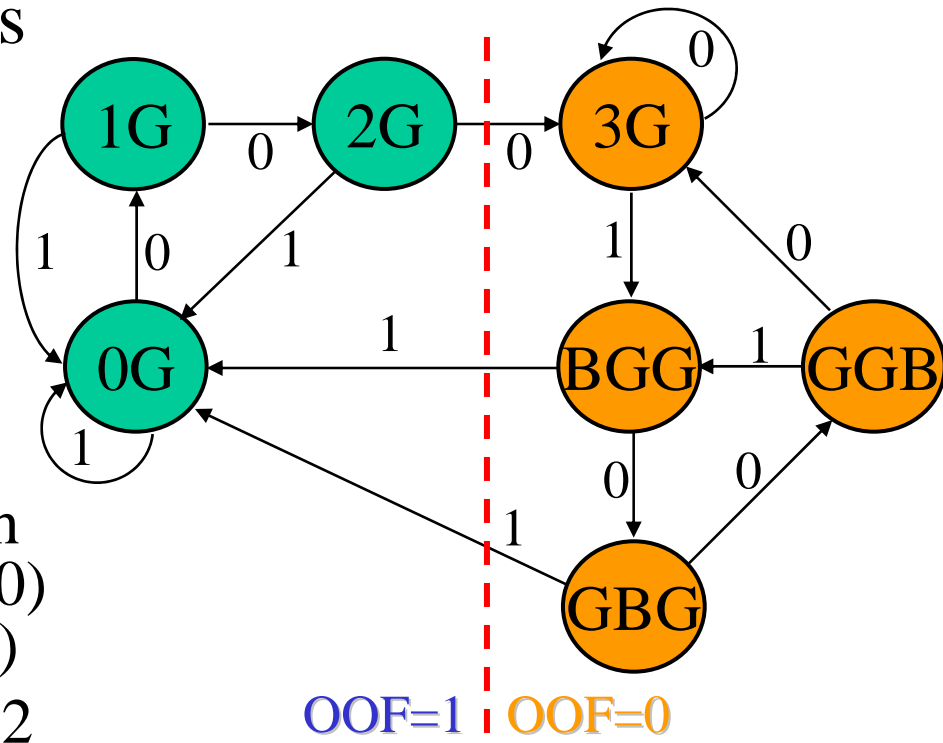


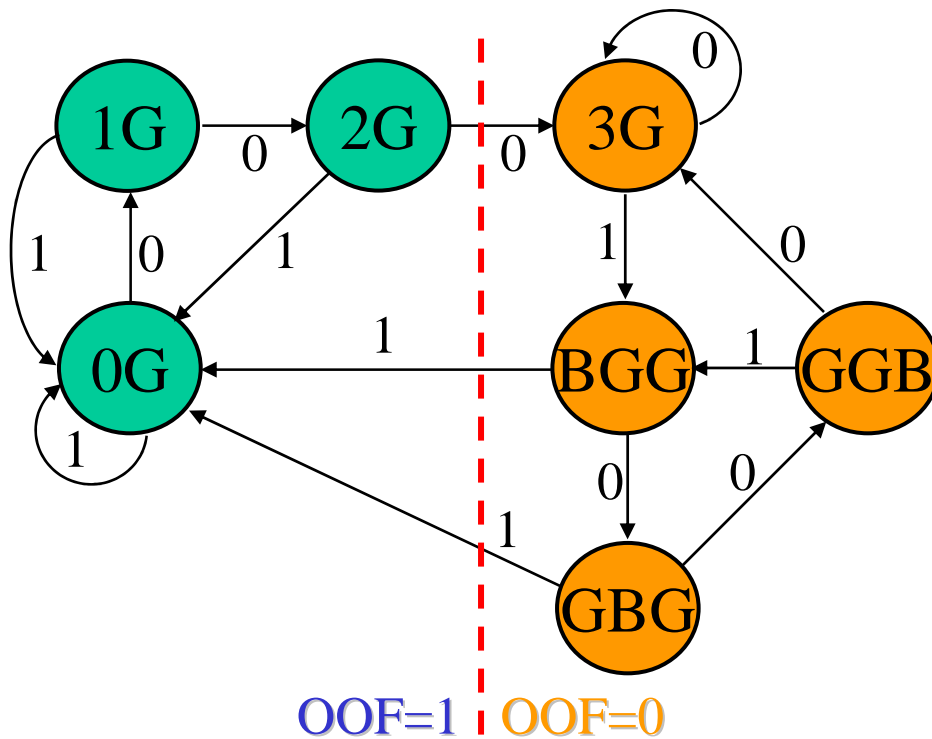
Synchronization Algorithm Example

- States can be represented as variables
 - Instead of binary state assignments
- Example: framer algorithm
 - When out-of-frame (OOF=1) it takes 3 consecutive frames with no framing errors (FE=0) to go in-frame (OOF=0)
 - When in-frame it takes 2 consecutive frames to go out-of-frame



