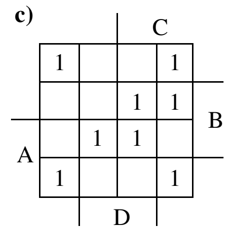
$\Sigma m(3, 5, 6, 7)$

b)



$\Sigma m(3, 4, 5, 7, 9, 13, 14, 15)$

c)



$\Sigma m(0, 2, 6, 7, 8, 10, 13, 15)$

2-19.*

a) $Prime = XZ, WX, \overline{X}\overline{Z}, W\overline{Z}$
$Essential = XZ, \overline{X}\overline{Z}$

b) $Prime = CD, AC, \overline{B}\overline{D}, \overline{A}BD, \overline{B}C$
$Essential = AC, \overline{B}\overline{D}, \overline{A}BD$

c) $Prime = AB, AC, AD, B\overline{C}, \overline{B}D, \overline{C}D$
$Essential = AC, B\overline{C}, \overline{B}D$

2-20.

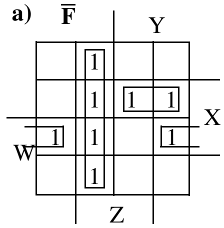
a) $Prime = \overline{X}Y, \overline{X}\overline{Z}, W\overline{Y}\overline{Z}, WX\overline{Y}, X\overline{Y}Z, \overline{W}XZ, \overline{W}YZ$
$Essential = \overline{X}Y, \overline{X}\overline{Z}$
$F = \overline{X}Y + XZ + WX\overline{Y} + \overline{W}XZ$

b) $Prime = \overline{A}B\overline{C}, \overline{A}CD, ABC, A\overline{C}D, BD$
$Essential = \overline{A}B\overline{C}, \overline{A}CD, ABC, A\overline{C}D$
$Redundant = BD$
$F = \overline{A}B\overline{C} + \overline{A}CD + ABC + A\overline{C}D$

c) $Prime = \overline{Y}\overline{Z}, W\overline{Y}, \overline{W}\overline{Z}, WXZ, XYZ, \overline{W}XY$
$Essential = W\overline{Y}, \overline{W}\overline{Z}$
$Redundant = \overline{Y}\overline{Z}$
$F = W\overline{Y} + \overline{W}\overline{Z} + XYZ$

2-21.

a) $\overline{F}$

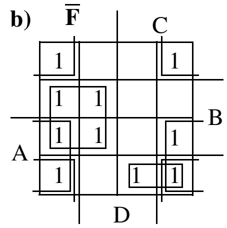


$\overline{F} = \Sigma m(1, 5, 6, 7, 9, 12, 13, 14)$

$F = \overline{\overline{Y}Z + WX\overline{Z} + \overline{W}XY}$

$F = (Y + \overline{Z})(\overline{W} + \overline{X} + Z)(W + \overline{X} + \overline{Y})$

b) $\overline{F}$



$\overline{F} = \Sigma m(0, 2, 4, 5, 8, 10, 11, 12, 13, 14)$

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

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

2-22.*

a) s.o.p. $CD + A\overline{C} + \overline{B}D$
p.o.s. $(\overline{C} + D)(A + D)(A + \overline{B} + C)$

b) s.o.p. $\overline{A}\overline{C} + \overline{B}\overline{D} + A\overline{D}$
p.o.s. $(\overline{C} + \overline{D})(\overline{A} + \overline{D})(A + \overline{B} + \overline{C})$

c) s.o.p. $\overline{B}\overline{D} + \overline{A}BD + (\overline{A}BC \ \ or\ \ \overline{A}C\overline{D})$
p.o.s. $(\overline{A} + \overline{B})(B + \overline{D})(\overline{B} + C + D)$

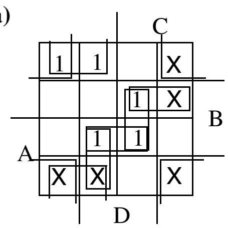
2-23.

a) s.o.p. $\overline{A}\overline{B}\overline{C} + \overline{A}BD + ABC + A\overline{B}\overline{D}$
or $\overline{A}\overline{C}D + BCD + AC\overline{D} + \overline{B}\overline{C}\overline{D}$
p.o.s. $(A + B + \overline{C})(A + \overline{B} + D)(\overline{A} + \overline{B} + C)(\overline{A} + B + \overline{D})$
or $(A + \overline{C} + D)(\overline{B} + C + D)(\overline{A} + C + \overline{D})(B + \overline{C} + \overline{D})$

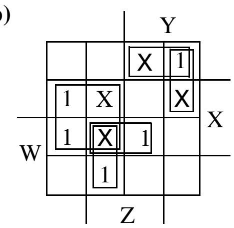
b) s.o.p. $\overline{Z} + \overline{W}X + \overline{X}\overline{Y}$
p.o.s. $(\overline{W} + \overline{X} + \overline{Z})(X + \overline{Y} + \overline{Z})$

2-24.

