

State Machine Examples

Last updated 2/23/21

State Machine Examples

- These slides provide examples of the Finite State Machine process

State Machine Examples

- Toll Booth
 - Specifications
 - \$0.25 required to open the gate
 - Pennies are not allowed (fall through the selector box)
 - Nickels, Dimes, Quarters only
 - Gate must close after vehicle leaves
 - No change given
 - No backing out

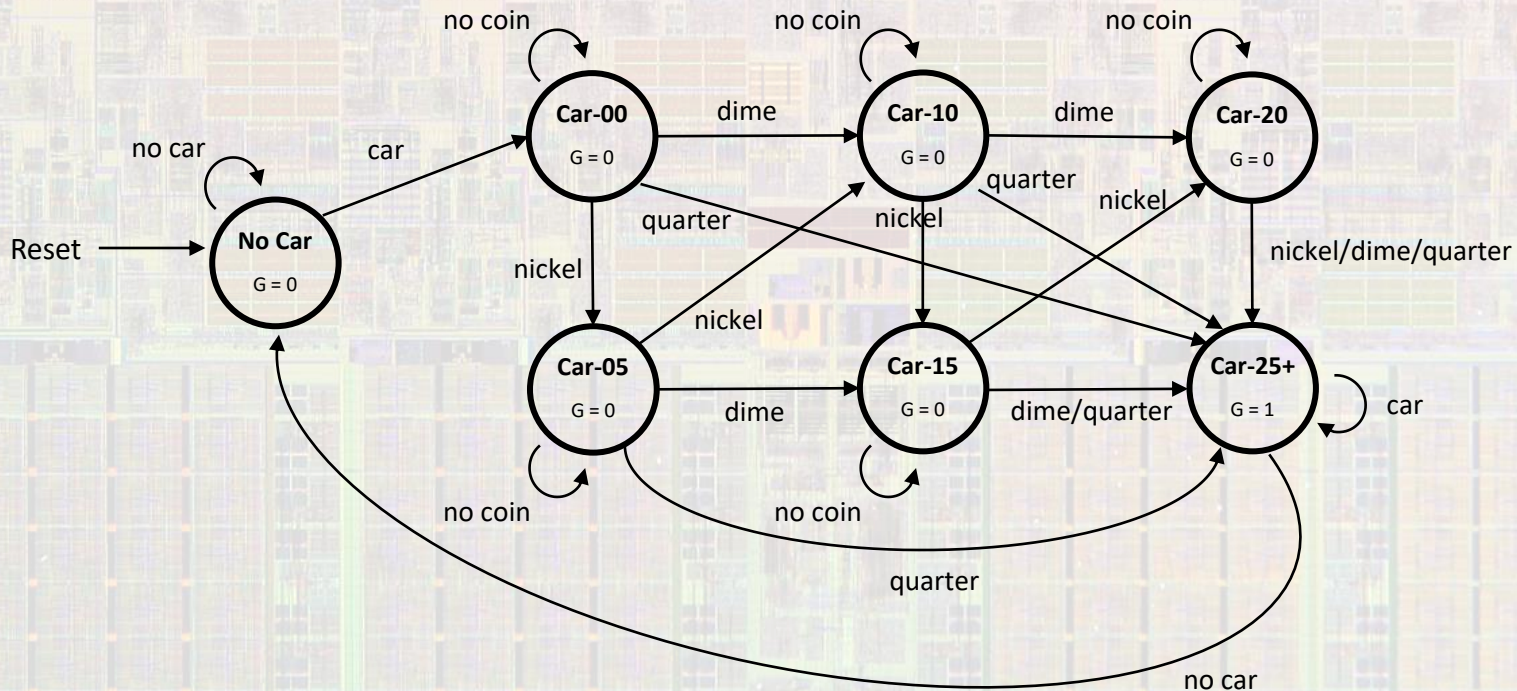
State Machine Examples

- Toll Booth
 - States
 - No car
 - Car, \$0.00
 - Car, \$0.05
 - ...
 - Car, \$0.25 or more
 - Inputs
 - Car
 - Coin Detector (nickel, dime, quarter)
 - Outputs
 - Gate

State Machine Examples

- Toll Booth
- State transition diagram

Note: this is for illustrative purpose - we would never make a state machine like this



State Machine Examples

- Toll Booth
 - I/O Encoding
 - Vehicle(V): 0 = no car, 1 = car
 - Coins: 00 = no coin, 01 = nickel, 10 = dime, 11 = quarter
 - Gate: 0 = closed, 1 = open

State Machine Examples

- Toll Booth

- State transition table

Current State	Inputs		Next State
	Car	Coin	
No Car	NC	X	No Car
No Car	C	X	Car-00
Car-00	C	0	Car-00
Car-00	C	5	Car-05
Car-00	C	10	Car-10
Car-00	C	25	Car-25+
Car-05	C	0	Car-05
Car-05	C	5	Car-10
Car-05	C	10	Car-15
Car-05	C	25	Car-25+

