Digital Engineering

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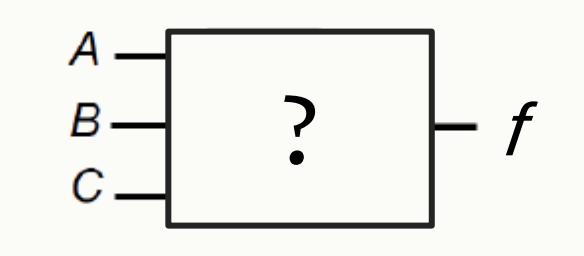
Lecture 3
Truth Table

Logic Circuit Design

- You will be given a word description for the function required to be implemented.
- Example:
  - Design a 3-bit prime number detector circuit.
  - Design a prime number detector circuit for the numbers 0-7.
  - Given a 3-bit input N = ABC, design a circuit that will output f=1 in case of N = prime number in binary, and output f=0 otherwise.



Truth Table

- The first step is to construct the circuit truth table.
- It tells what the function will output in each case of input.
- How many inputs ??
- Remember: An n binary bit is used to represent 2^n numbers with the values $0 \rightarrow 2^{n-1}$
- The input range is 0-7. Then, we have 3 inputs (3 binary bit ABC).

A	B	C	f

Truth Table

- Regardless of the circuit or its functionality.
- In the input side we need to put all the input combinations.
- How to fill those combinations?

A	B	C	f
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

Truth Table

- The number of rows = 2^n, where n is the number of inputs.
- Here n=3 then the number of rows = $2^3 = 8$

A	B	C	f

Truth Table

- In the right most bit, fill in `0,1,0,1,0,1,...` from top to down.

A	B	C	f
		0	
		1	
		0	
		1	
		0	
		1	
		0	
		1	

Truth Table

- In the right most bit, fill in 0,1,0,1,0,1,… from top to down.
- In the second right most bit, fill in 0,0, 1,1, 0,0, 1,1, … from top to down.

A	B	C	f
	0	0	
	0	1	
	1	0	
	1	1	
	0	0	
	0	1	
	1	0	
	1	1	

Truth Table

- In the right most bit, fill in 0,1,0,1,0,1,… from top to down.
- In the second right most bit, fill in 0,0, 1,1, 0,0, 1,1, … from top to down.
- In the next bit, fill in 0,0,0,0, 1,1,1,1, … top to down.
- Repeat till the left most bit.

A	B	C	f
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

Truth Table

- Till now, we constructed the input side only. It is the same in any 3-input circuit.
- Now, it is required to construct the output side.

A	B	C	f
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

Truth Table

- From the word description of the circuit, the output f=1 in case of N = prime number in binary, and the output f=0 otherwise.

Decimal	A	B	C	f
0	0	0	0	
1	0	0	1	
2	0	1	0	
3	0	1	1	
4	1	0	0	
5	1	0	1	
6	1	1	0	
7	1	1	1	

Truth Table

- From the word description of the circuit, the output f=1 in case of N = prime number in binary, and the output f=0 otherwise.

- Done with the truth table.

Decimal	A	B	C	f
0	0	0	0	0
1	0	0	1	0
2	0	1	0	1
3	0	1	1	1
4	1	0	0	0
5	1	0	1	1
6	1	1	0	0
7	1	1	1	1

Truth Table

- This is the first step in designing a circuit.
- The next step is to convert it into circuit. How?
- We will learn many ways along the course.

Decimal	A	B	C	f
0	0	0	0	0
1	0	0	1	0
2	0	1	0	1
3	0	1	1	1
4	1	0	0	0
5	1	0	1	1
6	1	1	0	0
7	1	1	1	1

Truth Table from Equation

- This is another case.
- Given a function equation.
  Example: $F = A \cdot \bar{B} + C$
- It is required to find its truth table.

- How many inputs ??

Truth Table from Equation

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- Given a function equation. Example: $F = A \cdot \bar{B} + C$
- It is required to find its truth table.

A	B	C	F

- How many inputs ?? n=3 (ABC)
- How many rows ??

Truth Table from Equation

- This is another case.
- Given a function equation. Example: $F = A \cdot \bar{B} + C$
- It is required to find its truth table.

- How many inputs ?? n=3 (ABC)
- How many rows ?? 2^n=8
- How to fill the input side (ABC columns) ??

A	B	C	F

Truth Table from Equation

- This is another case.
- Given a function equation. Example: $F = A \cdot \bar{B} + C$
- It is required to find its truth table.

- How many inputs ?? n=3 (ABC)
- How many rows ?? 2^n=8
- How to fill the input side (ABC columns) ??

