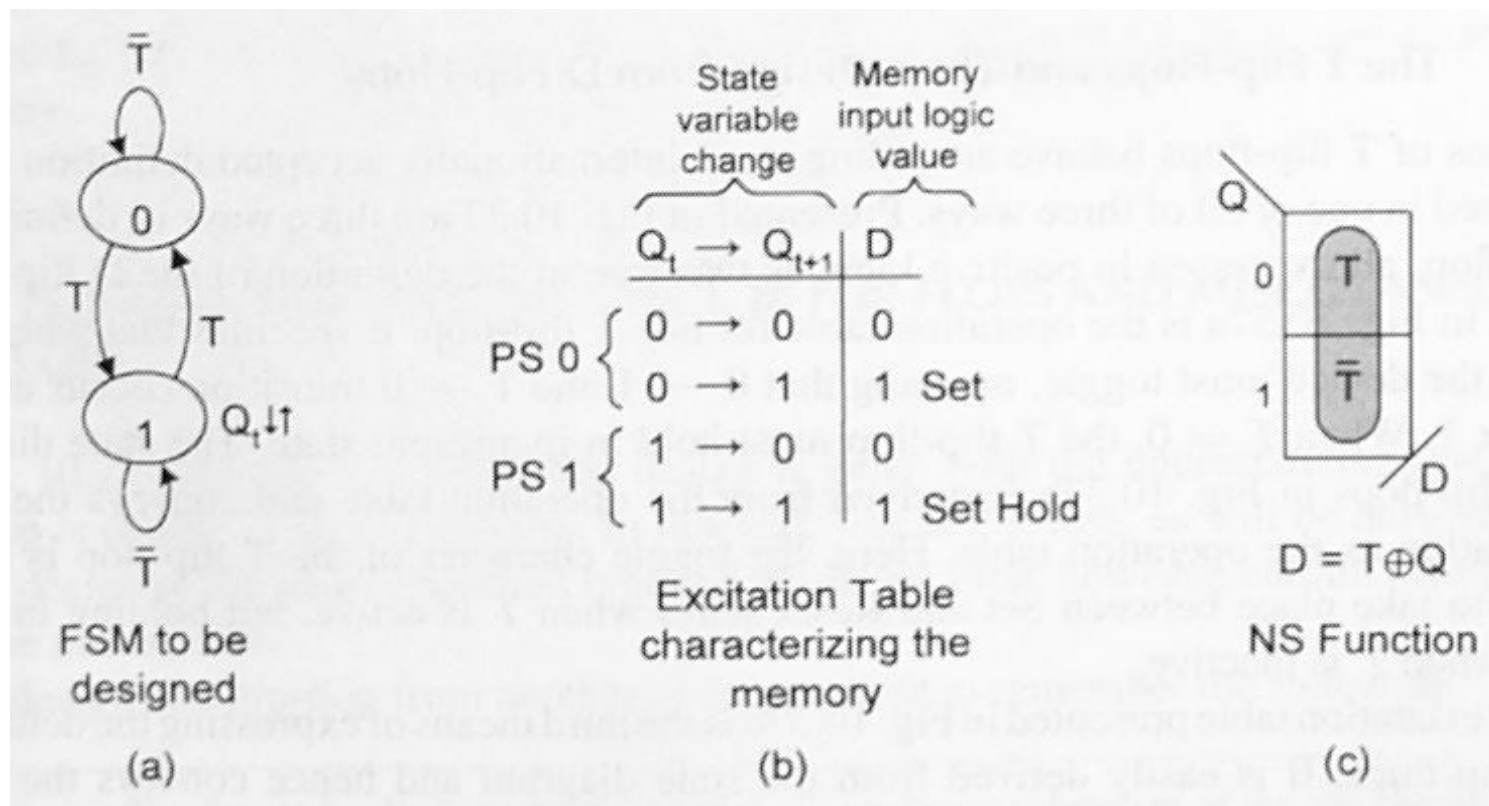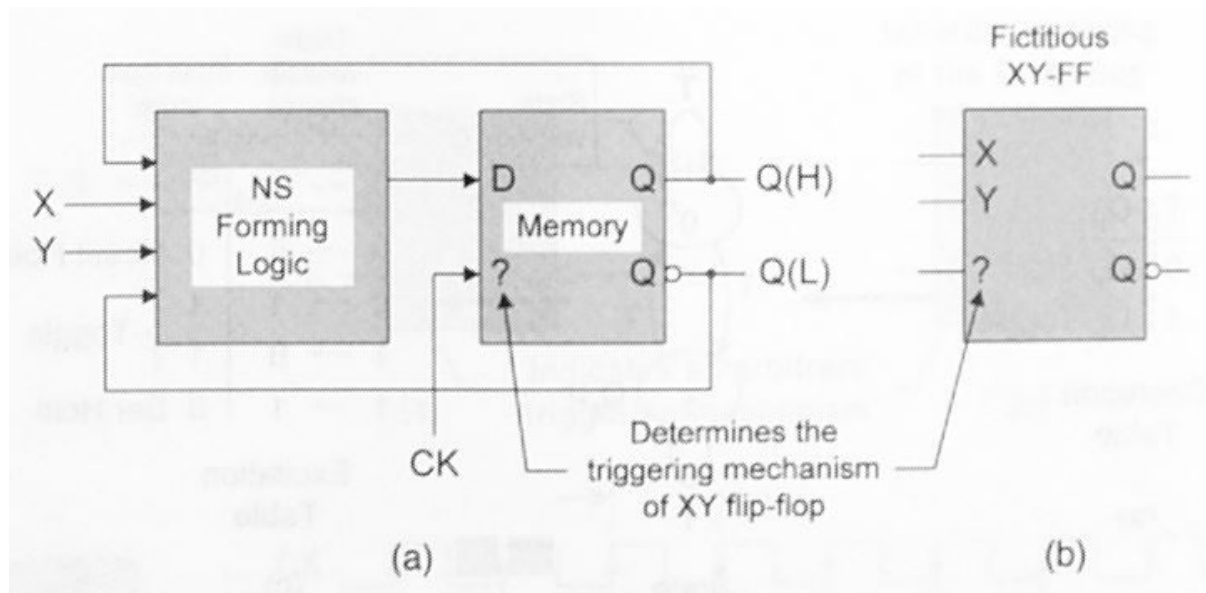# Further Consideration of State Machine Operation