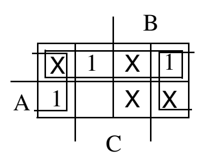
a)



b)



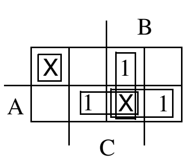
c)



$F = \overline{B}\overline{C} + BCD + ABD$ $F = X\overline{Y} + W\overline{Y}Z + WXZ + (\overline{W}\overline{X}Y \text{ or } \overline{W}Y\overline{Z})$ $F = \overline{A} + \overline{C}$

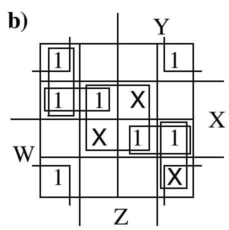
2-25.*

a)



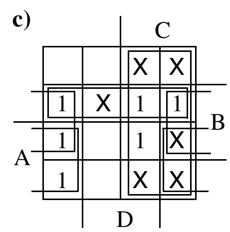
Primes $= AB, AC, BC, \overline{A}\overline{B}\overline{C}$
Essential $= AB, AC, BC$
$F = AB + AC + BC$

b)



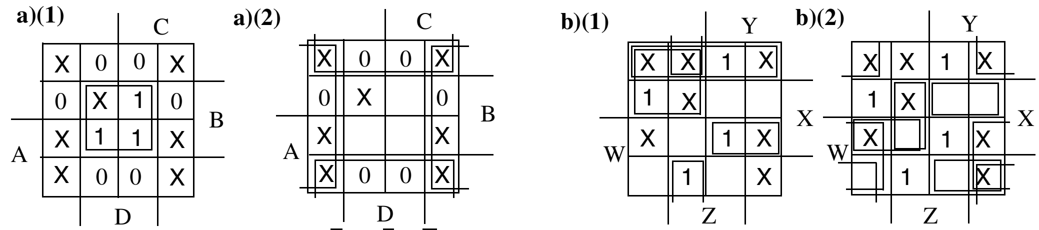
Primes $= \overline{X}\overline{Z}, XZ, \overline{W}X\overline{Y}, WXY, \overline{W}\overline{Y}\overline{Z}, WY\overline{Z}$
Essential $= \overline{X}\overline{Z}$
$F = \overline{X}\overline{Z} + \overline{W}X\overline{Y} + WXY$

c)



Primes $= \overline{A}B, C, A\overline{D}, B\overline{D}$
Essential $= C, A\overline{D}$
$F = C + A\overline{D} + (B\overline{D} \text{ or } \overline{A}B)$

2-26.



a)(1) $F = BD$

a)(2) $\overline{F} = \overline{B} + \overline{D}$

$F = BD$

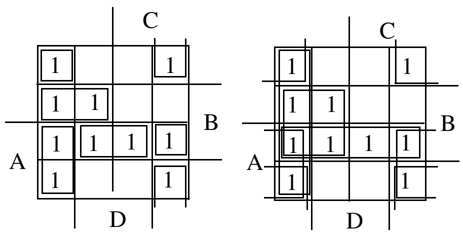
b)(1) $F = \overline{W}\,\overline{X} + \overline{W}\,\overline{Y} + \overline{X}\,\overline{Y}Z + WXY$

b)(2) $\overline{F} = (W\overline{Z} \text{ or } \overline{X}\,\overline{Z}) + \overline{W}XY + W\overline{X}Y + (WX\overline{Y} \text{ or } X\overline{Y}Z)$

$F = ((\overline{W} + Z) \text{ or } (X + Z))(W + \overline{X} + \overline{Y})(\overline{W} + X + \overline{Y}) + (\overline{W} + \overline{X} + Y) \text{ or } (\overline{X} + Y + \overline{Z})$

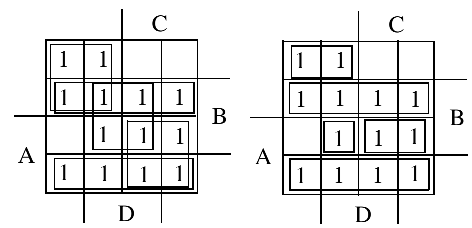
2-27.

a) $F = \overline{A}\,\overline{B}\,\overline{C}\,\overline{D} + \overline{A}B\overline{C} + A\overline{C}\,\overline{D} + ABD + ABC\overline{D} + \overline{B}C\overline{D}$



There are other solutions depending on how ties are resolved.