Current State	Inputs		Next State
	Car	Coin	
Car-10	C	0	Car-10
Car-10	C	5	Car-15
Car-10	C	10	Car-20
Car-10	C	25	Car-25+
Car-15	C	0	Car-15
Car-15	C	5	Car-20
Car-15	C	10	Car-25+
Car-15	C	25	Car-25+
Car-20	C	0	Car-20
Car-20	C	5	Car-25+
Car-20	C	10	Car-25+
Car-20	C	25	Car-25+
Car-25+	C	X	Car-25+
Car-25+	0	X	No Car

State Machine Examples

- Toll Booth
 - Assign value for the state variable for each state
 - 7 states \rightarrow 3 bits
 - No Car – 000
 - Car-00 – 001
 - Car-05 – 010
 - Car-10 – 011
 - Car-15 – 100
 - Car-20 – 101
 - Car-25+ - 110

State Machine Examples

- Toll Booth

- Create truth tables

Current State	Inputs		Next State
	Car	Coin	
000	0	X	000
000	1	X	001
001	1	00	001
001	1	01	010
001	1	10	011
001	1	11	110
010	1	00	010
010	1	01	011
010	1	10	100
010	1	11	110

Current State	Inputs		Next State
	Car	Coin	
011	1	00	011
011	1	01	100
011	1	10	101
011	1	11	110
100	1	00	100
100	1	01	101
100	1	10	110
100	1	11	110
101	1	00	101
101	1	01	110
101	1	10	110
101	1	11	110
110	1	X	110
110	0	X	000

Current State	Output
000	0
001	0
010	0
011	0
100	0
101	0
110	1

State Machine Examples

- Toll Booth
- Minimize logic
 - Ignore the car input (we can deal with it at the end)

		S1				S1'							
		C0	C0'	C0'C0	C0	C0'	C0'C0	C0	C0'	C0'C0	C0	C0'	C0'C0
S2	S0'	2	2	2	2	1	1	1	1	1	1	1	1
	S0	5	4	6	7	9	8	6	7	9	8	6	7
S2'	S0'	1	1	1	1	7	6	4	5	7	6	4	5
	S0	3	2	4	5	3	2	0	1	3	2	0	1
		C1'				C1				C1'			

NS2

		S1				S1'							
		C0	C0'	C0'C0	C0	C0'	C0'C0	C0	C0'	C0'C0	C0	C0'	C0'C0
S2	S0'	1	1	1	1	1	1	1	1	1	1	1	1
	S0	x	x	x	x	1	1	1	1	1	1	1	1
S2'	S0'	1	0	1	1	1	0	0	0	0	0	0	0
	S0	0	0	1	1	0	0	0	0	0	0	0	0
		C1'				C1				C1'			

NS1

		S1				S1'							
		C0	C0'	C0'C0	C0	C0'	C0'C0	C0	C0'	C0'C0	C0	C0'	C0'C0
S2	S0'	1	1	1	1	1	1	0	0	1	1	0	0
	S0	x	x	x	x	1	1	0	1	1	0	1	1
S2'	S0'	0	1	0	1	1	1	0	1	1	0	1	1
	S0	1	1	0	1	0	0	0	0	0	0	0	0
		C1'				C1				C1'			

NS0

		S1				S1'							
		C0	C0'	C0'C0	C0	C0'	C0'C0	C0	C0'	C0'C0	C0	C0'	C0'C0
S2	S0'	0	0	0	0	0	0	0	0	1	0	0	1
	S0	x	x	x	x	0	0	1	0	0	1	0	0
S2'	S0'	0	1	1	0	0	1	1	0	0	1	1	0
	S0	1	0	0	0	1	1	1	1	1	1	1	1
		C1'				C1				C1'			

State Machine Examples

- Toll Booth

- Minimize logic

- Ignore the car input (we can deal with it at the end)

NS2

		S1				S1'					
		C0	C0'	C0'C0	C0'C0'	C0	C0'	C0'C0	C0'C0'		
S2	S0'	1	1	1	1	1	1	1	1		
	S0	x	x	x	x	1	1	1	1		
	S2'	1	0	1	1	1	0	0	0		
S2'	S0'	0	0	1	1	0	0	0	0		
		C1'		C1		C1'					

$$S2 + S1C1 + S1S0C1'CO + S1'S0C1CO$$

NS1

		S1				S1'					
		C0	C0'	C0'C0	C0'C0'	C0	C0'	C0'C0	C0'C0'		
S2	S0'	1	1	1	1	1	1	0	0		
	S0	x	x	x	x	1	1	0	1		
	S2'	0	1	0	1	1	1	0	1		
S2'	S0'	1	1	0	1	0	0	0	0		
		C1'		C1		C1'					

$$S2S1 + S2C1 + S1C1CO + S1C1'CO' + S1'S0C1 + S1S0'C1' + S1'S0C1'CO$$

NS0

		S1				S1'					
		C0	C0'	C0'C0	C0'C0'	C0	C0'	C0'C0	C0'C0'		
S2	S0'	0	0	0	0	0	0	0	1		
	S0	x	x	x	x	0	0	1	0		
	S2'	0	1	1	0	0	1	1	0		
S2'	S0'	1	0	0	0	1	1	1	1		
		C1'		C1		C1'					

