

XMUT 202

Digital Electronics

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Victoria

UNIVERSITY OF WELLINGTON

*Te Whare Wānanga
o te Ūpoko o te Ika a Māui*



CAPITAL CITY UNIVERSITY

Boolean Algebra - Basic Rules

1. $A + 0 = A$

2. $A + 1 = 1$

3. $A \cdot 0 = 0$

4. $A \cdot 1 = A$

5. $A + A = A$

6. $A + \bar{A} = 1$

7. $A \cdot A = A$

8. $A \cdot \bar{A} = 0$

9. $\overline{\bar{A}} = A$

10. $A + AB = A$

11. $A + \bar{A}B = A + B$

12. $(A + B)(A + C) = A + BC$

Simplification from looping:

Pair: Looping a pair of adjacent 1's eliminate the variable that appears in complemented and uncomplemented form.

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Quad: Looping 4 adjacent 1's eliminate the two variables that appears in complemented and uncomplemented form.

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Pair: Looping a pair of adjacent 1's eliminate the variable that appears in complemented and uncomplemented form.

Quad: Looping 4 adjacent 1's eliminate the two variables that appears in complemented and uncomplemented form.

Octet: Looping 8 adjacent 1's eliminate the three variables that appears in complemented and uncomplemented form.

Complete K-Map simplification process

1. Construct the K map, place 1s as per the truth table.
2. Loop 1s that are **not adjacent** to any other 1s.
3. Loop 1s that are in **pairs** *and cannot be looped into quads or octets*.
4. Loop 1s in **octets** (8) even if they have already been looped.
5. Loop **quads** (4) that have one or more 1s not already looped.
6. Loop any pairs (2) necessary to **include 1s not already looped**.
7. Form the OR sum of terms generated by each loop.

Example (a) K-Map simplification

Simplify the following Boolean expression:

$$\bar{A}\bar{B}\bar{C}\bar{D} + \bar{A}\bar{B}\bar{C}D + \bar{A}B\bar{C}\bar{D} + A\bar{B}\bar{C}\bar{D} + ABCD + A\bar{B}CD$$

Example (a) K-Map simplification

Simplify the following Boolean expression:

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

↑
Sum of Product (SOP) expression

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	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$				
$\bar{A}B$				
AB				
$A\bar{B}$				

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	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$				1
$\bar{A}B$		1	1	
AB		1	1	
$A\bar{B}$			1	

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	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
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3. Loop 1s that are in pairs *and cannot be looped into quads or octets*.
4. Loop 1s in octets (8) *even if they have already been looped. (none here)*
5. Loop quads (4) that have one or more 1s not already looped.
6. Loop any pairs (2) necessary to *include 1s not already looped*.
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	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$				1
$\bar{A}B$		1	1	
AB		1	1	
$A\bar{B}$			1	

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	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
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	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$				1
$\bar{A}B$		1	1	
AB		1	1	
$A\bar{B}$			1	

$$BD + ACD + \bar{A}\bar{B}C\bar{D}$$

1. Construct the K map, place 1s as per the truth table.
2. Loop 1s that are not adjacent to any other 1s.
3. Loop 1s that are in pairs *and cannot be looped into quads or octets*.
4. Loop 1s in octets (8) *even if they have already been looped*.
5. Loop quads (4) that have one or more 1s not already looped.
6. Loop any pairs (2) necessary to *include 1s not already looped*.
7. Form the OR sum of terms generated by each loop.

