

Assignment 4: Digital circuit

Attention: Recommend using \LaTeX to complete your work. You can use any tool, such as Logisim, Visio, Draw.io, PowerPoint, etc., to create diagrams. However, handwritten or hand-drawn content is not acceptable.

1 Combinational logic

Analyze the circuit shown in Fig. 1 and answer the following questions:

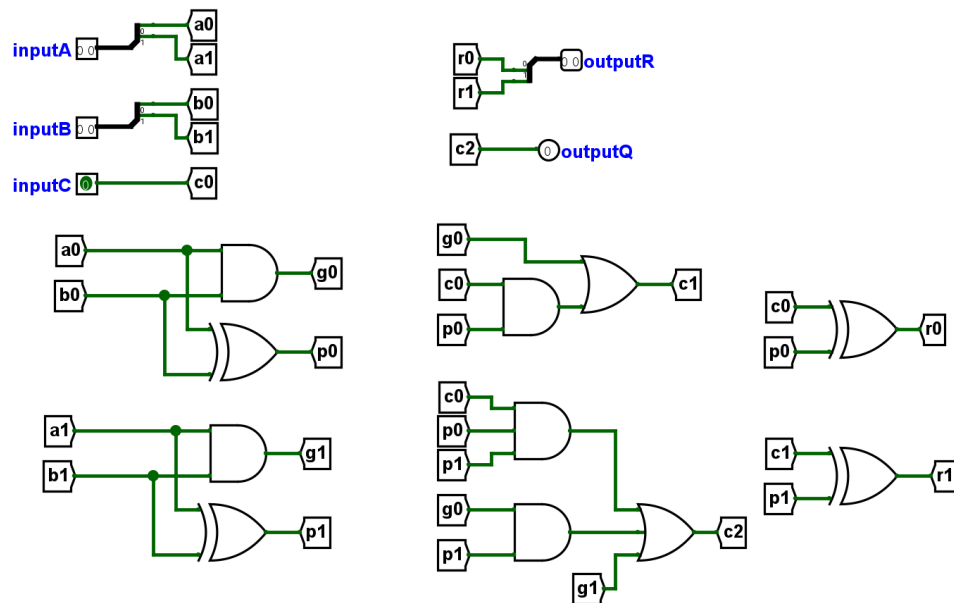


Figure 1: A 2-bit arithmetic circuit

- Draw the truth table of this circuit. [10 pt]
- Which kind of arithmetic operation (addition, subtraction, multiplication, division, shift, or comparison) is performed by this circuit? What are the advantages and disadvantages of the circuit in Fig. 1 compared to the corresponding arithmetic circuit mentioned in Digital circuits I? [10 pt]
- Assume that all 2-input logic gates have 1 ns delay, all 3-input logic gates have 2 ns delay, and other delays are not considered. Calculate the max delay of this circuit. [10 pt]

Answer to Question 1

(a)

a_0	a_1	b_0	b_1	c_0	g_0	p_0	g_1	p_1	c_1	c_2	r_0	r_1
0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	1	0	0	0	0	0	0	1	0
0	0	0	1	0	0	0	0	1	0	0	0	1
0	0	0	1	1	0	0	0	1	0	0	1	1
0	0	1	0	0	0	1	0	0	0	0	1	0
0	0	1	0	1	0	1	0	0	1	0	0	1
0	0	1	1	0	0	1	0	1	0	0	1	1
0	0	1	1	1	0	1	0	1	1	1	0	0
0	1	0	0	0	0	0	0	1	0	0	0	1
0	1	0	0	1	0	0	0	1	0	0	1	1
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0	1	1	1	0	0	1	1	0	1	1	0	0
0	1	1	1	1	0	1	1	0	1	1	1	0
1	0	0	0	0	0	1	0	0	0	0	1	0
1	0	0	0	1	0	1	0	0	1	0	0	1
1	0	0	1	0	0	1	0	1	0	0	1	1
1	0	0	1	1	0	1	0	1	0	1	0	0
1	0	1	0	0	1	0	0	0	1	0	0	1
1	0	1	0	1	1	0	0	0	1	0	1	1
1	0	1	1	0	1	0	0	1	1	1	0	0
1	0	1	1	1	1	0	0	1	1	1	1	0
1	1	0	0	0	0	1	0	1	0	0	1	1
1	1	0	0	1	0	1	0	1	1	1	0	0
1	1	0	1	0	0	1	1	0	0	1	1	0
1	1	0	1	1	0	1	1	0	1	1	0	1
1	1	1	0	0	1	0	0	1	1	1	0	0
1	1	1	0	1	1	0	0	1	1	1	1	0
1	1	1	1	0	1	0	1	0	1	1	0	1
1	1	1	1	1	1	0	1	0	1	1	1	1

(b) Addition.