$$S1S0CO' + S2'S1'CO' + S2'S1'S0' + S1'S0C1'CO' + S1'S0'C1'CO + S2'S0'C1'CO$$

State Machine Examples

- Toll Booth
 - Minimize logic
 - Add in the car input

$$NS2 = \text{car}(S2 + S1C1 + S1S0C1'C0 + S1'S0C1C0)$$

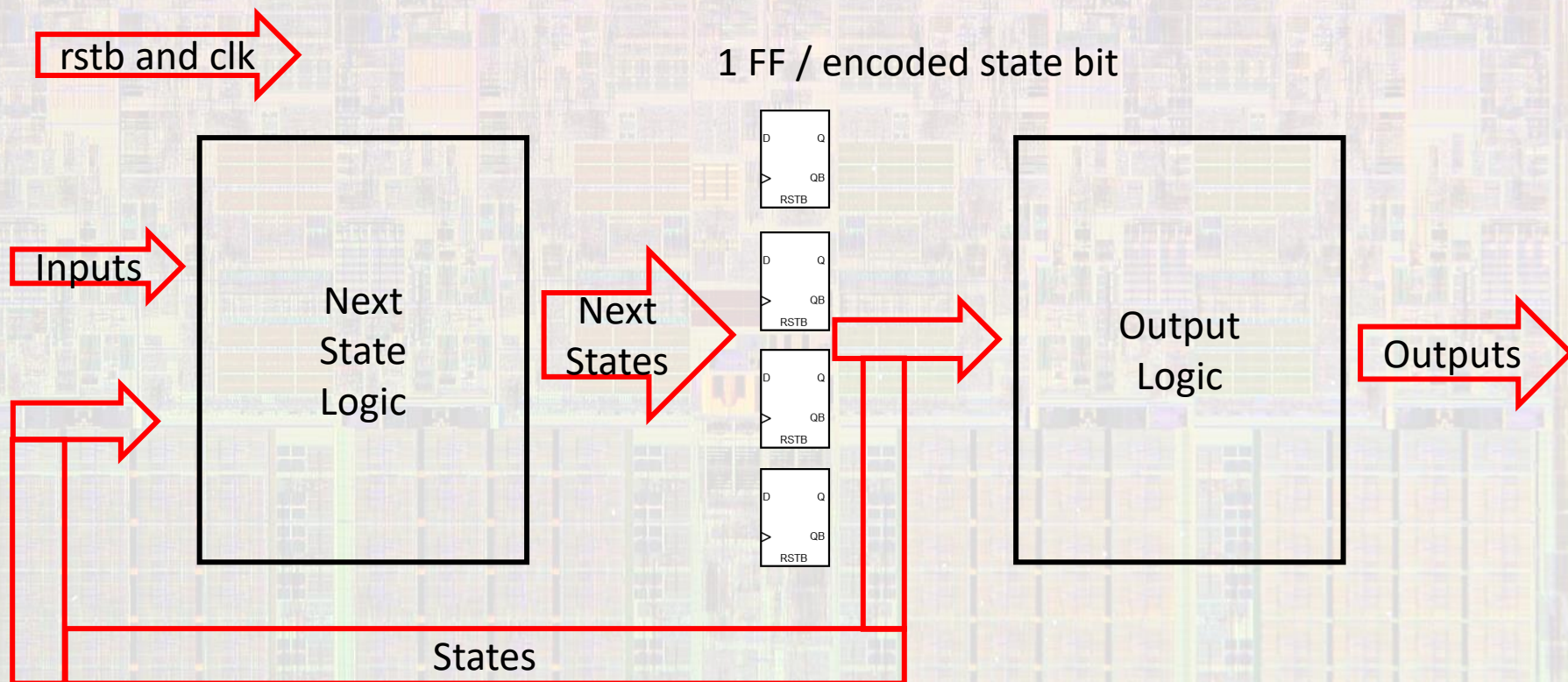
$$NS1 = \text{car}(S2S1 + S2C1 + S1C1C0 + S1C1'C0' + S1'S0C1 + S1S0'C1' + S1'S0C1'C0)$$

$$NS0 = \text{car}(S1S0C0' + S2'S1'C0' + S2'S1'S0' + S1'S0C1'C0' + S1'S0'C1'C0 + S2'S0'C1'C0)$$

