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CSCI 150
Introduction to Digital and Computer System Design
Lecture 4: Sequential Circuit Flashback

Jetic Gū

2020 Summer Semester (S2)

Overview

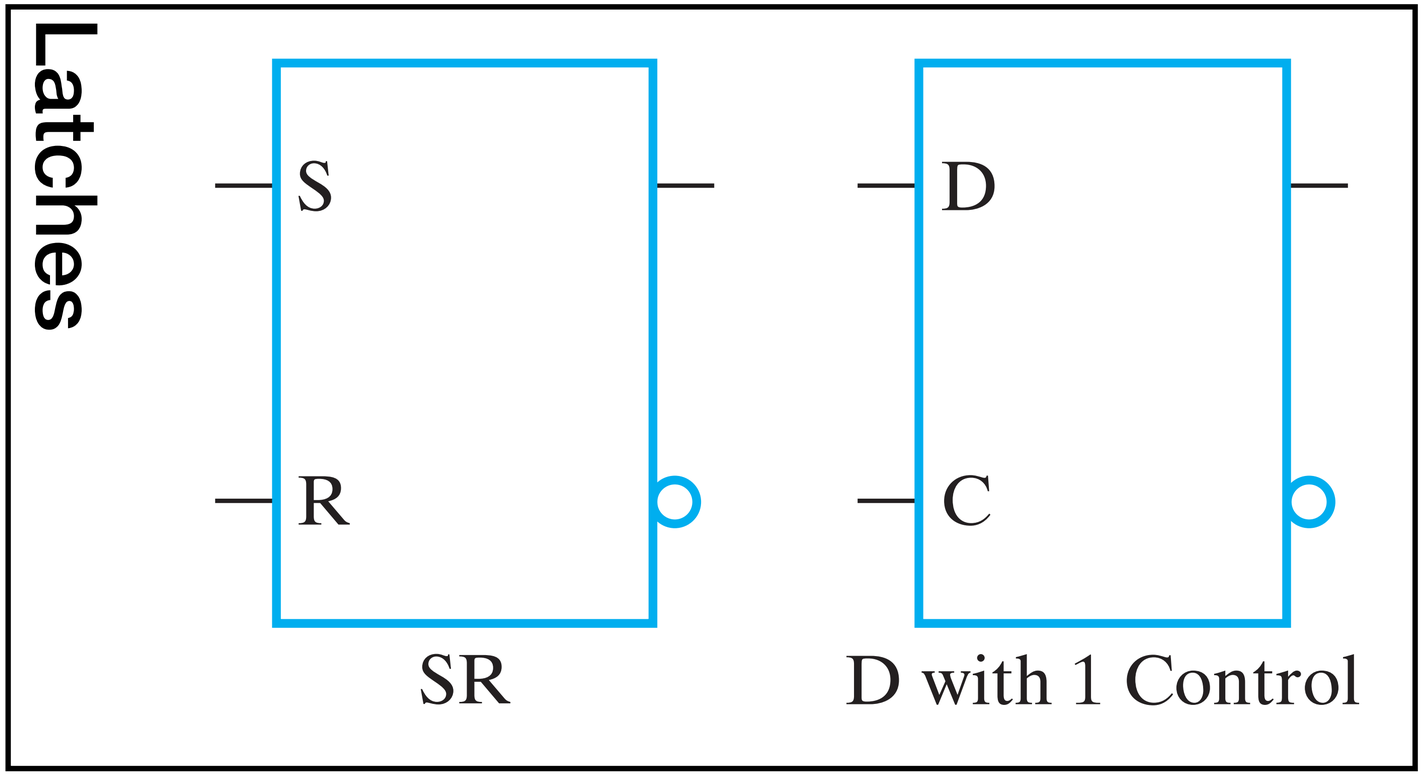
- Focus: Sequential Circuit Exercises
- Architecture: von Neumann
- Textbook v4: Ch5; v5: Ch4
- Core Ideas:
    1. Latches and Flip-Flips
    2. State Diagram and State Table
    3. Exercise

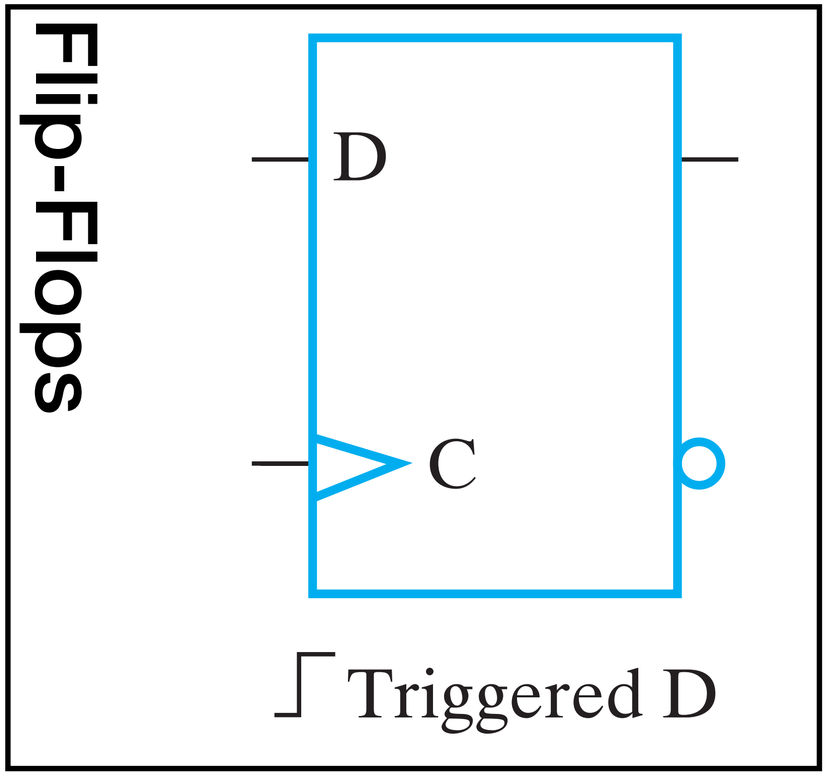
How to study for CSCI 150

- You have to study
  - Attend lectures and pay attention
  - Do you OWN Homework and Labs
  - ASK if you have questions

Concept

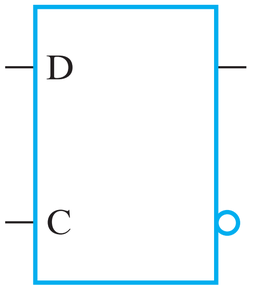
Latches and Flip-Flops



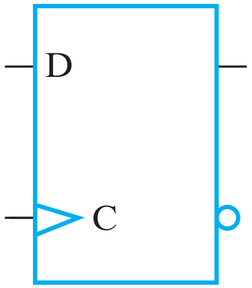


Latches and Flip-Flops

- Latches are Transparent
  - Internal values change immediately after C pin receives positive signal
- Flip-Flops
  - Two latches: one changes immediately, the other changes at the next step

