Embedded System Design Project

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Introduction

- Use of the LogixPro PLC simulator to solve exercises of PLC programming
- 2 different approach:
  - Output based: a rung for each output
  - FSA based: system modeled on a finite state machine (Moore, Mealy)

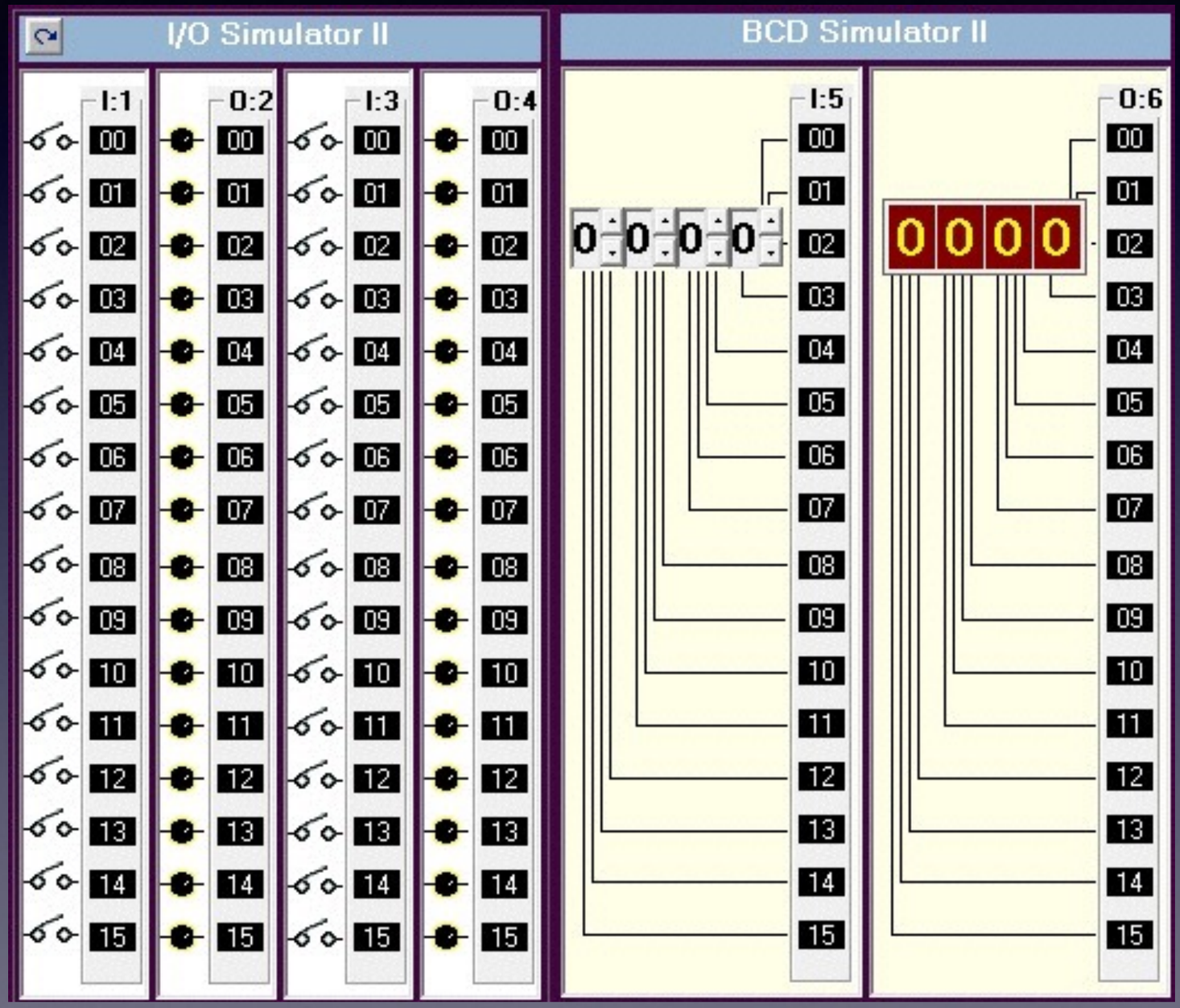
Excercises

1. Relay Logic
2. Door Simulator
3. Silo
4. Batch Mixing

Excercise 1

Relay Logic

System Overview



Controlling one light from two locations

- Create, enter and test a program which will perform the common electrical function of controlling a light from two different locations.

- Utilize toggle switch (I:1/00) and switch (I:1/01) to control Lamp (O:2/00)... (Hint: If both switches are On or if both switches are Off, then the Lamp should be On!)

