State Machine Design Procedure

1. Build state/output table (or state diagram) from word description using state names.
2. Minimize number of states (optional).
3. State Assignment: Choose state variables and assign bit combinations to named states.
4. Build transition/output table from state/output table (or state diagram) by substituting state variable combinations instead of state names.
5. Choose flip-flop type (D, J-K, etc.)
6. Build excitation table for flip-flop inputs from transition table.
7. Derive excitation equations from excitation table.
8. Derive output equations from transition/output table.
9. Draw logic diagram with excitation logic, output logic, and state memory elements.

State Machine Design Using J-K Flip-Flops

- **State machine design step 6 (building excitation table for flip-flop inputs from transition table):**
  - When using D flip-flops, since the next state Q* = D, the excitation table is the same as the transition table with Q* replaced with D.
  - In the case of J-K flip-flops, the next state is given by:
    $Q^* = J \cdot Q' + K' \cdot Q$
  - In this case we cannot rearrange the characteristic equation to find separate equations for J, K.
  - Instead an application (or excitation) table for J-K flip-flops is used to obtain the corresponding values of J, K for a given Q to Q* transition:

Q	Q*	J	K
0	0	0	d
0	1	1	d
1	0	d	1
1	1	d	0

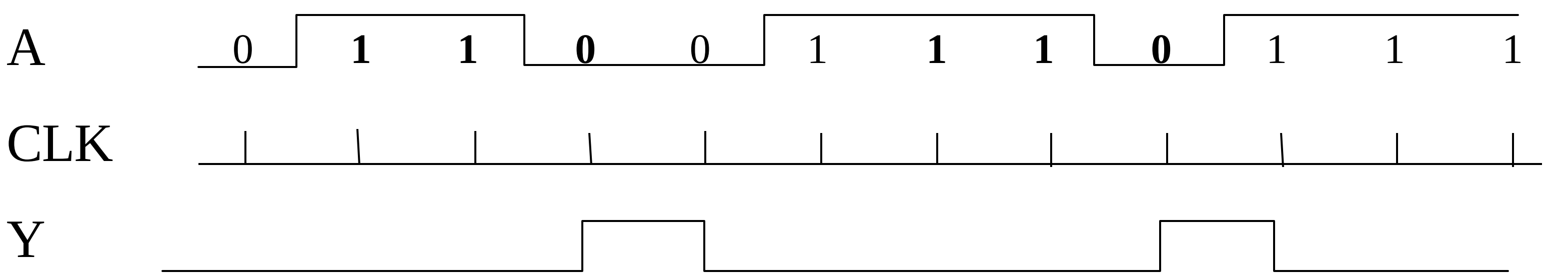
J-K Flip-Flop Excitation Table

State Machine Design Example 1:

110 Detector (Repeated Using J-K Flip-Flops)

- **Word description (110 input sequence detector):**
  - **Design a state machine with input A and output Y.**
  - **Y should be 1 whenever the sequence 1 1 0 has been detected on A on the last 3 consecutive rising clock edges (or ticks).**
  - **Otherwise, Y = 0**

- **Timing diagram interpretation of word description (only rising clock edges are shown):**