Three topics today

- More detail about basic flip-flops
- State machine next state logic design
- State machine timing

Q(H)

Q(L)

NS
Forming
Logic

Memory

D   Q

?   Q

X
Y

CK

Determines the
triggering mechanism
of XY flip-flop

(a)

Fictitious
XY-FF

X

Y

?

Q

Q

(b)

FSM to be
designed

(a)

State variable change		Memory input logic value
$Q_t \rightarrow Q_{t+1}$		D
PS 0	$0 \rightarrow 0$	0
	$0 \rightarrow 1$	1 Set
PS 1	$1 \rightarrow 0$	0
	$1 \rightarrow 1$	1 Set Hold

Excitation Table
characterizing the
memory

(b)

$$D = T \oplus Q$$

NS Function

(c)

Recall the resolver circuit for creating an edge triggered F/F and creation of the next state logic where the state number is binary encoded:
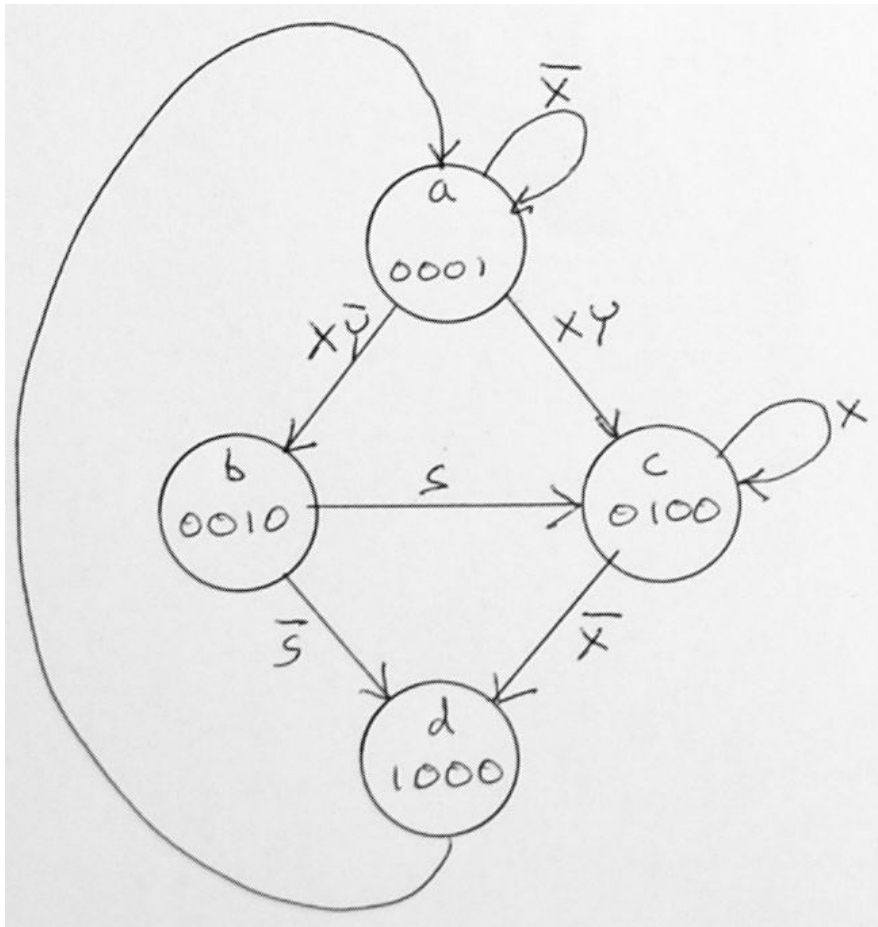