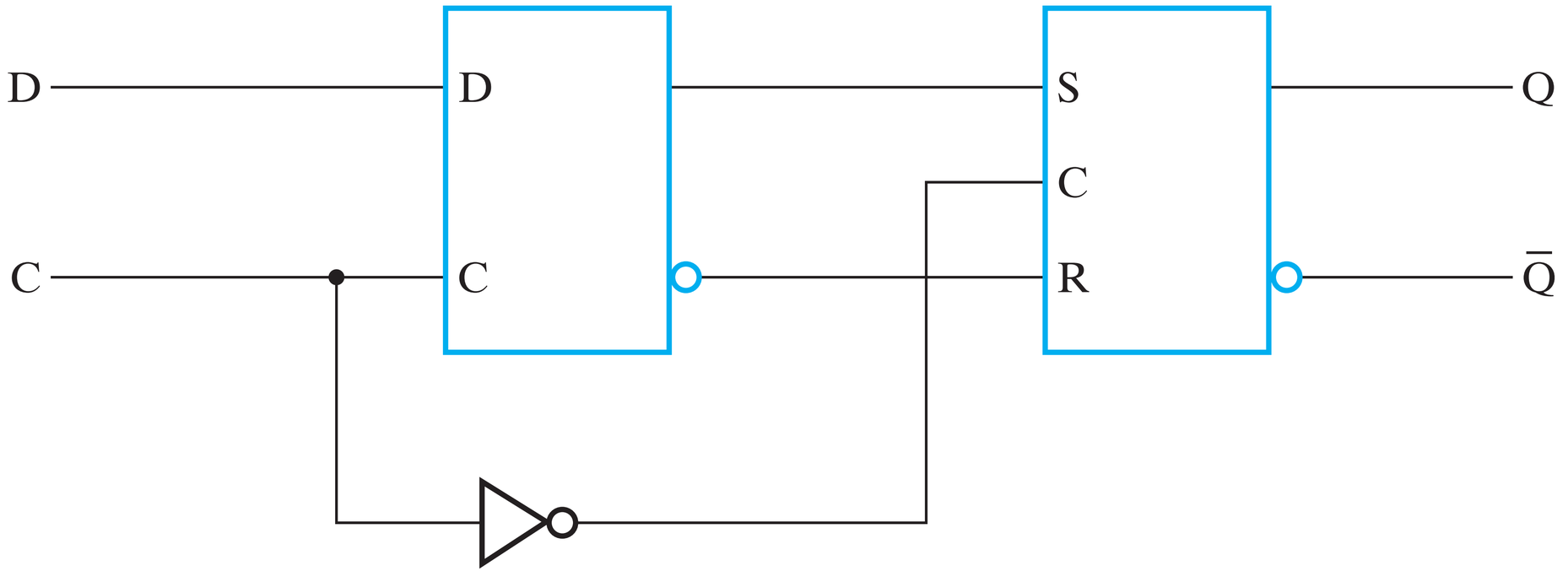


D with 1 Control



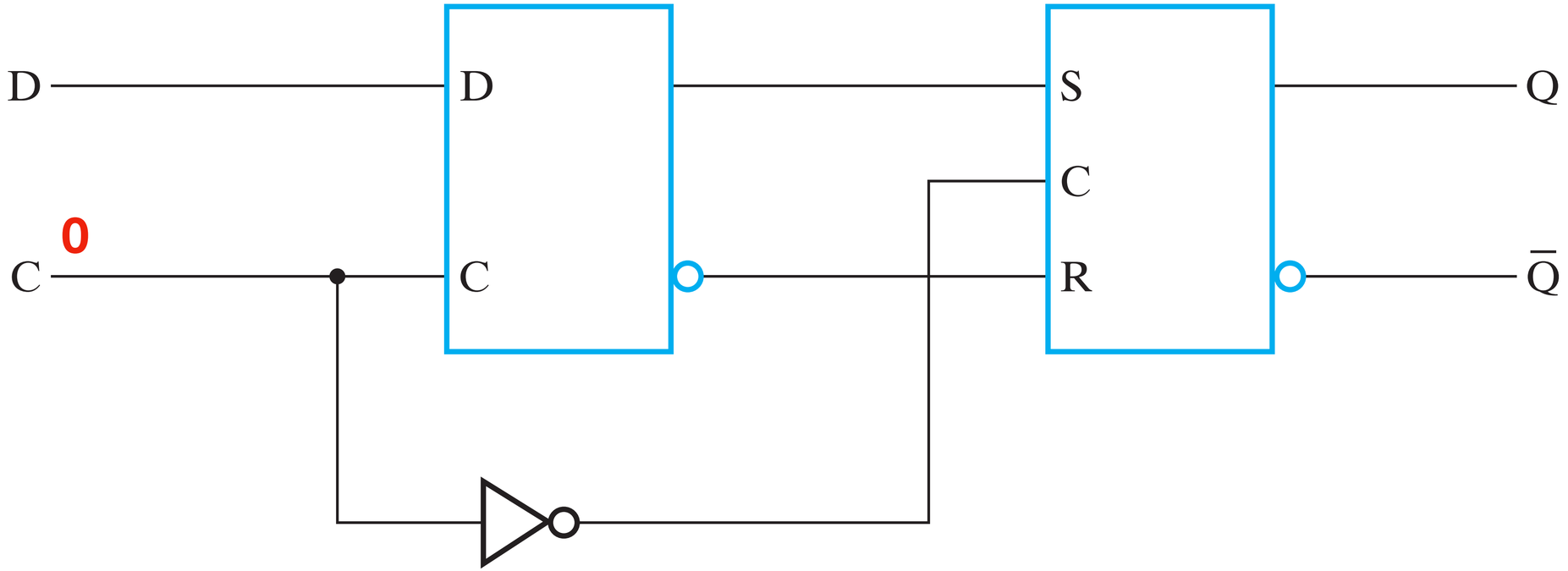
Triggered D

D Flip-Flop



- Replaces SR master in SR Master-Slave with D master Latch
- **Negative Edge Triggered** D (Flip-Flop): $C = 1$ -> $C = 0$

D Flip-Flop



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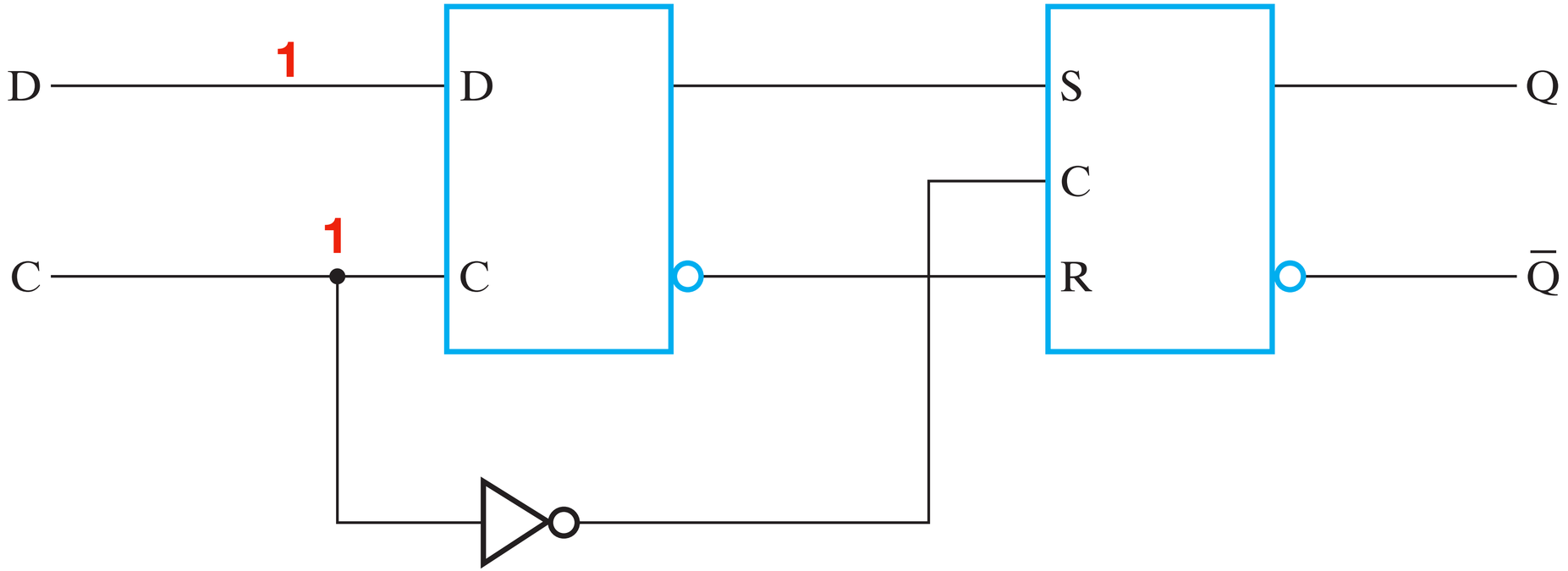
Demo