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

Truth Table from Equation

- This is another case.
- Given a function equation. Example: $F = A \cdot \bar{B} + C$
- It is required to find its truth table.

- How many inputs ?? n=3 (ABC)
- How many rows ?? 2^n=8
- How to fill the input side (ABC columns) ??

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

Truth Table from Equation

- This is another case.
- Given a function equation. Example: $F = A \cdot \bar{B} + C$
- It is required to find its truth table.

- How many inputs ?? n=3 (ABC)
- How many rows ?? 2^n=8
- How to fill the input side (ABC columns) ??

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

Truth Table from Equation

- This is another case.
- Given a function equation. Example: $F = A \cdot \bar{B} + C$
- It is required to find its truth table.
- How do you think we could fill in the output side??
- Previously we had a word description. Now how??

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

Truth Table from Equation

- This is another case.
- Given a function equation. Example: $F = A \cdot \bar{B} + C$
- It is required to find its truth table.
- Substitute in the equation.

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

Truth Table from Equation

- This is another case.
- Given a function equation. Example: $F = A \cdot \bar{B} + C$
- It is required to find its truth table.
- Substitute in the equation.

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

Truth Table from Equation

- This is another case.
- Given a function equation. Example: $F = A \cdot \bar{B} + C$
- It is required to find its truth table.
- Substitute in the equation.
- Done.

A	B	C	F
0	0	0	0
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	1

Truth Table of Dual Function

- Remember: To get the dual of a function: Replace operators: $+ \leftrightarrow \cdot$ and replace constants $0 \leftrightarrow 1$: (Variables are not changed).
  - Example: $F = A \cdot \bar{B} + C$
  - Then: $F^D = (A + \bar{B}) \cdot C$
- Given the truth table of F.
- How do you think could we get the truth table of F^D ??

A	B	C	F
0	0	0	0
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	1

Truth Table of Dual Function

- Remember: To get the dual of a function: Replace operators: $+ \leftrightarrow \cdot$ and replace constants $0 \leftrightarrow 1$: (Variables are not changed).
- From this rule, replace all constants $0 \leftrightarrow 1$
- This is the truth table but with reversed rows.

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

Truth Table of Dual Function

- Remember: To get the dual of a function: Replace operators: $+ \leftrightarrow \cdot$ and replace constants $0 \leftrightarrow 1$: (Variables are not changed).
- From this rule, replace all constants $0 \leftrightarrow 1$
- This is the truth table but with reversed rows.
- Rearrange the rows. Reverse them up down.

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

Truth Table of Dual Function

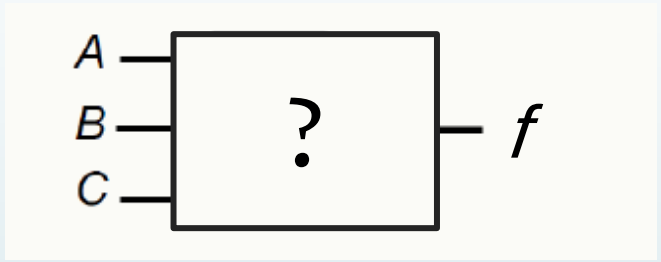
- Check it by substituting in the equation $F^D = (A + \bar{B}) \cdot C$

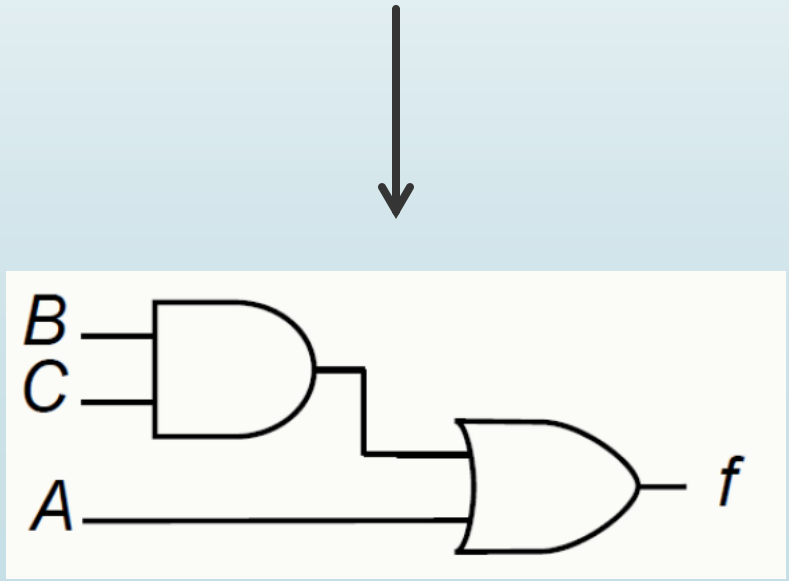
- Done.