(a)
Resolver FSM to be designed
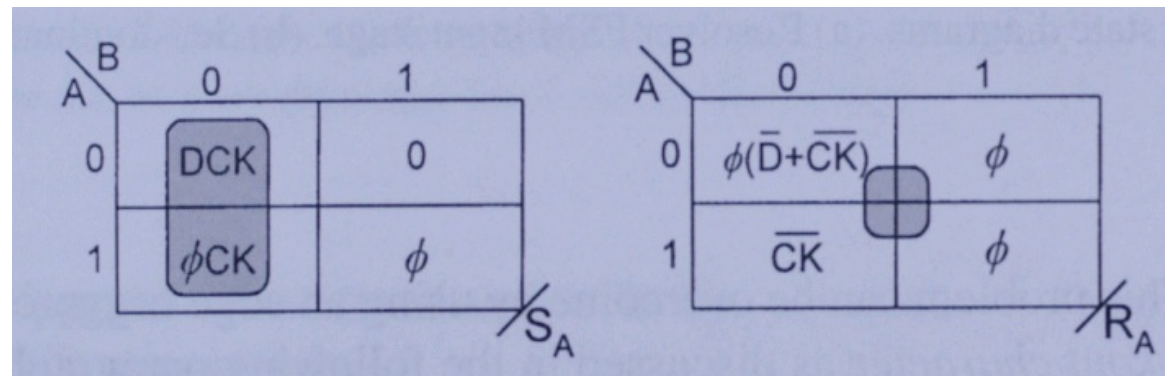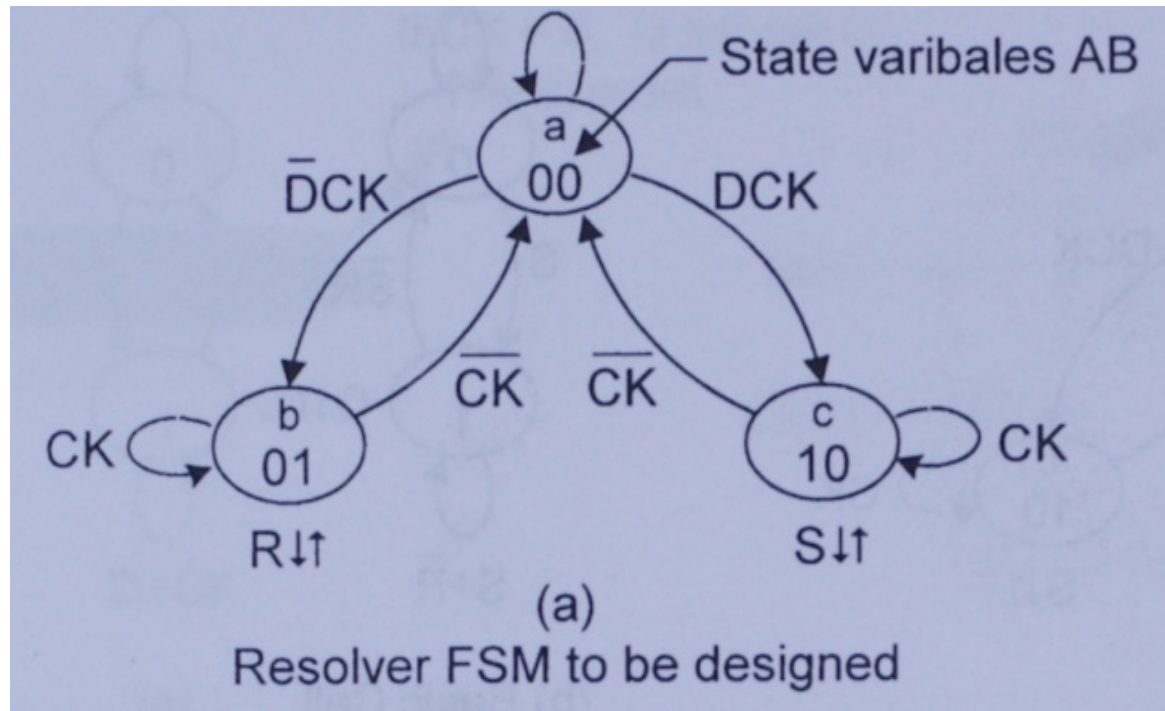
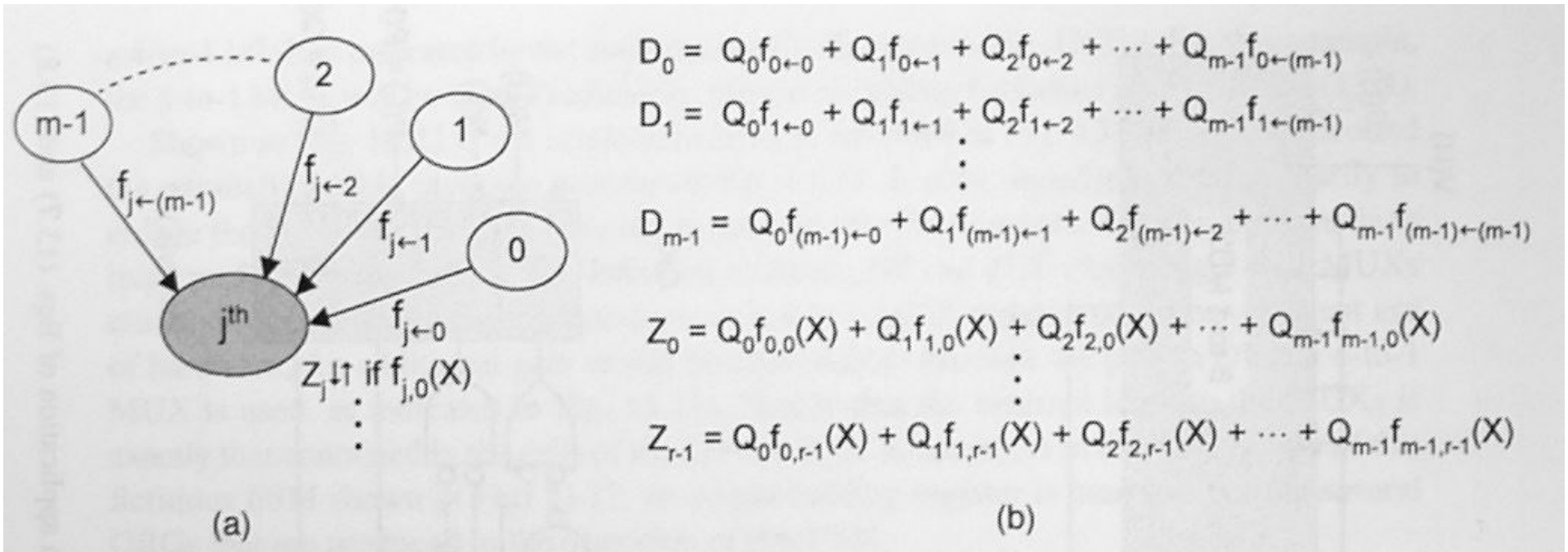Next