D Flip-Flop



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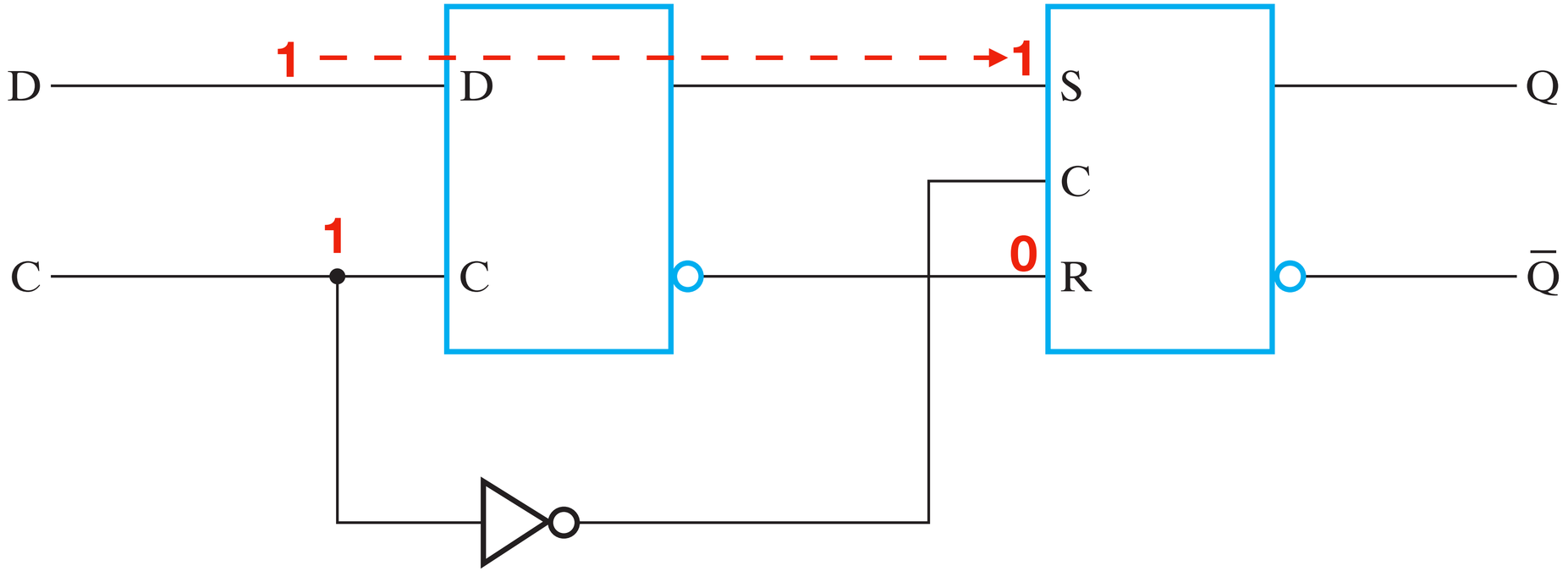

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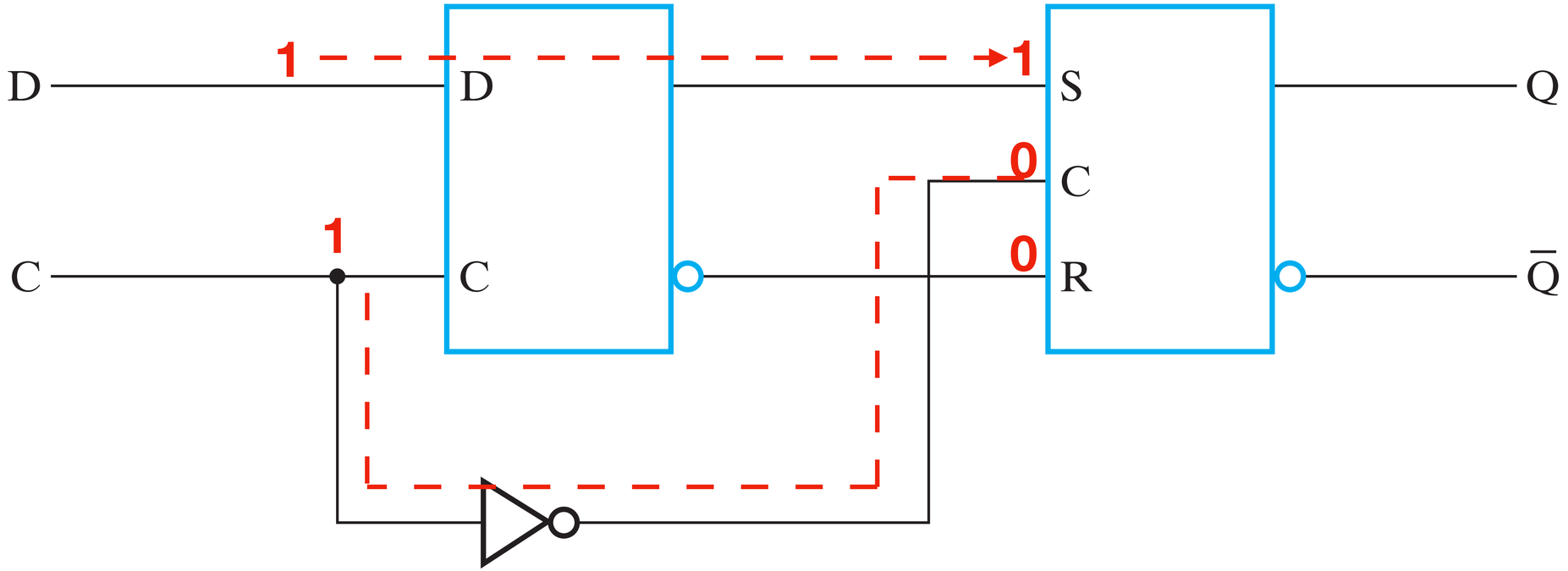