$$\text{Gate} = S2S1S0'$$

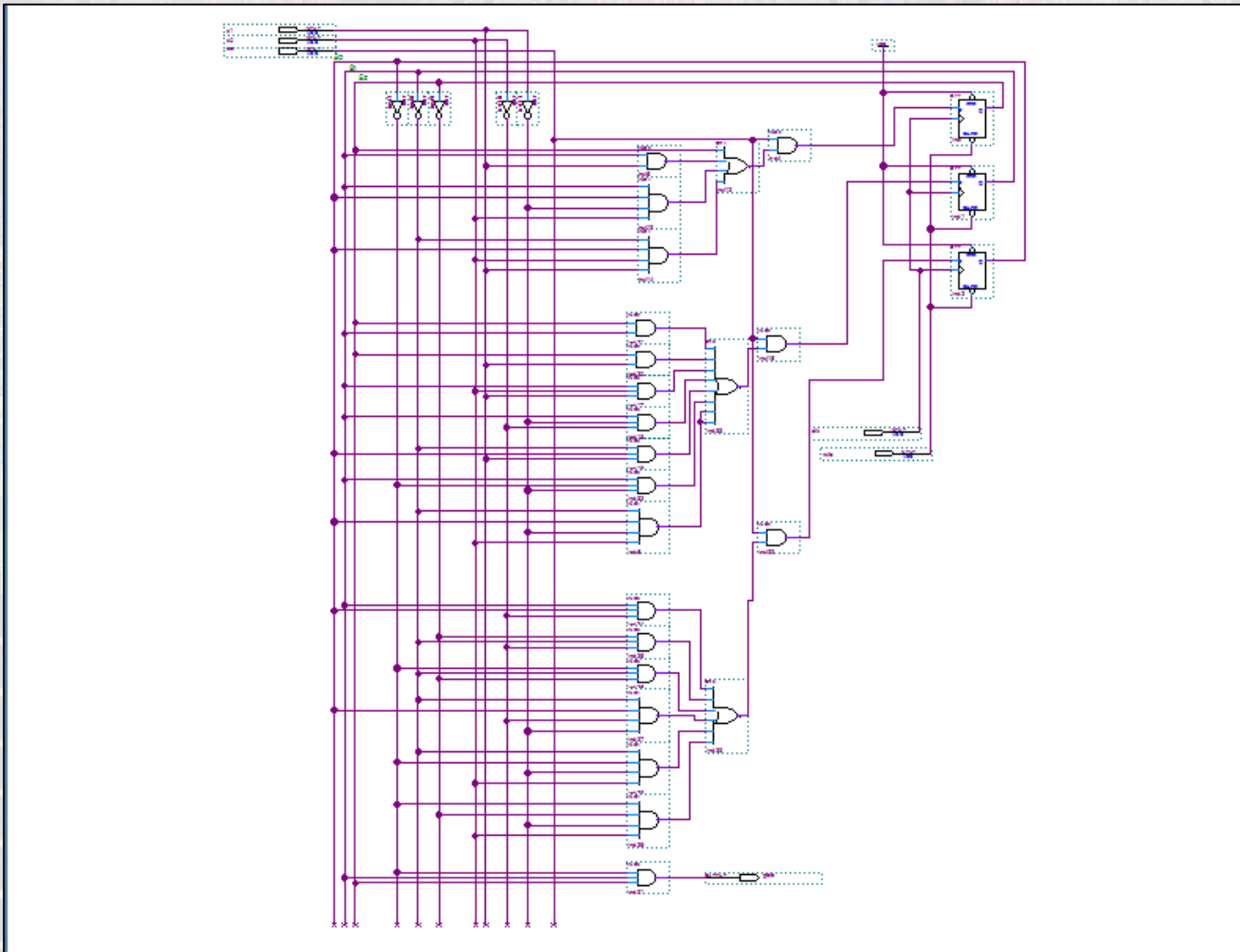
State Machine Examples

- State Diagram
- Schematic



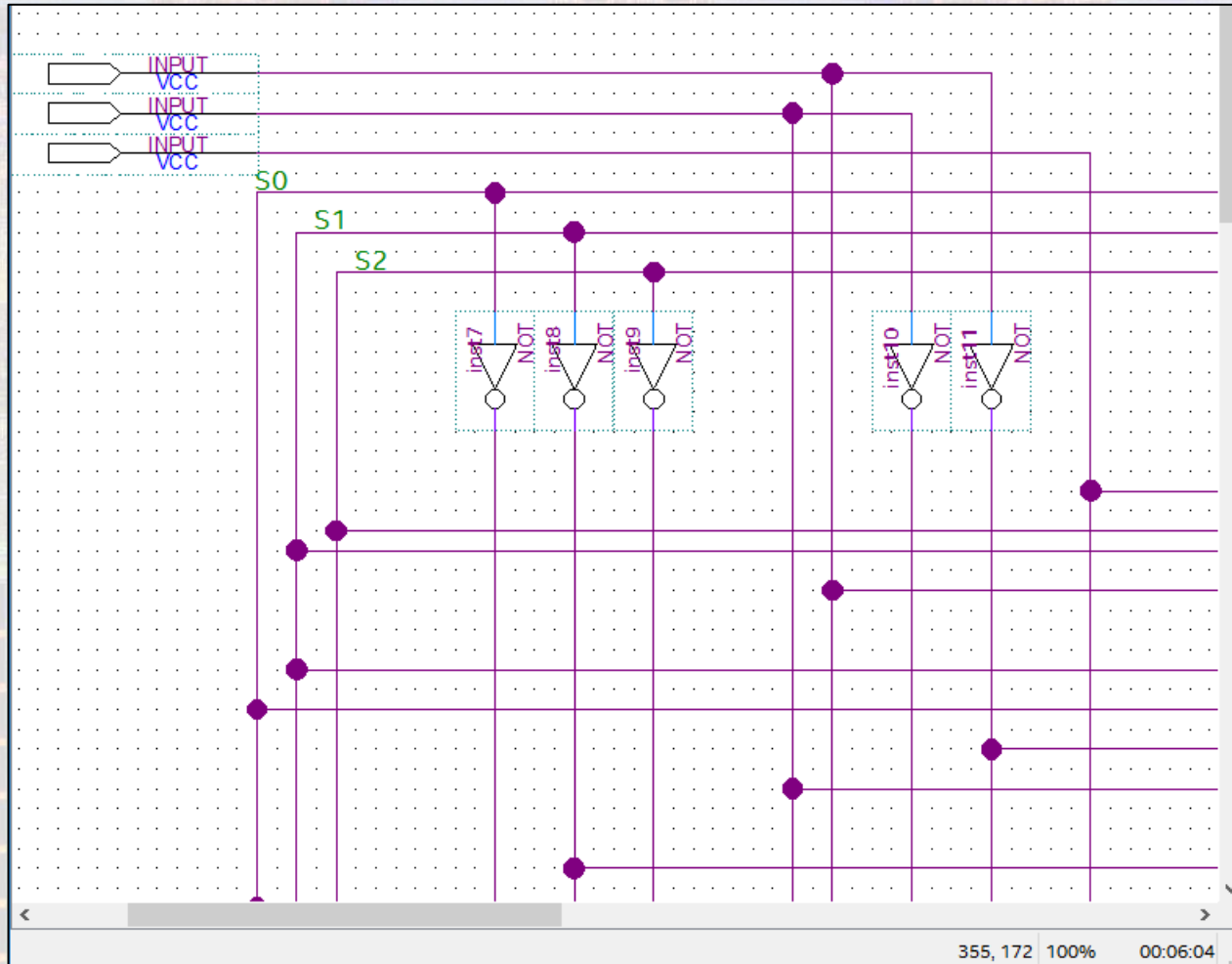
State Machine Examples

- Toll Booth



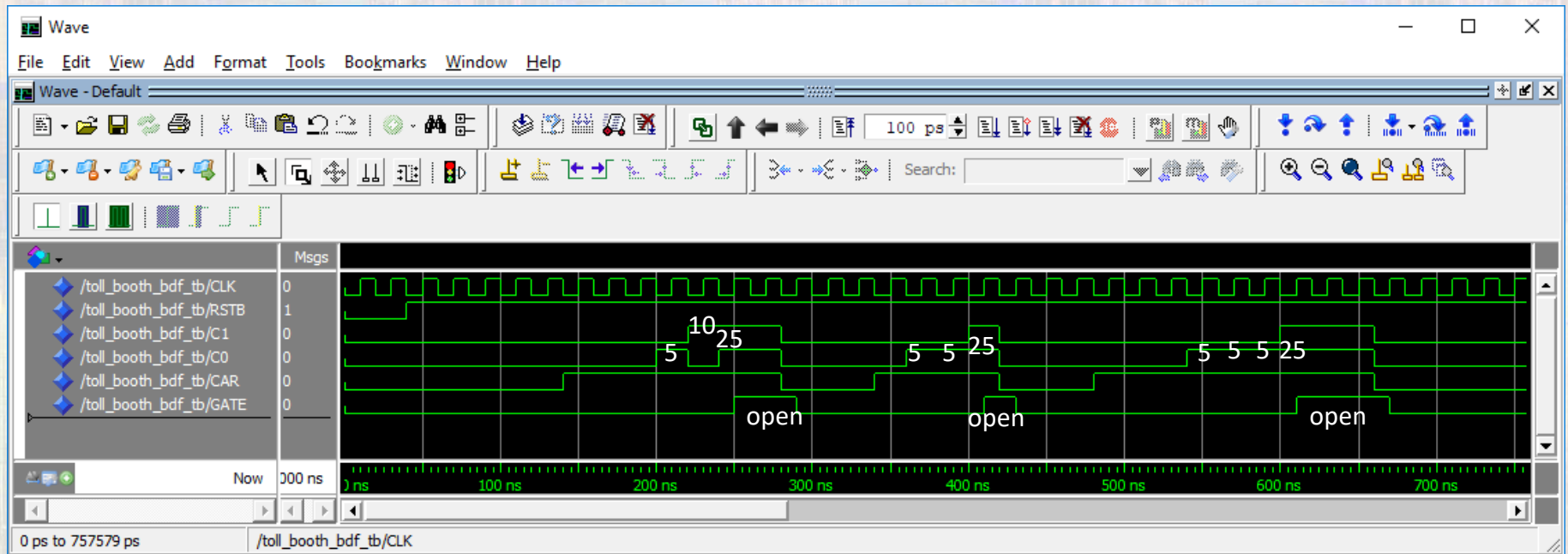
State Machine Examples

- Toll Booth



State Machine Examples

- Toll Booth



State Machine Examples

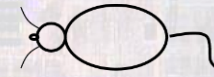
- Robo-Mouse
 - Mouse in a maze
 - Mouse has whiskers right and left pointing slightly forward