state logic design using one-hot encoding
    The state number, in binary, is all zeros except one digit is a one
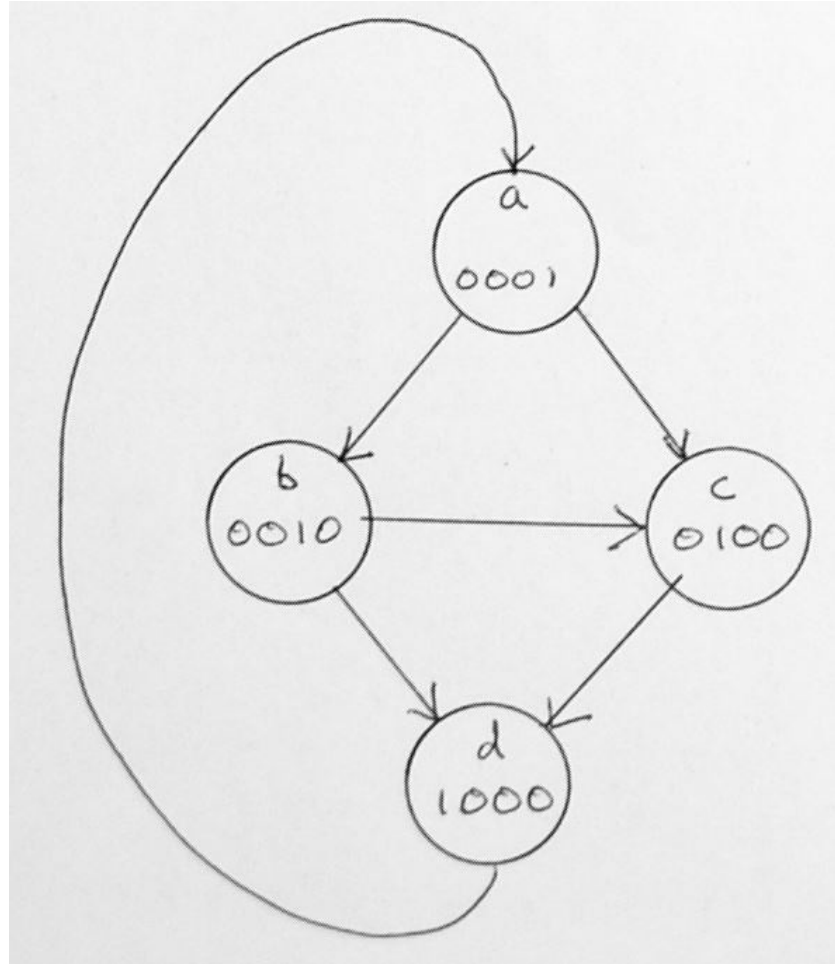
