Combinational Logic

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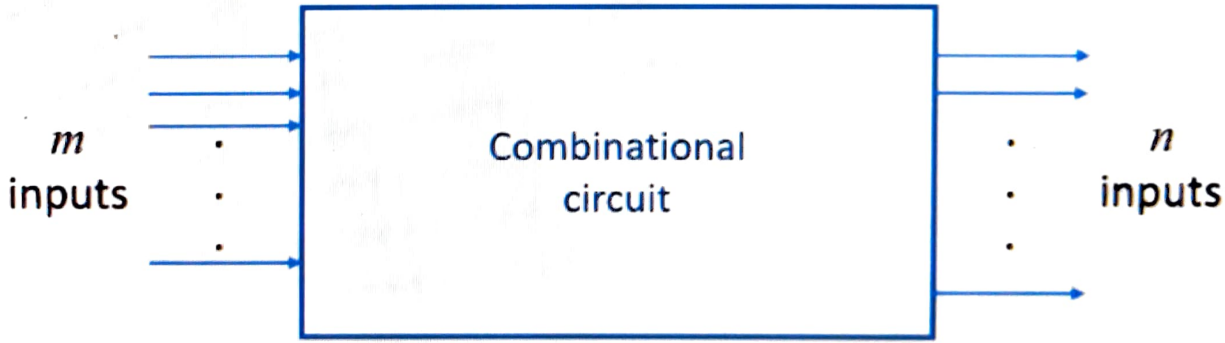
Logic Circuits

- Combinational circuit
  - Logic gate circuit, whose output at a particular time instant is dependent on input combination at that particular time instant
- Sequential circuit
  - Logic gate circuit + Storage element
  - Output depends on the input combination and the state of the memory element

Combinational Circuit

- Logic circuit that consists of interconnection of logic gates
- For m inputs, the possible combinations of binary inputs = 2^m
- For each possible input combination, there is one possible value at the output
- A combinational circuit can be described by truth table



Block diagram of combinational circuit

Combinational Circuits

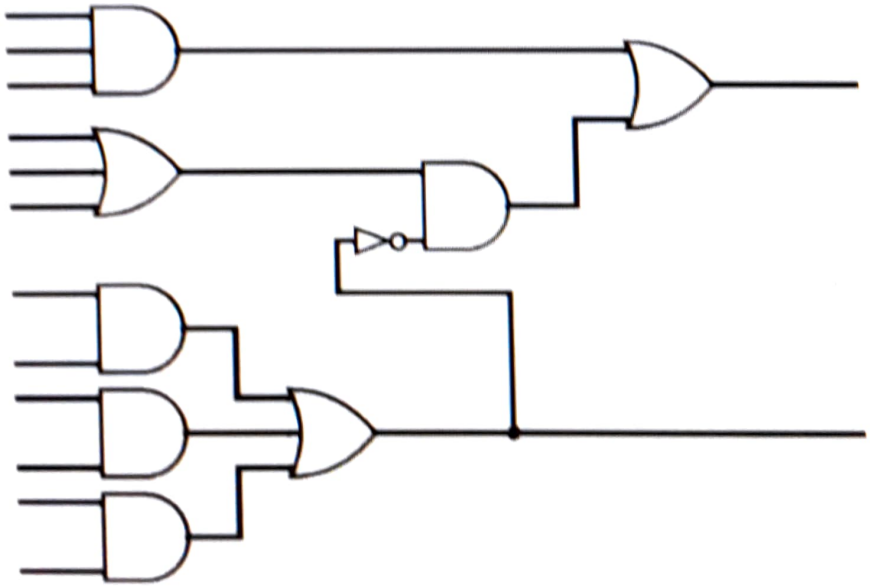
- Binary Adder, Subtractor
- Decimal Adder
- Binary multiplier
- Magnitude comparator
- Decoder
- Encoder
- Multiplexer

Analysis of Combinational Circuit

- Determine the function the circuit implements
- Start with
  - Logic circuit
  - Boolean functions
  - Truth table
  - Explanation of the circuit operation
- Make sure the circuit is not sequential
- Make sure there is no feedback path or memory elements

Procedure to obtain Boolean function from logic circuit

- **Label all gate first stage outputs with unique names**
- **Proceed to the next stage, till you reach final output**



