

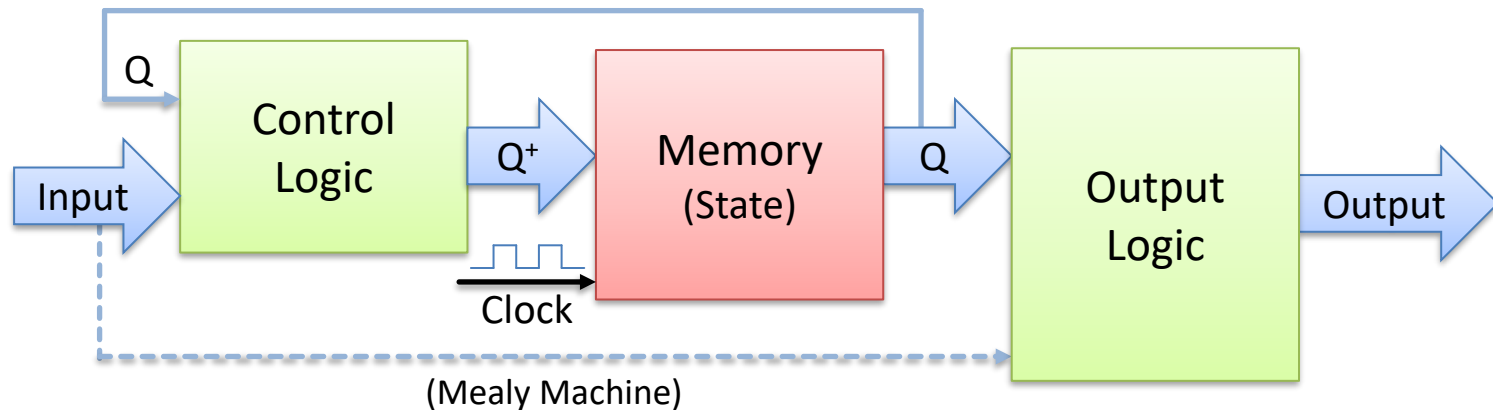
Sequential Circuits

Digital Electronics

by Wolfgang Neff

Sequential Circuits (1)

- Representations of Sequential Circuits
 - Mealy Machine (dashed arrow allowed)
 - Moore Machine (dashed arrow not allowed)



Sequential Circuits (2)

- Design of Sequential Circuits
 - Create the state diagram
 - Number of states
 - Transitions and conditions
 - Encode the states
 - One D flip-flops per power of two (per bit)
 - Design the control logic
 - Start with the transition table
 - Design the output logic

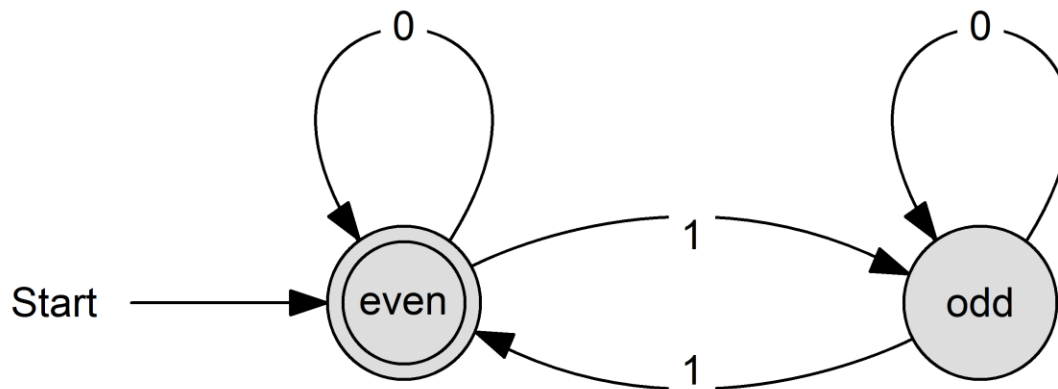
Sequential Circuits (3)

- Example 1

- Assignment

- Design a sequential circuit which outputs 1 if an even number of 1 was read.