G=good frame (no framing error, FE=0)
B=bad frame (framing error, FE=1)

Framer Example (continued)



Current State	Next State		Output OOF
	FE=0	FE=1	
0G	1G	0G	1
1G	2G	0G	1
2G	3G	0G	1
3G	3G	BGG	0
BGG	GBG	0G	0
GBG	GGB	0G	0
GGB	3G	BGG	0

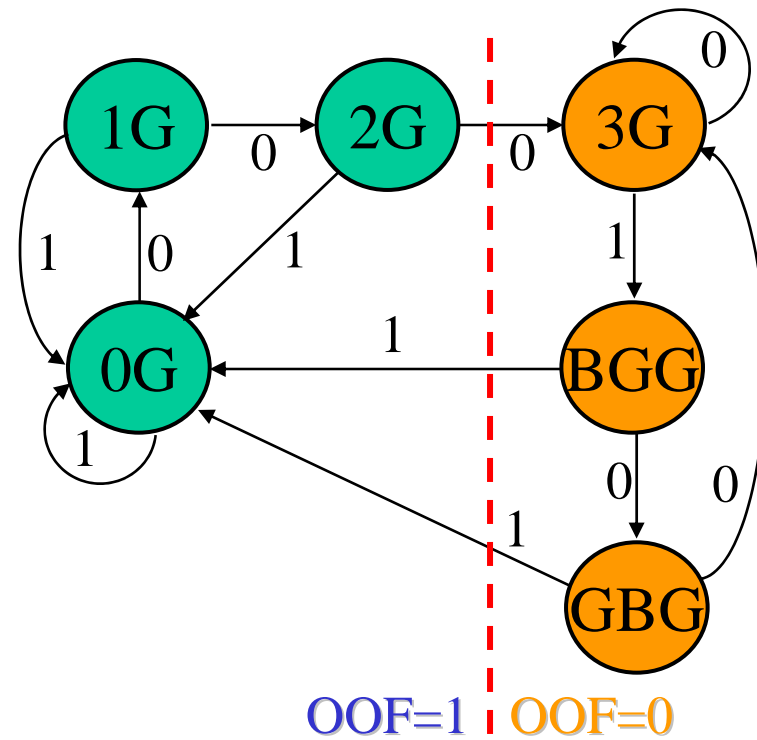
Note alternate form of state table

State Reduction

- Minimizing the number of states usually helps to:
 - Minimize # of flip-flops required for FSM
 - Minimum # FFs = $\lceil \log_2(\#states) \rceil$
 - Minimize # gates (gate I/O) required for FSM
 - More Xs in K-maps
- Two states are equivalent if for all combinations of inputs:
 - They give the same outputs
 - They send the circuit either to the same state or to equivalent states
- When two states are equivalent one state can be removed without altering behavior of the circuit

Framer State Reduction Example

Current State	Next State		Output OOF
	FE=0	FE=1	
0G	1G	0G	1
1G	2G	0G	1
2G	3G	0G	1
3G	3G	BGG	0
BGG	GBG	0G	0
GBG	GGB	0G	0
GGB	3G	BGG	0



Equivalent states in red => remove GGB state & change GGB to 3G

State Assignment

- Assignment of binary values to states
 - Determines locations of 1s in K-maps
 - Determines locations of Xs in K-maps
 - Helps to optimize in resultant circuit in terms of:
 - ✓ Area
 - » # gates
 - » # gate I/O
 - ✓ Performance – to maximize operating frequency
 - » Gate delay
 - » Propagation delay

Framer State Assignment Example

Assign #1 (xyz)	Assign #2 (xyz)	Current State	Next State		OOF
			FE=0	FE=1	
000	000	0G	1G	0G	1
100	001	1G	2G	0G	1
110	010	2G	3G	0G	1
111	011	3G	3G	BGG	0
011	100	BGG	GBG	0G	0
101	101	GBG	3G	0G	0

x \ yz	00	01	11	10
0	1	X	0	X
1	1	0	0	1

$$\text{OOF} = z'$$

x \ yz	00	01	11	10
0	1	1	0	1
1	0	0	X	X

$$\text{OOF} = x'y' + yz'$$

Green state assignment gives fewer gates & gate I/O for output OOF

Framer State Assignment Example

Assign #1 (xyz)	Assign #2 (xyz)	Current State	Next State	
			FE=0	FE=1
000	000	0G	1G	0G
100	001	1G	2G	0G
110	010	2G	3G	0G
111	011	3G	3G	BGG
011	100	BGG	GBG	0G
101	101	GBG	3G	0G

