# Lecture 4 Review

# Question #1

- Find the groupings in the following K-Map

| | $\overline{C} \cdot \overline{D}$ | $\overline{C} \cdot D$ | $C \cdot D$ | $C \cdot \overline{D}$ |
|---|---|---|---|---|
| $\overline{A} \cdot \overline{B}$ | 1 | 0 | X | 1 |
| $\overline{A} \cdot B$ | X | 0 | X | 1 |
| $A \cdot B$ | 1 | X | 1 | 1 |
| $A \cdot \overline{B}$ | 1 | X | X | X |

- Produce a logical equation for these groupings:

$A + \overline{D}$

# Question #1: alternative

- Find the groupings in the following K-Map

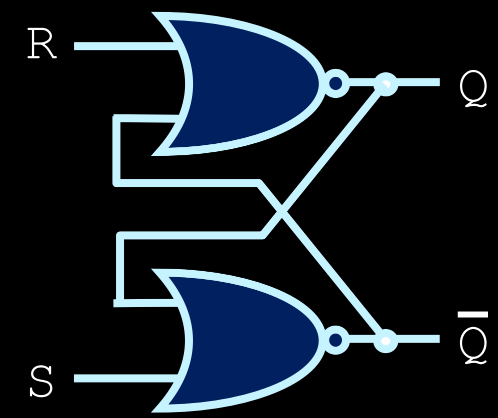
| | $\overline{C}\cdot\overline{D}$ | $\overline{C}\cdot D$ | $C\cdot D$ | $C\cdot\overline{D}$ |
|---|---|---|---|---|
| $\overline{A}\cdot\overline{B}$ | 1 | 0 | X | 1 |
| $\overline{A}\cdot B$ | X | 0 | X | 1 |
| $A\cdot B$ | 1 | X | 1 | 1 |
| $A\cdot\overline{B}$ | 1 | X | X | X |

- Produce a logical equation for these groupings:

$\overline{D} + C$

# Question #2

- Complete the truth table




| S | R | $Q_T$ | $\overline{Q}_T$ | $Q_{T+1}$ | $\overline{Q}_{T+1}$ |
|---|---|---|---|---|---|
| | | | | | |

← Hold

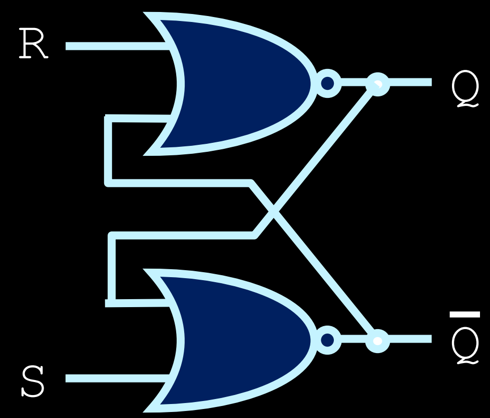
← Reset

← Set

← Forbidden

# Question #2

- Complete the truth table




| S | R | $Q_T$ | $\overline{Q}_T$ | $Q_{T+1}$ | $\overline{Q}_{T+1}$ |
|---|---|---|---|---|---|
| 0 | 0 | 0 | 1 | 0 | 1 |
| 0 | 0 | 1 | 0 | 1 | 0 |
| 0 | 1 | X | X | 0 | 1 |
| 1 | 0 | X | X | 1 | 0 |
| 1 | 1 | X | X | 0 | 0 |

← Hold

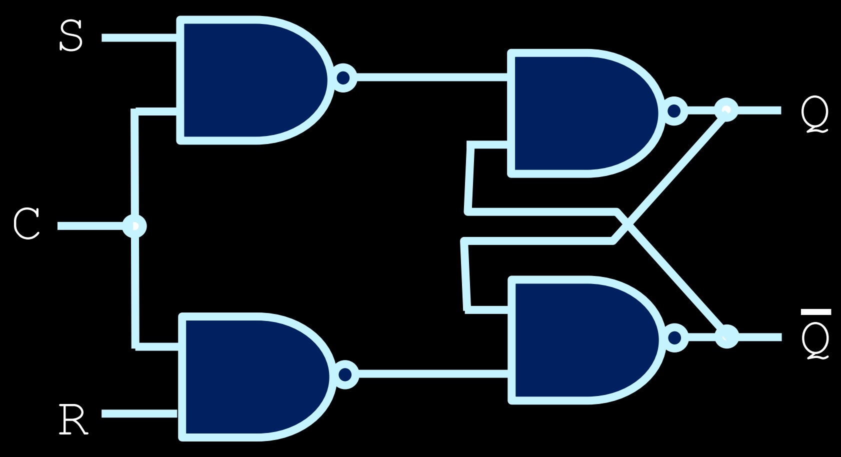
← Reset

← Set

← Forbidden

# Question #3

- What are the output values from Q and $\overline{Q}$ given the following inputs on S, R and C?

