2. MODELING OF ELECTRONIC SYSTEMS

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Basic Concepts

The relationship between inputs and outputs defines the behavior of the system

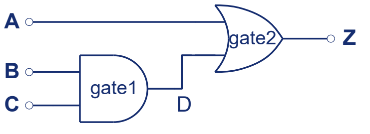
Some examples of models used to describe an electronic system are …

- Structural models
- Functional models at logic level
- Behavioral models (VHDL, Verilog or even C)

Structural Models

- The structural models describe the system as a set of sub-systems or components
- The *smallest* components (lowest hierarchical level) are called **primitives**
- Block diagrams and schematics are examples of structural models

Graphical representation



Textual representation

```
module gate (Z, A, B, C);
input A, B, C;
output Z;
wire D;
  and gate1 (D, B, C);
  or gate2 (Z, A, D);
endmodule
```


Functional Models at Logic Level

Truth tables and primitive cubes

The function Z($\mathbf{x}_1$, $\mathbf{x}_2$, … , $\mathbf{x}_n$) needs a table with $\mathbf{2^n}$ entries to be fully defined

If the number of outputs of Z is **m**, then we will need **m** tables to describe the function

When the tables are compressed using the “*don´t care*” symbols, we obtain a representation called **cubic notation**

Functional Models at Logic Level

Truth table

x_1	x_2	x_3	**Z**
0	0	0	**1**
0	0	1	**1**
0	1	0	**0**
0	1	1	**1**
1	0	0	**1**
1	0	1	**1**
1	1	0	**0**
1	1	1	**0**

Primitive cubes

x_1	x_2	x_3	**Z**
x	1	0	**0**
1	1	x	**0**
x	0	x	**1**
0	x	1	**1**

Functional Models at Logic Level

Sequential circuits

- A sequential function can be modeled as a **Finite State Machine (FSM)**
- The FSMs …
  - present a finite number of internal states
  - change from one state to another in response to some external inputs
  - can be described using **state transition tables** or **state diagrams**

Functional Models at Logic Level

State transition table

	Condition		
Present state	**X**	**Y**	**Z**
A	…	…	…
B	…	<next state>, <output>	…
C	…	…	…

The transitions between states are synchronous to a clock signal

The outputs can be associated to the present state **(Moore machines)** or associated to the state transitions **(Mealy machines)**

The example represented in the table corresponds to a Mealy machine

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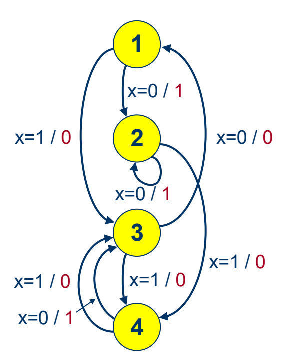
Functional Models at Logic Level

State transition table

	Input (x)	
Present state	**0**	**1**
1	2,1	3,0
2	2,1	4,0
3	1,0	4,0
4	3,1	3,0

<next state>, <output>

State diagram



The state is stored in flip-flops

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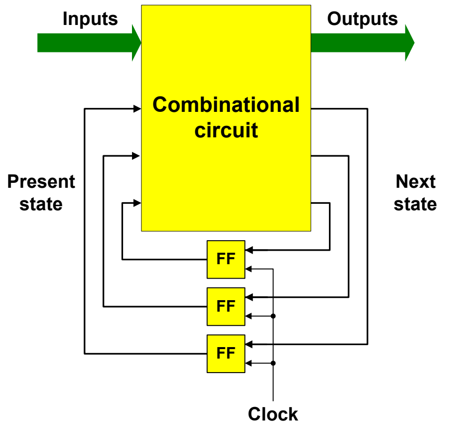
Functional Models at Logic Level

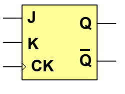
Canonical structure of a synchronous sequential circuit



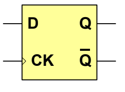
Functional Models at Logic Level

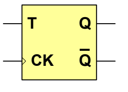
Description of three types of flip-flops

	JK			
Q	**00**	**01**	**11**	**10**
0	0	0	1	1
1	1	0	0	1



	D	
Q	**0**	**1**
0	0	1
1	0	1



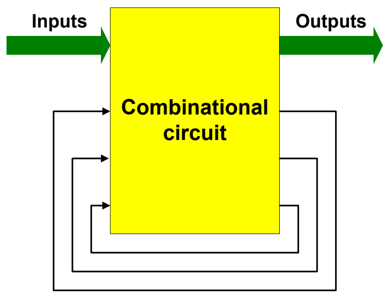


	T	
Q	**0**	**1**
0	0	1
1	1	0

The flip-flops are finite state machines with 2 states

Functional Models at Logic Level

Canonical structure of an asynchronous sequential circuit



There is no clock signal

Functional Models at Logic Level

State transition table (asynchronous circuit)

	Inputs (x_1 x_2)			
Present state	**00**	**01**	**11**	**10**
1	**1**,0	5,1	2,0	**1**,0
2	1,0	**2**,0	**2**,0	5,1
3	**3**,1	2,0	4,0	**3**,0
4	3,1	5,1	**4**,0	**4**,0
5	3,1	**5**,1	4,0	**5**,1