Here is the same state diagram with branching conditions added
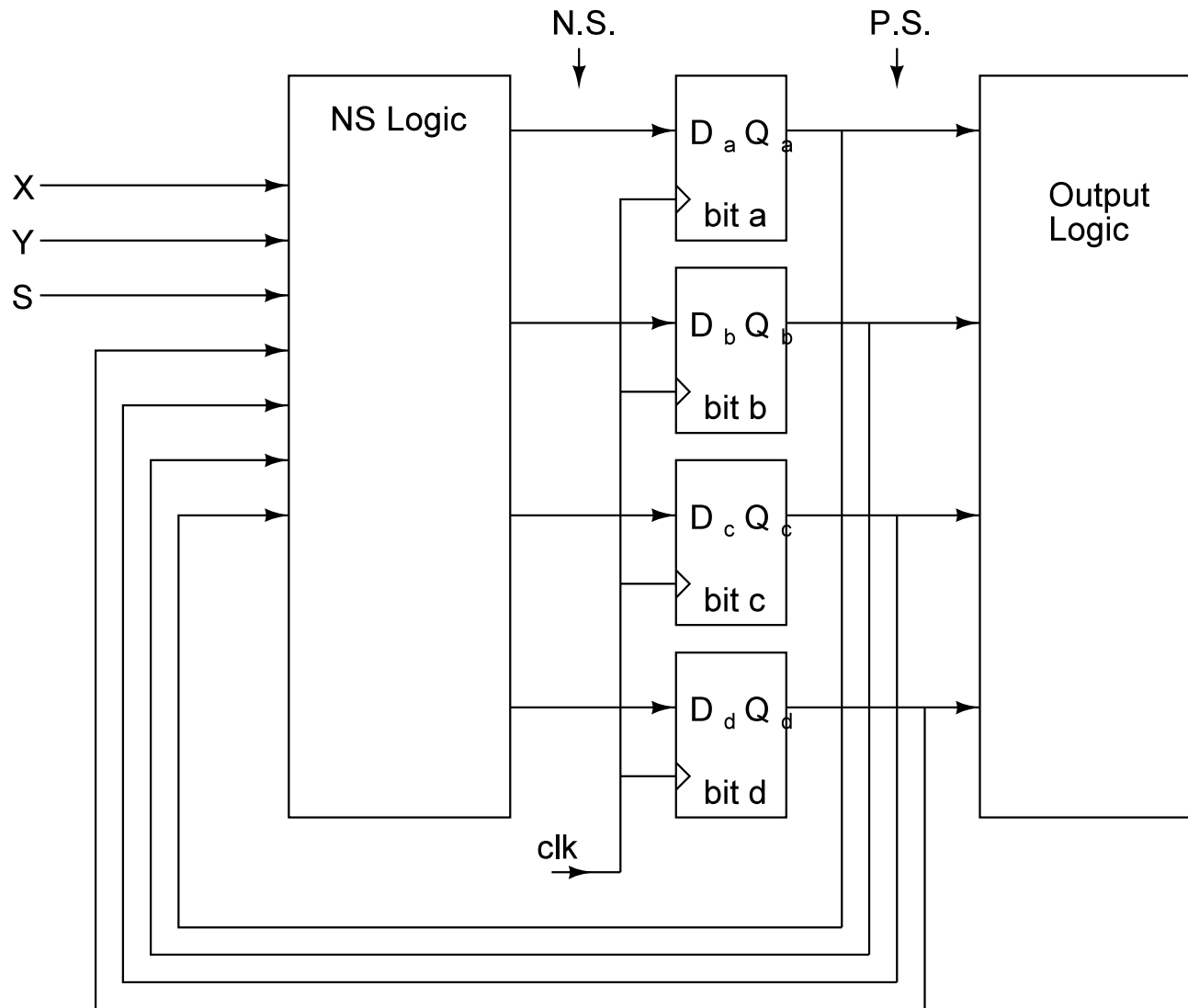
Formal definition of one-hot encoding