- Cheese is at the exit

State Machine Examples

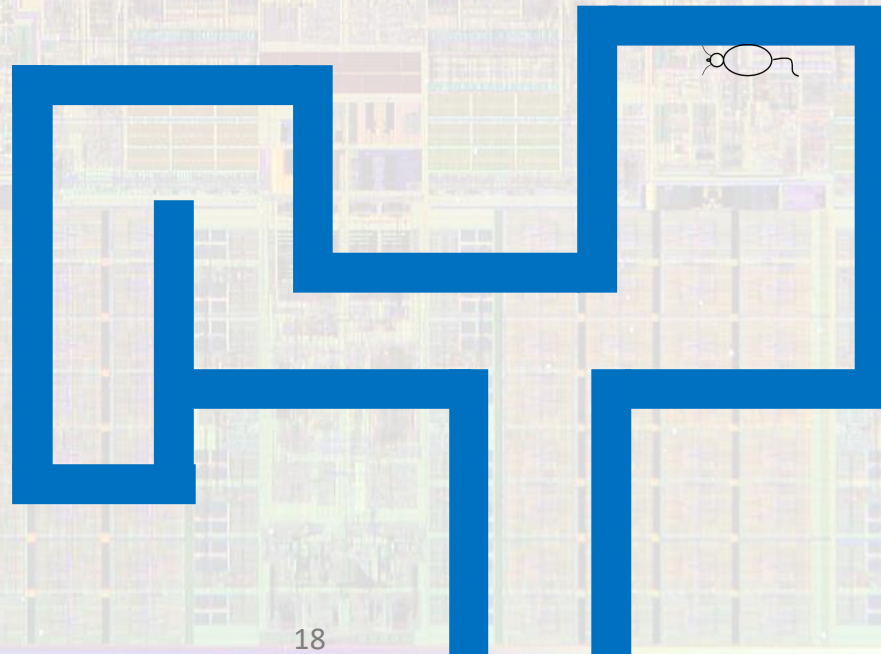
- Robo-Mouse



- Mouse in a maze

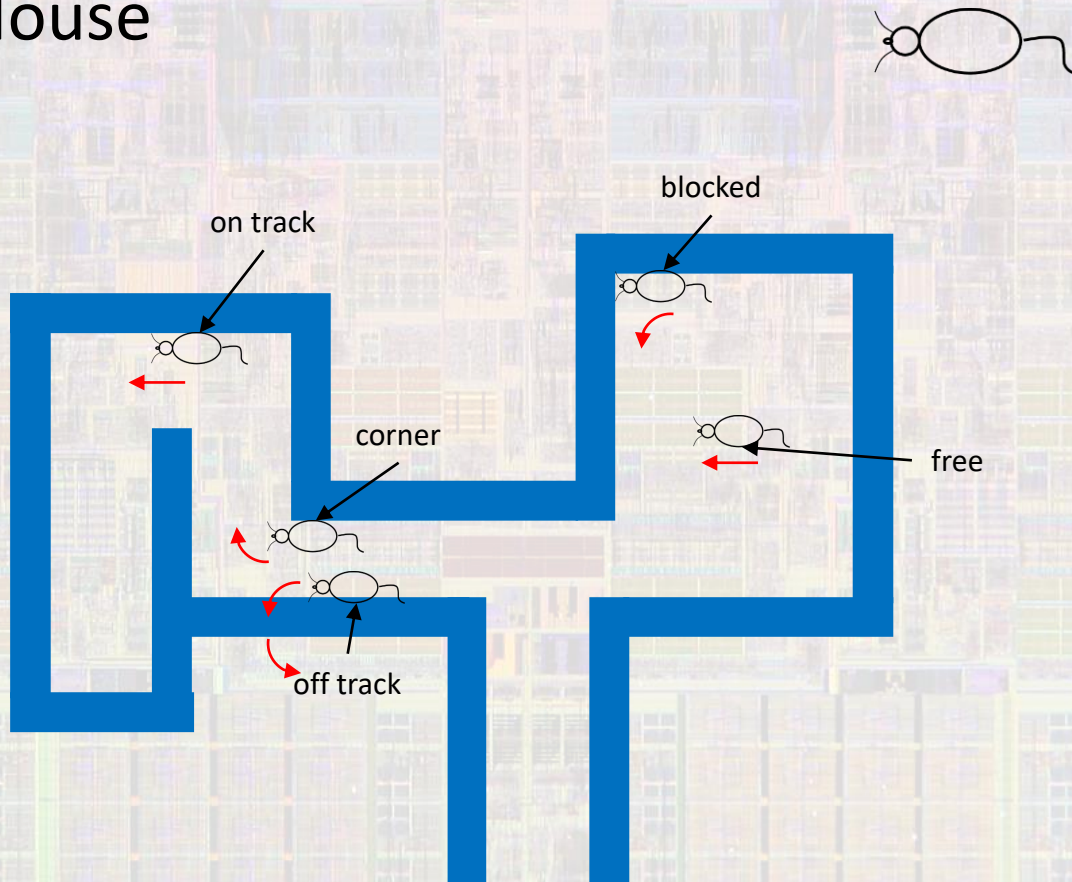
- To get to the exit our mouse knows that all it must do is always stay to one side (left or right)

- *All lanes must be at least wide enough for mouse with 1 whisker not touching*



State Machine Examples

- Robo-Mouse



State Machine Examples

- Robo-Mouse

- States

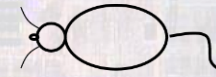
- On Track
 - Corner
 - Off Track
 - Blocked
 - Free