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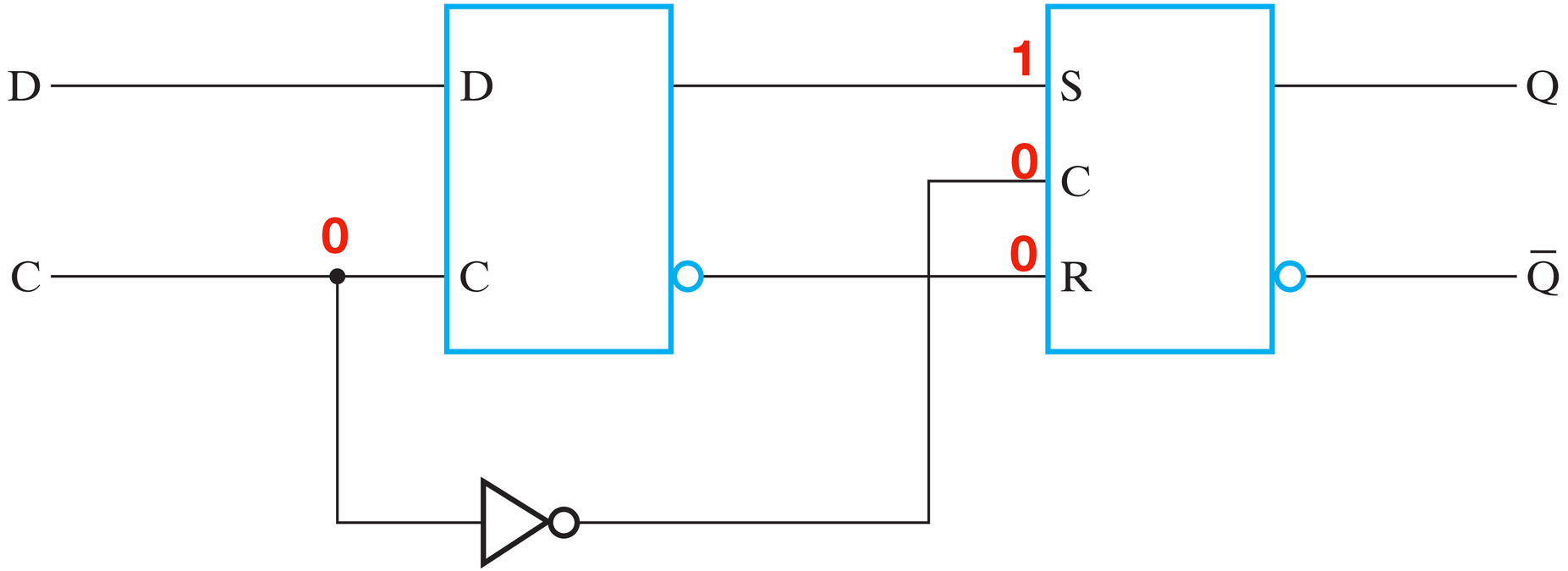

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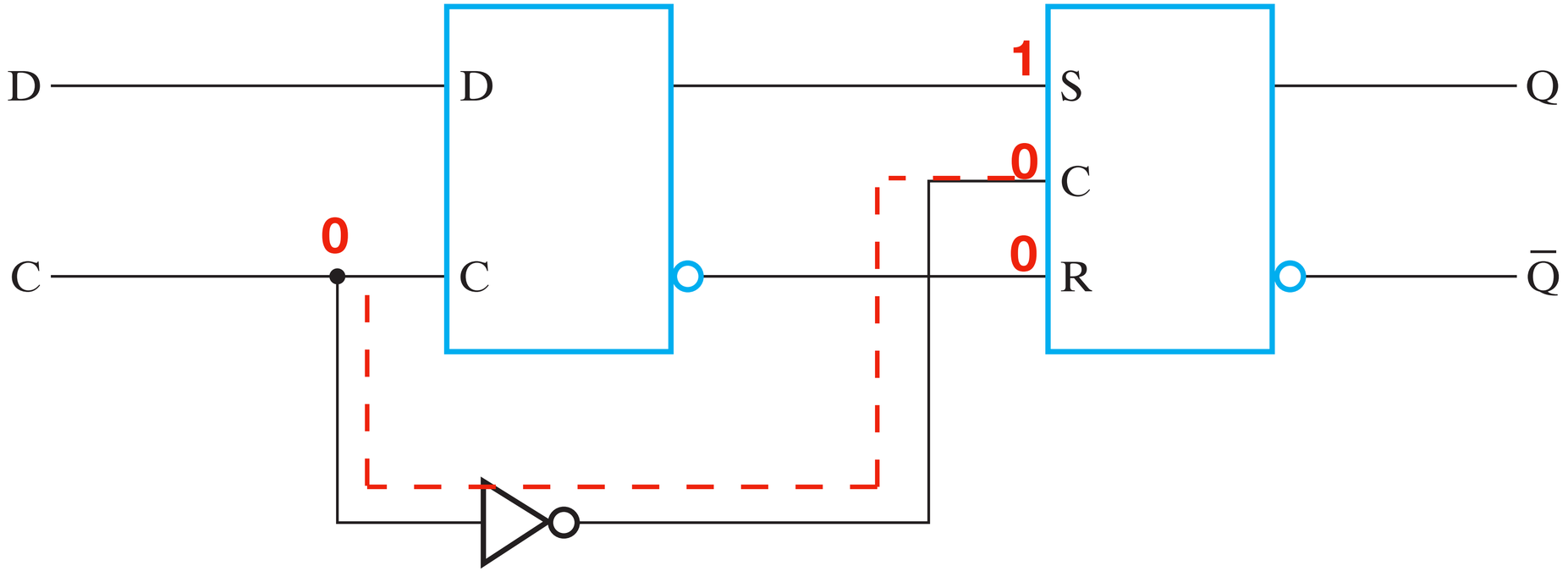

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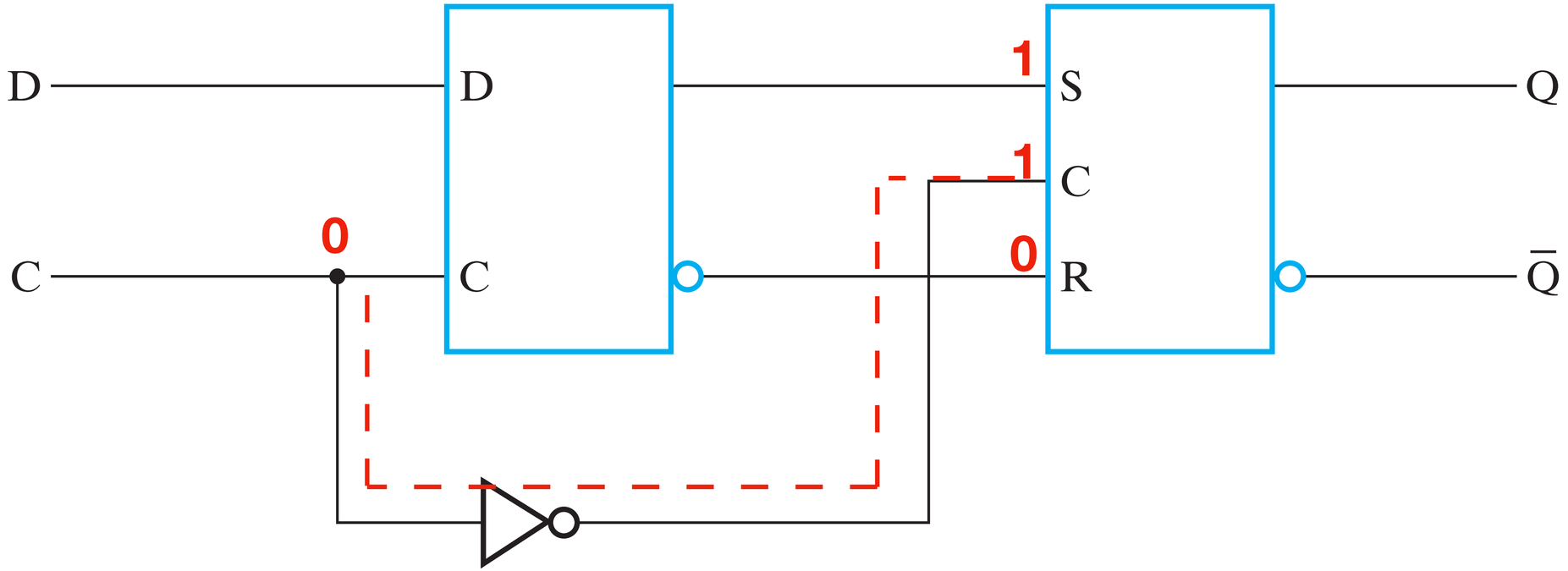