$$D_0 = Q_0 f_{0\leftarrow 0} + Q_1 f_{0\leftarrow 1} + Q_2 f_{0\leftarrow 2} + \cdots + Q_{m-1} f_{0\leftarrow(m-1)}$$

$$D_1 = Q_0 f_{1\leftarrow 0} + Q_1 f_{1\leftarrow 1} + Q_2 f_{1\leftarrow 2} + \cdots + Q_{m-1} f_{1\leftarrow(m-1)}$$

$$\vdots$$

$$D_{m-1} = Q_0 f_{(m-1)\leftarrow 0} + Q_1 f_{(m-1)\leftarrow 1} + Q_2 f_{(m-1)\leftarrow 2} + \cdots + Q_{m-1} f_{(m-1)\leftarrow(m-1)}$$

$$Z_0 = Q_0 f_{0,0}(X) + Q_1 f_{1,0}(X) + Q_2 f_{2,0}(X) + \cdots + Q_{m-1} f_{m-1,0}(X)$$

$$\vdots$$

$$Z_{r-1} = Q_0 f_{0,r-1}(X) + Q_1 f_{1,r-1}(X) + Q_2 f_{2,r-1}(X) + \cdots + Q_{m-1} f_{m-1,r-1}(X)$$
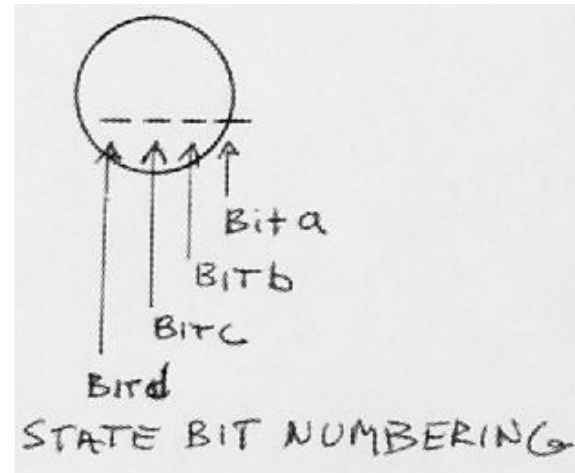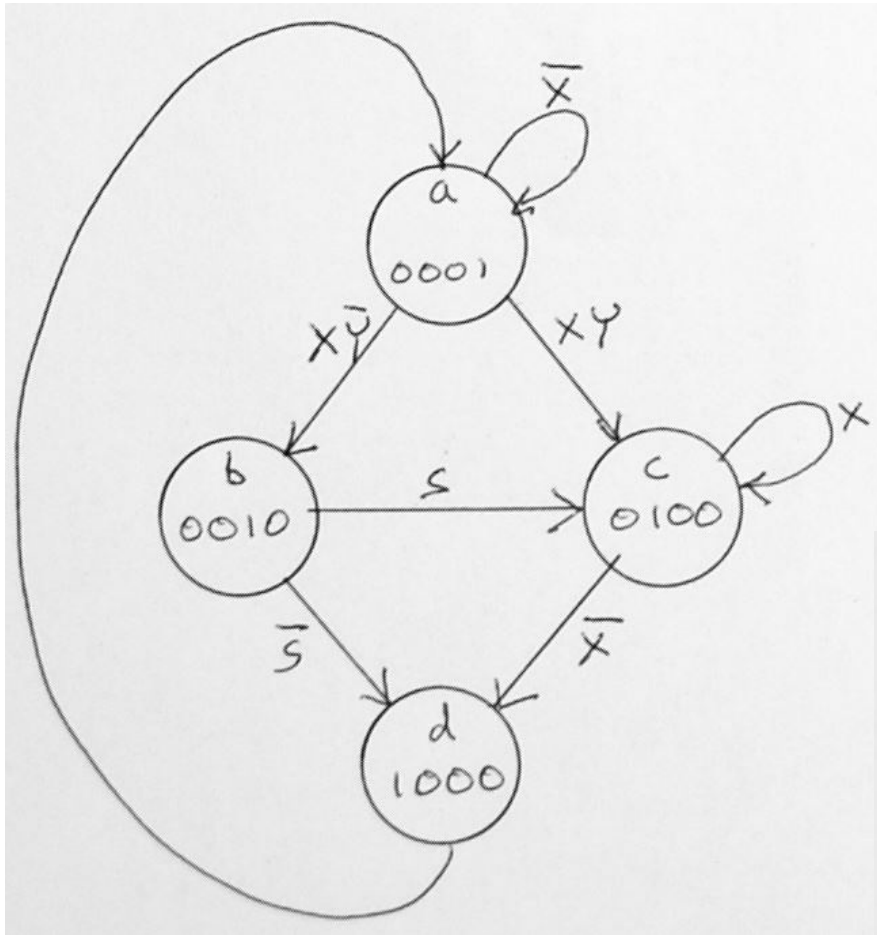
(a)

