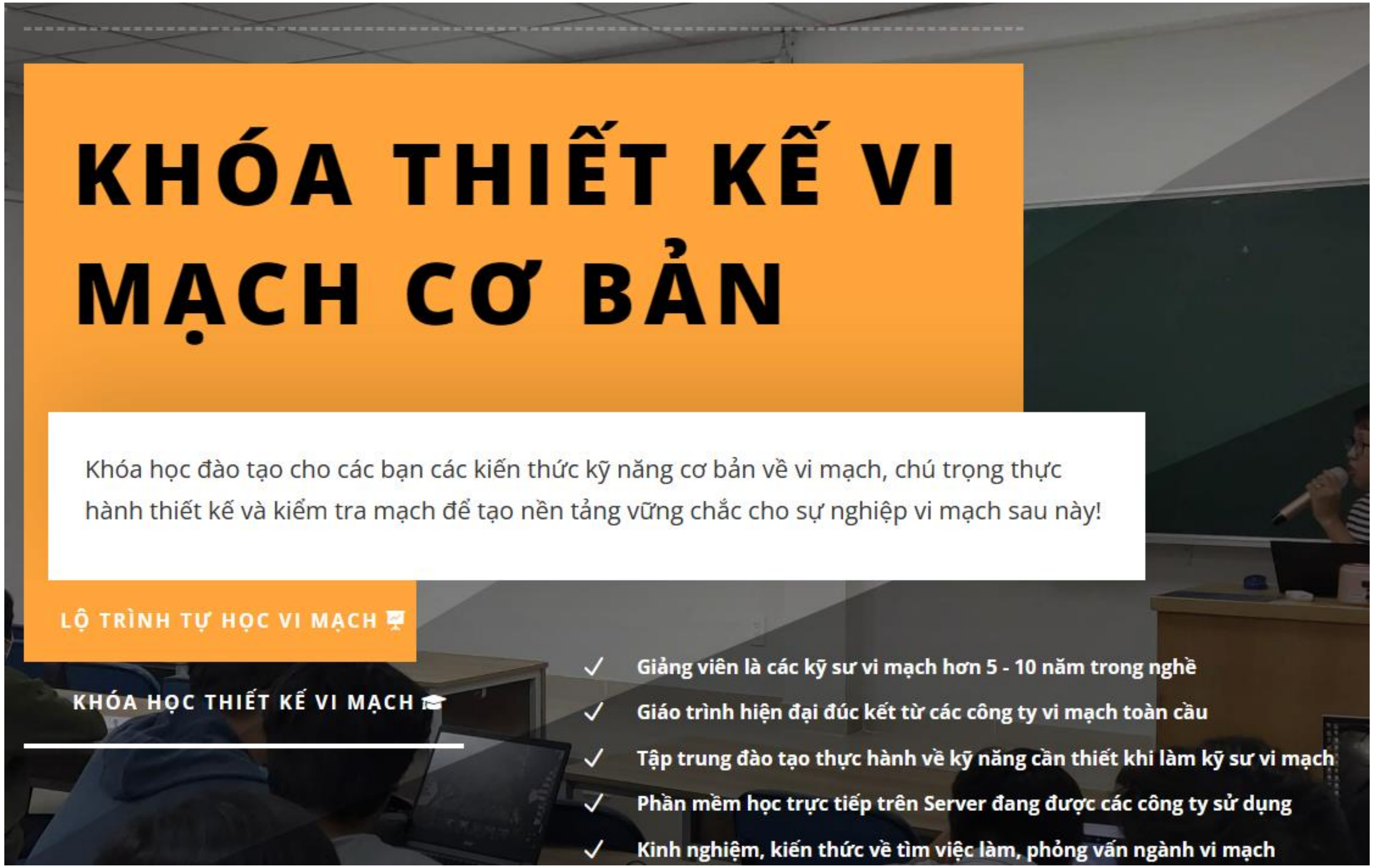
IC OVERVIEW
RTL DESIGN AND VERIFICATION

COURSE INTRODUCTION

[Khóa Học Thiết Kế Vi Mạch Cơ Bản - Trung Tâm Đào Tạo Thiết Kế Vi Mạch ICTC]



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COURSE INTRODUCTION

SUMMARY

HOMEWORK

QUESTION

SELF-LEARNING

Session 3: Optimize Boolean Functions and Introduction To Combinational and Sequential Circuits

1. K-map
2. Combinational Circuit
3. Sequential Circuit

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KARNAUGH MAP

Karnaugh map it is a graphical representation of a truth table for a Boolean function. Karnaugh maps are helpful for simplifying Boolean expressions and minimizing the number of terms in a logic function.