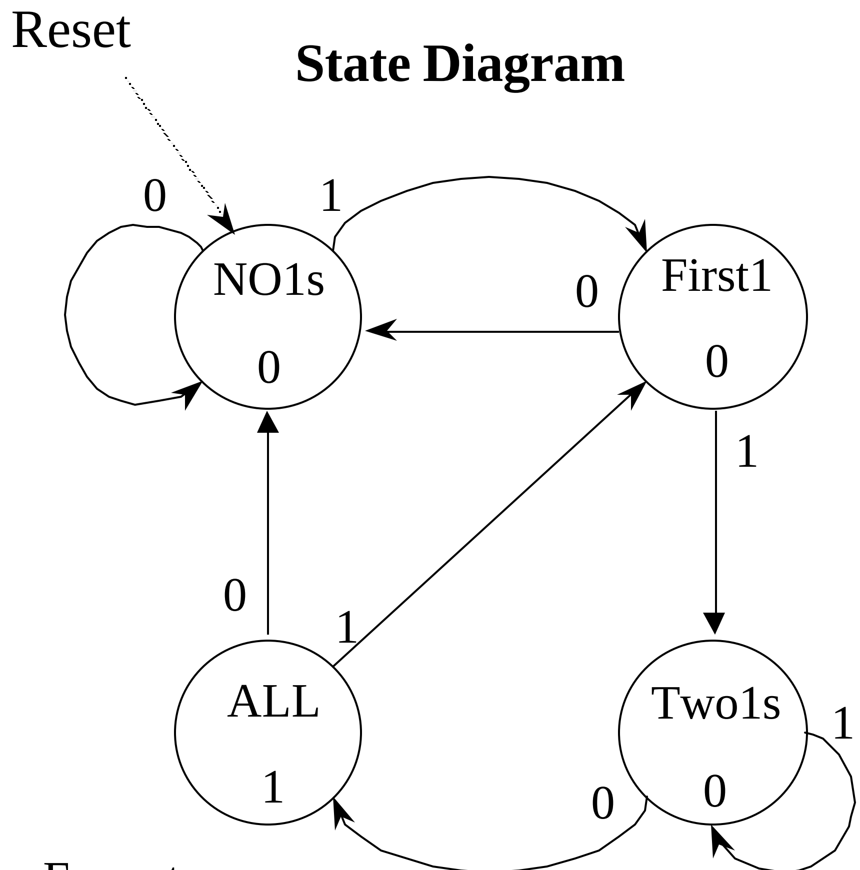
State Machine Design Example 1: 110 Detector
Step 1: State/Output Table and Diagram

State Table

S	A = 0	A = 1	Y
No1s	No1s	First1	0
First1	No1s	Two1s	0
Two1s	ALL	Two1s	0
ALL	No1s	First1	1

S*

State Diagram



Format:
Arc: input A
Node: state/output Y

State Machine Design Example 1: 110 Detector
Using J-K Flip-flops

- **Steps 1-4: No change.**

Transition Table (step 4):

Q1	Q2	A = 0	A = 1	Y
0	0	00	01	0
0	1	00	11	0
1	1	10	11	0
1	0	00	01	1

Q1* Q2*

Q	Q*	J	K
0	0	0	d
0	1	1	d
1	0	d	1
1	1	d	0

J-K Flip-Flop Excitation Table

Excitation table (Step 6):

Q1	Q2	A = 0	A = 1	Y
0	0	0d, 0d	0d, 1d	0
0	1	0d, d1	1d, d0	0
1	1	d0, d1	d0, d0	0
1	0	d1, 0d	d1, 1d	1

J1 K1, J2 K2

- **Step 5: Choose J-K Flip-Flops**
- **Step 6: Excitation table: Use J-K Flip-Flop Excitation Table.**

State Machine Design Example 1: 110 Detector Using J-K FF
Steps 7, 8 : Excitation/Output Equations

- **Step 7: Excitation equations: J1, K1, J2, K2 = F (A, Q1, Q2)**

J1 :

A \ Q1 Q2	00	01	11	10
0	0	0	d	d
1	0	1	d	d

J1 = Q2•A

J2 :

A \ Q1 Q2	00	01	11	10
0	0	d	d	0
1	1	d	d	1

J2 = A

K1 :

A \ Q1 Q2	00	01	11	10
0	d	d	0	1
1	d	d	0	1

K1 = Q2’

K2 :

A \ Q1 Q2	00	01	11	10
0	d	1	1	d
1	d	0	0	d

K2 = A’

- **Step 8: Output equation: Y = G (Q1, Q2)**

Y = Q1•Q2’ (directly read from transition table)