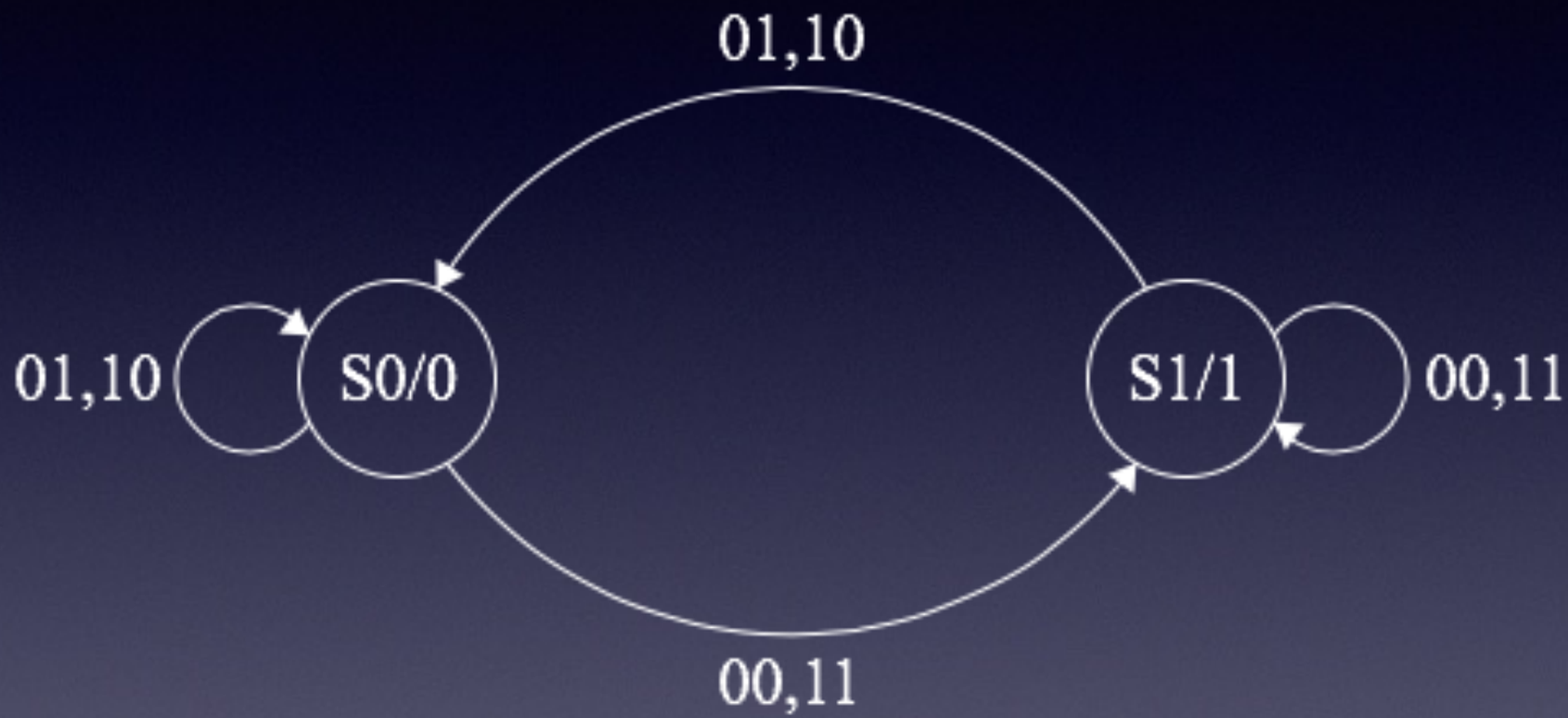
Truth table

Switch 0	Switch 1	Lamp
0	0	1
0	1	0
1	0	0
1	1	1

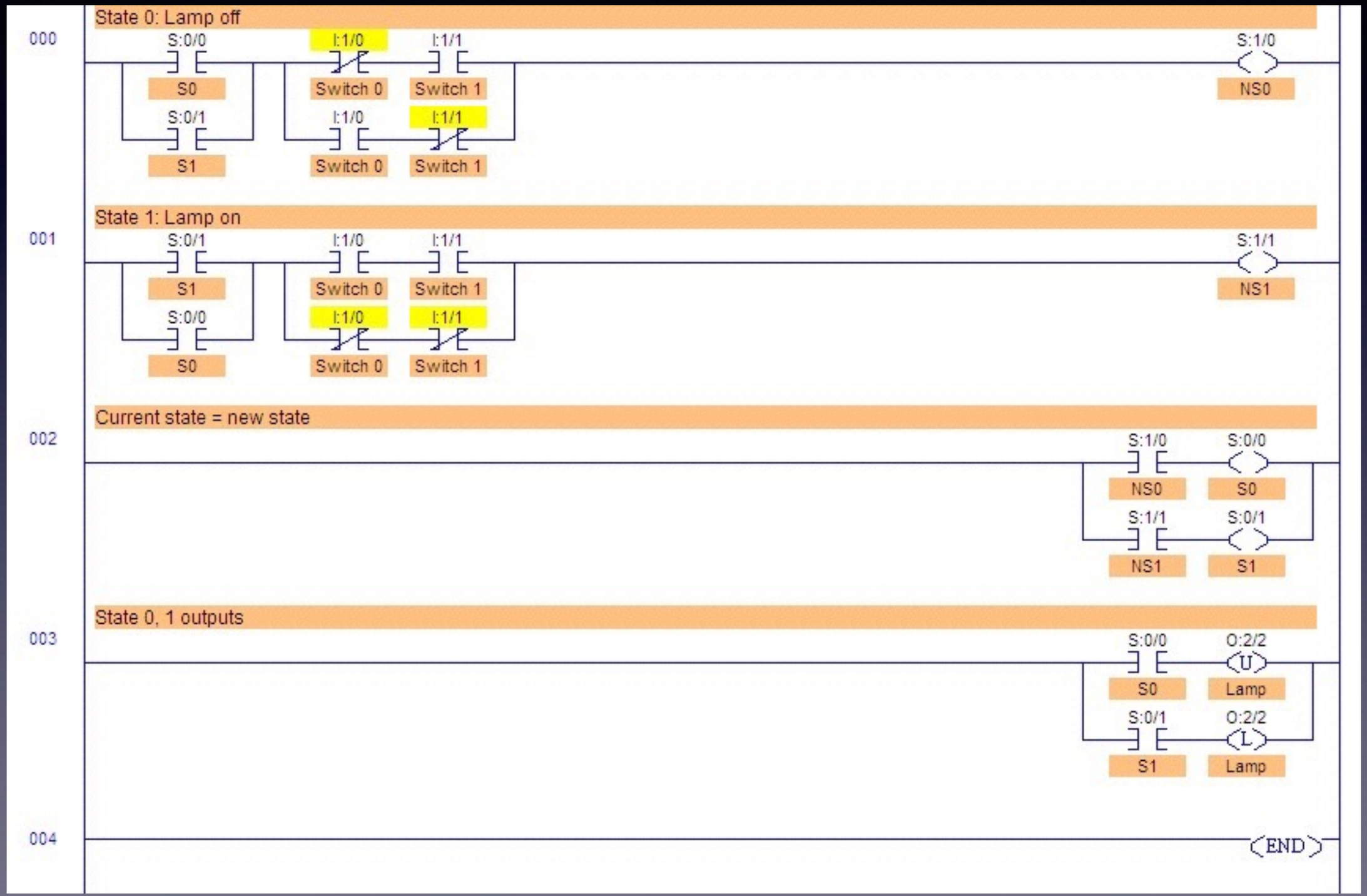
Ladder


000
I:1/0
Switch 0
I:1/1
Switch 1
I:1/1
Switch 1
I:1/0
Switch 0
O:2/2
Lamp
001
END

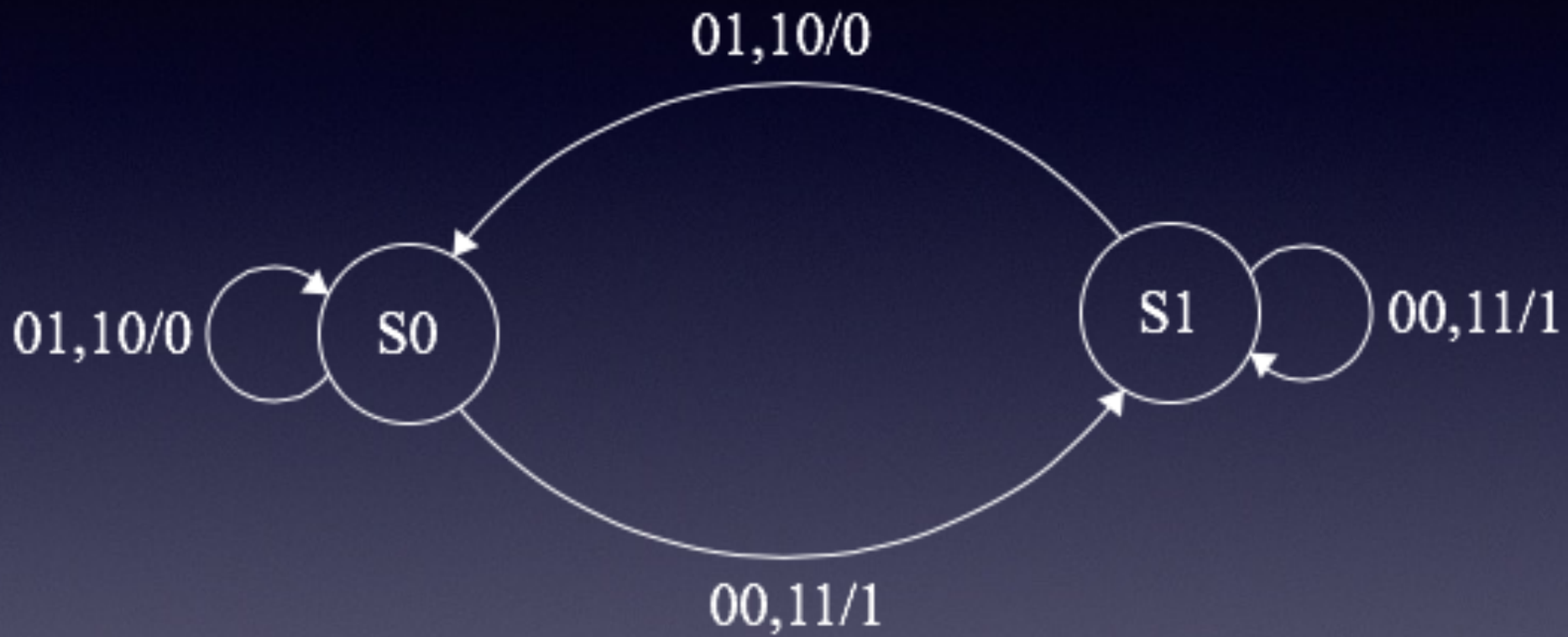
Moore Diagram



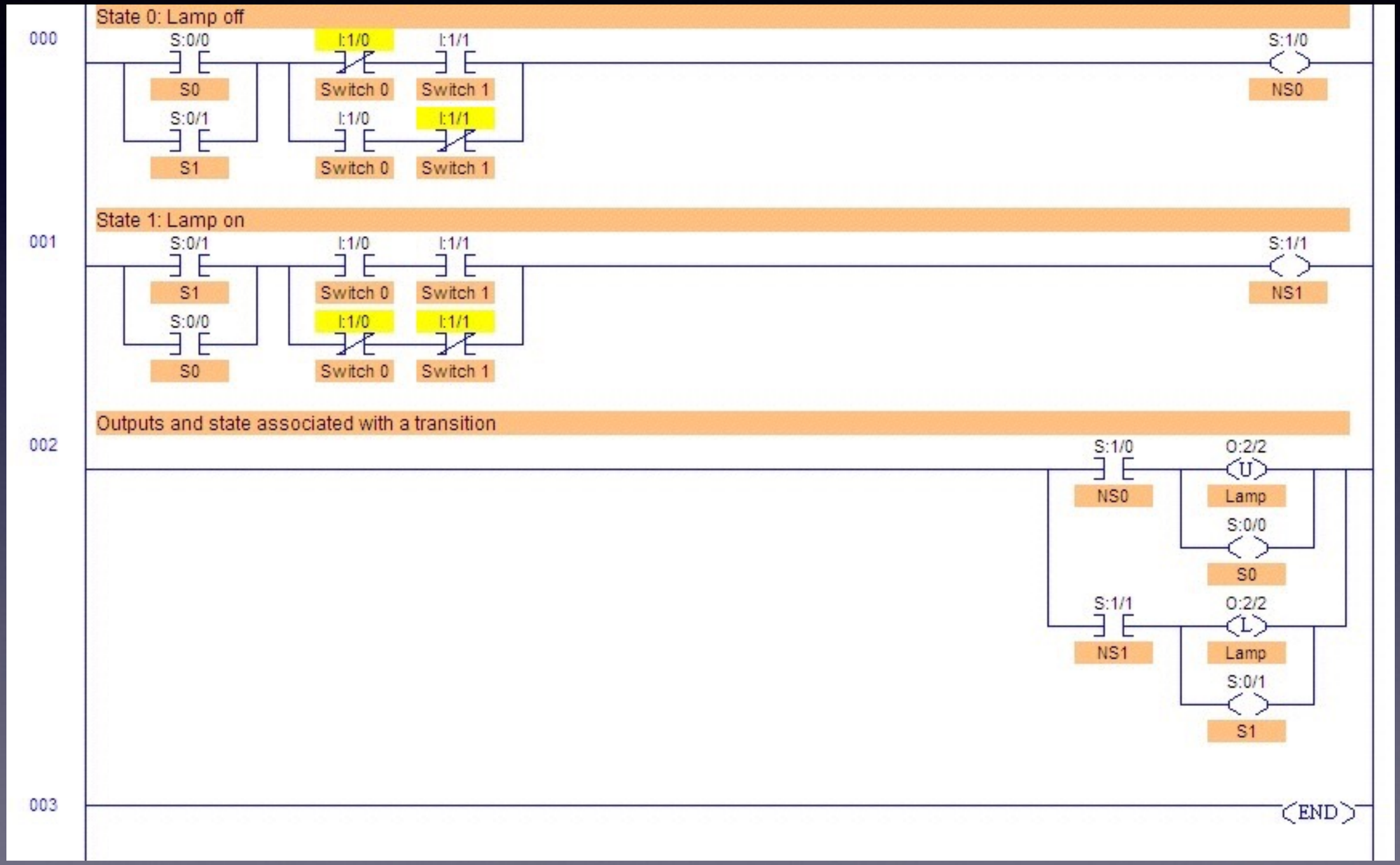
Moore based ladder



Mealy Diagram



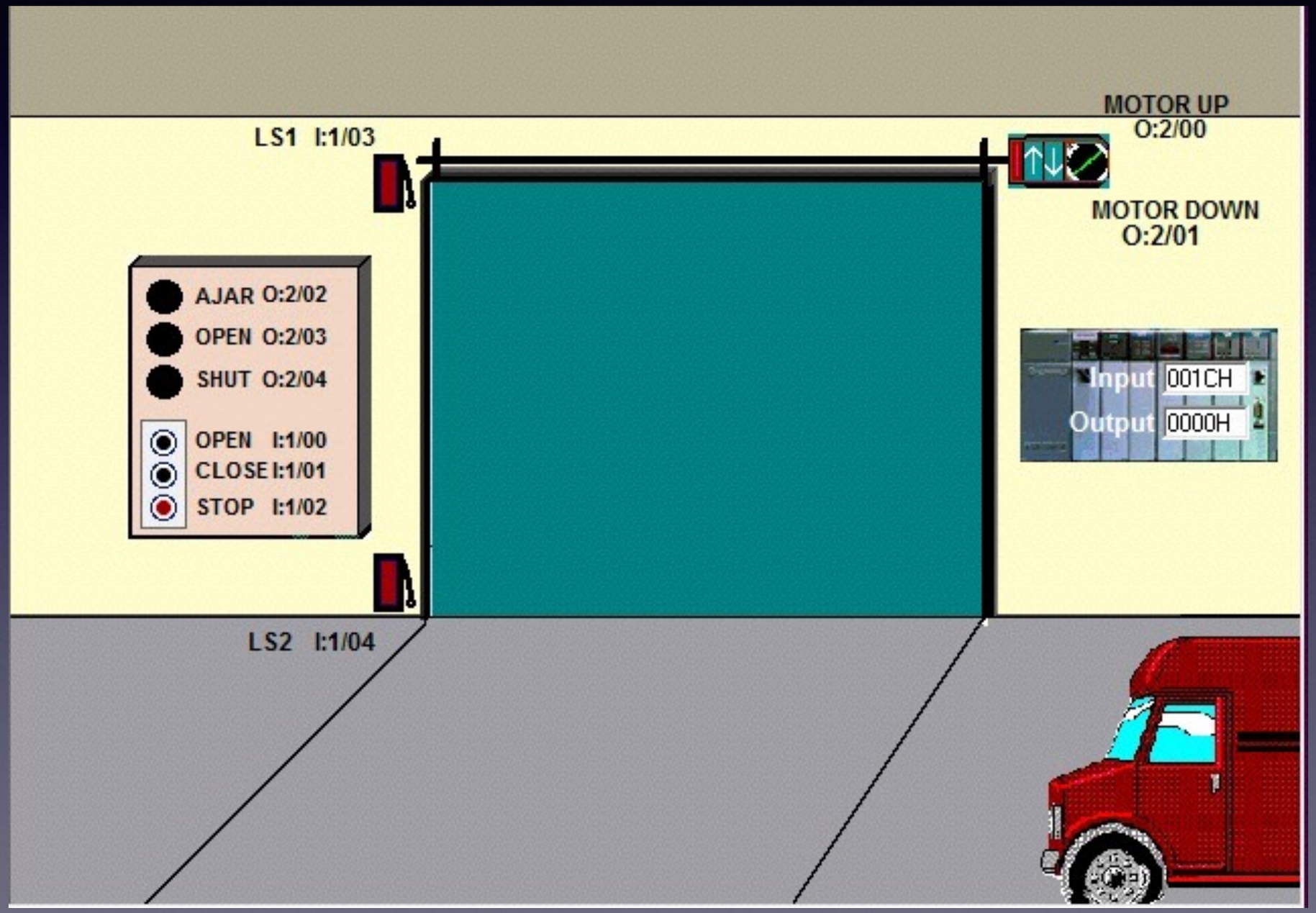
Mealy based ladder



Excercise 2

Door Simulator

System Overview



Excercise 2.1

- Pressing the Open Switch will cause the door to move upwards (open) if not already fully open. The opening operation will continue as long as the switch is held down. If the switch is released, or if limit switch LS1 opens, the door movement will halt immediately.

- Pressing the Close Switch will cause the door to move down (close) if not already fully closed. The closing operation will continue as long as the switch is held down. If the switch is released, or if limit switch LS2 closes, the door movement will halt immediately.

- If the Door is already fully opened, Pressing the Open Switch will Not energize the motor.

- If the Door is already fully closed, Pressing the Close Switch will Not energize the motor.

- Under no circumstance will both motor windings be energized at the same time.

- The Open Lamp will be illuminated if the door is in the Fully Open position.

- The Shut Lamp will be illuminated if the door is in the Fully Closed position.