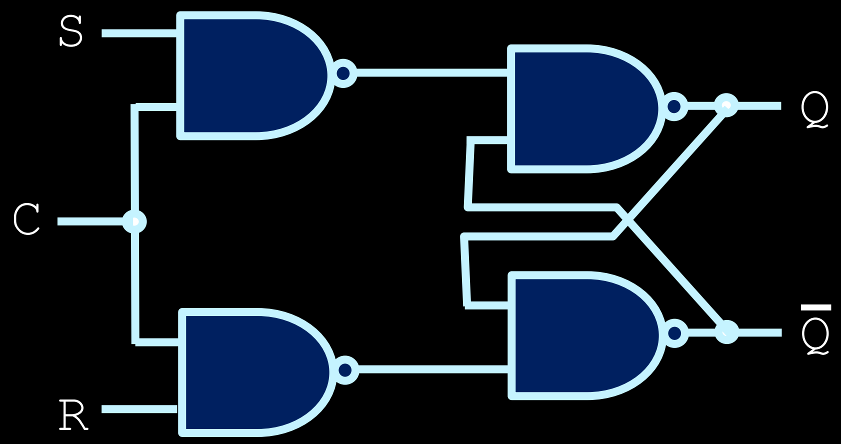



Time ↓

| S | R | C | Q | $\overline{Q}$ |
|---|---|---|---|---|
| 0 | 0 | 1 | | |
| 1 | 0 | 1 | | |
| 1 | 0 | 0 | | |
| 0 | 0 | 0 | | |
| 0 | 1 | 0 | | |
| 0 | 1 | 1 | | |

# Question #3

- What are the output values from Q and $\overline{Q}$ given the following inputs on S, R and C?