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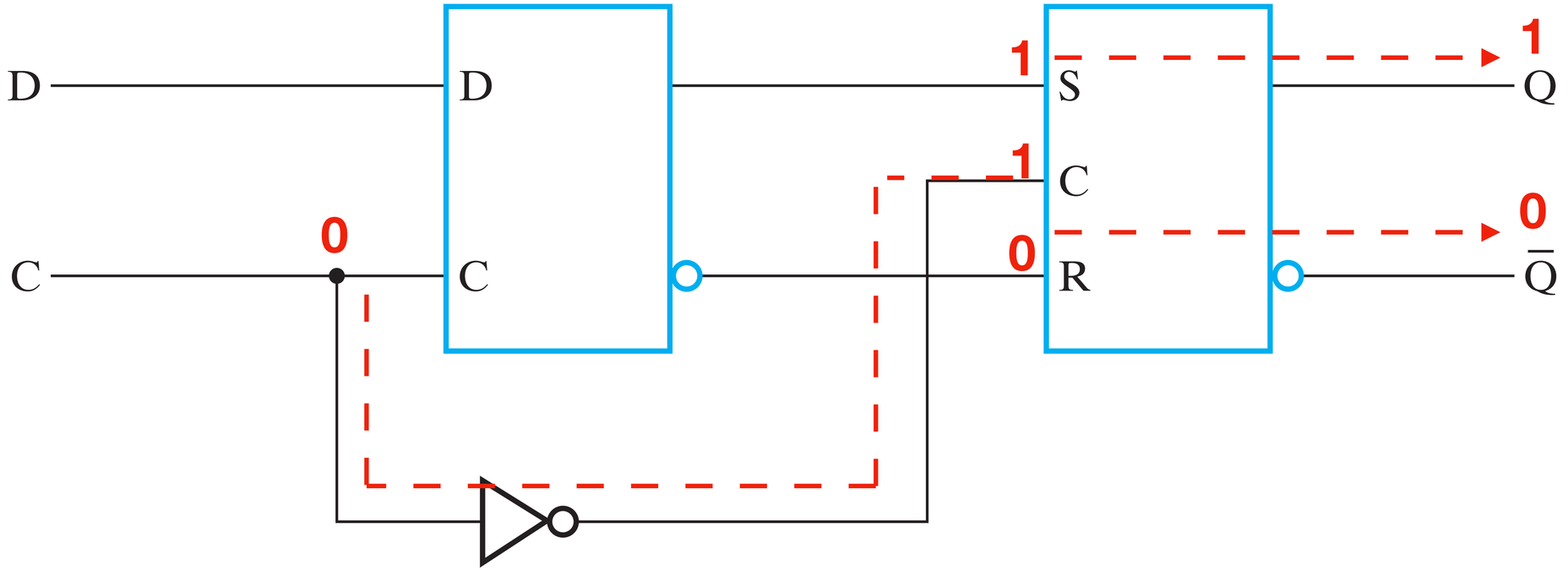

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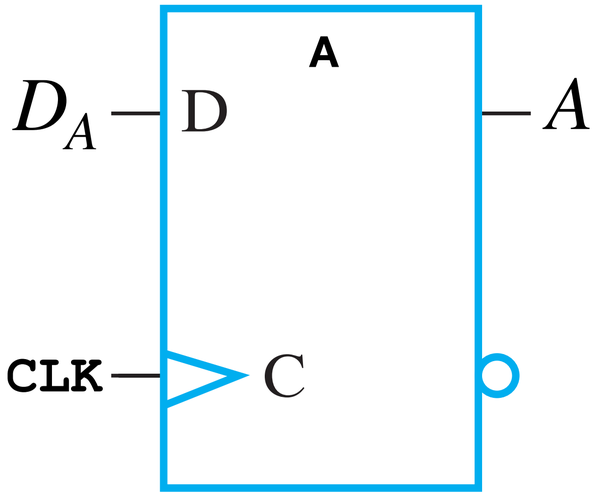
Demo

P2
Circuit

Sequential Circuit Analysis

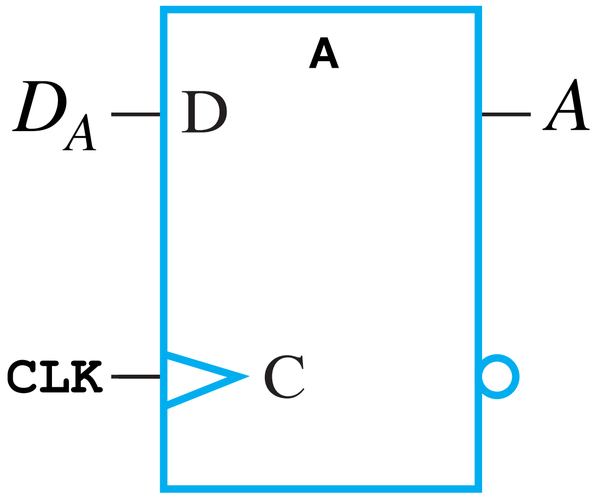
- Any D flip-flop named A in a sequential circuit at anytime
  - Is giving out A (present state)
  - Is receiving D_A (next state)
  - State Table: treat A as input, D_A as output in Truth Table