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K-map to represent F(A,B) - SOP

A	B	minterms	
0	0	$\overline{A}\,\overline{B}$	m0
0	1	$\overline{A}B$	m1
1	0	$A\overline{B}$	m2
1	1	AB	m3

	$\overline{B}$	B
$\overline{A}$	$\overline{A}\,\overline{B}$	$\overline{A}B$
A	$A\overline{B}$	AB

A \ B	0	1
0	m0	m1
1	m2	m3

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KARNAUGH MAP – 2 VARIABLES

Optimize K-map rules:

- ❑ Make the group of 1s, which are adjacent to each other.
- ❑ This group should be in the power of 2. For example, in case of the 2 variables map, we can make the group of two 1s or group of four 1s, but can not make the group of three 1s.
- ❑ Ensure that during the grouping, all the 1s in the maps are covered.
- ❑ During grouping, even if the 2 groups overlap with each other, it's alright.
- ❑ After grouping, keep the common variables (not change) in each group.

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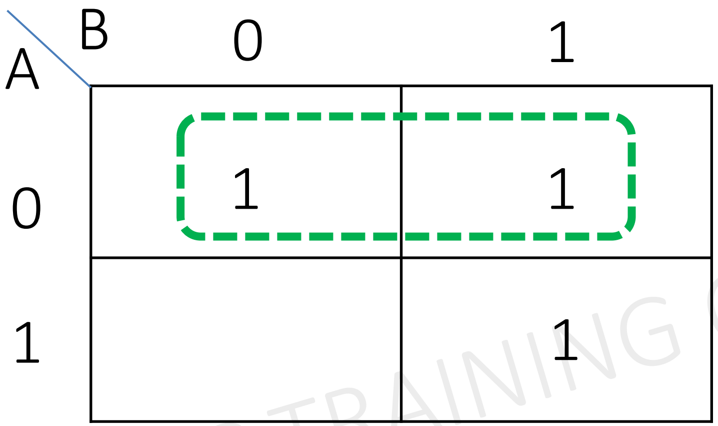
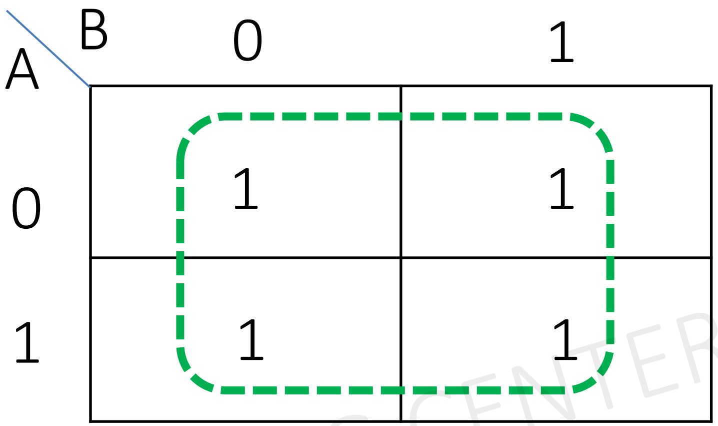
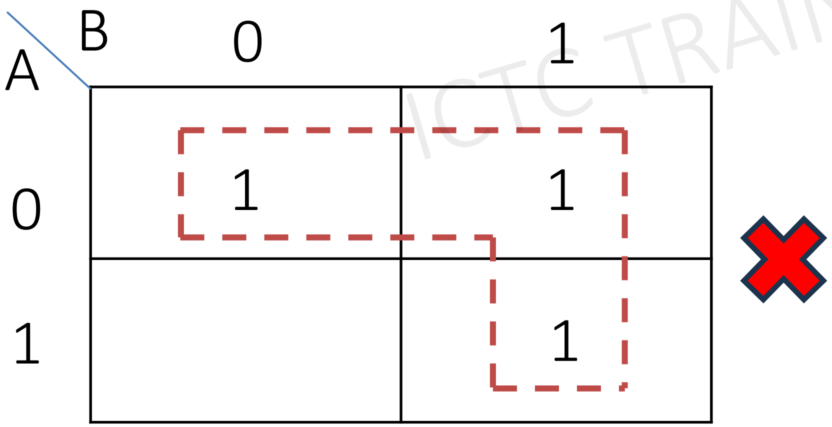
KARNAUGH MAP – 2 VARIABLES GROUPING