Stable configurations (marked in red and bold in the table):

<next state> = <present state>

Functional Models at Logic Level

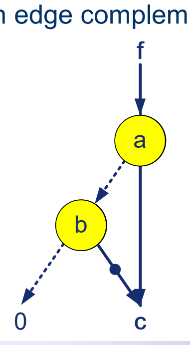
Binary Decision Diagrams (BDD)

- Describes a circuit functionality as a **graph**
- It is a very compact representation of a Boolean function
- The output value is obtained by traversing the graph, analyzing the input values in a given sequence
- The BDDs are extensively used in the CAD tools, namely, in the logic synthesis
- The size of the BDD depends on the ordering of the variables

Functional Models at Logic Level

Binary Decision Diagrams (BDD)

- The procedure starts at the root of the graph
- In each node, we decide to follow the left edge or the right edge depending on the value of the variable (0 or 1), respectively
- A circle in an edge complements the value of the variable associated to that edge



$f = \bar{a}.b.\bar{c} + a.c$

Evaluate **f** for …

1. **abc** = **001**
2. **a** = **1**

Functional Models at Logic Level

Binary Decision Diagram (BDD)

a	b	c	f
0	0	0	**0**
0	0	1	**0**
0	1	0	**1**
0	1	1	**0**
1	0	0	**0**
1	0	1	**1**
1	1	0	**0**
1	1	1	**1**

$f = \bar{a}.b.\bar{c} + a.c$

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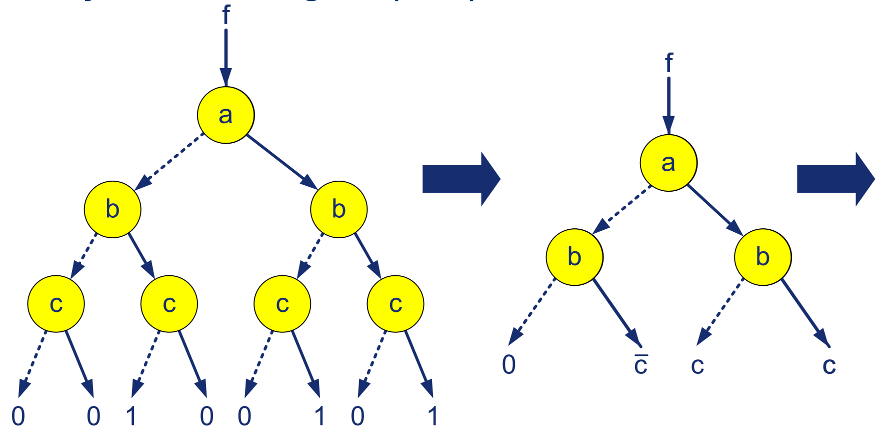
Functional Models at Logic Level

Binary Decision Diagram (BDD)



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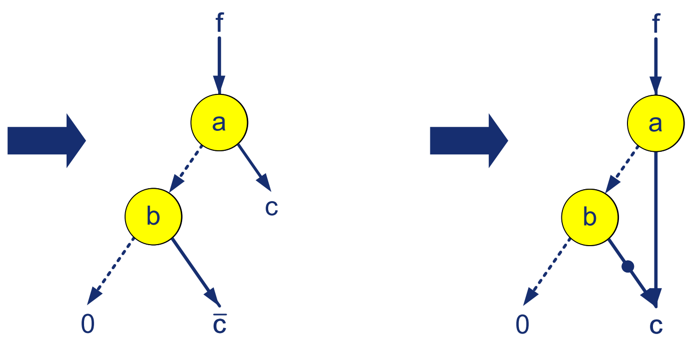
Functional Models at Logic Level

Binary Decision Diagram (BDD)



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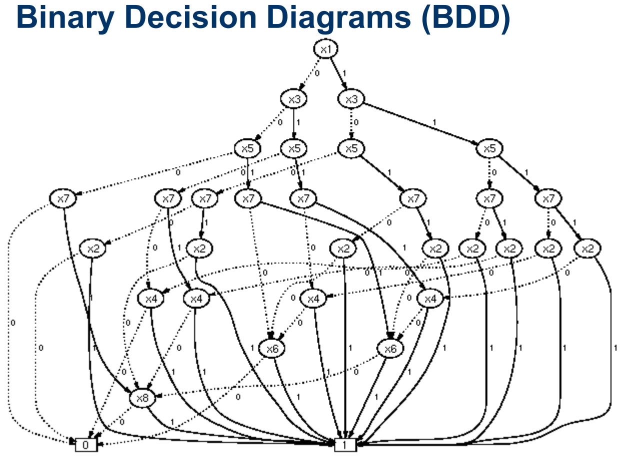
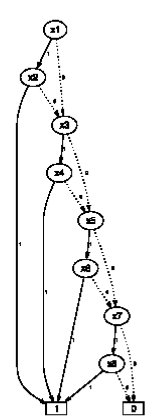
Functional Models at Logic Level

Binary Decision Diagrams (BDD)



Bad variable ordering



Good variable ordering

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