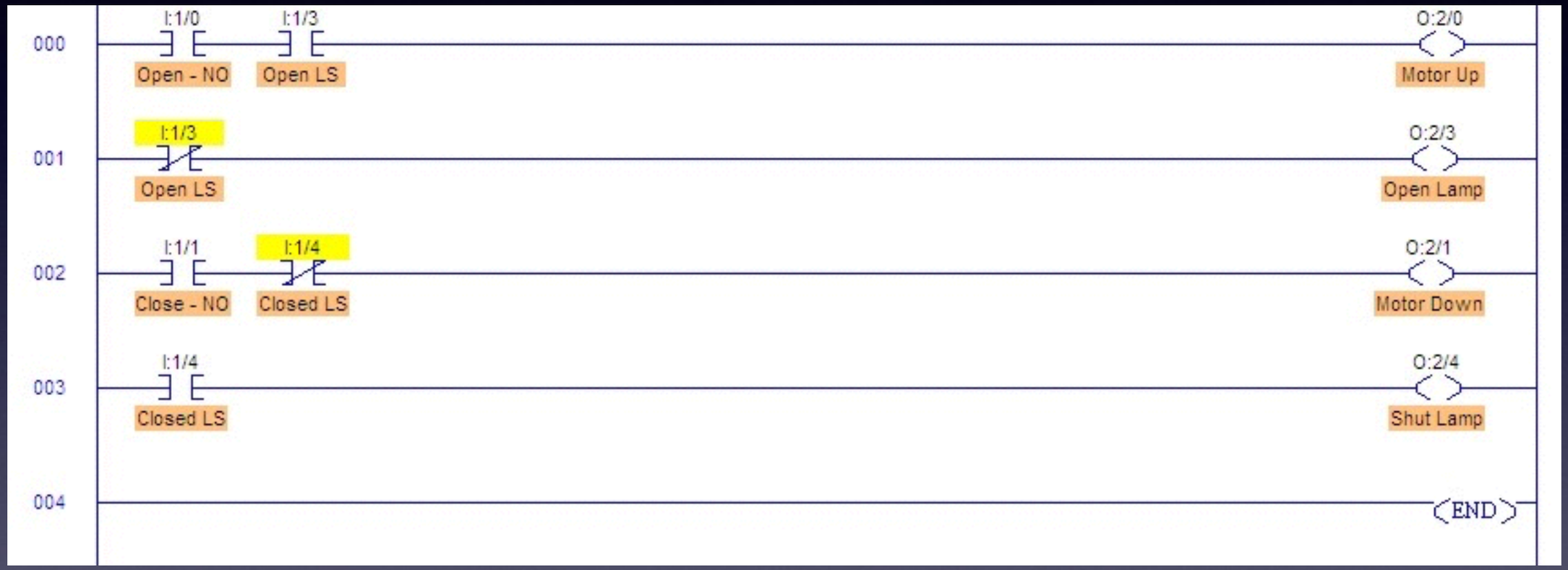
Inputs table

Name	Meaning
I:1/0	Open switch
I:1/1	Close switch
I:1/3	Open limit switch
I:1/4	Closed limit switch

Outputs table

Name	Meaning
O:2/0	Motor up
O:2/1	Motor down
O:2/3	Open lamp
O:2/4	Shut lamp

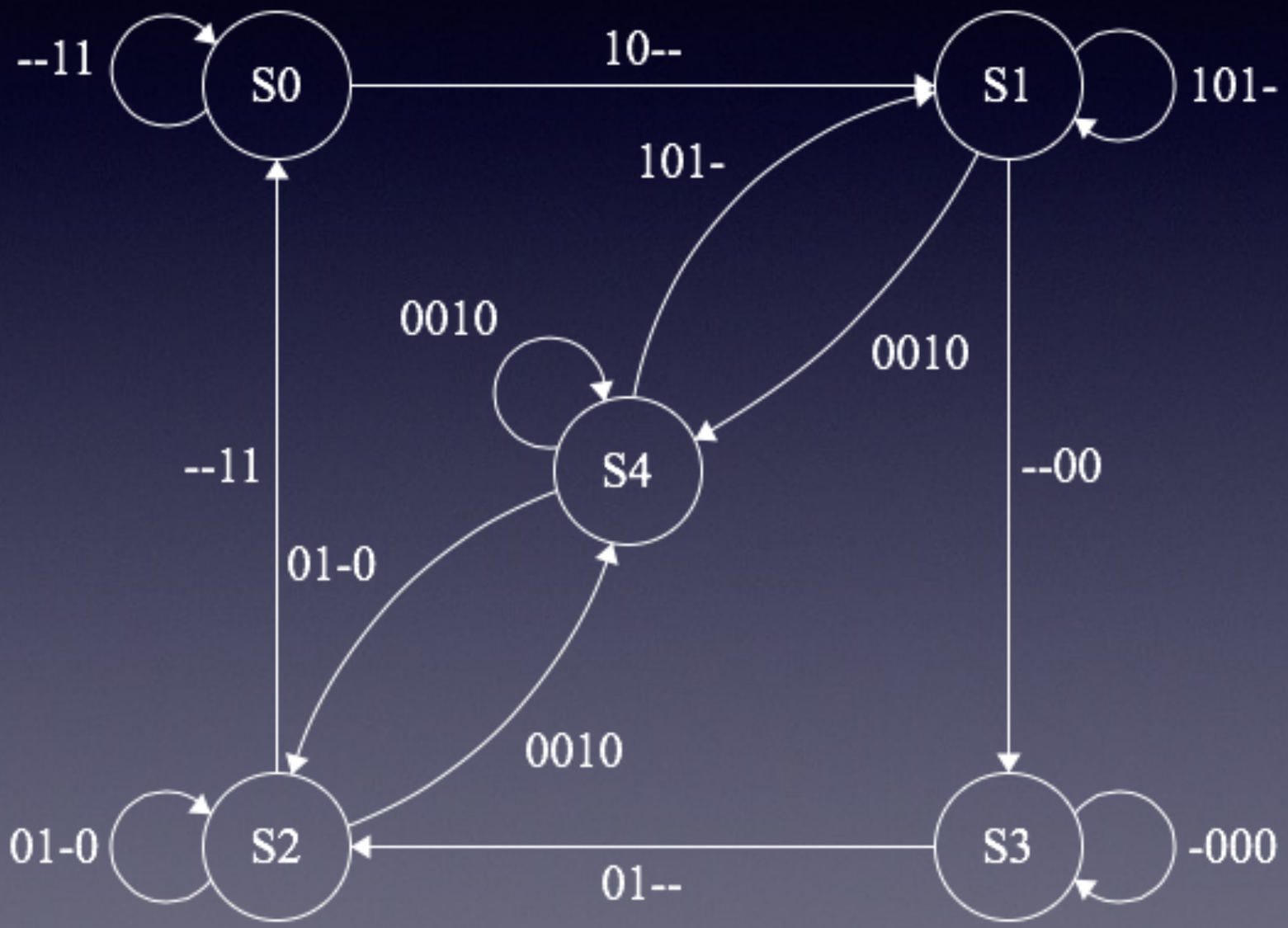
Ladder


000
I:1/0
Open - NO
I:1/3
Open LS
O:2/0
Motor Up
001
I:1/3
Open LS
O:2/3
Open Lamp
002
I:1/1
Close - NO
I:1/4
Closed LS
O:2/1
Motor Down
003
I:1/4
Closed LS
O:2/4
Shut Lamp
004
END

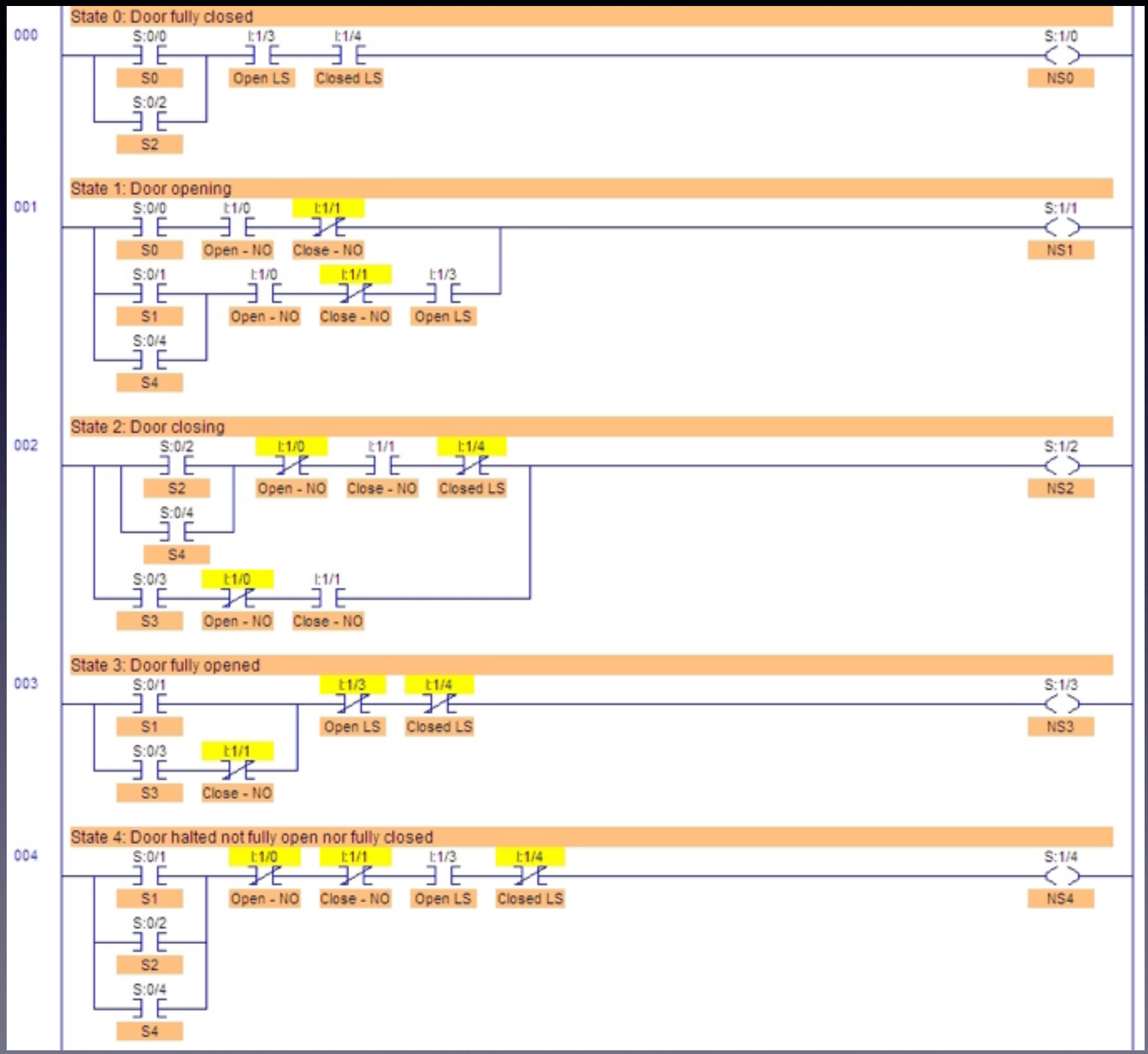
State table

Name	Meaning	Motor Up	Motor Down	Open Lamp	Shut Lamp
S0	Door fully closed	0	0	0	**1**
S1	Door opening	**1**	0	0	0
S2	Door closing	0	**1**	0	0
S3	Door fully open	0	0	**1**	0
S4	Door halted	0	0	0	0

Moore Diagram



Moore based ladder



Excercise 2.2

- Door movement will halt immediately when the Stop Switch is initially pressed, and will remain halted if the switch is released.

- Pressing the Open Switch will cause the door to Open if not already fully open. The opening operation will continue to completion even if the switch is released.

- Pressing the Close Switch will cause the door to Close if not already fully shut. The closing operation will continue to completion even if the Switch is released.

- The Ajar Lamp will be illuminated if the door is NOT in either the fully closed or fully opened position.