- Create the state diagram



Sequential Circuits (4)

- Example I (continued)

- Number of states

- Even, odd \rightarrow 2 states $\rightarrow 2^1 \rightarrow$ 1 bit \rightarrow 1 D flip-flop

- Encode the states

- Even bit count: 0, 2, 4, 6, ...
- Odd bit count: 1, 3, 5, 7, ...
- Even \rightarrow 0
- Odd \rightarrow 1

State	Encoding
Even	0
Odd	1

Sequential Circuits (5)

- Example I (continued)
 - Design the control logic
 - There is one flip-flop (Q)
 - There is one input line (a)
 - There are the following transitions and conditions

Q	a	Q^+
0 (Even)	0	0 (Even)
0 (Even)	1	1 (Odd)
1 (Odd)	0	1 (Odd)
1 (Odd)	1	0 (Even)

a Input

Q Current State

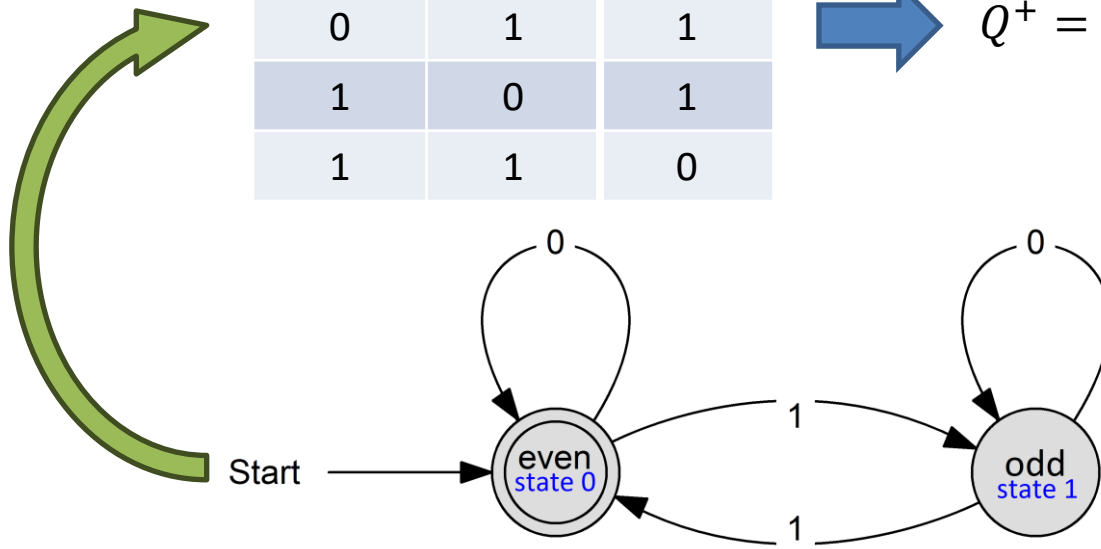
Q^+ Subsequent State

Sequential Circuits (6)

- Example I (continued)
 - Get the switching function

Q	a	Q ⁺
0	0	0
0	1	1
1	0	1
1	1	0

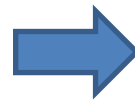
➔ $Q^+ = Q \oplus a$



Sequential Circuits (7)

- Example I (continued)
 - Define the output
 - State Q is the input of the output logic
 - An even number of 1 is found \rightarrow the output is 1
 - Get the switching function