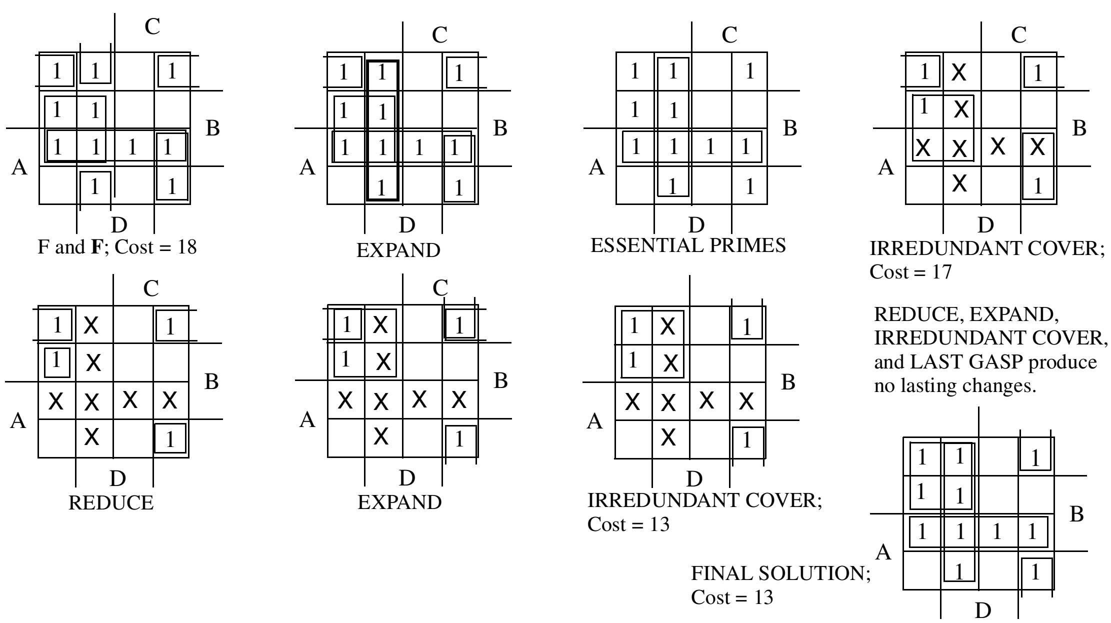
b) $F = \overline{A}\,\overline{C} + \overline{A}B + BD + AC + A\overline{B}$



There are other solutions depending on how ties are resolved.

2-28.+

$F = \overline{A}\,\overline{B}\,\overline{D} + \overline{B}\,\overline{C}\,D + B\overline{C} + AB + AC\overline{D}$



F and **F**; Cost = 18

EXPAND

ESSENTIAL PRIMES

IRREDUNDANT COVER; Cost = 17

REDUCE

EXPAND

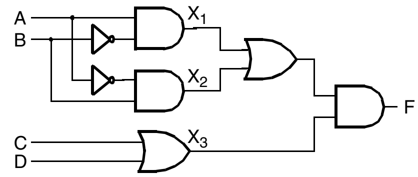
IRREDUNDANT COVER; Cost = 13

REDUCE, EXPAND, IRREDUNDANT COVER, and LAST GASP produce no lasting changes.

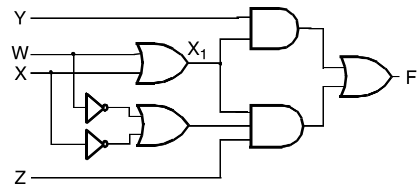
FINAL SOLUTION; Cost = 13

2-29.

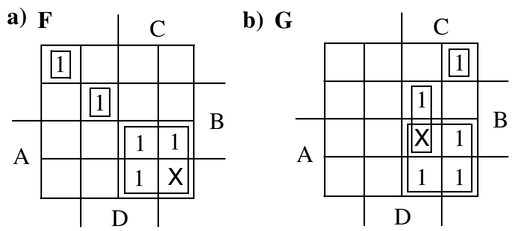
a)
$$F = A\bar{B}C + \bar{A}BC + A\bar{B}D + \bar{A}BD$$
$$X_1 = A\bar{B}$$
$$X_2 = \bar{A}B$$
$$F = X_1C + X_1D + X_2C + X_2D$$
$$= (X_1 + X_2)(C + D)$$
$$X_3 = C + D$$
$$F = (X_1 + X_2)X_3$$



b)
$$F = WY + XY + \bar{W}XZ + W\bar{X}Z$$
$$= (W + X)Y + (\bar{W}X + W\bar{X})Z$$
$$= (W + X)Y + (W + X)(\bar{W} + \bar{X})Z$$
$$X_1 = W + X$$
$$F = X_1Y + X_1(\bar{W} + \bar{X})Z$$



2-30.