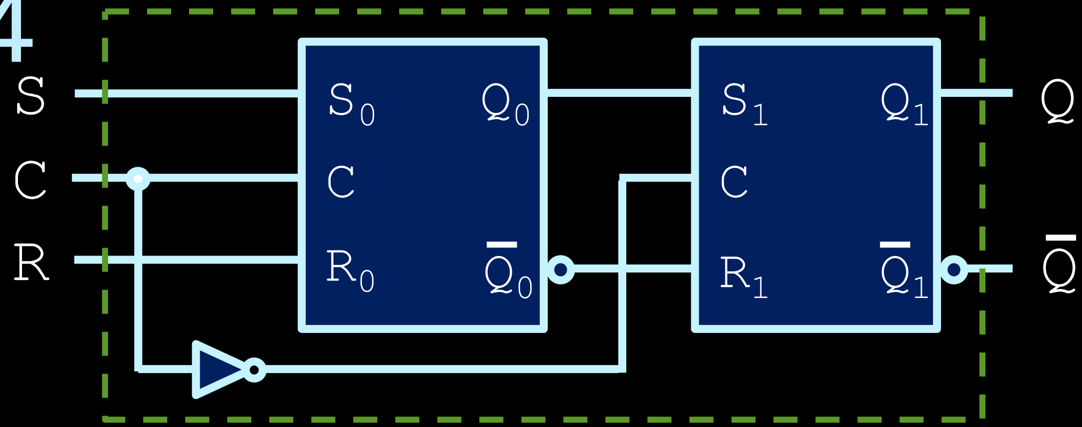


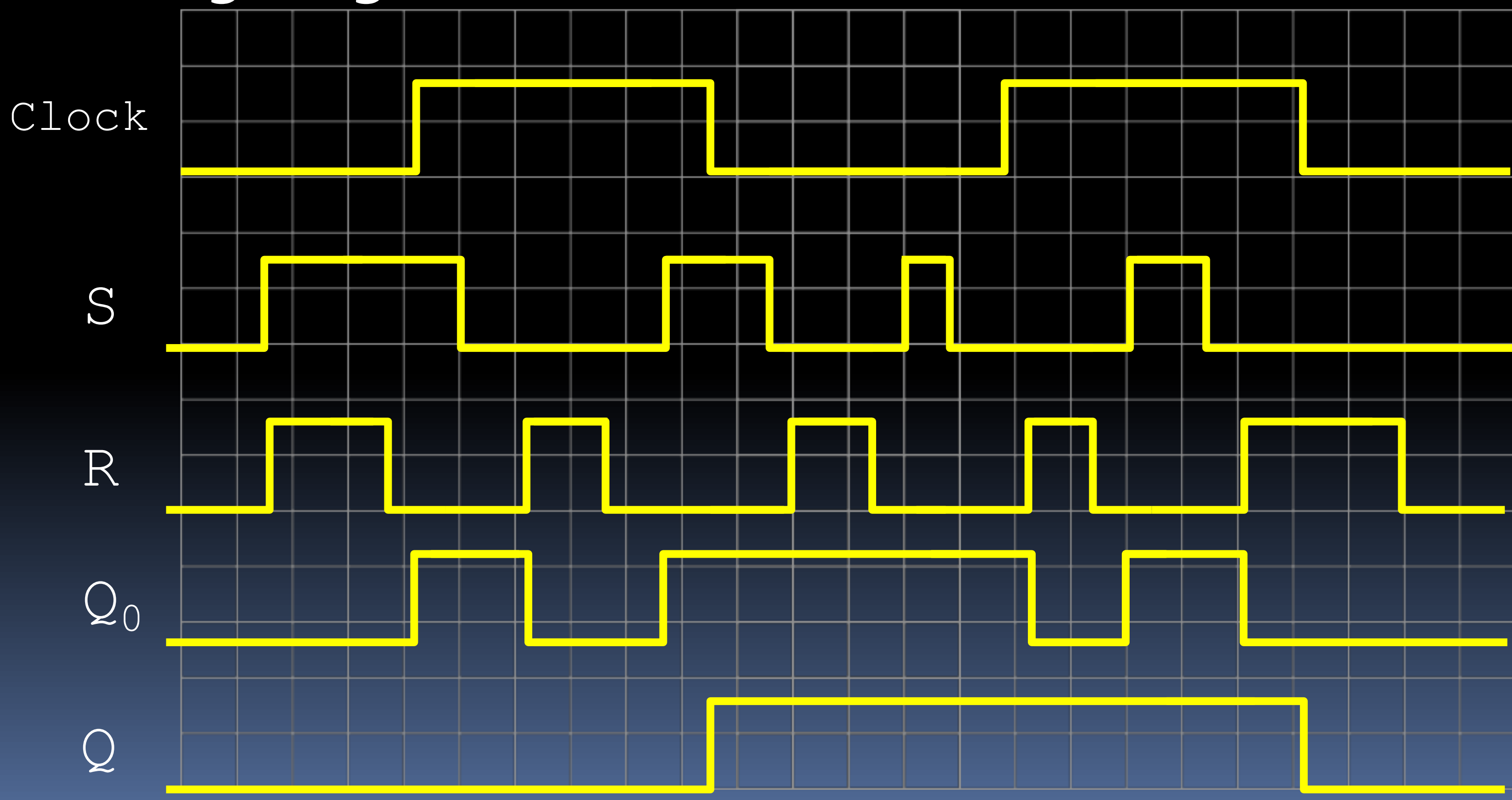

Time ↓

| S | R | C | Q | $\overline{Q}$ |
|---|---|---|---|---|
| 0 | 0 | 1 | ? | ? |
| 1 | 0 | 1 | 1 | 0 |
| 1 | 0 | 0 | 1 | 0 |
| 0 | 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 1 | 0 |
| 0 | 1 | 1 | 0 | 1 |

# Question #4

- Assuming all inputs start low, complete the timing diagram



# Lecture 5 Review

# Question #1

Assume we want to build a change machine

- We can add either $0.05 or $0.10 at a time
- We want to keep track of the current amount in the machine
- We can hold a maximum of $0.50
- Draw the state diagram