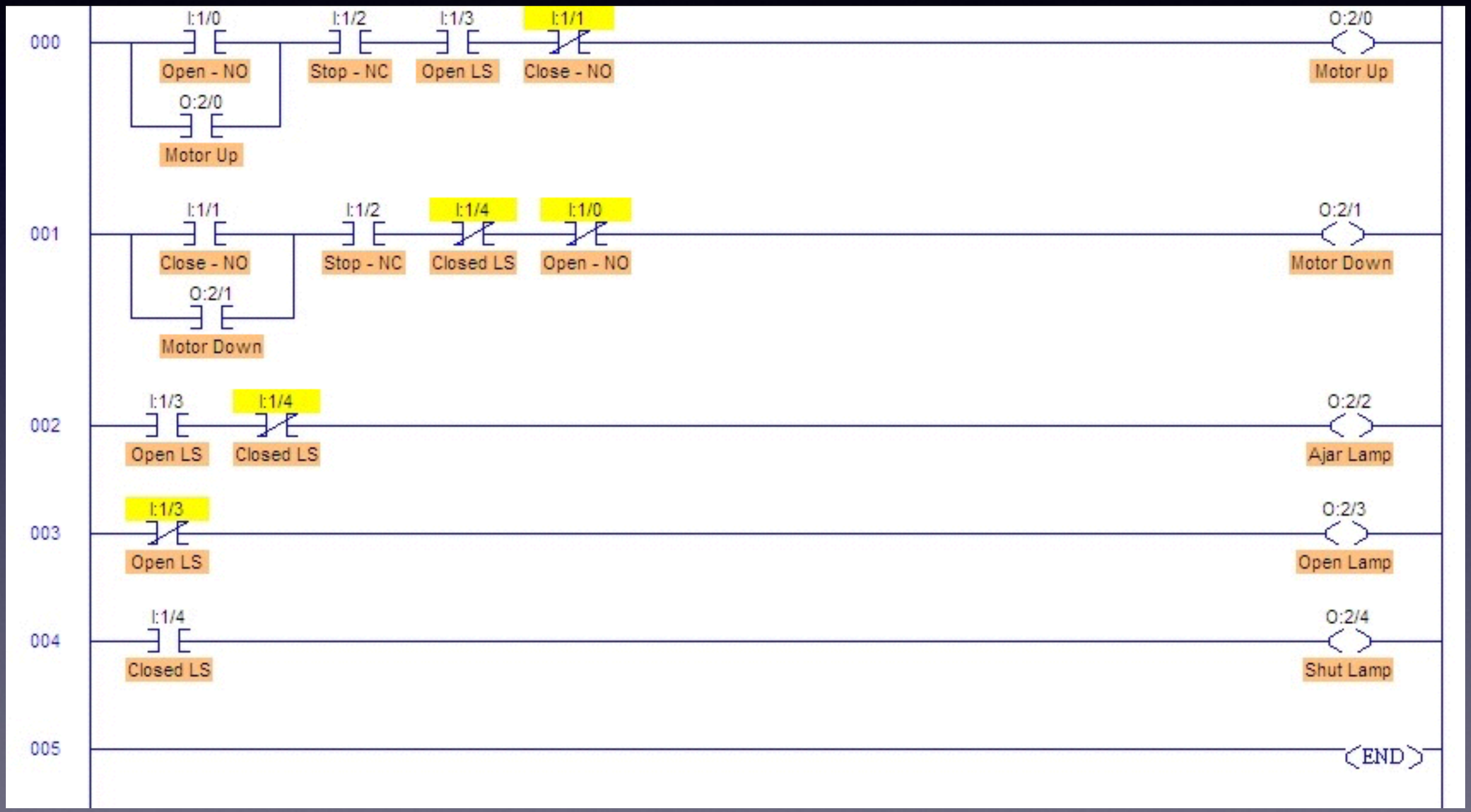
Inputs table

Name	Meaning
I:1/0	Open switch
I:1/1	Close switch
I:1/2	Stop switch
I:1/3	Open limit switch
I:1/4	Closed limit switch

Outputs table

Name	Meaning
O:2/0	Motor up
O:2/1	Motor down
O:2/2	Ajar lamp
O:2/3	Open lamp
O:2/4	Shut lamp

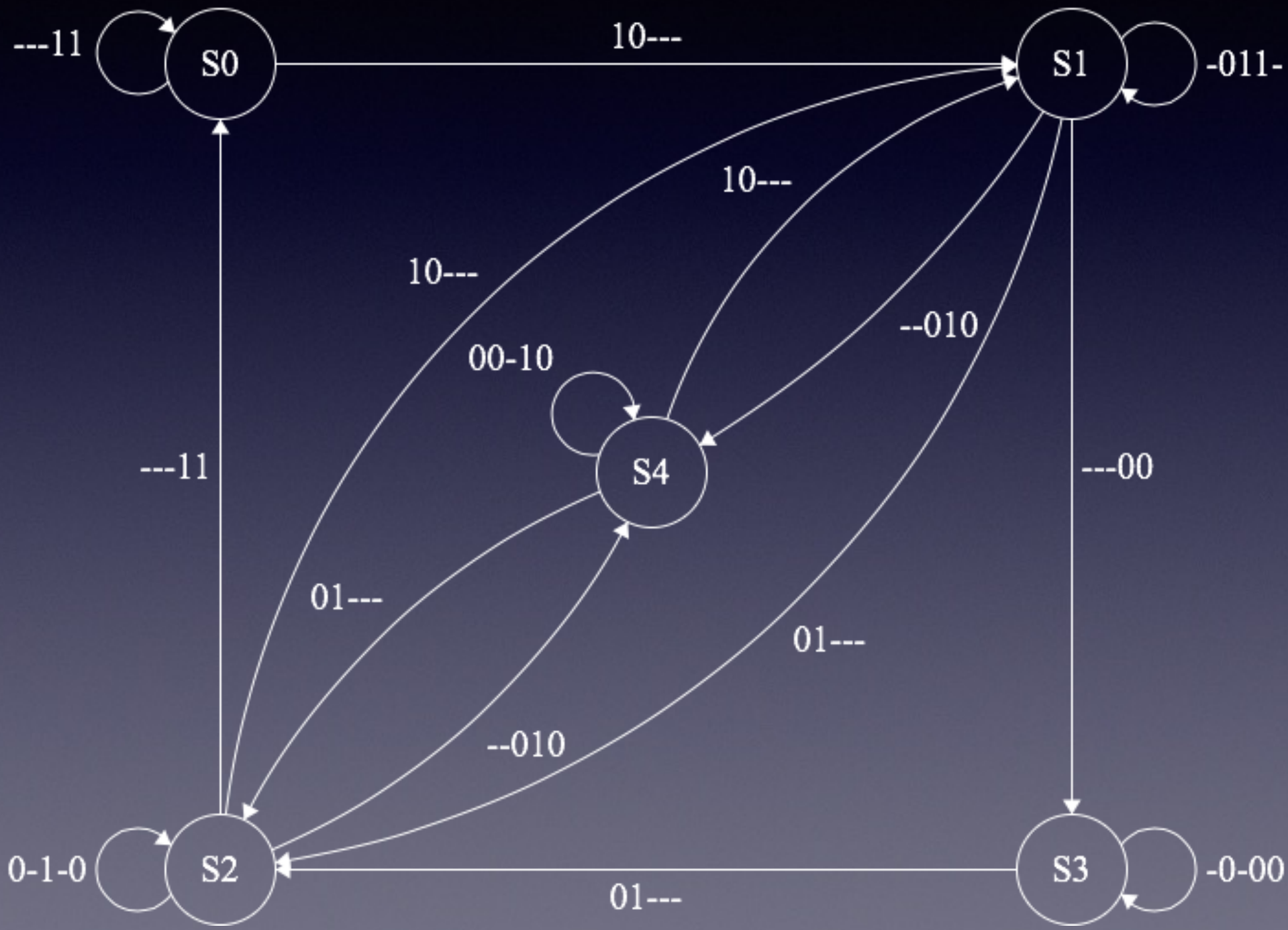
Ladder


000
I:1/0
Open - NO
O:2/0
Motor Up
I:1/2
Stop - NC
I:1/3
Open LS
I:1/1
Close - NO
O:2/0
Motor Up
001
I:1/1
Close - NO
O:2/1
Motor Down
I:1/2
Stop - NC
I:1/4
Closed LS
I:1/0
Open - NO
O:2/1
Motor Down
002
I:1/3
Open LS
I:1/4
Closed LS
O:2/2
Ajar Lamp
003
I:1/3
Open LS
O:2/3
Open Lamp
004
I:1/4
Closed LS
O:2/4
Shut Lamp
005
END

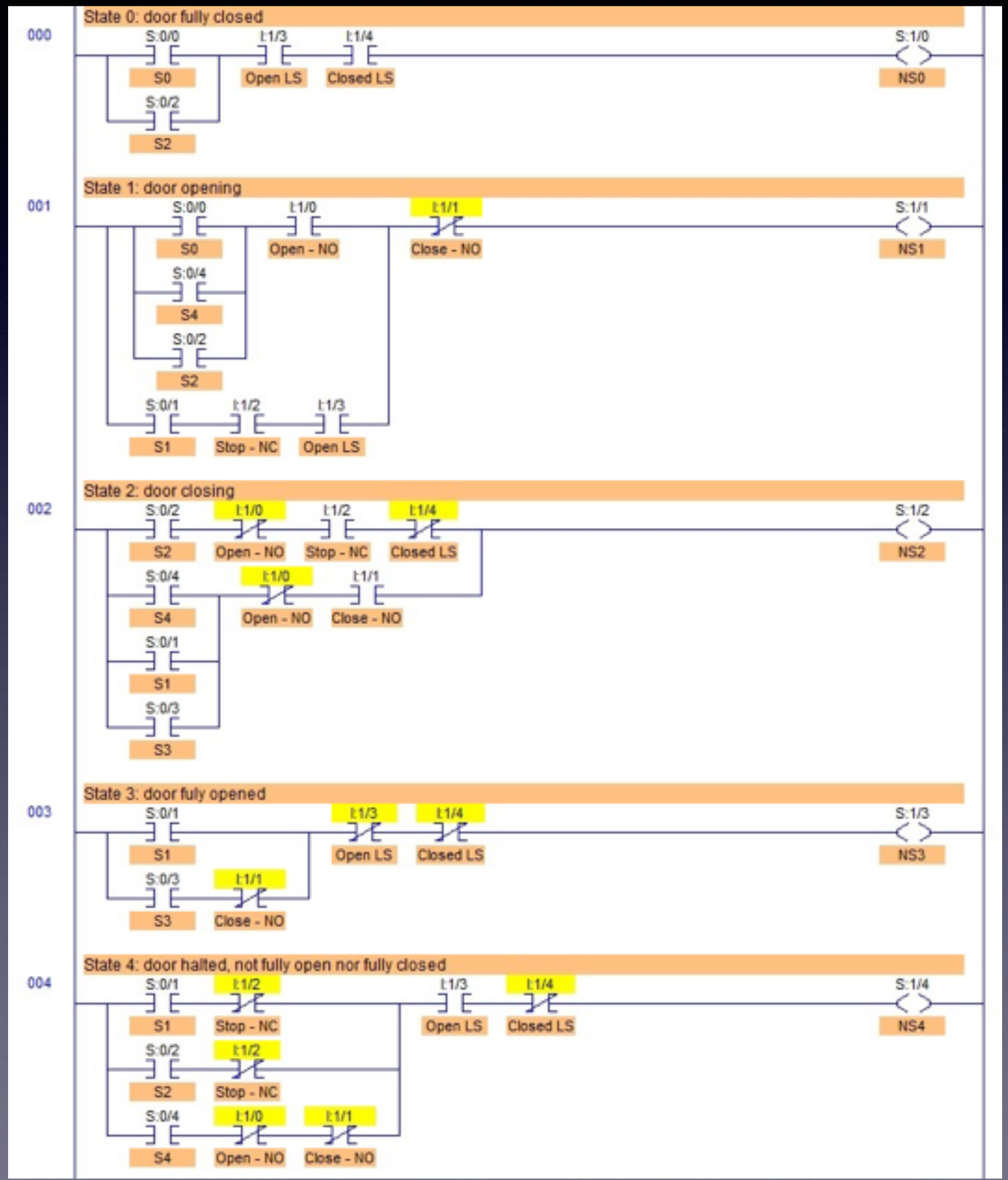
State table

Name	Meaning	Motor Up	Motor Down	Ajar Lamp	Open Lamp	Shut Lamp
S0	Door fully closed	0	0	0	0	**1**
S1	Door opening	**1**	0	0	0	0
S2	Door closing	0	**1**	0	0	0
S3	Door fully open	0	0	0	**1**	0
S4	Door halted	0	0	**1**	0	0