P2
Circuit

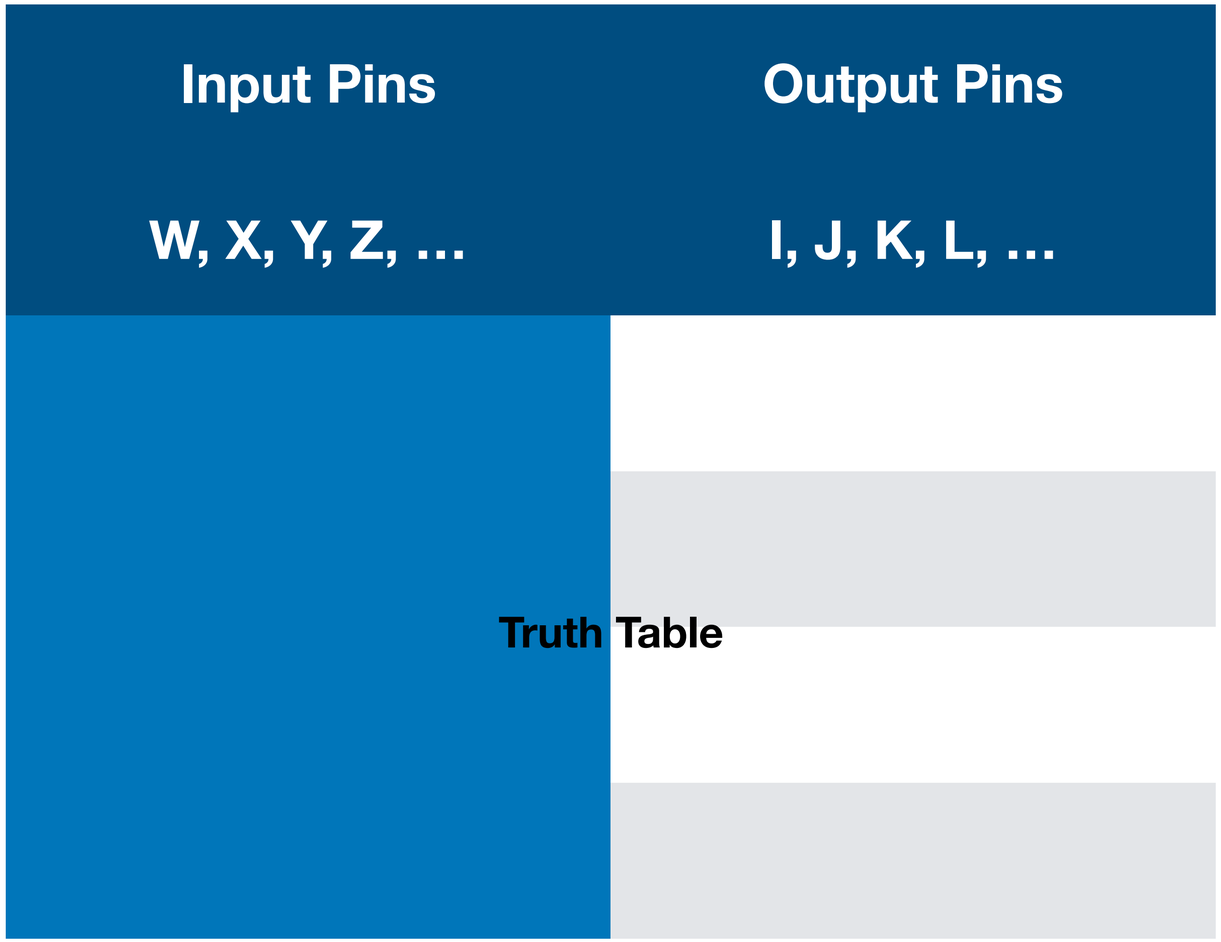
Sequential Circuit Analysis

- When multiple Flip-Flops 0,1,…,n-1 are in a circuit
  - the combined internal value $A_{n-1:0}$ is called the present state
  - the combined receiving value $D_{A_{n-1:0}}$ is called the next state



P2
Circuit

State Table



P2
Circuit

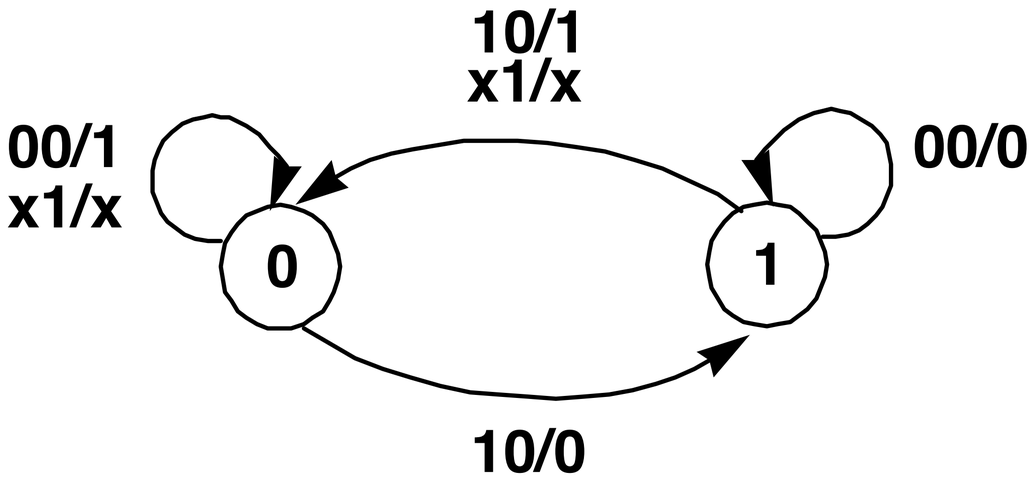
State Table

Present State	Input Pins	Output Pins	Next State
A, B, C, D, …	W, X, Y, Z, …	I, J, K, L, …	D_A, D_B, D_C, D_D, …

P2
Circuit

State Diagram

- State transitions
- Transition Conditions and Output Conditions



P2
Circuit

State Diagram

- State transitions
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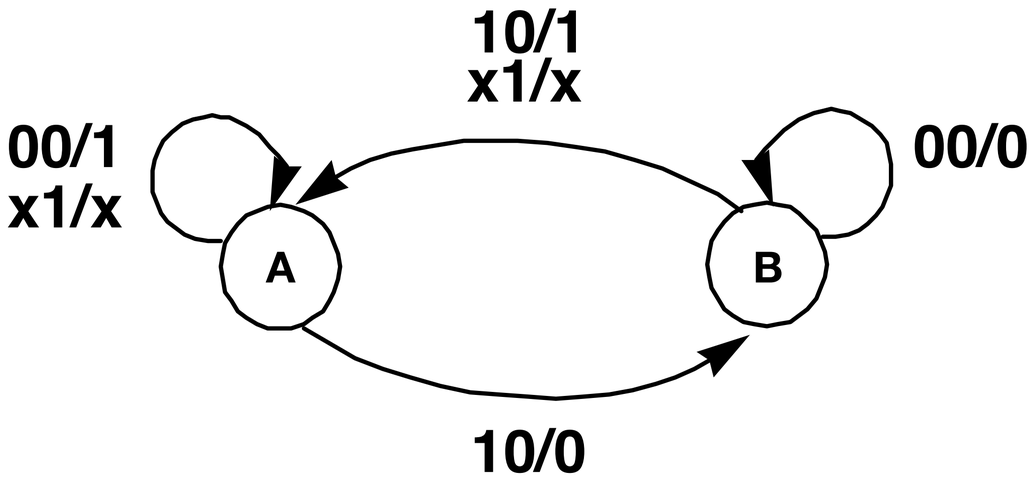

State Assignments

- Given states written in variables A, B, C, D, E…
  - Sequential assignment, n states, $\log n$ bits
    - $A = 000$, $B = 001$, $C = 010$, $D = 011$, $E = 100$, …
  - One-hot assignment, n states, n bits
    - $A = 00000001$, $B = 00000010$, $C = 00000100$, $D = 00001000$, $E = 00010000$, …

Concept

P2
Circuit

Equation Determination

- Input equation for $D_{A_{n-1:0}}$, using $A_{n-1:0}$ as input
- Output equation for actual outputs

Concept

P3
Exercise

Question

$$D_A = BY + \overline{A}Y, D_B = \overline{Y}, Z = \overline{A}\,\overline{B}$$

1. Identify flip-flops (present states and next states), inputs, and outputs
   - Present State: AB; Next State: $D_A D_B$; Input: Y; Output: Z;
2. Draw State Table / State Diagram

Exercise

P3
Exercise

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Present state		Input	Next state		Output
A	***B***	***Y***	***A***	***B***	***Z***
0	0	0	0	1	1
0	0	1	1	0	1
0	1	0	0	1	0
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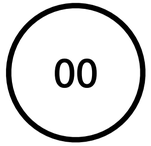

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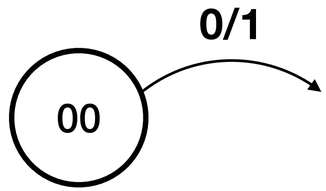

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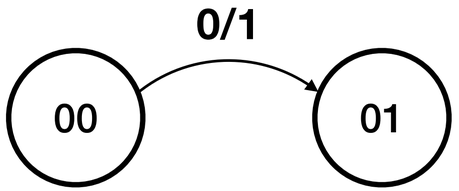

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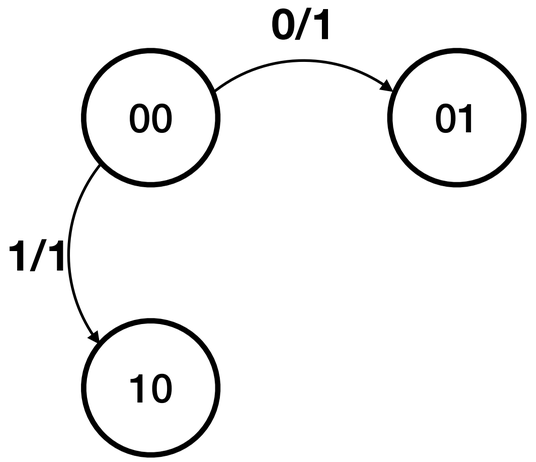