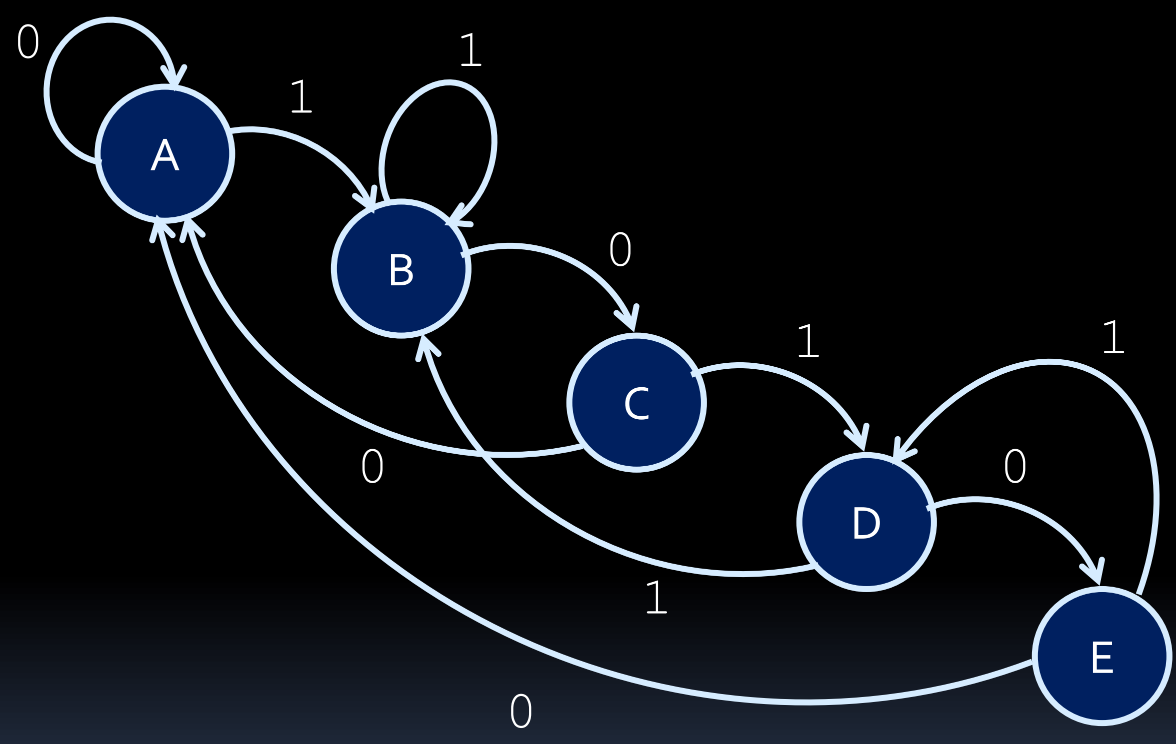
# Question #1b

- How many flip-flops would you need to implement the following finite state machine (FSM)?
  - 11 states
  - # flip-flops = $\lceil \log_2 (\text{\# of states}) \rceil$
  - # flip-flops = 4

# Question 2: Barcode Reader

- When scanning UPC barcodes, the laser scanner looks for black and white bars that indicate the start of the code.
- If black is read as a `1` and white is read as a `0`, the start of the code (from either direction) has a `1010` pattern.
  - Can you create a state machine that detects this pattern?