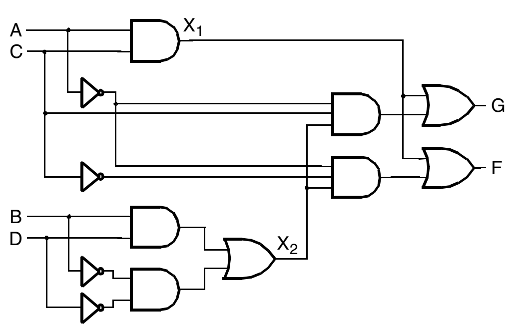


$$F = AC + \bar{A}B\bar{C}D + \bar{A}\bar{B}\bar{C}\bar{D}$$
$$= AC + \bar{A}\bar{C}(BD + \bar{B}\bar{D})$$

$$G = AC + BCD + \bar{A}\bar{B}C\bar{D}$$
$$= AC + (ABCD + \bar{A}BCD) + \bar{A}\bar{B}C\bar{D}$$
$$= AC + \bar{A}C(BD + \bar{B}\bar{D})$$

$$X_1 = AC$$
$$X_2 = BD + \bar{B}\bar{D}$$

$$F = X_1 + \bar{A}\bar{C}X_2 \qquad G = X_1 + \bar{A}CX_2$$



2-31.

a)
$$F = AB(\overline{C\bar{D} + \bar{C}D}) + \bar{B}(C\bar{D} + \bar{C}D) + \bar{A}(\overline{B + CD})$$
$$= AB(\bar{C} + D)(C + \bar{D}) + \bar{B}(C\bar{D} + \bar{C}D) + \bar{A}(\bar{B}(\bar{C} + \bar{D}))$$
$$= AB\bar{C}\bar{D} + ABCD + \bar{B}C\bar{D} + \bar{B}\bar{C}D + \bar{A}\bar{B}\bar{C} + \bar{A}\bar{B}\bar{D}$$

b)
$$T = YZ(W + \bar{X}) + \bar{Y}\bar{Z}(\bar{W}Y + X)$$
$$= WYZ + \bar{X}YZ + X\bar{Y}\bar{Z}$$

2-32.*

$X \oplus Y = X\overline{Y} + \overline{X}Y$

$\text{Dual }(X \oplus Y) = \text{Dual }(X\overline{Y} + \overline{X}Y)$

$= (X + \overline{Y})(\overline{X} + Y)$

$= \overline{\overline{X}Y + X\overline{Y}}$

$= \overline{X\overline{Y} + \overline{X}Y}$

$= \overline{X \oplus Y}$

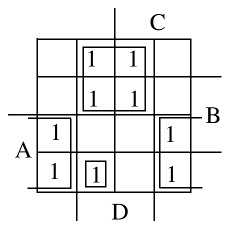
2-33.

$AB\overline{C}D + A\overline{D} + \overline{A}D = AB\overline{C}D + (A \oplus D)$

Note that $X + Y = (X \oplus Y) + XY$

Letting $X = AB\overline{C}D$ and $Y = A \oplus D$,

We can observe from the map below or determine algebraically that XY is equal to 0.



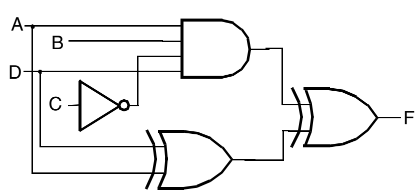
For this situation,

$X + Y = (X \oplus Y) + XY$

$= (X \oplus Y) + 0$

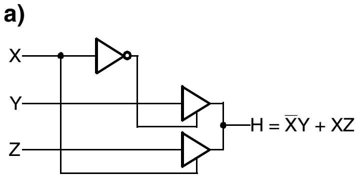
$= X \oplus Y$

So, we can write $F(A, B, C, D) = X \oplus Y = AB\overline{C}D \oplus (A \oplus D)$

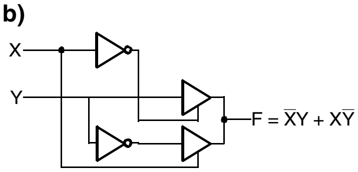


2-34.

a)

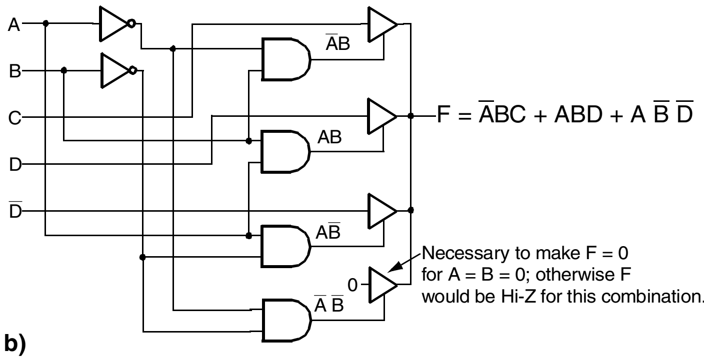


b)



2-35.

a)



b)

There are no three-state output conflicts.