ShanghaiTech University
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Student name:
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CS110: Computer Architecture
Spring, 2024

Assignment 4: Digital circuit Solution

Attention: Recommend using LaTeXto 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:

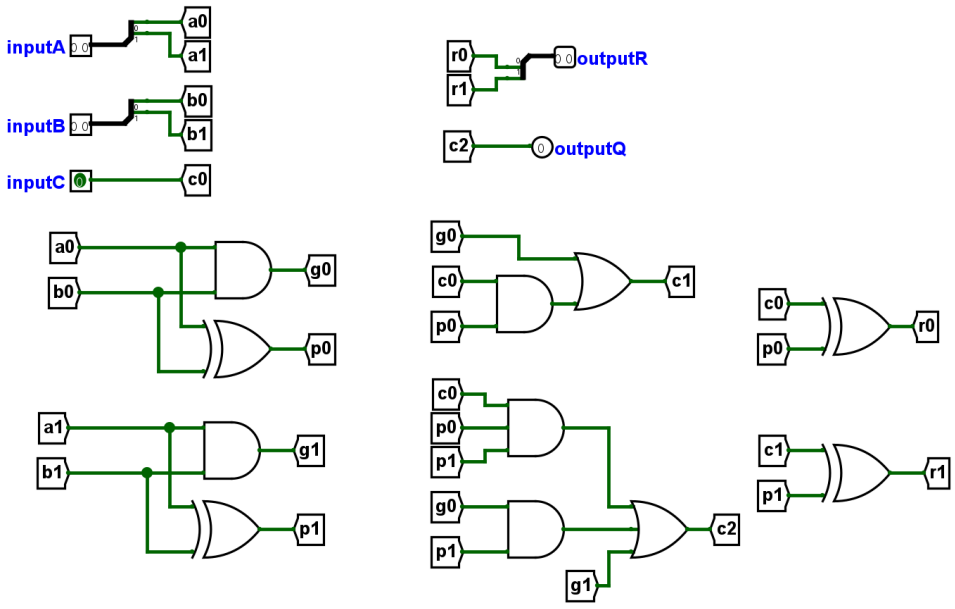

Figure 1: A 2-bit arithmetic circuit

(a) Draw the truth table of this circuit.**[10 pt]**

(b) 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]**

(b) 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) This is the truth table of a 2-bits adder.

(b) Addition. Advantages: Faster and lower latency. Disadvantages: Larger area and more complex structure. Other reasonable answers will be scored as appropriate, but incorrect answers will not be scored.

(c) 5ns. a1/b1→ p1→ c2 (a0/b0→ p0→ c2)

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]**

Figure 2: The counter cycles through the process of counting from 0 to 5.

Answer to Question 2

The answer to this question is not unique. But it needs to meet:

- Using the methods taught in class (write down the process).
- Drawing FSM.

This is one of the possible solution:

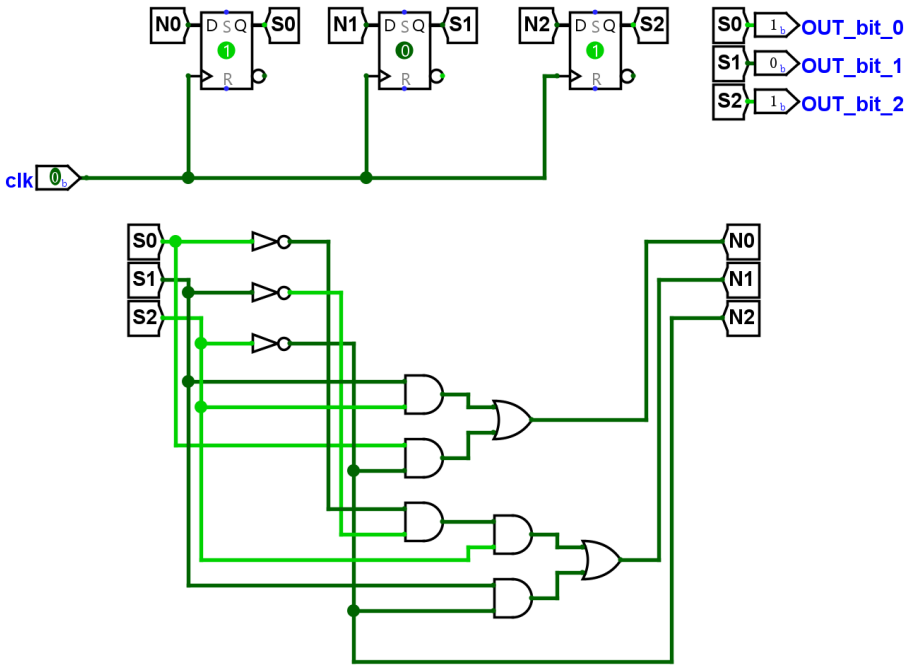

Figure 3: one of the possible solution for problem 2.

Please note that circuits without output pins are incomplete, which may result in a deduction of points as appropriate.

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) Here are one possible solution:

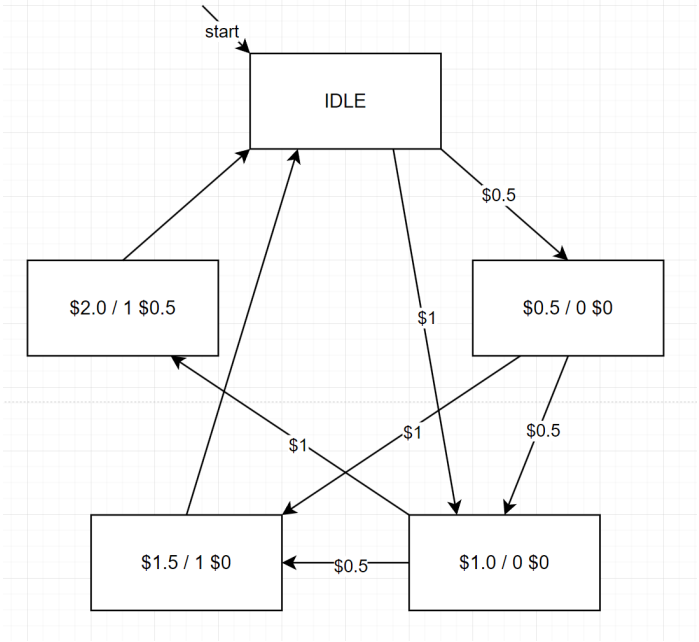

Figure 4: one possible solution of Moore machine

(a) Here are one possible solution:

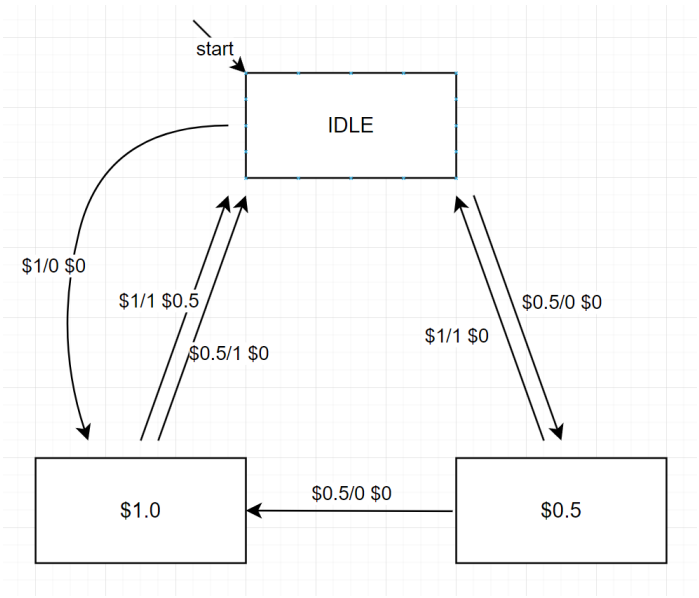

Figure 5: one possible solution of Mealy machine

(c) Yes. Any reasonable answer can be scored.