# Step #1: Draw state diagram



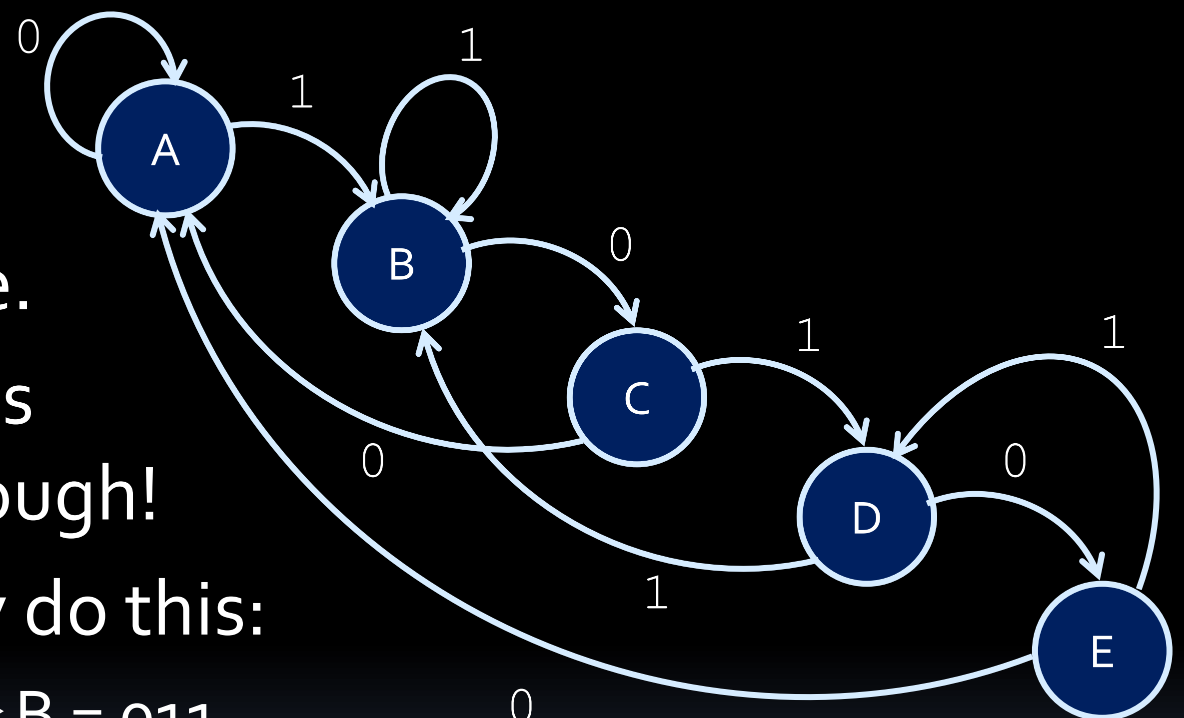
# Step #2: State Table

- Write state table with Z
- Output Z is determined by the current state.
  - Denotes Moore machine.
- Next step: allocate flip-flops values to each state.
  - How many flip-flops will we need for 5 states?
    - # flip-flops = $\lceil \log(\text{\# of states}) \rceil$

| Present State | X | Z | Next State |
|---|---|---|---|
| A | 0 | 0 | A |
| A | 1 | 0 | B |
| B | 0 | 0 | C |
| B | 1 | 0 | B |
| C | 0 | 0 | A |
| C | 1 | 0 | D |
| D | 0 | 0 | E |
| D | 1 | 0 | B |
| E | 0 | 1 | A |
| E | 1 | 1 | D |