Example (b) K-Map simplification

Simplify the following truth table:

A	B	C	D	X
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	1
0	1	0	0	1
0	1	0	1	1
0	1	1	0	1
0	1	1	1	1
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	0
1	1	0	0	1
1	1	0	1	1
1	1	1	0	0
1	1	1	1	0

Example (b) K-Map simplification

Simplify the following truth table:

A	B	C	D	X
0	0	0	0	0
0	0	0	1	0
0	0	1	0	0
0	0	1	1	1
0	1	0	0	1
0	1	0	1	1
0	1	1	0	1
0	1	1	1	1
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	0
1	1	0	0	1
1	1	0	1	1
1	1	1	0	0
1	1	1	1	0

Example (b) K-Map simplification

Simplify the following Boolean expression:

$$\bar{A}\bar{B}CD + \bar{A}B\bar{C}\bar{D} + \bar{A}B\bar{C}D + \bar{A}BCD + \bar{A}BC\bar{D} + AB\bar{C}\bar{D} + AB\bar{C}D$$

1. Construct the K map, place 1s as per the truth table.
2. Loop 1s that are not adjacent to any other 1s.
3. Loop 1s that are in pairs *and cannot be looped into quads or octets*.
4. Loop 1s in octets (8) *even if they have already been looped*.
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6. Loop any pairs (2) necessary to *include 1s not already looped*.
7. Form the OR sum of terms generated by each loop.

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	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$			1	
$\bar{A}B$	1	1	1	1
AB	1	1		
$A\bar{B}$				

1. Construct the K map, place 1s as per the truth table.
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3. Loop 1s that are in pairs *and cannot be looped into quads or octets*.
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Simplify the following Boolean expression:

$$\bar{A}\bar{B}CD + \bar{A}B\bar{C}\bar{D} + \bar{A}B\bar{C}D + \bar{A}BCD + \bar{A}BC\bar{D} + A\bar{B}\bar{C}\bar{D} + A\bar{B}\bar{C}D$$

	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$			1	
$\bar{A}B$	1	1	1	1
AB	1	1		
$A\bar{B}$				

1. Construct the K map, place 1s as per the truth table.
2. Loop 1s that are not adjacent to any other 1s (none)
3. Loop 1s that are in pairs *and cannot be looped into quads or octets.*
4. Loop 1s in octets (8) *even if they have already been looped.*
5. Loop quads (4) that have one or more 1s not already looped.
6. Loop any pairs (2) necessary to *include 1s not already looped.*
7. Form the OR sum of terms generated by each loop.

Example (b) K-Map simplification

Simplify the following Boolean expression:

$$\bar{A}\bar{B}CD + \bar{A}B\bar{C}\bar{D} + \bar{A}B\bar{C}D + \bar{A}BCD + \bar{A}BC\bar{D} + AB\bar{C}\bar{D} + AB\bar{C}D$$

	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$			1	
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	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$			1	
$\bar{A}B$	1	1	1	1
AB	1	1		
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1. Construct the K map, place 1s as per the truth table.
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3. Loop 1s that are in pairs *and cannot be looped into quads or octets*.
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5. Loop quads (4) that have one or more 1s not already looped.
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	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$			1	
$\bar{A}B$	1	1	1	1
AB	1	1		
$A\bar{B}$				

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	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$			1	
$\bar{A}B$	1	1	1	1
AB	1	1		
$A\bar{B}$				

1. Construct the K map, place 1s as per the truth table.
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5. Loop quads (4) that have one or more 1s not already looped.
6. Loop any pairs (2) *necessary to include 1s not already looped (none here)*
7. Form the OR sum of terms generated by each loop.

Example (b) K-Map simplification

Simplify the following Boolean expression:

$$\bar{A}\bar{B}CD + \bar{A}B\bar{C}\bar{D} + \bar{A}B\bar{C}D + \bar{A}BCD + \bar{A}BC\bar{D} + AB\bar{C}\bar{D} + AB\bar{C}D$$

	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$			1	
$\bar{A}B$	1	1	1	1
AB	1	1		
$A\bar{B}$				

$$B\bar{C} + \bar{A}CD + \bar{A}B$$

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7. Form the OR sum of terms generated by each loop.