- Inputs

- Left Whisker
 - Right Whisker

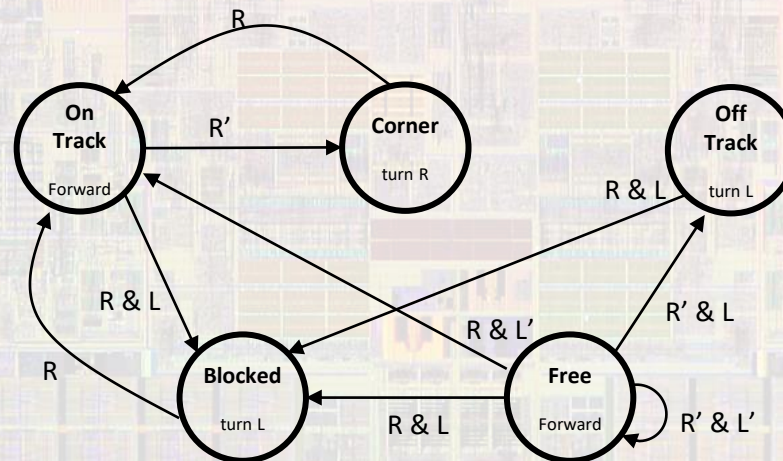
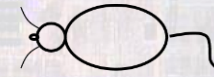
- Outputs

- Forward
 - Turn Left
 - Turn Right



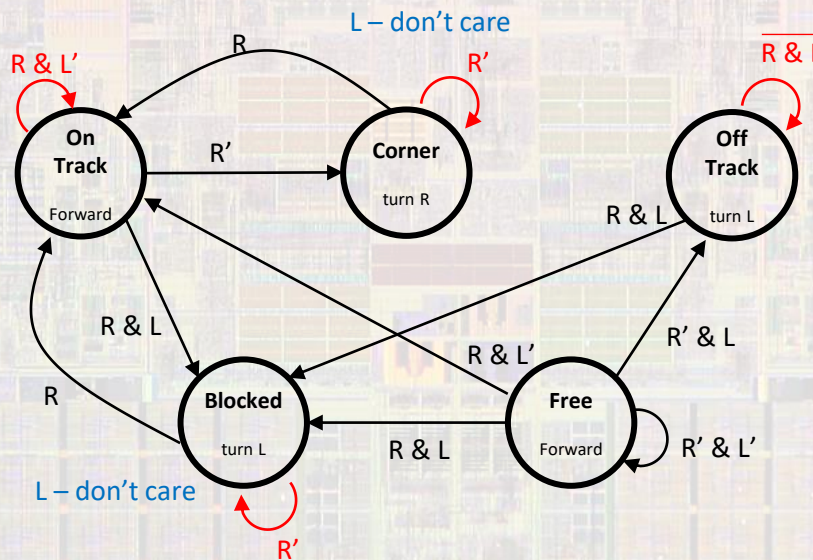
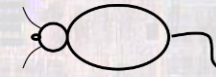
State Machine Examples

- Robo-Mouse



State Machine Examples

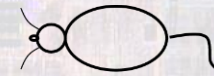
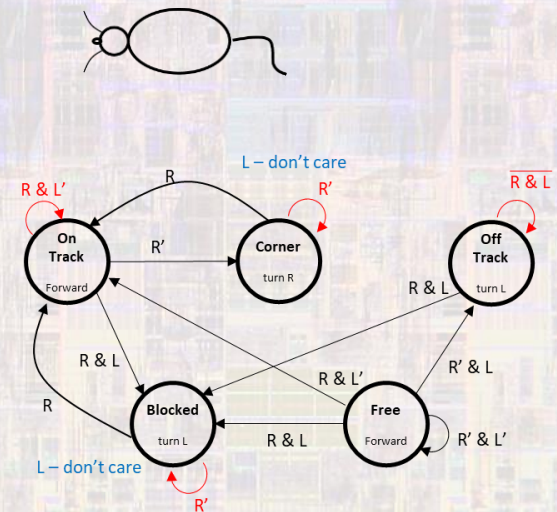
- Robo-Mouse



State Machine Examples

- Robo-Mouse
 - I/O Encoding

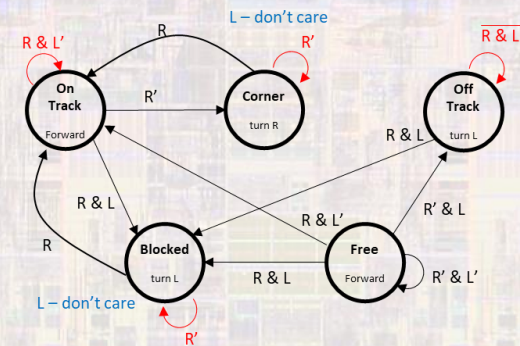
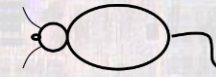
- Inputs
 - Left whisker – 0/1
 - Right whisker – 0/1
- Outputs
 - Forward – 11
 - Turn Left – 10
 - Turn Right - 01