(b)

Below are equations that summarize next state logic D and output logic Z

$$D_j = \sum_{k=0}^{m-1} Q_k \cdot f_{j\leftarrow k} \quad \text{and} \quad Z_l = \sum_{j=0}^{m-1} Q_j \cdot f_{j,l}(X)$$

For the four-state example, here is the circuit:
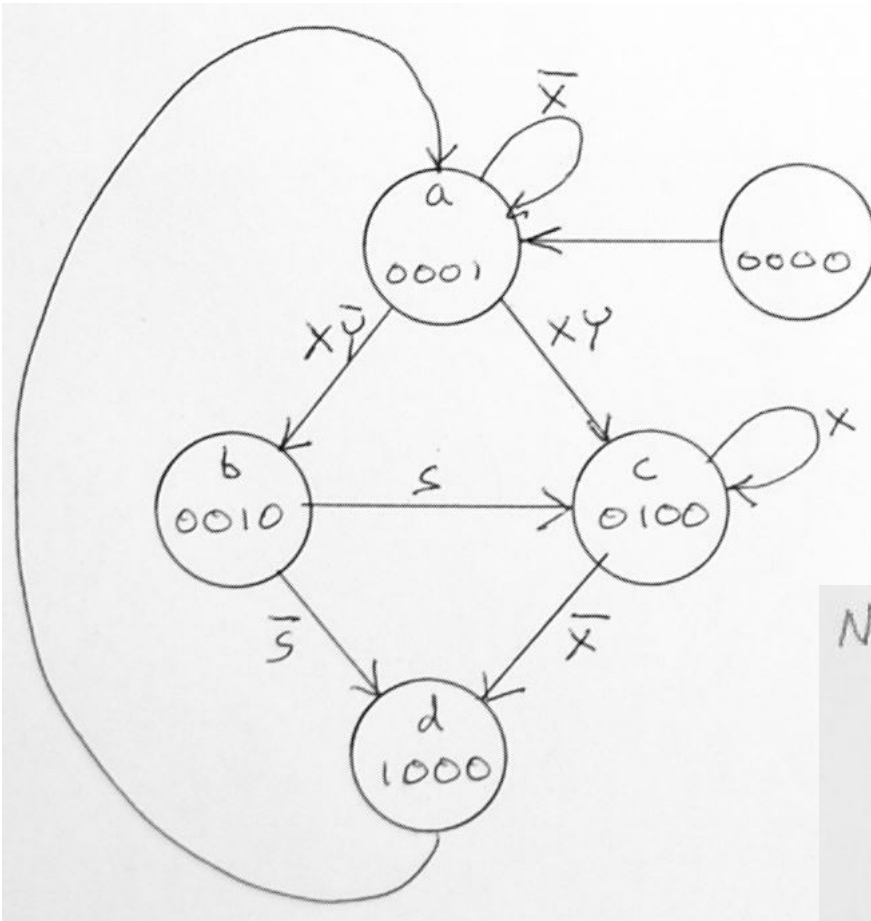
Here is the logic for each state bit.

STATE BIT NUMBERING

NEXT STATE LOGIC

$$D_a = \bar{X} Q_a + Q_d$$

$$D_b = X \bar{Y} Q_a$$

$$D_c = XY Q_a + S Q_b + X Q_c$$

$$D_d = \bar{S} Q_b + \bar{X} Q_c$$

One-hot plus one state coding: Adds an initial state to force transition to a desired state at system start-up.

NEXT STATE LOGIC

$$D_a = \bar{X} Q_a + Q_d + \overline{Q_d \bar{Q_c} \bar{Q_b} \bar{Q_a}}$$

$$D_b = X\bar{Y} Q_a$$

$$D_c = XY Q_a + S Q_b + X Q_c$$

$$D_d = \bar{S} Q_b + \bar{X} Q_c$$

TRANSITION FROM 0000

A more complex example.