Moore Diagram



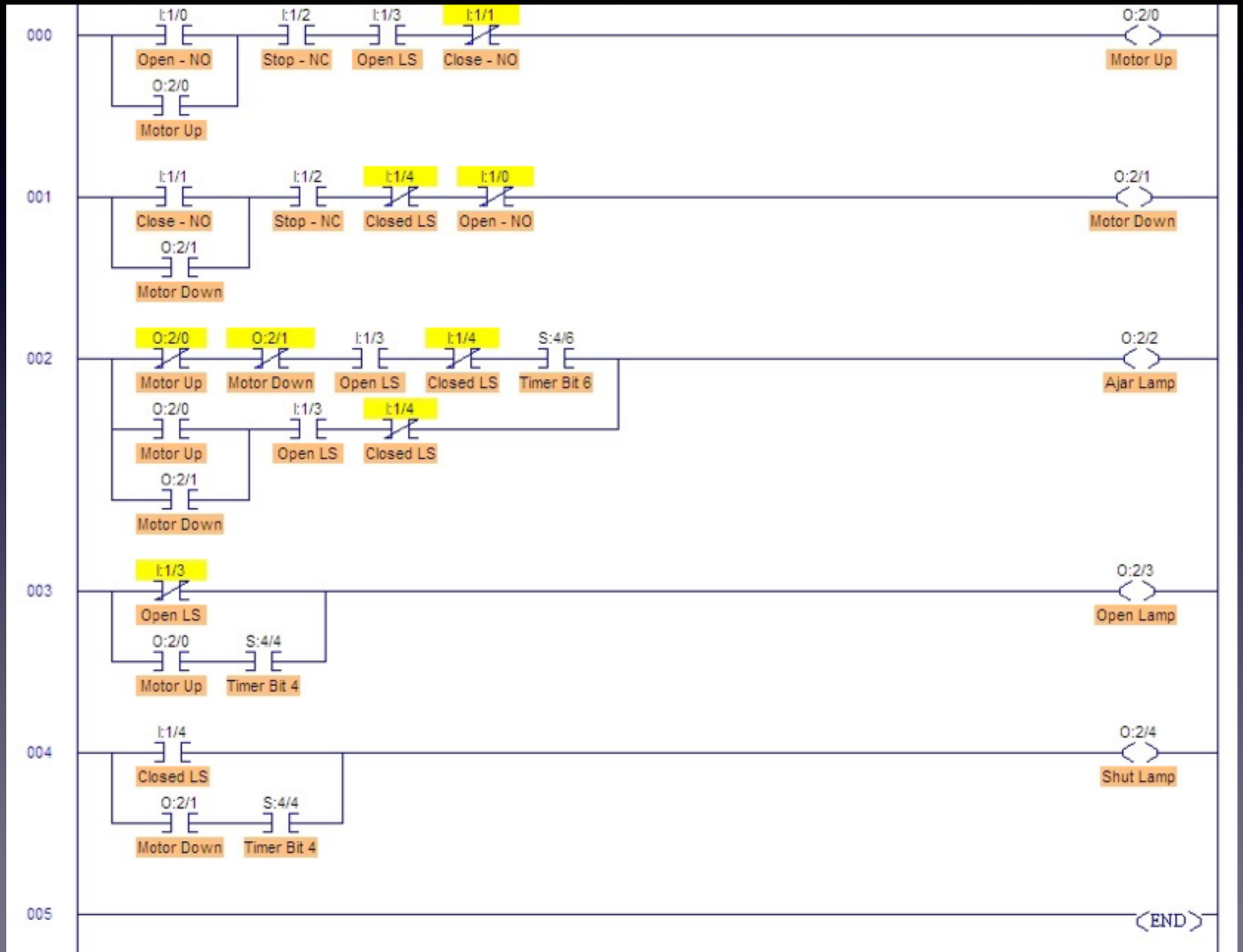
Moore based ladder



Excercise 2.3

- If the Door is fully open, the Open lamp will be energized but not flashing as was the case before.
- If the Door is opening, the Open lamp will flash while the door is in motion.
- If the Door is fully closed, the Shut lamp will be energized but not flashing as was the case before.
- If the Door is closing, the Shut lamp will flash while the door is in motion.
- The Ajar Lamp will flash if the door is stationary, and is not in the fully open or fully closed position. The Ajar Lamp will flash at a slower rate (1/4) then the other lamps.
- The Ajar Lamp will be illuminated in a steady state if the door is in motion.

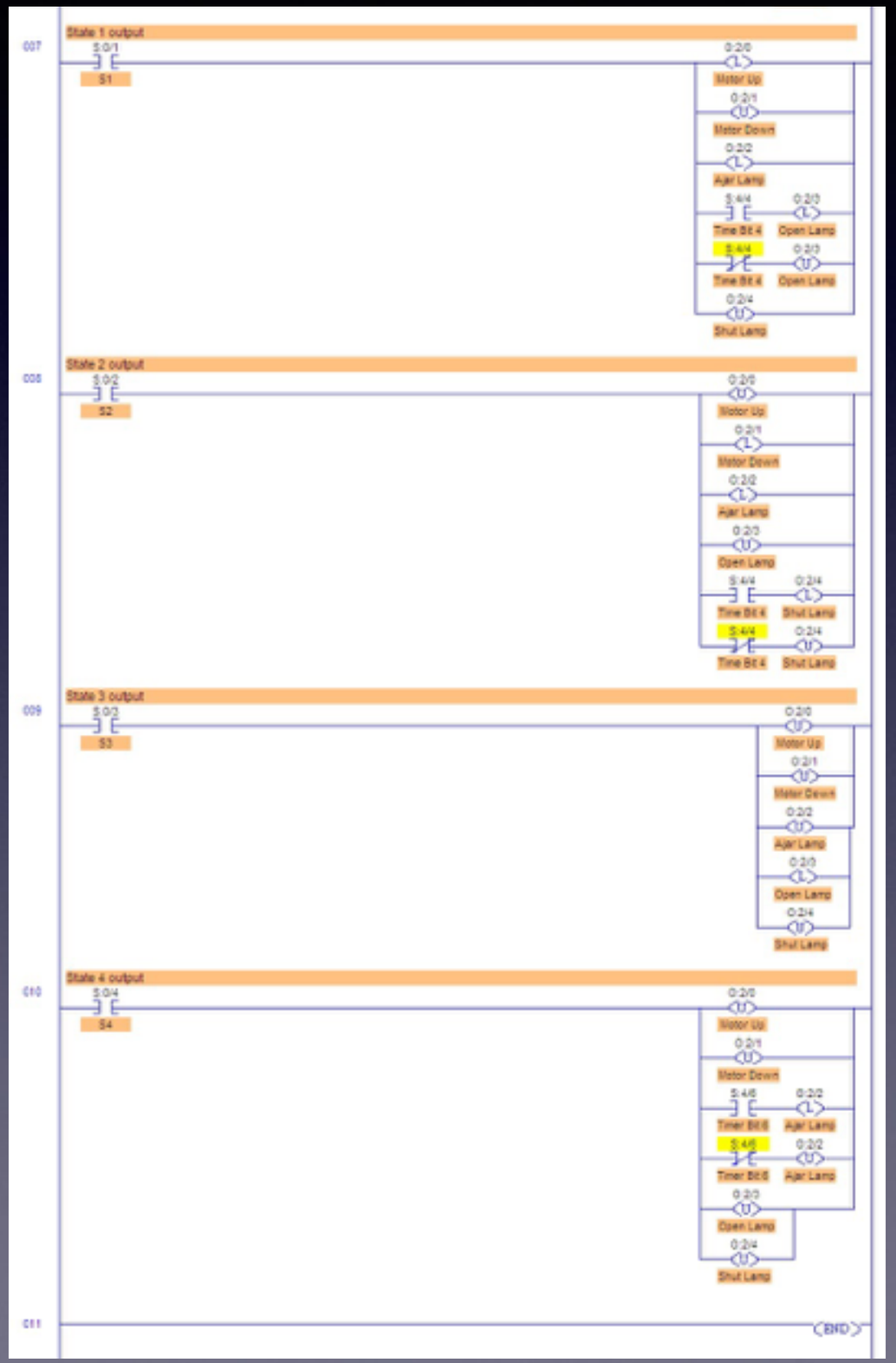
Ladder


000
I:1/0
Open - NO
I:1/2
Stop - NC
I:1/3
Open LS
I:1/1
Close - NO
O:2/0
Motor Up
O:2/0
Motor Up
001
I:1/1
Close - NO
I:1/2
Stop - NC
I:1/4
Closed LS
I:1/0
Open - NO
O:2/1
Motor Down
O:2/1
Motor Down
002
O:2/0
Motor Up
O:2/1
Motor Down
I:1/3
Open LS
I:1/4
Closed LS
S:4/6
Timer Bit 6
O:2/2
Ajar Lamp
O:2/0
Motor Up
I:1/3
Open LS
I:1/4
Closed LS
O:2/1
Motor Down
003
I:1/3
Open LS
O:2/3
Open Lamp
O:2/0
Motor Up
S:4/4
Timer Bit 4
004
I:1/4
Closed LS
O:2/4
Shut Lamp
O:2/1
Motor Down
S:4/4
Timer Bit 4
005
END

State table

Name	Meaning	Motor Up	Motor Down	Ajar Lamp	Open Lamp	Shut Lamp
S0	Door fully closed	0	0	0	0	**1**
S1	Door opening	**1**	0	**1**	**L**	0
S2	Door closing	0	**1**	**1**	0	**L**
S3	Door fully open	0	0	0	**1**	0
S4	Door halted	0	0	**L**	0	0

Moore based ladder



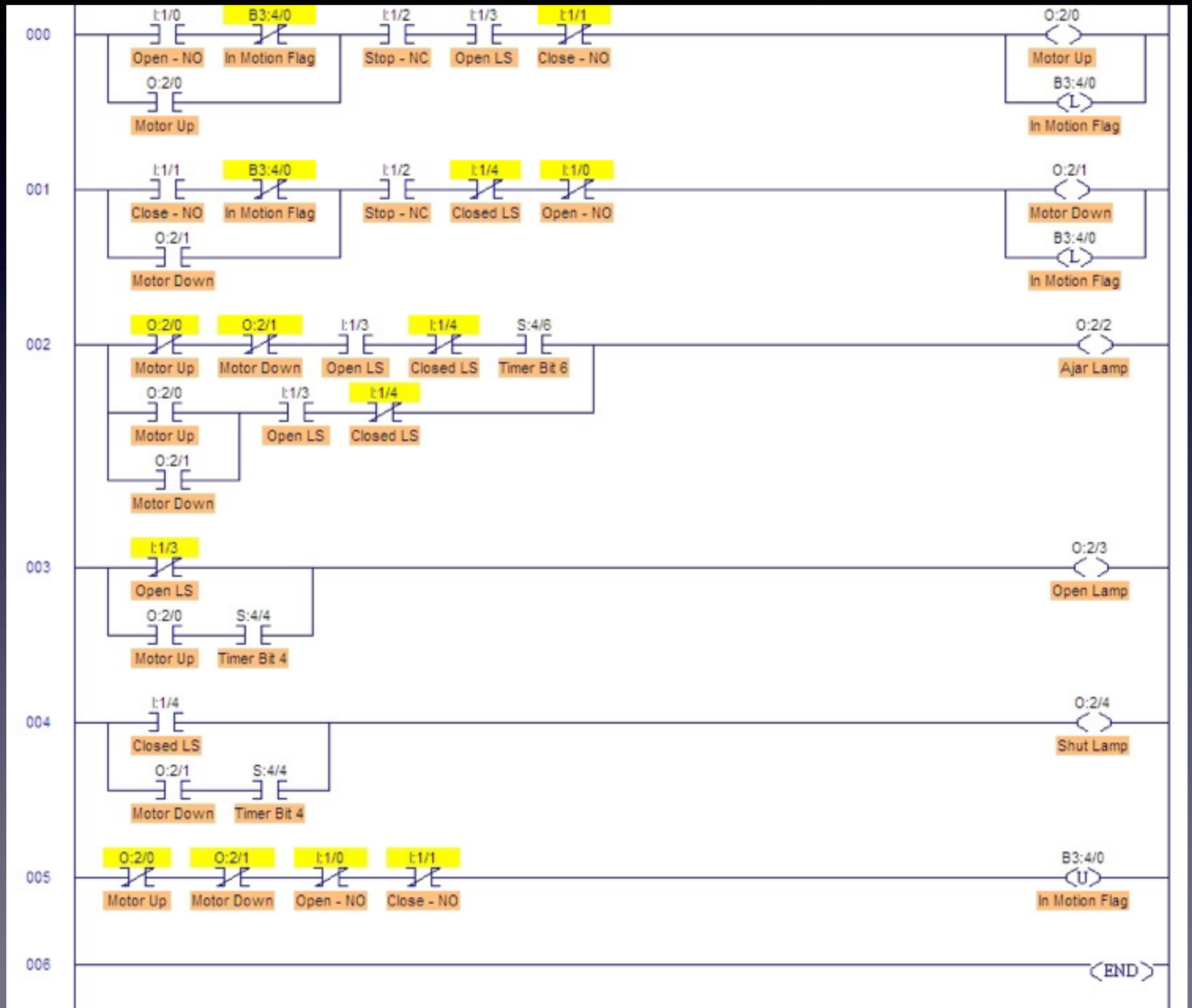
Excercise 2.4

- If the door is currently opening, pressing the Close Switch will immediately halt movement. Door movement will remain halted when the switch is released.