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KARNAUGH MAP – 2 VARIABLES

F(A,B) = A'.B' + A'.B + A.B

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

A \ B	0	1
0	1	1
1		1

F(A,B) = A' + B

F(A,B) = A'.B + A.B'

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

A	0	1
0		1
1	1	

Can not be simplified !!!

F(A,B) = A'.B + A.B'

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KARNAUGH MAP – 3 VARIABLES

K-map to represent F(A,B,C) - SOP

A	B	C	minterms
0	0	0	m0
0	0	1	m1
0	1	0	m2
0	1	1	m3
1	0	0	m4
1	0	1	m5
1	1	0	m6
1	1	1	m7

A \ BC	00	01	11	10
0	m0	m1	m3	m2
1	m4	m5	m7	m6

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KARNAUGH MAP – 3 VARIABLES

Simplify below Boolean function: F(A,B,C) = $\sum(0,1,3,5)$

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	0
1	1	1	0

A \ BC	00	01	11	10
0	m0	m1	m3	m2
1	m4	m5	m7	m6

A \ BC	00	01	11	10
0	1	1	1	
1		1		

F(A,B,C) = A'.B' + A'.C + B'.C

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KARNAUGH MAP – 3 VARIABLES - GROUPING

F(A,B,C) = $\sum(0,2)$

A \ BC	00	01	11	10
0	1			1
1				

F(A,B,C) = $\sum(1,3,5,7)$

A \ BC	00	01	11	10
0		1	1	
1		1	1	

F(A,B,C) = $\sum(4,6)$

A \ BC	00	01	11	10
0				
1	1			1

F(A,B,C) = $\sum(0,2,4,6)$

A \ BC	00	01	11	10
0	1			1
1	1			1

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KARNAUGH MAP – 3 VARIABLES

Practice: simplify below Boolean function

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

A \ BC	00	01	11	10
0				
1				

F(A,B,C)=

$F(A,B,C) = \sum(0,1,2,3,4,6)$

A \ BC	00	01	11	10
0				
1				

F(A,B,C)=

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KARNAUGH MAP – 3 VARIABLES

When the SOP Boolean functions is not enough (lack of variables to form a minterm).

For example:

F(A,B,C) = A’ + A.B’ + A.B.C’

A	B	C	F
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	0

A \ BC	00	01	11	10
0	m0	m1	m3	m2
1	m4	m5	m7	m6

A \ BC	00	01	11	10
0	1	1	1	1
1	1	1		1

F(A,B,C)=

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When the SOP Boolean functions is not enough (lack of variables to form a minterm).

For example:

F(A,B,C) = A’ + A.B’ + A.B.C’

A	B	C	minterms
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	

A \ BC	00	01	11	10
0	m0	m1	m3	m2
1	m4	m5	m7	m6

A \ BC	00	01	11	10
0	1	1	1	1
1	1	1		1

F(A,B,C)= A’ + B’ + C’

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<u>Homework1</u>:

- ❑ As we already used K-map to simplified the expression in above example. Let's use Boolean Algebra to prove that:

  $F(A,B,C) = A' + A.B' + A.B.C' = A' + B' + C'$

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K-map to represent F(A,B,C,D) - SOP