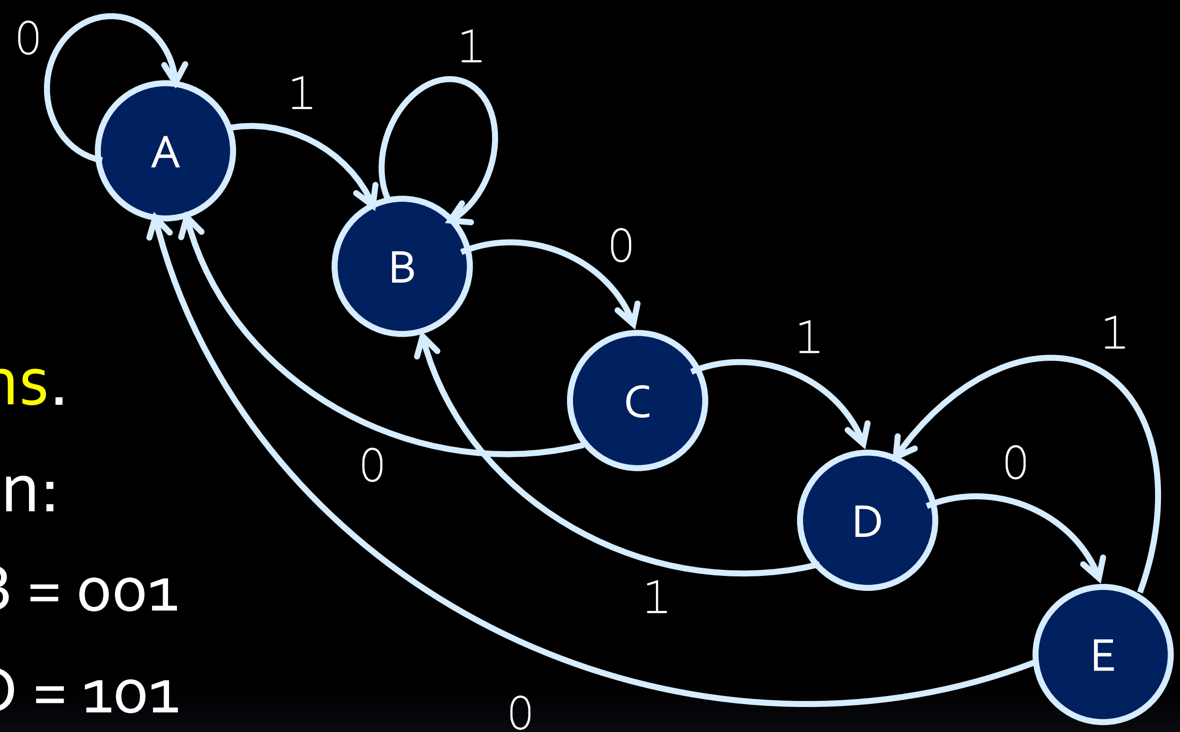
# Step #3: Flip-Flop Assignment

- 3 flip-flops needed here.
- Assign states carefully though!
- Can't simply do this:
  - A = 100
  - B = 011
  - C = 010
  - D = 001
  - E = 000




**Why not?**

# Step #3: Flip-Flop Assignment




- Be careful of race conditions.
- Better solution:
  - A = 000
  - B = 001
  - C = 011
  - D = 101
  - E = 100
- Still has race conditions (C→D, C→A), but is safer.
  - "Safer" is defined according to output behaviour.
  - Sometimes, extra flip-flops are used for extra insurance.

# Step #4: Redraw State Table

- From here, we can construct the K-maps for the state logic combinational circuit.
  - Derive equations for each flip-flop value, given the previous values and the input X.
  - Three equations total, plus one more for Z (trivial for Moore machines).

| $F_2$ | $F_1$ | $F_0$ | X | Z | $F_2$ | $F_1$ | $F_0$ |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 |
| 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 |
| 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 |

# Step 5: Circuit design

- Karnaugh map for $F_2$:

| | $\overline{F_0}\cdot\overline{X}$ | $\overline{F_0}\cdot X$ | $F_0\cdot X$ | $F_0\cdot\overline{X}$ |
|---|---|---|---|---|
| $\overline{F_2}\cdot\overline{F_1}$ | 0 | 0 | 0 | 0 |
| $\overline{F_2}\cdot F_1$ | X | X | 1 | 0 |
| $F_2\cdot F_1$ | X | X | X | X |
| $F_2\cdot\overline{F_1}$ | 0 | 1 | 0 | 1 |

$$F_2 = F_1X + F_2\overline{F_0}X + F_2F_0\overline{X}$$

# Step 5: Circuit design

- Karnaugh map for $F_1$:

| | $\overline{F_0} \cdot \overline{X}$ | $\overline{F_0} \cdot X$ | $F_0 \cdot X$ | $F_0 \cdot \overline{X}$ |
|---|---|---|---|---|
| $\overline{F_2} \cdot \overline{F_1}$ | 0 | 0 | 0 | 1 |
| $\overline{F_2} \cdot F_1$ | X | X | 0 | 0 |
| $F_2 \cdot F_1$ | X | X | X | X |
| $F_2 \cdot \overline{F_1}$ | 0 | 0 | 0 | 0 |

$$F_1 = \overline{F_2}\,\overline{F_1}\,F_0\,\overline{X}$$

# Step 5: Circuit design

- Karnaugh map for $F_0$:

| | $\overline{F_0} \cdot \overline{X}$ | $\overline{F_0} \cdot X$ | $F_0 \cdot X$ | $F_0 \cdot \overline{X}$ |
|---|---|---|---|---|
| $\overline{F_2} \cdot \overline{F_1}$ | 0 | 1 | 1 | 1 |
| $\overline{F_2} \cdot F_1$ | X | X | 1 | 0 |
| $F_2 \cdot F_1$ | X | X | X | X |
| $F_2 \cdot \overline{F_1}$ | 0 | 1 | 1 | 0 |

$$F_0 = X + \overline{F_2}\,\overline{F_1}F_0$$

# Step 5: Circuit design

- Output value Z goes high based on the following output equation:

$$Z = F_2\overline{F_1}\,\overline{F_0}$$

- Note: All of these equations would be different, given different flip-flop assignments!
  - Practice alternate assignment for the midterm ☺