- If the door is currently closing, pressing the Open Switch will immediately halt movement. Door movement will remain halted when the switch is released.

- Once movement is halted, and all push buttons have been released, then door motion in either direction can once again be initiated by pressing the appropriate Open or Close button.

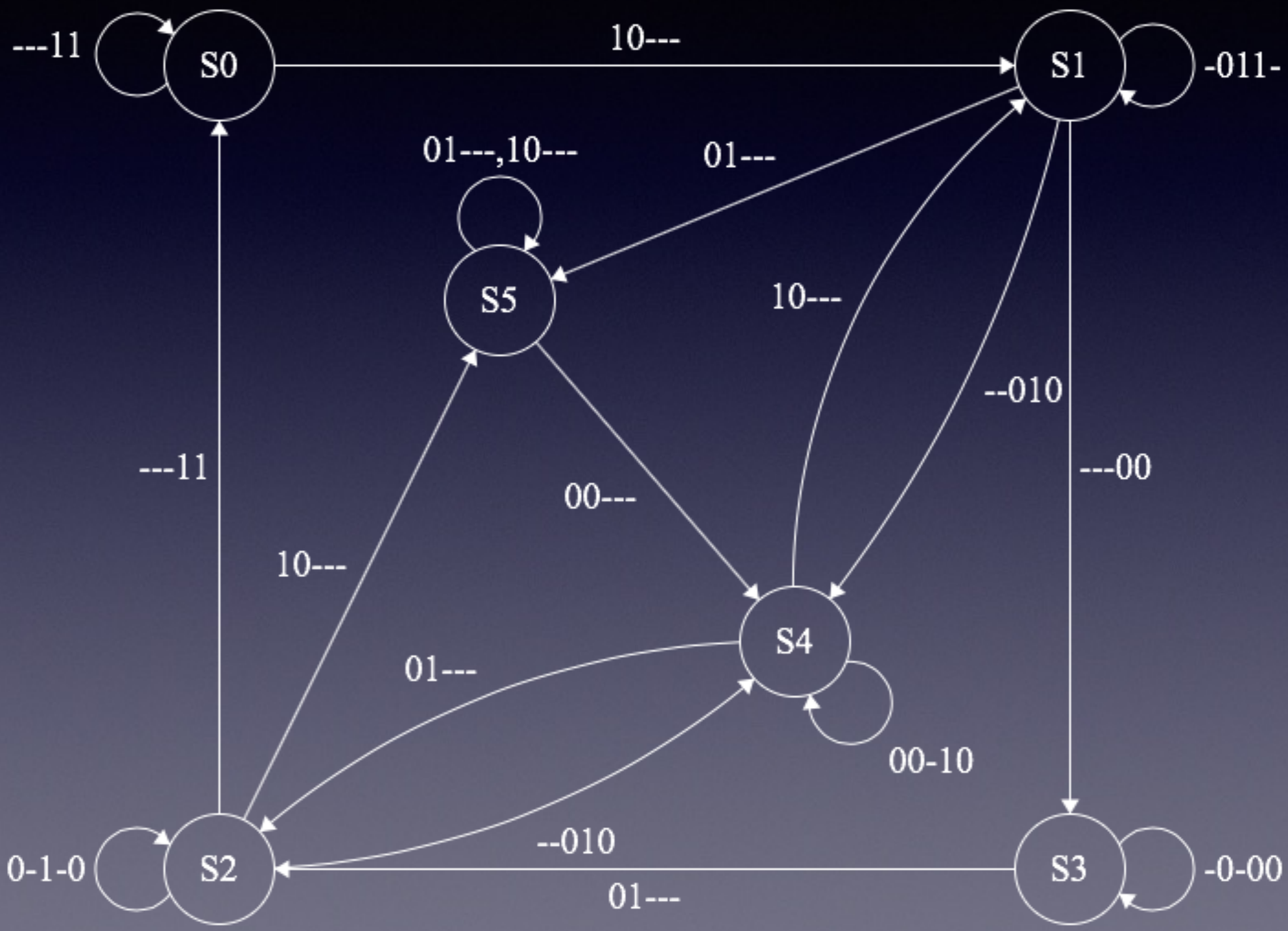
Ladder


000
I:1/0
Open - NO
B3:4/0
In Motion Flag
I:1/2
Stop - NC
I:1/3
Open LS
I:1/1
Close - NO
O:2/0
Motor Up
O:2/0
Motor Up
B3:4/0
In Motion Flag
001
I:1/1
Close - NO
B3:4/0
In Motion Flag
I:1/2
Stop - NC
I:1/4
Closed LS
I:1/0
Open - NO
O:2/1
Motor Down
O:2/1
Motor Down
B3:4/0
In Motion Flag
002
O:2/0
Motor Up
O:2/1
Motor Down
I:1/3
Open LS
I:1/4
Closed LS
S:4/6
Timer Bit 6
O:2/2
Ajar Lamp
O:2/0
Motor Up
I:1/3
Open LS
I:1/4
Closed LS
O:2/1
Motor Down
003
I:1/3
Open LS
O:2/3
Open Lamp
O:2/0
Motor Up
S:4/4
Timer Bit 4
004
I:1/4
Closed LS
O:2/4
Shut Lamp
O:2/1
Motor Down
S:4/4
Timer Bit 4
005
O:2/0
Motor Up
O:2/1
Motor Down
I:1/0
Open - NO
I:1/1
Close - NO
B3:4/0
In Motion Flag
006
END

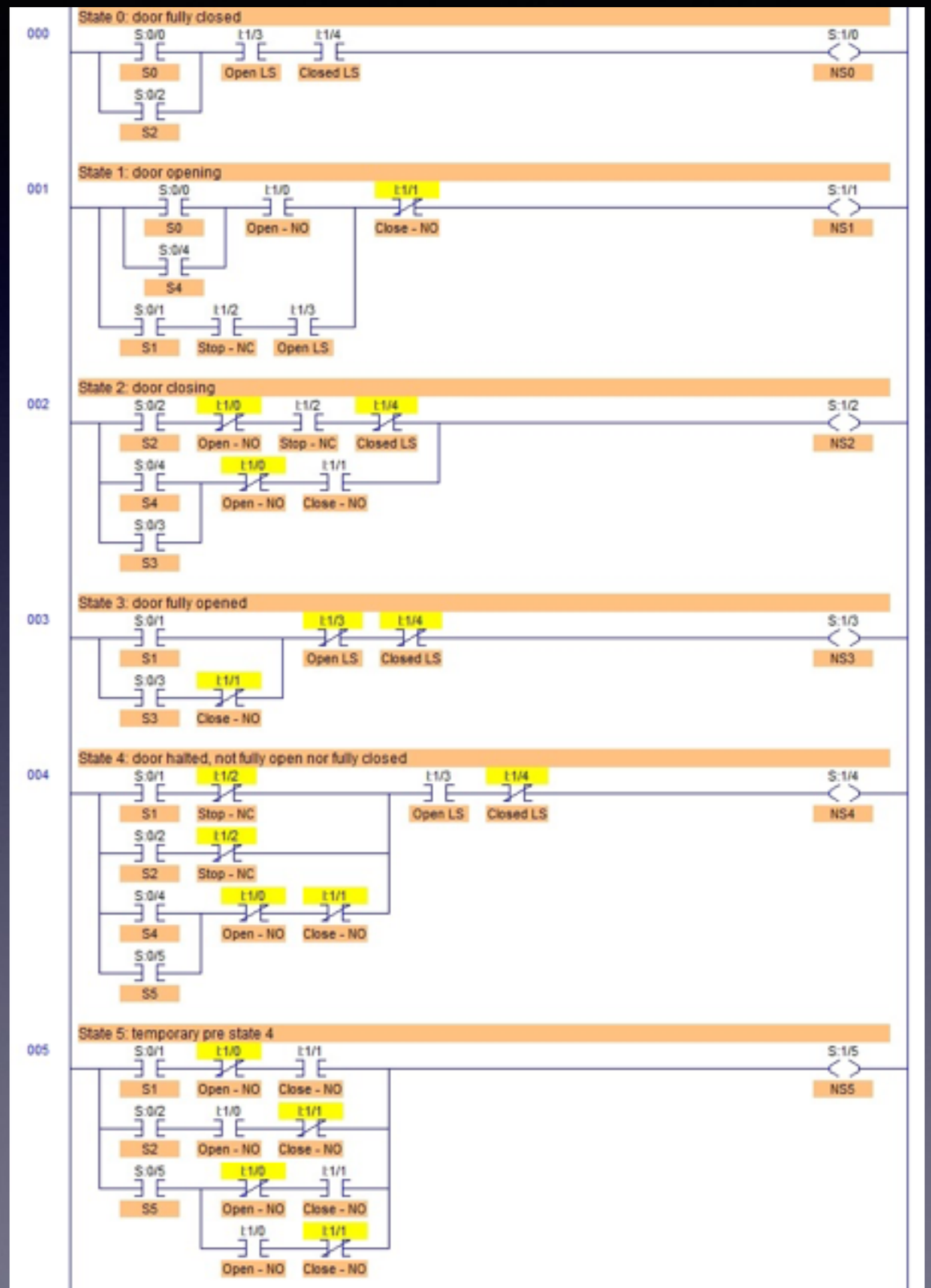
State table

Name	Meaning	Motor Up	Motor Down	Ajar Lamp	Open Lamp	Shut Lamp
S0	Door fully closed	0	0	0	0	**1**
S1	Door opening	**1**	0	**1**	**L**	0
S2	Door closing	0	**1**	**1**	0	**L**
S3	Door fully open	0	0	0	**1**	0
S4	Door halted	0	0	**L**	0	0