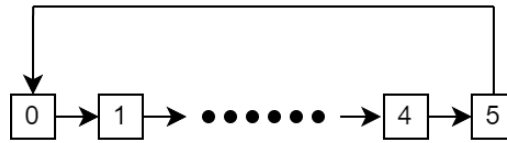
Advantages: faster.

Disadvantages: more difficult to understand, and more expensive to implement(need more gates).

(c) The max delay is $1ns+2ns+2ns= 5ns$.

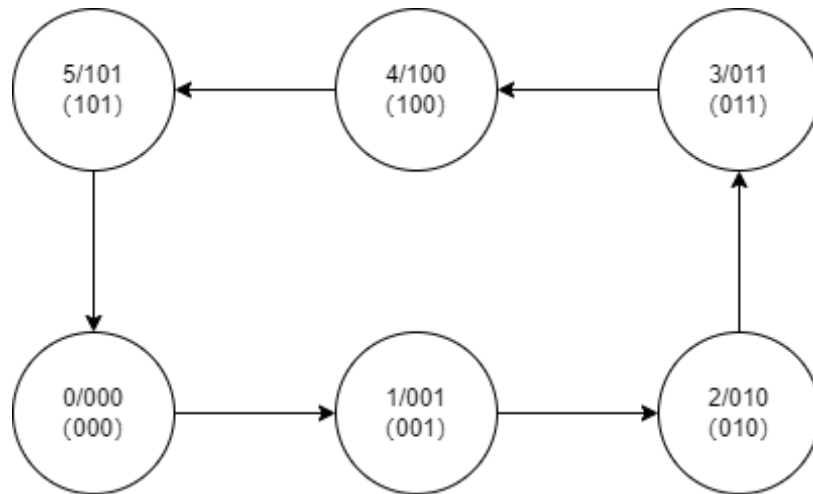
2 SDS

Draw a counter that counts from 0 to 5 using three D flip-flops (each flip-flops represents one output bit) and some 2-input logic gates (AND, OR, NOT). Please use the method taught in class to build a Moore FSM that implements the circular counter. Complete the state transition logic and output logic. **[35 pt]**



Answer to Question 2

State machine:



Truth table:

C_2	C_1	C_0	N_2	N_1	N_0
0	0	0	0	0	1
0	0	1	0	1	0
0	1	0	0	1	1
0	1	1	1	0	0
1	0	0	1	0	1
1	0	1	0	0	0

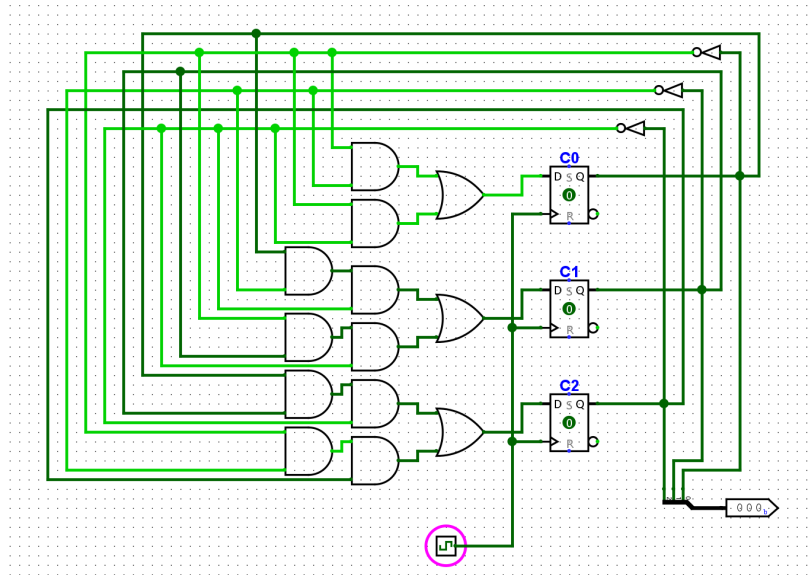
Logical expression: ($C_2C_1C_0$ stands for current state and $N_2N_1N_0$ stands for next state. The output is the same as next state.)