Try this one:

Simplify the following truth table using the K-Map method

5 minutes

A	B	C	D	X
0	0	0	0	0
0	0	0	1	1
0	0	1	0	0
0	0	1	1	0
0	1	0	0	0
0	1	0	1	1
0	1	1	0	1
0	1	1	1	1
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	1
1	1	0	0	1
1	1	0	1	1
1	1	1	0	0
1	1	1	1	1

Exercise: K-Map simplification

Boolean expression derived from the truth table:

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

	$\overline{C}\overline{D}$	$\overline{C}D$	CD	$C\overline{D}$
$\overline{A}\overline{B}$		1		
$\overline{A}B$		1	1	1
AB	1	1	1	
$A\overline{B}$			1	

Exercise: K-Map simplification

Boolean expression derived from the truth table:

$$\bar{A}\bar{B}\bar{C}\bar{D} + \bar{A}\bar{B}\bar{C}D + \bar{A}B\bar{C}\bar{D} + \bar{A}B\bar{C}D + A\bar{B}\bar{C}\bar{D} + A\bar{B}\bar{C}D + ABC\bar{D} + ABCD$$

	$\bar{C}\bar{D}$	$\bar{C}D$	CD	$C\bar{D}$
$\bar{A}\bar{B}$		1		
$\bar{A}B$		1	1	1
AB	1	1	1	
$A\bar{B}$			1	

1. Construct the K map, place 1s as per the truth table.
2. Loop 1s that are not adjacent to any other 1s.
3. Loop 1s that are in pairs *and cannot be looped into quads or octets*.
4. Loop 1s in octets (8) *even if they have already been looped*.
5. Loop quads (4) that have one or more 1s not already looped.
6. Loop any pairs (2) necessary to *include 1s not already looped*.
7. Form the OR sum of terms generated by each loop.

$$\bar{A}\bar{C}D + \bar{A}BC + AB\bar{C} + ACD$$

Don't Care Output Conditions

Can be changed 0/1 so that the simplest expression can be obtained from the K-map. Typically occurs when we know certain input conditions are impossible.

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Can be changed 0/1 so that the simplest expression can be obtained from the K-map. Typically occur when we know certain input conditions are impossible.

A	B	C	z
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	x
1	0	0	x
1	0	1	1
1	1	0	1
1	1	1	1

(a)

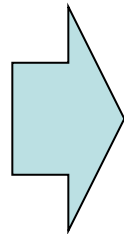
Don't care Output Conditions

Can be changed 0/1 so that the simplest expression can be obtained from the K-map. Typically occur when we know certain input conditions are impossible.

A	B	C	z
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	x
1	0	0	x
1	0	1	1
1	1	0	1
1	1	1	1

(a)

} "don't care"



	\bar{C}	C
$\bar{A}\bar{B}$	0	0
$\bar{A}B$	0	x
AB	1	1
$A\bar{B}$	x	1

(b)

Don't care Output Conditions

Can be changed 0/1 so that the simplest expression can be obtained from the K-map. Typically occur when we know certain input conditions are impossible.

A	B	C	z
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	x
1	0	0	x
1	0	1	1
1	1	0	1
1	1	1	1

} "don't care"

(a)

	\bar{C}	C
$\bar{A}\bar{B}$	0	0
$\bar{A}B$	0	x
AB	1	1
$A\bar{B}$	x	1

(b)

	\bar{C}	C
$\bar{A}\bar{B}$	0	0
$\bar{A}B$	0	0
AB	1	1
$A\bar{B}$	1	1

(c)

z = A

Example: Design a logic circuit for a three storey elevator.

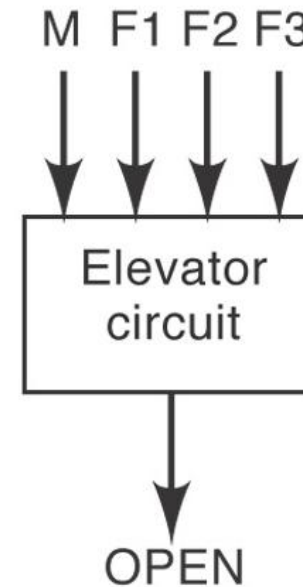


Example: Design a logic circuit for a three-storey elevator.

M = Logic signal indicating if the elevator is moving (M = 1) or stationary (M = 0)

F1, F2 and F3 are the floor level signals, normally LO but go HI when a particular floor is reached.