Moore Diagram



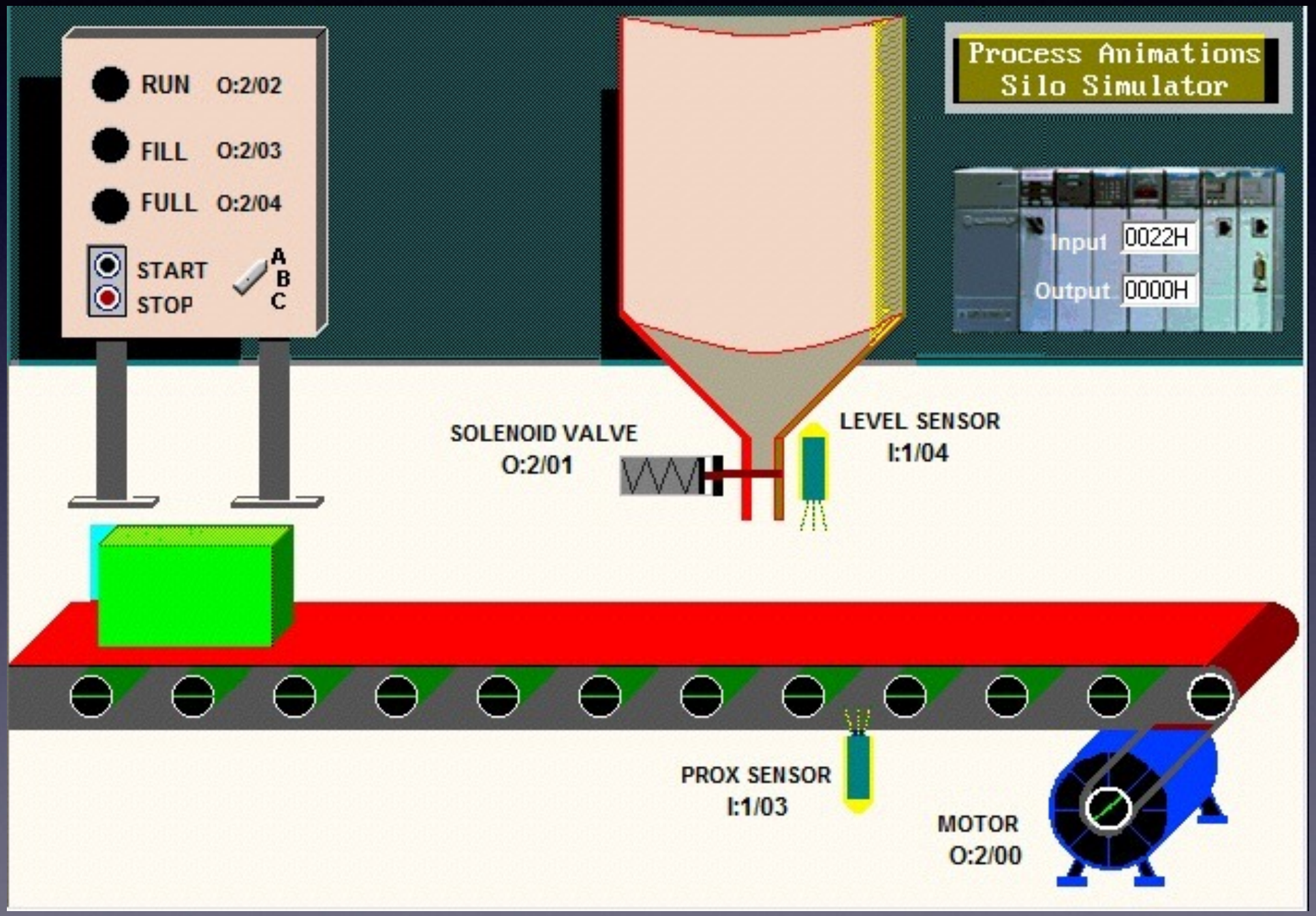
Moore based ladder



Excercise 3

Silo

System Overview



Excercise 3.1 - Continuous operation

- The sequence can be stopped and re-started at any time using the panel mounted Stop and Start switches.
- The RUN light will remain energized as long as the system is operating automatically.
- The RUN light, Conveyor Motor and Solenoid will de-energize whenever the system is halted via the STOP switch.
- The FILL light will be energized while the box is filling.
- The FULL light will energize when the box is full and will remain that way until the box has moved clear of the prox-sensor.

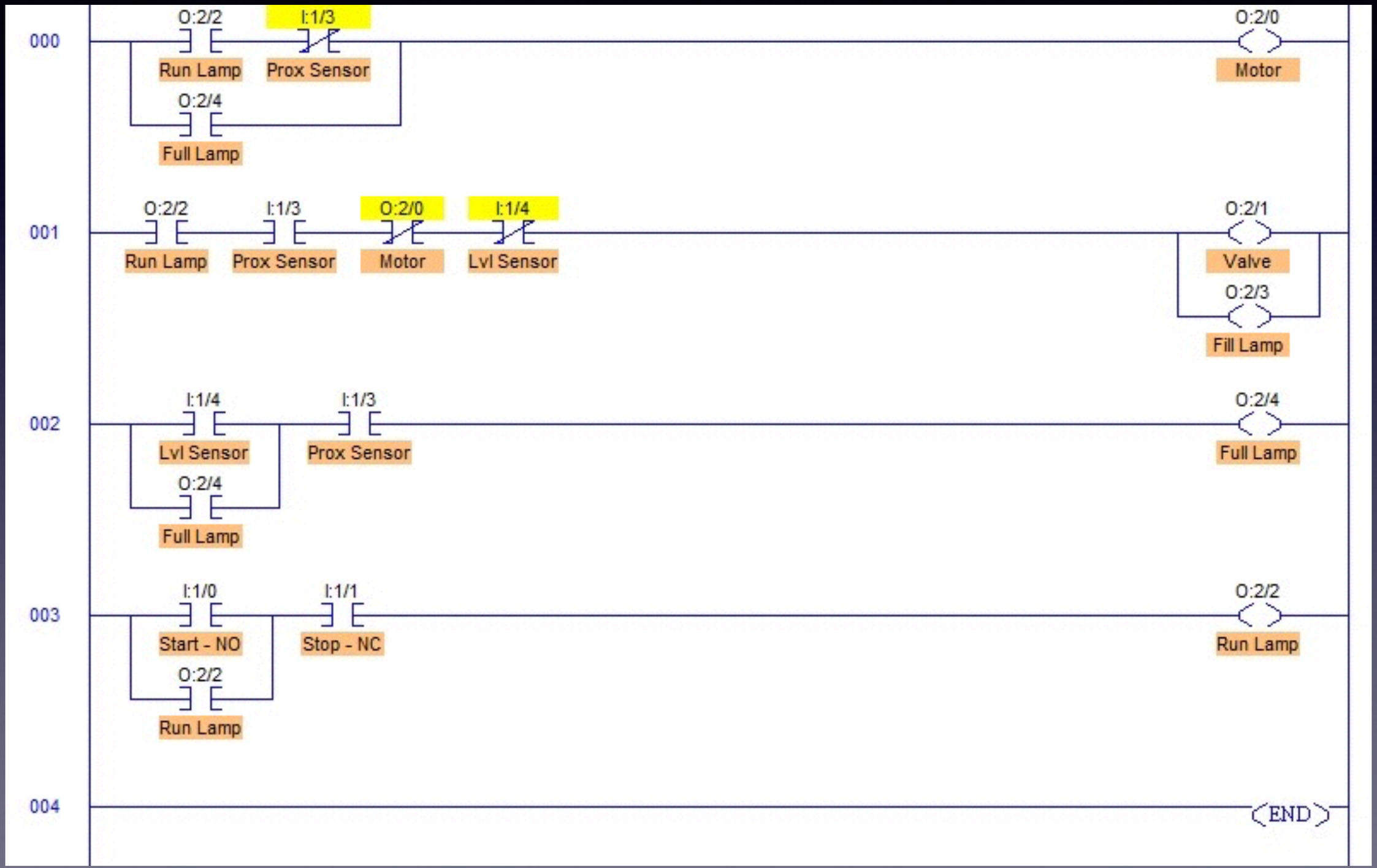
Inputs table

Name	Meaning
I:1/0	Start switch
I:1/1	Stop switch
I:1/3	Proximity sensor
I:1/4	Level sensor

Outputs table

Name	Meaning
O:2/0	Motor
O:2/1	Solenoid valve
O:2/2	Run lamp
O:2/3	Fill lamp
O:2/4	Full lamp

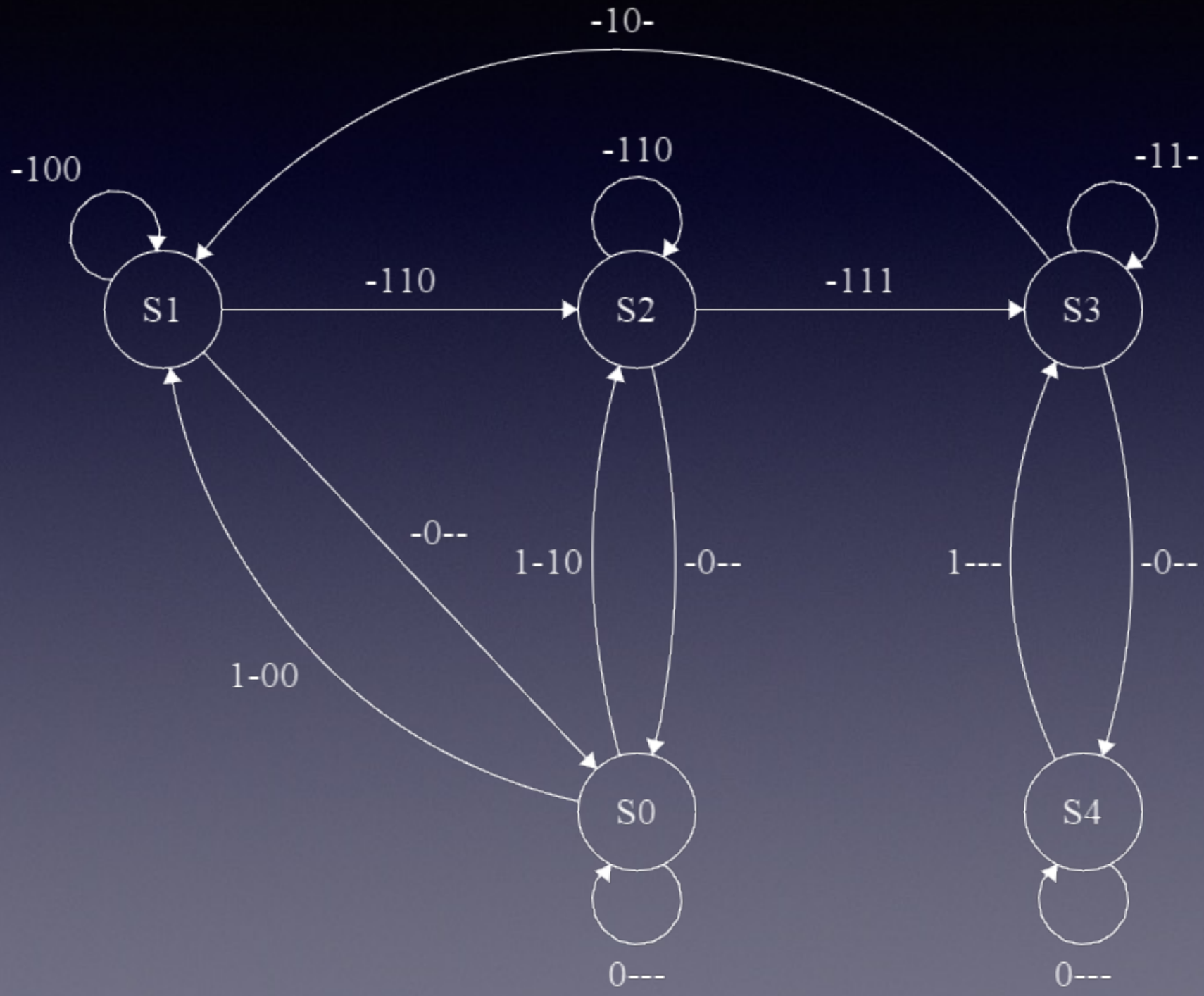
Ladder


000
O:2/2
Run Lamp
I:1/3
Prox Sensor
O:2/4
Full Lamp
O:2/0
Motor
001
O:2/2
Run Lamp
I:1/3
Prox Sensor
O:2/0
Motor
I:1/4
Lvl Sensor
O:2/1
Valve
O:2/3
Fill Lamp
002
I:1/4
Lvl Sensor
I:1/3
Prox Sensor
O:2/4
Full Lamp
O:2/4
Full Lamp
003
I:1/0
Start - NO
I:1/1
Stop - NC
O:2/2
Run Lamp
O:2/2
Run Lamp
004
END