Combinational Circuit

$$P = ABC$$

$$Q = A + B + C$$

$$R = AB$$

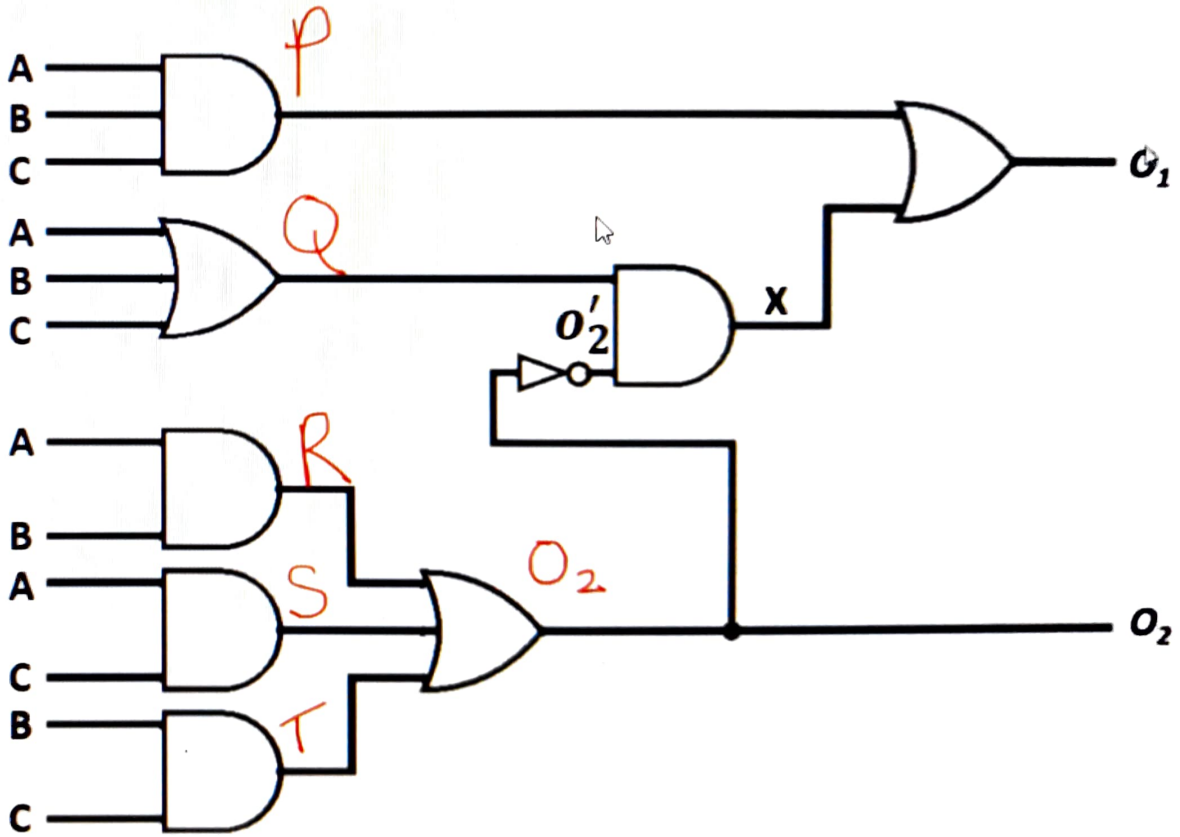
$$S = AC$$

$$T = BC$$

$$O_2 = R + S + T$$

$$O_2 = AB + AC + BC$$

$$O_1 = P + X = (ABC) + (QO_2')$$



Code conversion example combinational logic circuit

Decimal	Binary	Excess-3
0	0000	0011
1	0001	0100
2	0010	0101
3	0011	0110
4	0100	0111
5	0101	1000
6	0110	1001
7	0111	1010
8	1000	1011
9	1001	1100

Input BCD				Output Excess-3			
A	B	C	D	P	Q	R	S
0	0	0	0	0	0	1	1
0	0	0	1	0	1	0	0
0	0	1	0	0	1	0	1
0	0	1	1	0	1	1	0
0	1	0	0	0	1	1	1
0	1	0	1	1	0	0	0
0	1	1	0	1	0	0	1
0	1	1	1	1	0	1	0
1	0	0	0	1	0	1	1
1	0	0	1	1	1	0	0

K-maps for the output variables

P

AB \ CD	00	01	11	10
00				
01				
11				
10				

m_0	m_1	m_3	m_2
m_4	m_5	m_7	m_6
m_{12}	m_{13}	m_{15}	m_{14}
m_8	m_9	m_{11}	m_{10}

Q

AB \ CD	00	01	11	10
00				
01				
11				
10				

R

AB \ CD	00	01	11	10
00				
01				
11				
10				

S

AB \ CD	00	01	11	10
00				
01				
11				
10				

Don’t care conditions

- The six bit combinations not listed beyond 1001 for input are don’t-care combinations
- These values have no meaning in BCD and we assume that they will never occur in actual operation of the circuit
- Therefore we have the liberty to take either 0 or 1
- Don’t care is represented by X
- Idea is to get simple circuit

Binary	Excess-3
0000	0011
0001	0100
0010	0101
0011	0110
0100	0111
0101	1000
0110	1001
0111	1010
1000	1011
1001	1100

Four-variable K-map

m_0	m_1	m_3	m_2
m_4	m_5	m_7	m_6
m_{12}	m_{13}	m_{15}	m_{14}
m_8	m_9	m_{11}	m_{10}

Simplify the Boolean function given in standard SOP form

F = A′B′C′ + B′CD′ + A′BCD′ + AB′C′

Add missing variables

F = A′B′C′ (D+D′)+(A+A′) B′CD′ + A′BCD′ + AB′C′(D+D′)

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

K-maps for the output variables

P

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

m_0	m_1	m_3	m_2
m_4	m_5	m_7	m_6
m_{12}	m_{13}	m_{15}	m_{14}
m_8	m_9	m_{11}	m_{10}

Q

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

R

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

S

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

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B D + B C + A

K-maps for the output variables

P = A + BD + BC

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

m_0	m_1	m_3	m_2
m_4	m_5	m_7	m_6
m_{12}	m_{13}	m_{15}	m_{14}
m_8	m_9	m_{11}	m_{10}

Q

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

R

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

S

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