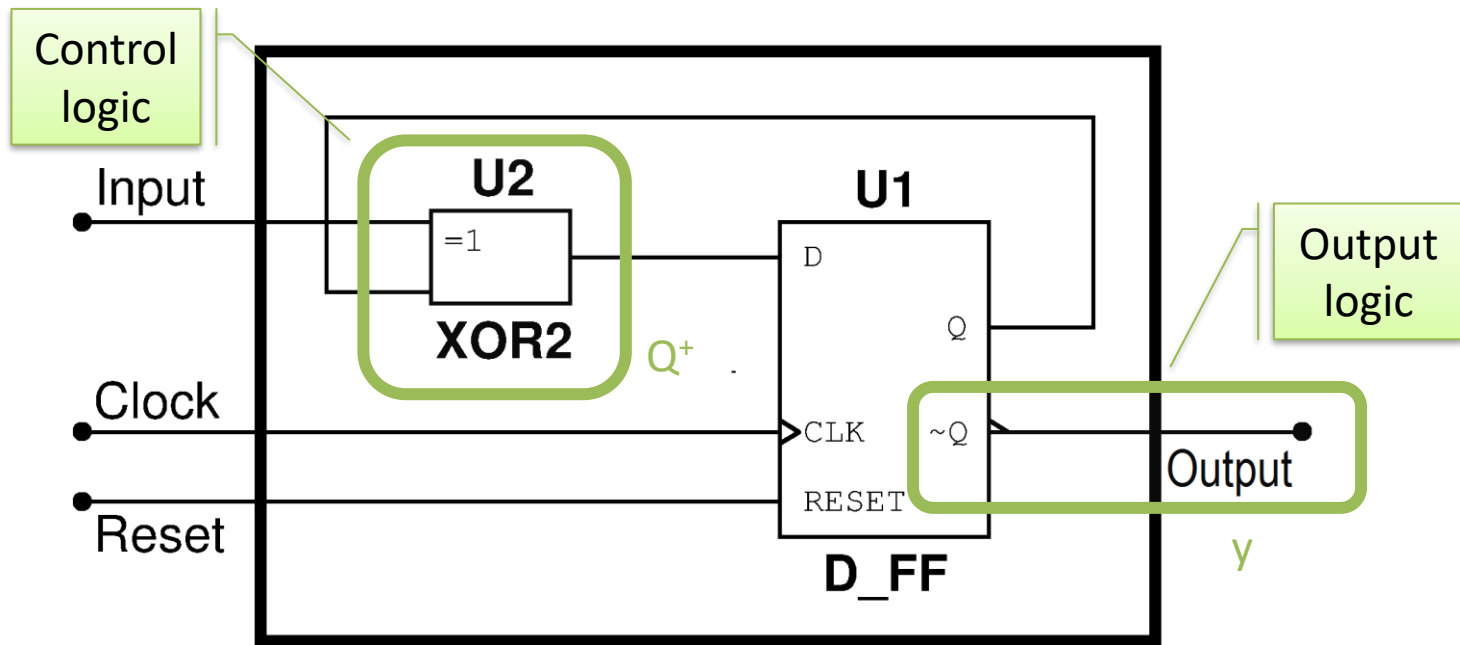
Q	y
0 (Even)	1
1 (Odd)	0



$$y(Q) = \neg Q$$

Sequential Circuits (8)