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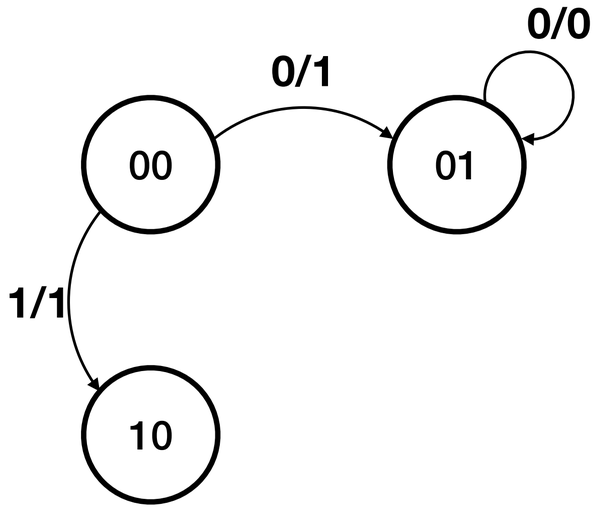

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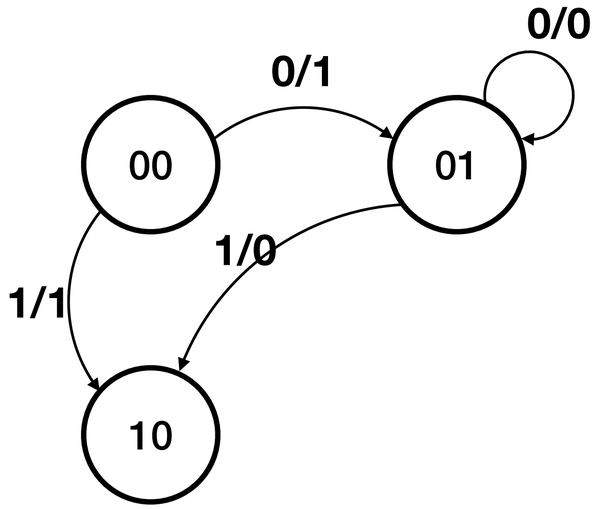

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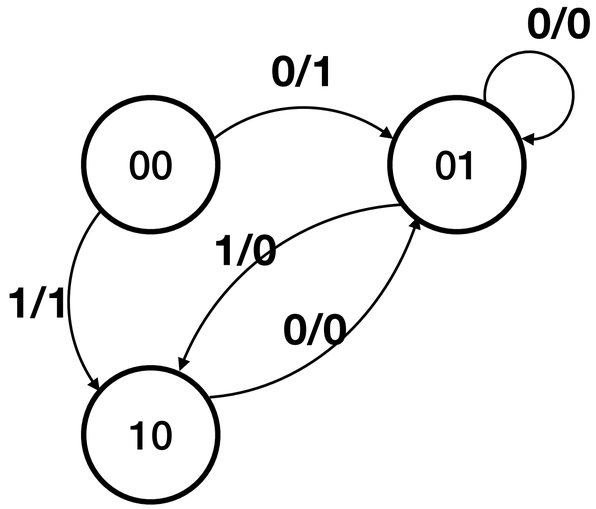

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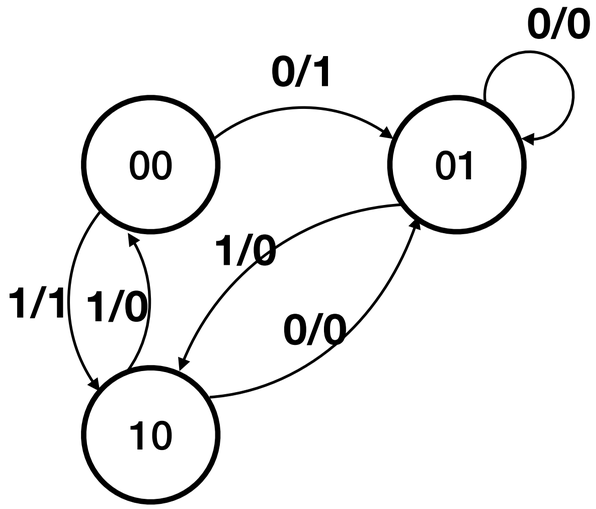

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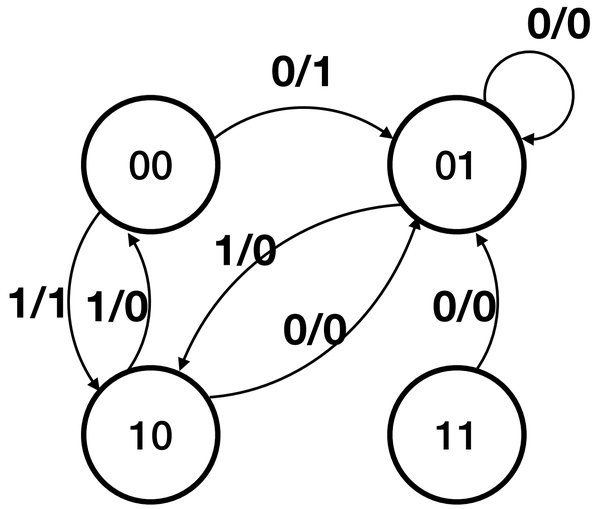

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1	1	0	0	1	0
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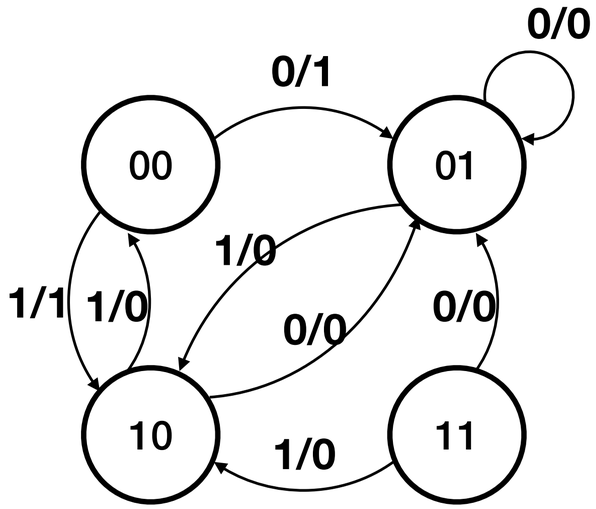


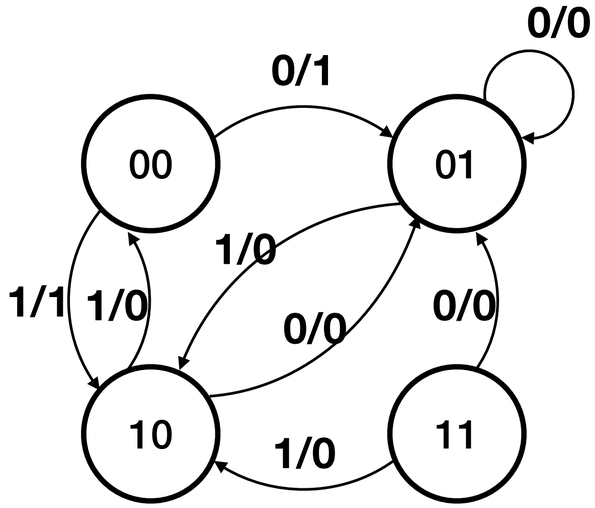
Exercise

P3
Exercise

Question

$$D_A = BY + \overline{A}Y, D_B = \overline{Y}, Z = \overline{A}\,\overline{B}$$

- Initial state 00
- Write down the state transition from input 0101
  - 00
- Write down the output
  -