State Machine Examples

- Robo-Mouse
- State Transition Table

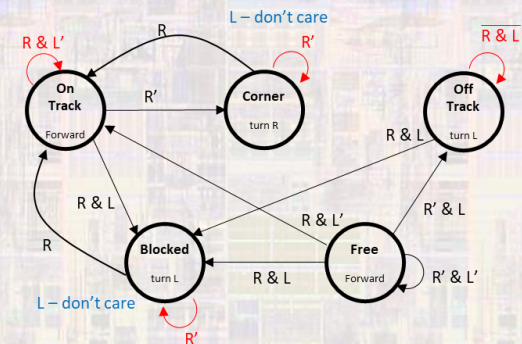
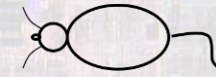
Current State	Inputs		Next State
	L wh	R wh	
On Track	x	N	Corner
On Track	Y	Y	Blocked
On Track	N	Y	On Track
Corner	x	Y	On Track
Corner	x	N	Corner
Blocked	x	Y	On Track
Blocked	X	N	Blocked
Free	N	N	Free
Free	N	Y	Off Track
Free	Y	N	On Track
Free	Y	Y	Blocked
Off Track	N	N	Off Track
Off Track	N	Y	Off Track
Off Track	Y	N	Off Track
Off Track	Y	Y	Blocked



State Machine Examples

- Robo-Mouse
 - Assign values for State Variables

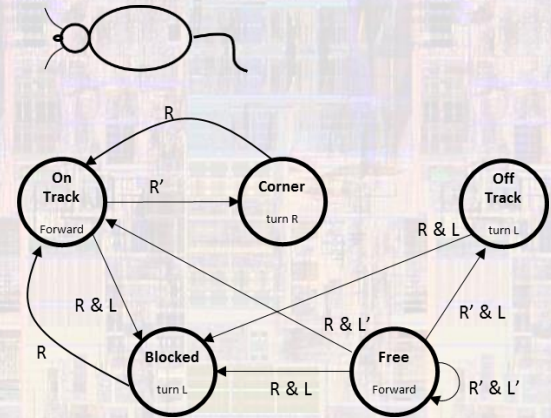
- On Track – 000
- Corner – 001
- Blocked – 010
- Free – 011
- Off Track - 100



State Machine Examples

- Robo-Mouse
- Assign values for State Variables

Current State	Inputs		Next State
	L wh	R wh	
000	x	N	001
000	Y	Y	010
000	N	Y	000
001	x	Y	000
001	x	N	001
010	x	Y	000
010	X	N	010
011	N	N	011
011	N	Y	100
011	Y	N	100
011	Y	Y	010
100	N	N	100
100	N	Y	100
100	Y	N	100
100	Y	Y	010



- On Track – 000
- Corner – 001
- Blocked – 010
- Free – 011
- Off Track - 100

State Machine Examples

- Robo-Mouse
- Minimize logic

		S1				S1'					
		R	R'	R'	R	R	R'	R'	R		
S2	S0'	2	2	2	2	1	1	1	1		
	S0	5	4	6	7	9	8	6	7		
S2'	S0	2	2	3	3	2	2	2	2		
	S0'	9	8	0	1	3	2	0	1		
		1	1	1	1	7	6	4	5		
		3	2	4	5						
		9	8	1	1	3	2	0	1		
			0	0	1						
		L'		L		L'					

		NS2									
		S1		S1'							
		R	R'	R'	R	R	R'	R'	R		
S2	S0'	0	0	0	0	0	1	1	1		
	S0	0	0	0	0	0	0	0	0		
S2'	S0	1	0	1	0	0	0	0	0		
	S0'	0	0	0	0	0	0	0	0		
		L'		L		L'					

		NS1									
		S1		S1'							
		R	R'	R'	R	R	R'	R'	R		
S2	S0'	0	0	0	0	1	0	0	0		
	S0	0	0	0	0	0	0	0	0		
S2'	S0	0	1	0	1	0	0	0	0		
	S0'	0	1	1	0	1	0	0	0		
		L'		L		L'					

		NS0									
		S1		S1'							
		R	R'	R'	R	R	R'	R'	R		
S2	S0'	0	0	0	0	0	0	0	0		
	S0	0	0	0	0	0	0	0	0		
S2'	S0	0	1	0	0	0	1	1	0		
	S0'	0	0	0	0	0	1	1	0		
		L'		L		L'					

State Machine Examples

- Robo-Mouse
- Minimize logic

NS2

		S1				S1'					
		R	R'	R'	R	R	R'	R'	R		
S2	S0'	0	0	0	0	0	1	1	1		
	S0	0	0	0	0	0	0	0	0		
S2'	S0	1	0	1	0	0	0	0	0		
	S0'	0	0	0	0	0	0	0	0		
		L'		L		L'					

$$S0S1S2'L'R + S0S1S2'LR' + S0'S1'S2R' + S0'S1'S2L'$$

NS1

		S1				S1'					
		R	R'	R'	R	R	R'	R'	R		
S2	S0'	0	0	0	0	0	1	0	0		
	S0	0	0	0	0	0	0	0	0		
S2'	S0	0	1	0	1	0	0	0	0		
	S0'	0	1	1	0	1	0	0	0		
		L'		L		L'					

$$S0'S1'S2LR + S0S1S2'LR + S0'S1'S2'LR + S1S2'L'R' + S0'S1S2'R'$$

NS0

		S1				S1'					
		R	R'	R'	R	R	R'	R'	R		
S2	S0'	0	0	0	0	0	0	0	0		
	S0	0	0	0	0	0	0	0	0		
S2'	S0	0	1	0	0	0	1	1	0		
	S0'	0	0	0	0	0	1	1	0		
		L'		L		L'					

$$S0S1S2'L'R' + S1'S2'R'$$