A	B	C	D	minterms
0	0	0	0	m0
0	0	0	1	m1
0	0	1	0	m2
0	0	1	1	m3
0	1	0	0	m4
0	1	0	1	m5
0	1	1	0	m6
0	1	1	1	m7
1	0	0	0	m8
1	0	0	1	m9
1	0	1	0	m10
1	0	1	1	m11
1	1	0	0	m12
1	1	0	1	m13
1	1	1	0	m14
1	1	1	1	m15

AB \ CD	00	01	11	10
00	m0	m1	m3	m2
01	m4	m5	m7	m6
11	m12	m13	m15	m14
10	m8	m9	m11	m10

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KARNAUGH MAP – 4 VARIABLES - GROUPING

Grouping of 4 and 8, as long as the 1s are adjacent

AB \ CD	00	01	11	10
00	1	1	1	1
01		1	1	
11		1	1	
10	1			1

AB \ CD	00	01	11	10
00	1	1	1	1
01		1	1	
11		1	1	
10	1	1	1	1

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KARNAUGH MAP – 4 VARIABLES

AB \ CD	00	01	11	10
00	m0	m1	m3	m2
01	m4	m5	m7	m6
11	m12	m13	m15	m14
10	m8	m9	m11	m10

$F(A,B,C,D) = \sum(0,2,5,9,10)$

AB \ CD	00	01	11	10
00	1			1
01		1		
11				
10		1		1

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KARNAUGH MAP – 4 VARIABLES

AB \ CD	00	01	11	10
00	m0	m1	m3	m2
01	m4	m5	m7	m6
11	m12	m13	m15	m14
10	m8	m9	m11	m10

$F(A,B,C,D) = \sum(0,2,5,9,10)$

AB \ CD	00	01	11	10
00	1			1
01		1		
11				
10		1		1

F(A,B,C,D) = A'.B'.D'+ A'.B.C'.D + A.B'.C'.D + B'.C.D'

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KARNAUGH MAP – 4 VARIABLES

$F(A,B,C,D) = \sum(4,5,6,7,9,13,14,15)$

AB \ CD	00	01	11	10
00	m0	m1	m3	m2
01	m4	m5	m7	m6
11	m12	m13	m15	m14
10	m8	m9	m11	m10

AB \ CD	00	01	11	10
00				
01	1	1	1	1
11		1	1	1
10		1		

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KARNAUGH MAP – 4 VARIABLES

$F(A,B,C,D) = \sum(4,5,6,7,9,13,14,15)$

AB \ CD	00	01	11	10
00	m0	m1	m3	m2
01	m4	m5	m7	m6
11	m12	m13	m15	m14
10	m8	m9	m11	m10

AB \ CD	00	01	11	10
00				
01	1	1	1	1
11		1	1	1
10		1		

$F(A,B,C,D) = A'.B + BC + A.C'.D$

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Practice: simplify below F(A,B,C,D) = $\sum(0,1,5,6,7,8,9,13,15)$

AB \ CD	00	01	11	10
00	m0	m1	m3	m2
01	m4	m5	m7	m6
11	m12	m13	m15	m14
10	m8	m9	m11	m10

AB \ CD	00	01	11	10
00				
01				
11				
10				

F(A,B,C,D) =

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KARNAUGH MAP – 4 VARIABLES

Practice: simplify below F(A,B,C,D) = $\sum(0,1,4,5,7,8,9,11,12,13,15)$

AB \ CD	00	01	11	10
00	m0	m1	m3	m2
01	m4	m5	m7	m6
11	m12	m13	m15	m14
10	m8	m9	m11	m10

AB \ CD	00	01	11	10
00				
01				
11				
10				

F(A,B,C,D) =

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Homework2:

- A circuit has 4 inputs A,B,C,D and 1 output Y. Design a combinational logic for Y to set Y to 1 whenever 2 or more inputs are equal to 1. Otherwise, Y is 0. Use SOP form.
- *Investigate 5 variable K-map and do the same requirement as above homework. Use SOP form.