$$N_0 = \overline{C_0}\overline{C_1} + \overline{C_0}C_2$$

$$N_1 = C_0\overline{C_1}\overline{C_2} + \overline{C_0}C_1\overline{C_2}$$

$$N_2 = C_0C_1\overline{C_2} + \overline{C_0}\overline{C_1}C_2$$

Circuit:



3 Finite state machine

The function of a vending machine which sells bottles of soda is described below:

- Each bottle costs \$1.50.
- The machine only accepts \$0.50 and \$1 coins. If a customer inserts enough coins, the machine will dispense a bottle of soda (FSM will output “1”, otherwise “0”) and returns change if needed , e.g., the output of DISPENSE states may be “1 \$0.5”, other states’ output may be “0 \$0”.
- The process happens one coin at a time, and there is no simultaneous insertion of multiple coins or shipping of multiple bottles. After each transaction, the vending machine enters the IDLE state.
- We don’t need to account for a scenario where a customer inserts coins but decides not to make a purchase.

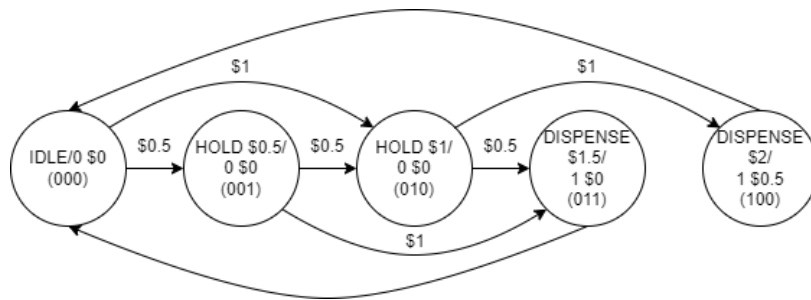
(a) Draw the FSM (Moore machine) for this vending machine.[15 pt]

(b) Draw the FSM (Mealy machine) for this vending machine.[10 pt]

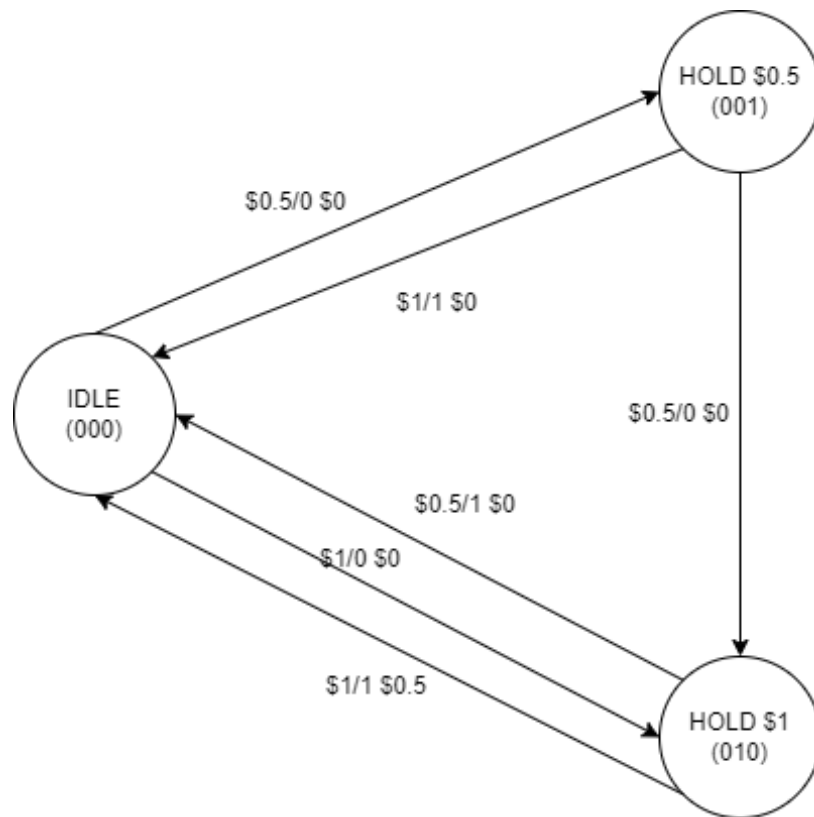
(c) Could Moore machines and Mealy machines be converted into each other to implement the same function? Compare their difference.[10 pt]

Answer to Question 3

(a)



(b)



(c) Yes, they could be converted to each other.

The difference is that a moore machine's output only depends on the current state, while the mealy machine's depends on both current state and input.