The circuit output (O/P) is the “Door Open” signal, should be normally LO but go HI when the door is to open



M	F1	F2	F3	OPEN
0	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	
1	0	0	0	
1	0	0	1	
1	0	1	0	
1	0	1	1	
1	1	0	0	
1	1	0	1	
1	1	1	0	
1	1	1	1	

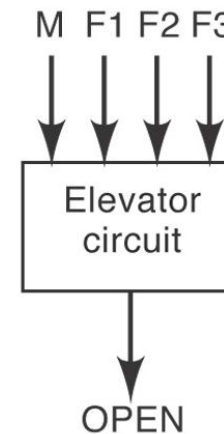
M = elevator moving

F1 = Floor 1

F2 – Floor 2

F3 – Floor 3

OPEN – elevator door opening



M	F1	F2	F3	OPEN
0	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	
1	0	0	0	
1	0	0	1	
1	0	1	0	
1	0	1	1	
1	1	0	0	
1	1	0	1	
1	1	1	0	
1	1	1	1	

- Can only be on one floor at a time (only one floor I/P can be HI) .
- The other floor I/P's are then don't care conditions.
- Use x to indicate the don't care conditions.
- Door can't open when moving!

M	F1	F2	F3	OPEN
0	0	0	0	0
0	0	0	1	1
0	0	1	0	1
0	0	1	1	X
0	1	0	0	1
0	1	0	1	X
0	1	1	0	X
0	1	1	1	X
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	X
1	1	0	0	0
1	1	0	1	X
1	1	1	0	X
1	1	1	1	X

- Can only be on one floor at a time (only one floor I/P can be HI) .
- The other floor I/P's are then don't care conditions.
- Use x to indicate the don't care conditions.
- Door can't open when moving!

M	F1	F2	F3	OPEN
0	0	0	0	0
0	0	0	1	1
0	0	1	0	1
0	0	1	1	X
0	1	0	0	1
0	1	0	1	X
0	1	1	0	X
0	1	1	1	X
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	X
1	1	0	0	0
1	1	0	1	X
1	1	1	0	X
1	1	1	1	X

- Can only be on one floor at a time (only one floor I/P can be HI) .
- The other floor I/P's are then don't care conditions.
- Use x to indicate the don't care conditions.
- Door can't open when moving!

$$OPEN = \overline{M}\overline{F1}\overline{F2}\overline{F3} + \overline{M}\overline{F1}\overline{F2}F3 + \overline{M}\overline{F1}F2\overline{F3}$$

	$\overline{F2}\overline{F3}$	$\overline{F2}F3$	$F2F3$	$F2\overline{F3}$
$\overline{M}\overline{F1}$	0	1	X	1
$\overline{M}F1$	1	X	X	X
$M F1$	0	X	X	X
$M \overline{F1}$	0	0	X	0

	$\overline{F_2}\overline{F_3}$	$\overline{F_2}F_3$	F_2F_3	$F_2\overline{F_3}$
$\overline{M}\overline{F_1}$	0	1	X	1
$\overline{M}F_1$	1	X	X	X
$M\overline{F_1}$	0	X	X	X
MF_1	0	0	X	0

	$\overline{F_2}\overline{F_3}$	$\overline{F_2}F_3$	F_2F_3	$F_2\overline{F_3}$
$\overline{M}\overline{F_1}$	0	1	1	1
$\overline{M}F_1$	1	1	1	1
$M\overline{F_1}$	0	0	0	0
MF_1	0	0	0	0

$$\text{OPEN} = \overline{M} (F_1 + F_2 + F_3)$$

Exercises

Use the **K-Map method** to simplify the following:

a) $AB + A(B + C) + B(B + C)$

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

c) $[\overline{A}\overline{B}(C + BD) + \overline{A}\overline{B}]C$

d) $\overline{A}BC + \overline{A}\overline{B}\overline{C} + \overline{A}\overline{B}\overline{C} + \overline{A}\overline{B}C + ABC$