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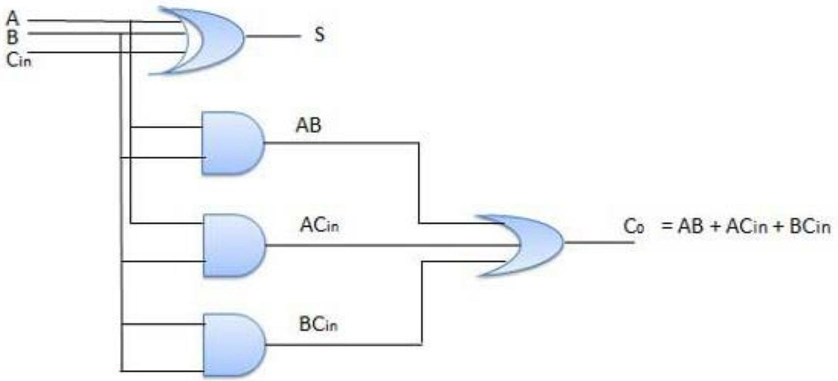
COMBINATIONAL CIRCUIT

Below is some characteristics of combinational circuit:

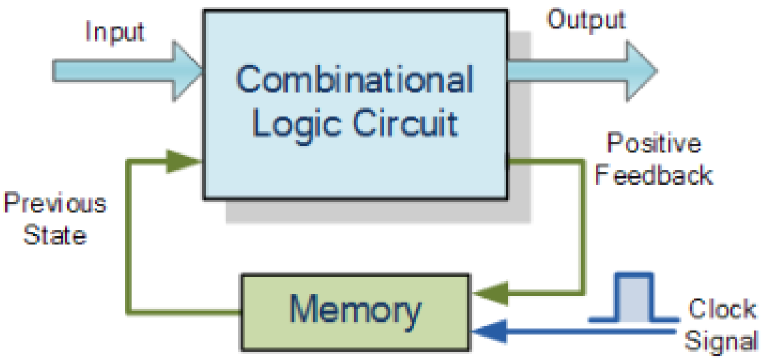
- **No feedback**: do not have feedback paths, meaning there are no elements that store information about previous inputs or outputs.
- **Instantaneous Output**: The output is a function only of the current input values, and there is no concept of time or sequence.
- **Truth Table**: The behavior of a combinational circuit is fully described by a truth table, which lists all possible combinations of input values and their corresponding output values.
- **Logic Gates**: Combinational circuits are constructed using basic logic gates such as AND, OR, NOT, XOR, and others.

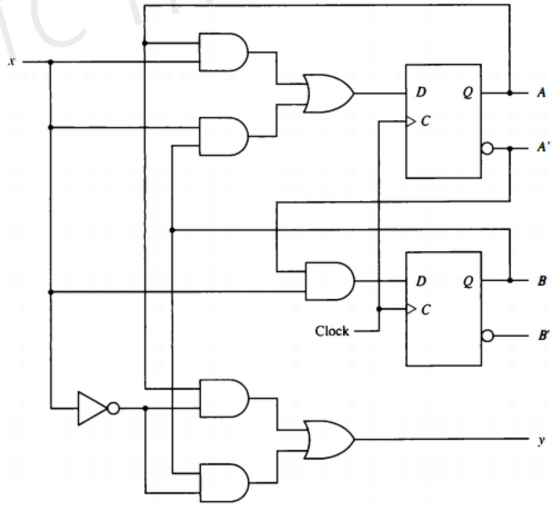


SEQUENTIAL CIRCUIT

Below is some characteristics of combinational circuit:

- **Memory Elements**: Sequential circuits include memory elements (such as flip-flops or latches) that store information about the past states of the circuit.
- **Feedback Paths**: Sequential circuits have feedback paths that allow the output to influence the input, creating a loop that enables the circuit to maintain and update its state.
- **Clock Signal**: The clock signal determines when the circuit should update its state, ensuring that changes happen at specific intervals.
- **State Transition**: The behavior of a sequential circuit is often described using a state diagram, which illustrates how the circuit transitions from one state to another based on input and clock signals.
- **Finite State Machines**: Sequential circuits are often implemented as finite state machines, where the circuit can exist in a finite number of states, and transitions between states are governed by specified conditions.





SUMMARY

SUMMARY:

- ❑ Karnaugh map is a very effective way to simplify Boolean functions.
- ❑ Combinational logic has no feedback path, the output changes immediately based on input.
- ❑ Sequential logic has feedback path to store the current state.

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