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

Truth Table of Unknown Circuit

- This is another case.
- This is reverse engineering.
- Given an unknown chip and it is required to find its truth table, equation and circuit diagram.

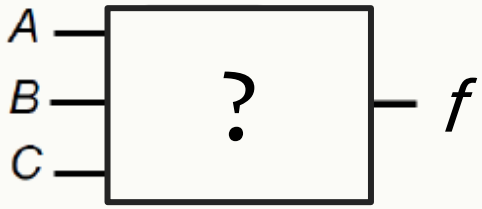




- First find the truth table and then use any of the upcoming methods to find the equation and circuit.

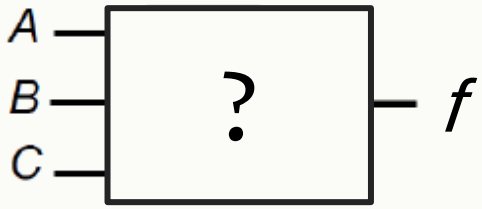
Truth Table of Unknown Circuit

- First construct the input side using the same previous steps.
- How many inputs ?? n=?



Truth Table of Unknown Circuit

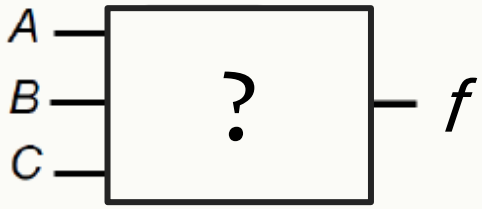
- First construct the input side using the same previous steps.
- How many inputs ?? n=3 (ABC)
- How many rows ??



A	B	C	F

Truth Table of Unknown Circuit

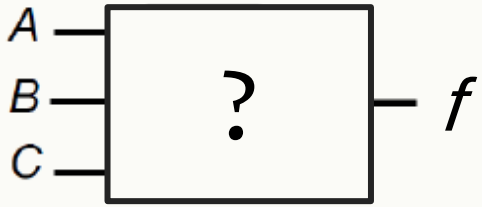
- First construct the input side using the same previous steps.
- How many inputs ?? n=3 (ABC)
- How many rows ?? $2^n=8$
- How to fill the input side (ABC columns) ??



A	B	C	F

Truth Table of Unknown Circuit

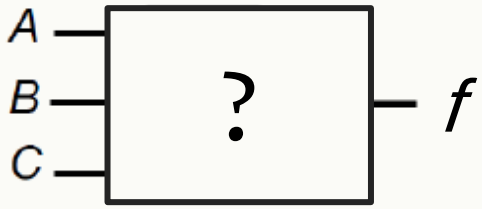
- First construct the input side using the same previous steps.
- How many inputs ?? n=3 (ABC)
- How many rows ?? $2^n=8$
- How to fill the input side (ABC columns) ?
- How do you think could we fill in the output side ??



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

Truth Table of Unknown Circuit

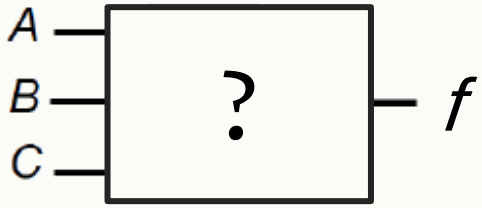
- First construct the input side using the same previous steps.
- How many inputs ?? n=3 (ABC)
- How many rows ?? $2^n=8$
- How to fill the input side (ABC columns) ?
- How do you think could we fill in the output side ?
- Do it empirically: Apply each input and measure the output.



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

Truth Table of Unknown Circuit

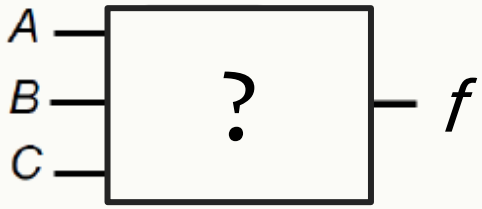
- First construct the input side using the same previous steps.
- How many inputs ?? n=3 (ABC)
- How many rows ?? $2^n=8$
- How to fill the input side (ABC columns) ?
- How do you think could we fill in the output side ?
- Do it empirically: Apply each input and measure the output.



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

Truth Table of Unknown Circuit

- First construct the input side using the same previous steps.
- How many inputs ?? n=3 (ABC)
- How many rows ?? $2^n=8$
- How to fill the input side (ABC columns) ?
- How do you think could we fill in the output side ?
- Do it empirically: Apply each input and measure the output. Done.



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