		yz			
		00	01	11	10
FE x	00	100	XXX	101	XXX
	01	110	111	111	111
	11	000	000	011	000
	10	000	XXX	000	XXX

$$D_x = FE'$$

$$D_y = FE'x + xyz$$

$$D_z = FE'z + FE'y + xyz$$

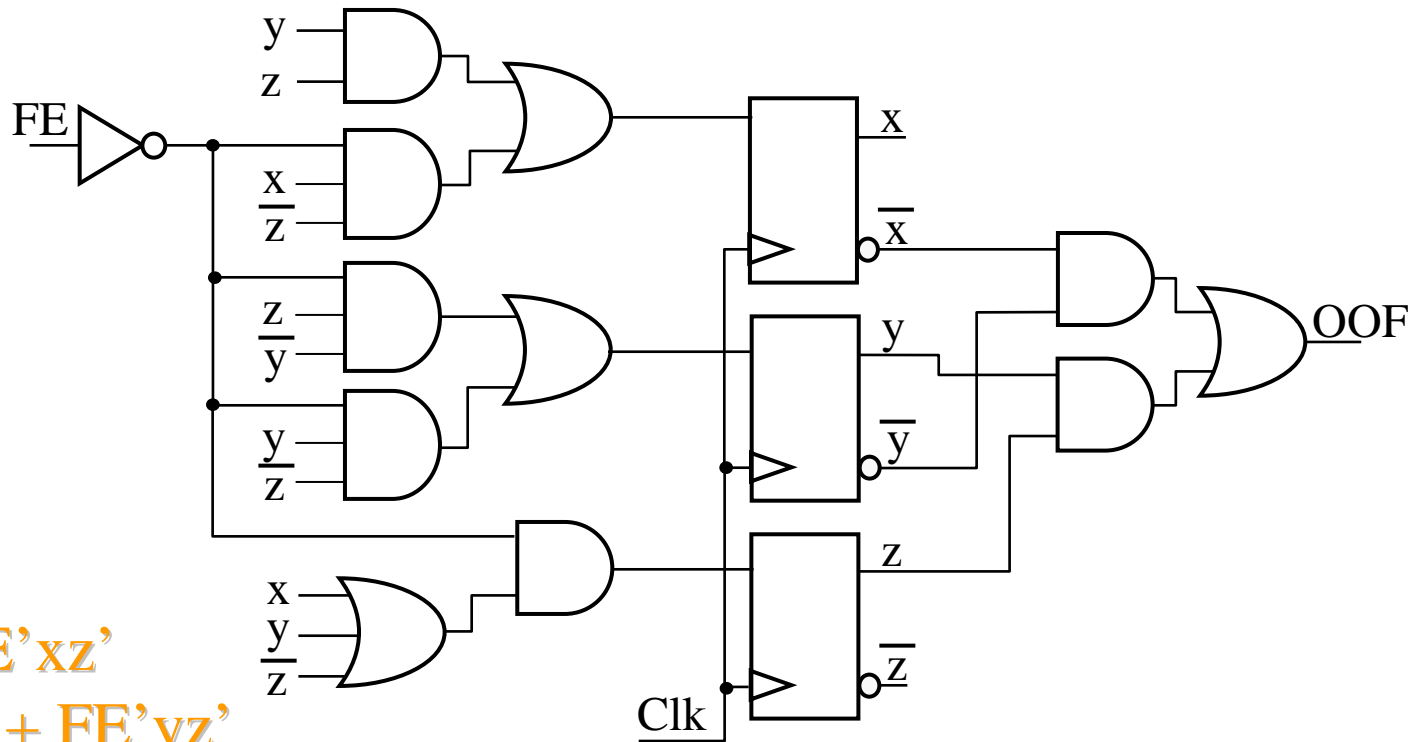
		yz			
		00	01	11	10
FE x	00	001	010	101	011
	01	101	011	XXX	XXX
	11	000	000	XXX	XXX
	10	000	000	100	000