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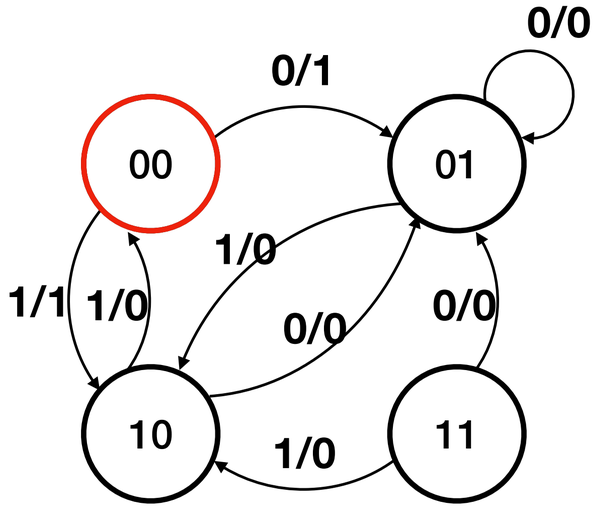

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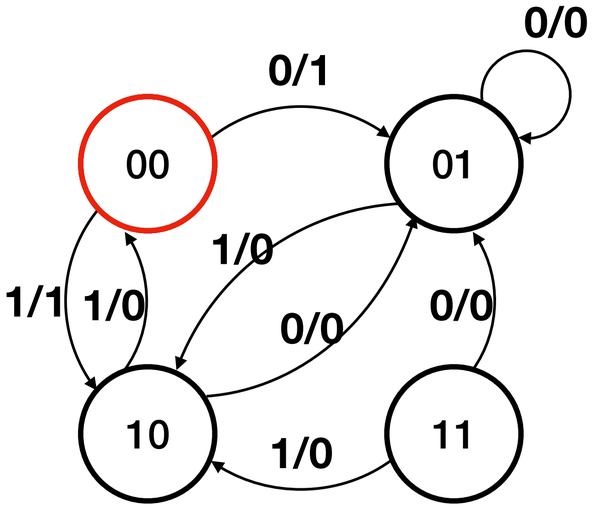
- Write down the output
  -



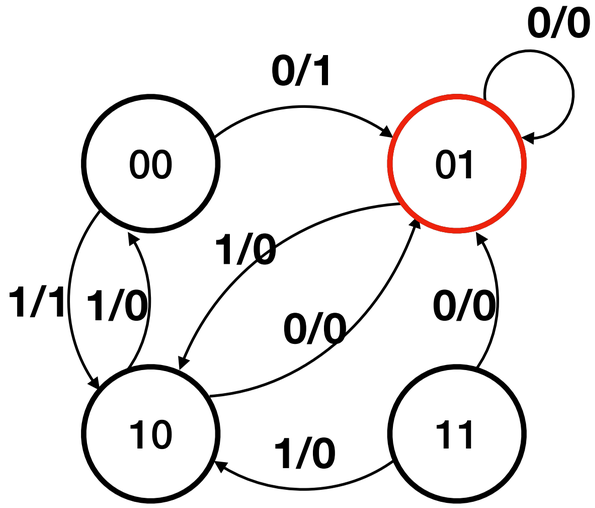
Exercise

P3
Exercise

Question

$$D_A = BY + \overline{A}Y, D_B = \overline{Y}, Z = \overline{A}\,\overline{B}$$

- Initial state 00
- Write down the state transition from input 0101
  - 00→01
- Write down the output
  - 1



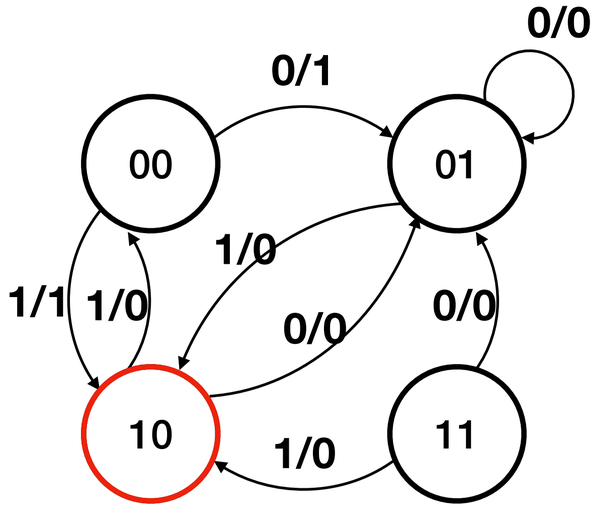
Exercise

P3
Exercise

Question

$$D_A = BY + \overline{A}Y, D_B = \overline{Y}, Z = \overline{A}\,\overline{B}$$

- Initial state 00
- Write down the state transition from input 0101
  - 00→01→10
- Write down the output
  - 10



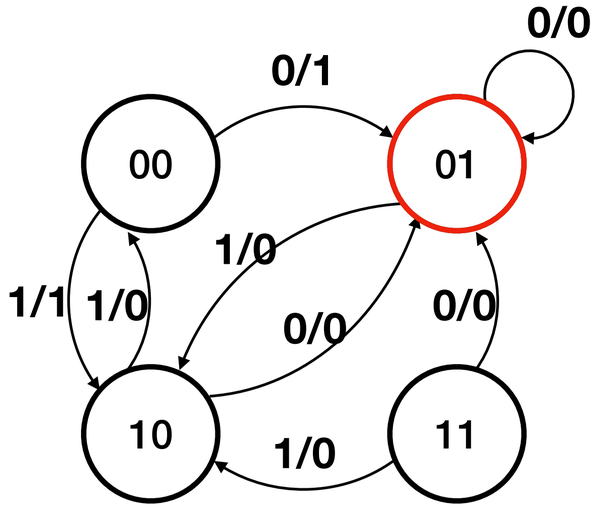
Exercise

P3
Exercise

Question

$$D_A = BY + \overline{A}Y, D_B = \overline{Y}, Z = \overline{A}\,\overline{B}$$

- Initial state 00
- Write down the state transition from input 0101
  - 00→01→10→01
- Write down the output
  - 100



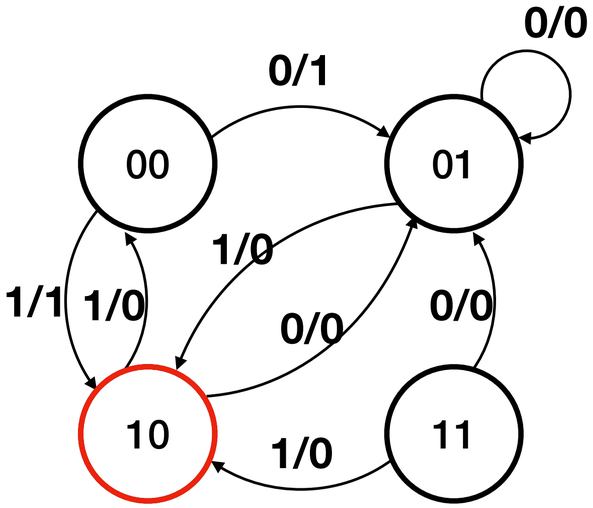
Exercise

P3
Exercise

Question

$$D_A = BY + \overline{A}Y, D_B = \overline{Y}, Z = \overline{A}\,\overline{B}$$

- Initial state 00
- Write down the state transition from input 0101
  - 00→01→10→01→10
- Write down the output
  - 1000



Exercise