- Example I (finished)
 - Draw the sequential circuit

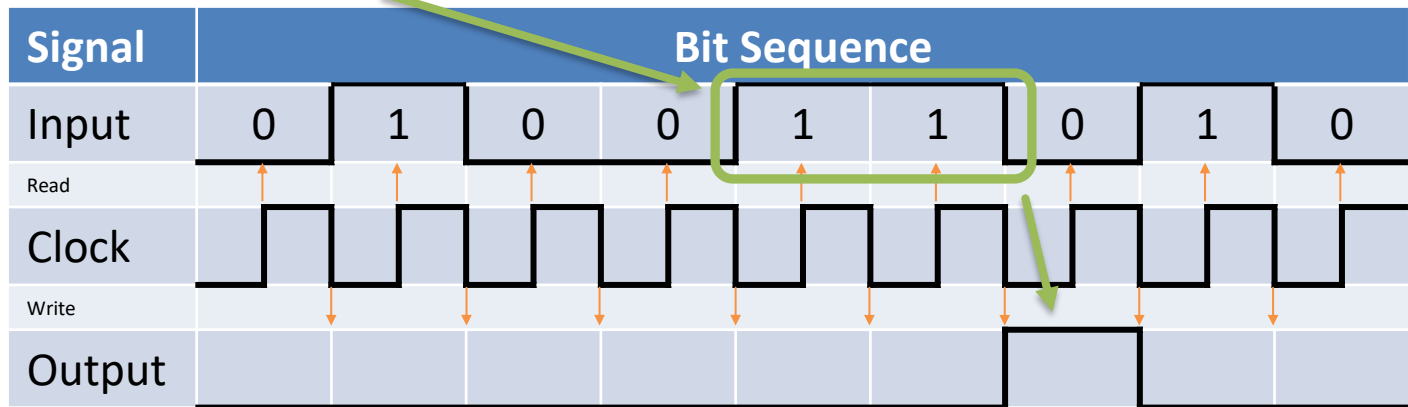


Sequential Circuits (9)

- Example II

- Assignment

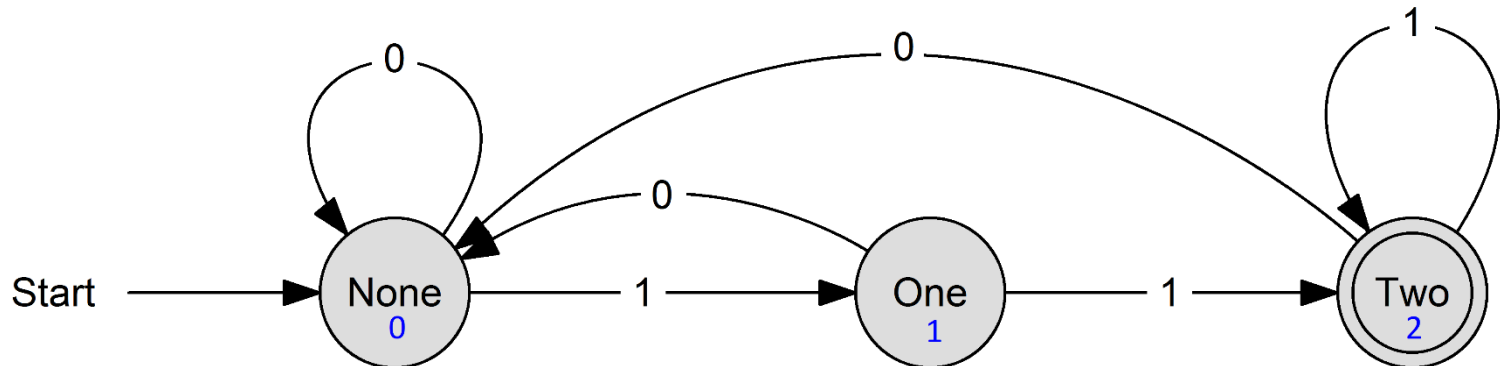
Find two subsequent 1 in a bit sequence



Pulse Diagram

Sequential Circuits (10)

- Example II (continued)
 - Number of states
 - None, one, two ones \rightarrow 3 states \rightarrow 2 bits
 - State diagram



Sequential Circuits (11)

- Example II (continued)
 - Control logic

Q_1	Q_0	a	Q_1^+	Q_0^+
0	0	0	0	0
0	0	1	0	1
0	1	0	0	0
0	1	1	1	0
1	0	0	0	0
1	0	1	1	0
1	1	0	X	X
1	1	1	X	X



State	n	Encoding	
None	0	0	0
One	1	0	1
Two	2	1	0

$Q_1 \quad Q_0$



$$Q_0^+ = a \wedge \neg Q_0 \wedge \neg Q_1$$

$$Q_1^+ = (a \wedge Q_1) \vee (a \wedge Q_0)$$

Sequential Circuits (12)

- Example II (finished)

– Output logic

Q_1	Q_0	y
0	0	0
0	1	0
1	0	1
1	1	X

$$y = Q_1$$