$$D_x = yz + FE'xz'$$

$$D_y = FE'y'z + FE'yz'$$

$$D_z = FE'z' + FE'y + FE'x \\ = FE'(x+y+z')$$

Framer State Assignment Example



$$Dx = yz + FE'xz'$$

$$Dy = FE'y'z + FE'yz'$$

$$Dz = FE'z' + FE'y + FE'x$$

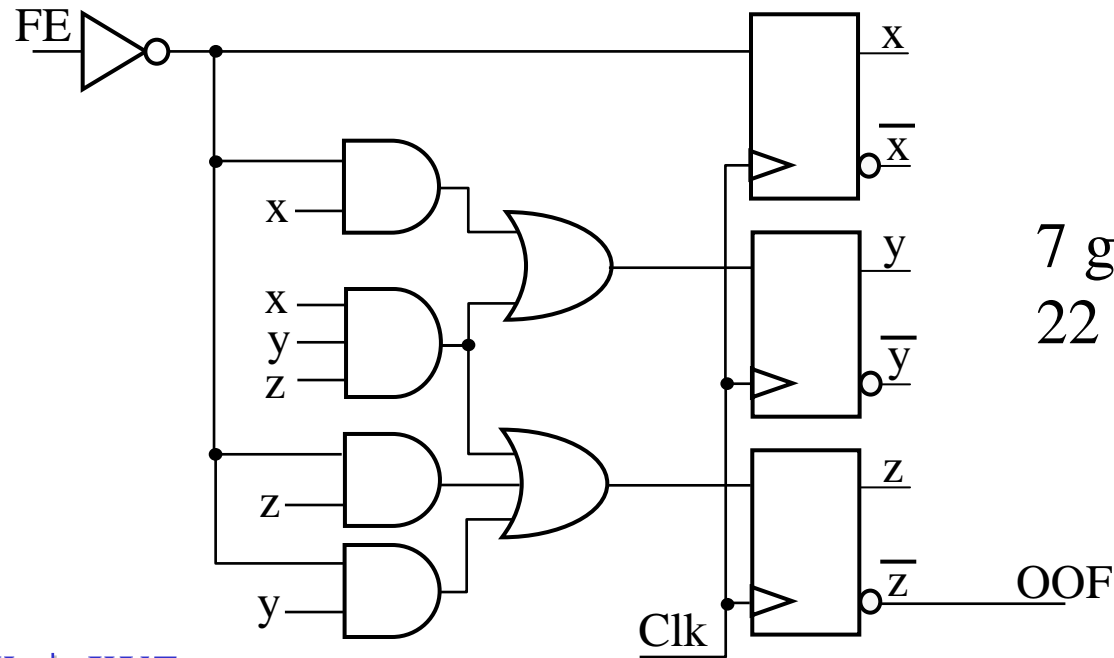
$$= FE'(x+y+z')$$

$$OOF = x'y' + yz'$$

12 gates

39 gate I/O

Framer State Assignment Example



7 gates
22 gate I/O

$$D_x = FE'$$

$$D_y = FE'x + xyz$$

$$D_z = FE'z + FE'y + xyz$$

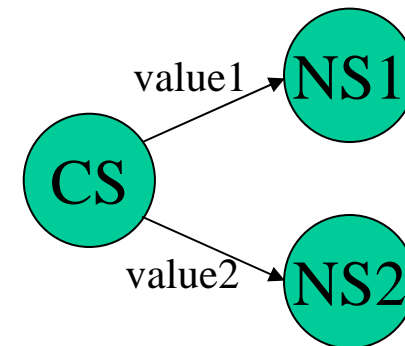
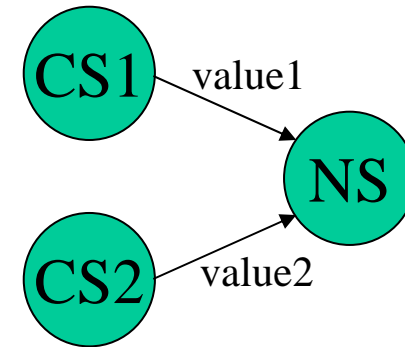
$$OOF = z'$$

Both circuits have identical behavior but choice of state assignment results in considerable difference in # gates and gate I/O for combinational logic

State Assignment Rules

- General rules for assigning states such that the 1s are grouped in the K-maps:
 1. States that have the same next states for a given input value should be given logically adjacent assignments
 2. States that are next states of a single present state under logically adjacent inputs should be given logically adjacent assignments

If value1=value2 then
CS1 & CS2 should have d=1



If value1 & value2 have d=1, then
NS1 & NS2 should have d=1

One-Hot FSMs

- One-hot is another state assignment method
 - Uses 1 state variable (and 1 FF) per state
 - Often uses more FFs but fewer combinational logic gates than traditional binary state assignments
- Two types of one-hot
 - One-hot-one
 - Each state has a single 1 in a field of 0s
 - One-hot-zero
 - One state is all 0s
 - Requires 1 less FFs than one-hot-one assignments

Curr. State	Assignment		Next State	
	1-hot-1	1-hot-0	FE=0	FE=1
0G	10000	00000	1G	0G
1G	01000	10000	2G	0G
2G	00100	01000	3G	0G
3G	00010	00100	3G	BGG
BGG	00001	00010	GBG	0G
GBG	00000	00001	3G	0G