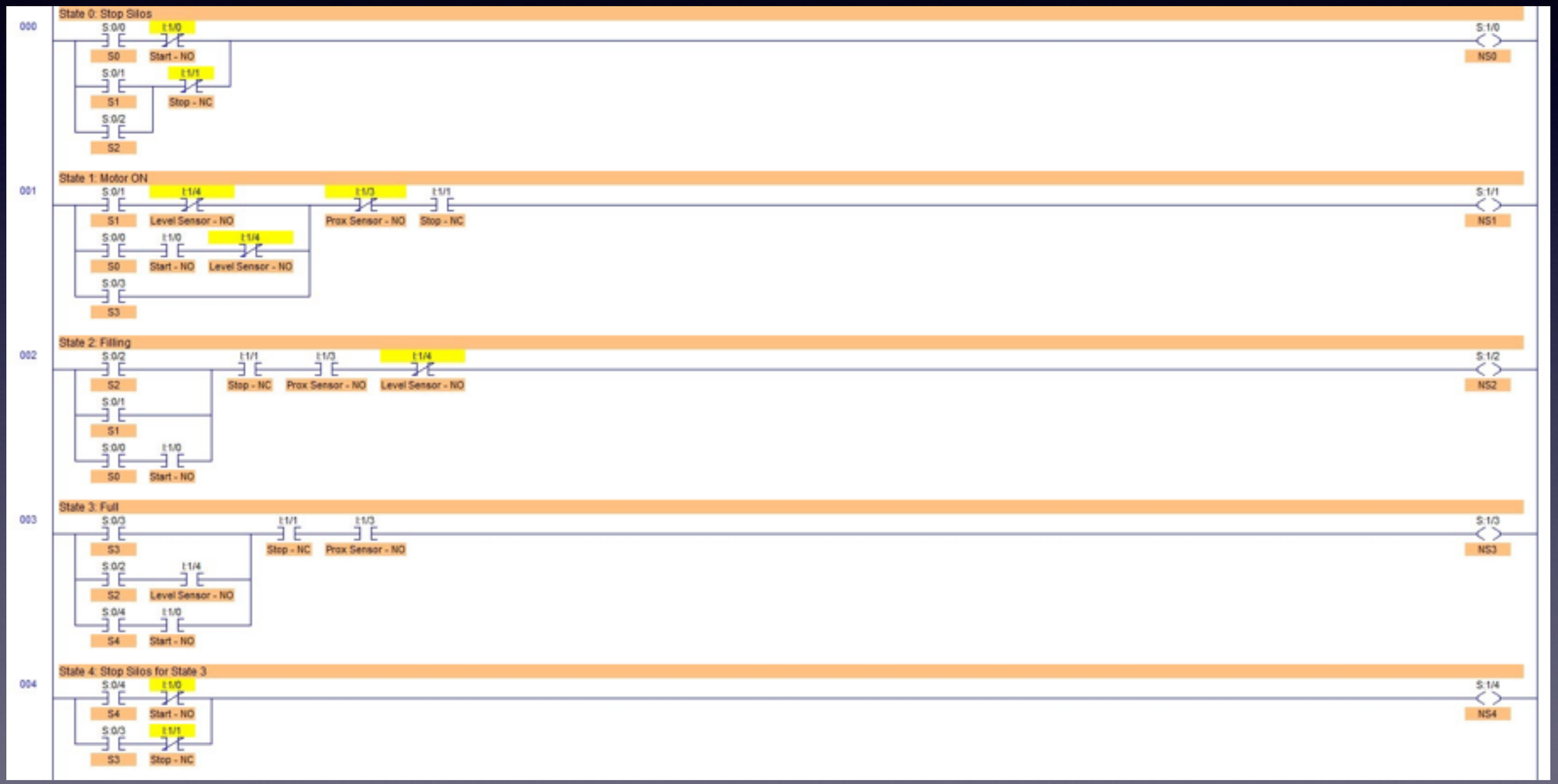
State table

Name	Meaning	Motor	Valve	Run lamp	Fill lamp	Full lamp
S0	Stop Motor for S1/S2	0	0	0	0	0
S1	Motor Activated	**1**	0	**1**	0	0
S2	Filling Activated	0	**1**	**1**	**1**	0
S3	Box Full	**1**	0	**1**	0	**1**
S4	Stop Motor for S3	0	0	0	0	0

Moore Diagram



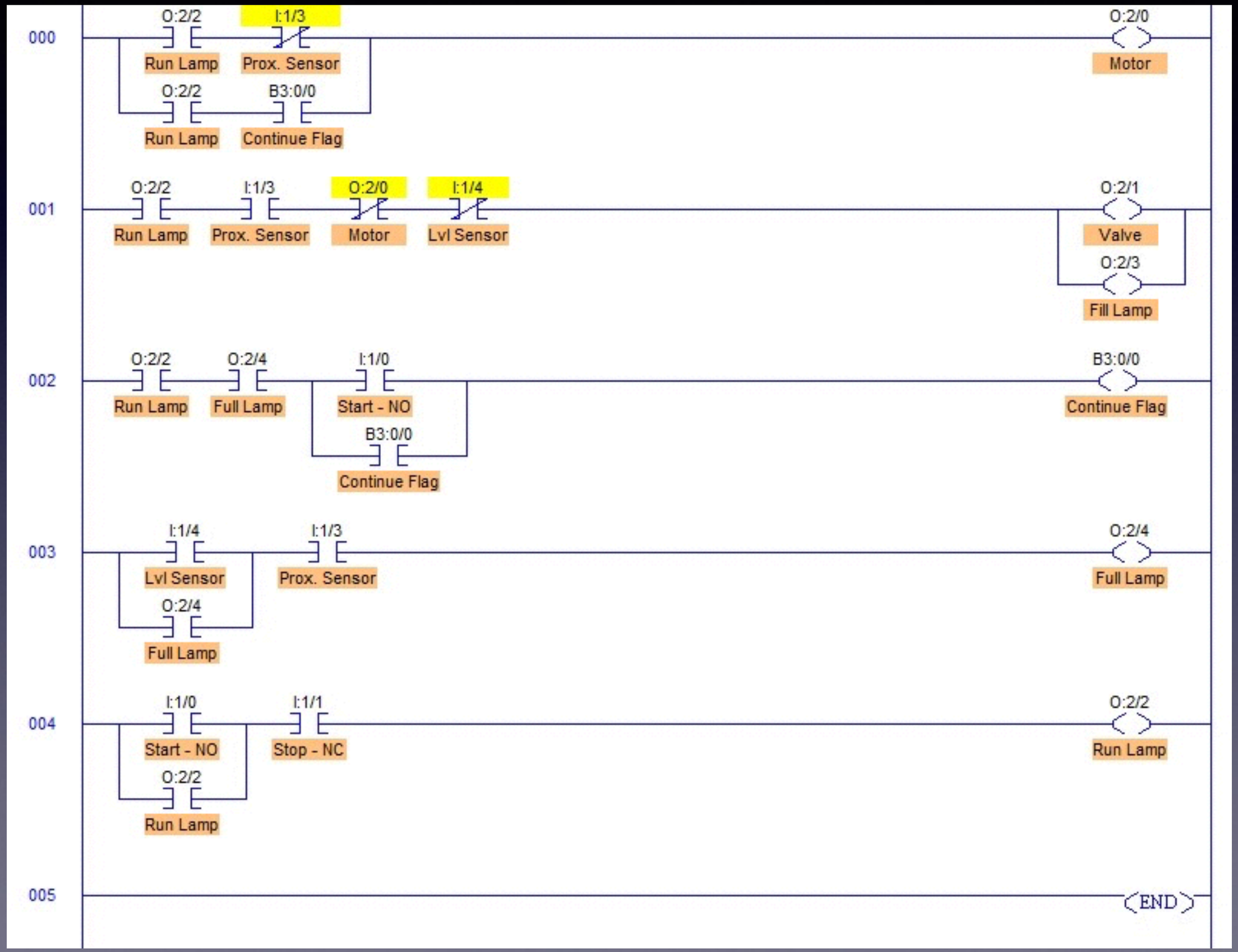
Moore based ladder



Excercise 3.2 - Container Filling with manual restart

- Stop the conveyor when the right edge of the box is first sensed by the prox-sensor.
- With the box in position and the conveyor stopped, open the solenoid valve and allow the box to fill. Filling should stop when the Level sensor goes true.
- The FILL light will be energized while the box is filling.
- The FULL light will energize when the box is full and will remain that way until the box has moved clear of the prox-sensor.
- Once the box is full, momentarily pressing the Start Switch will move the box off the conveyor and bring a new box into position. Forcing the operator to hold the Start button down until the box clears the prox-sensor is not acceptable.

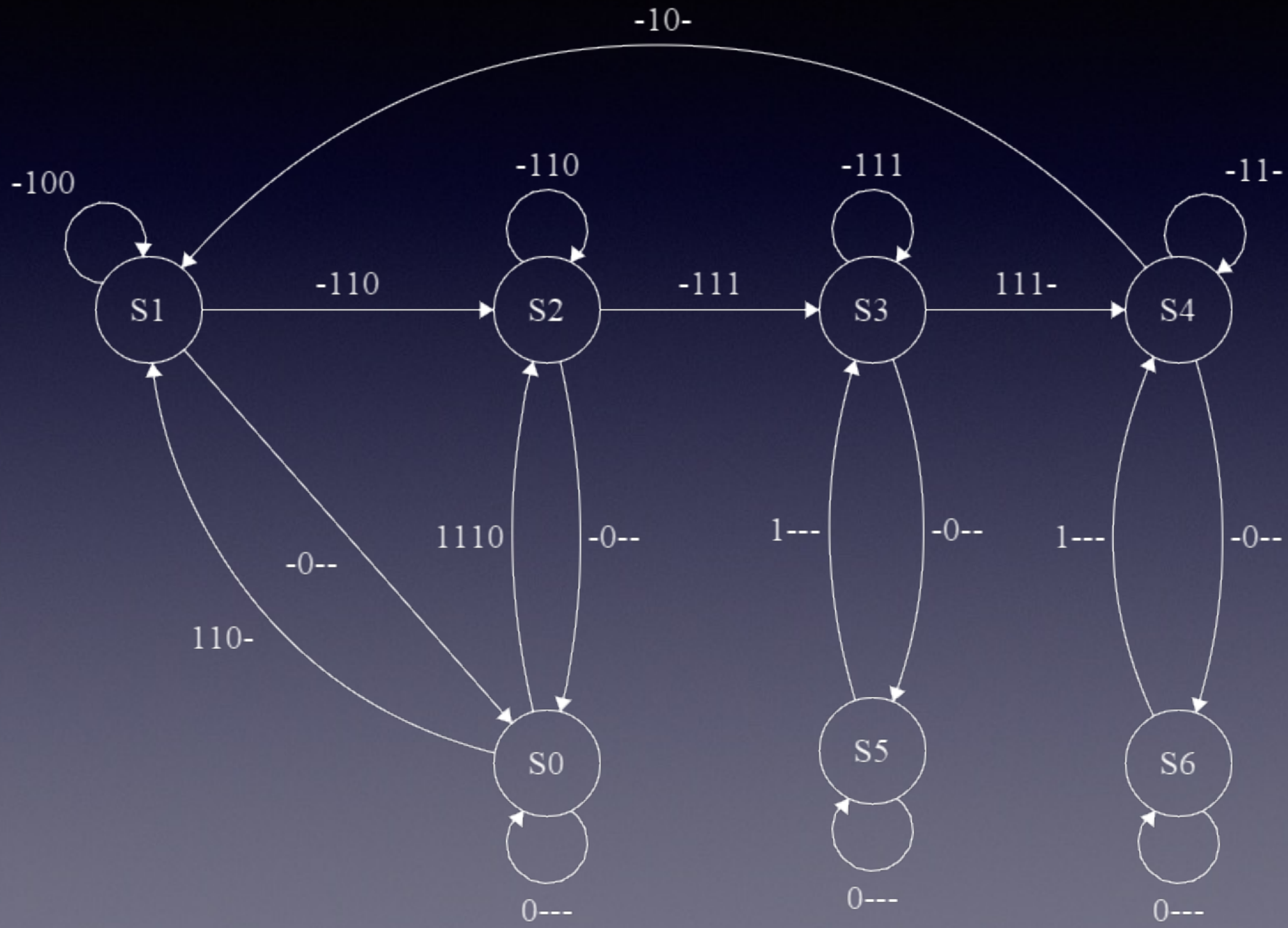
Ladder


000
O:2/2
Run Lamp
I:1/3
Prox. Sensor
O:2/2
Run Lamp
B3:0/0
Continue Flag
O:2/0
Motor
001
O:2/2
Run Lamp
I:1/3
Prox. Sensor
O:2/0
Motor
I:1/4
Lvl Sensor
O:2/1
Valve
O:2/3
Fill Lamp
002
O:2/2
Run Lamp
O:2/4
Full Lamp
I:1/0
Start - NO
B3:0/0
Continue Flag
B3:0/0
Continue Flag
003
I:1/4
Lvl Sensor
O:2/4
Full Lamp
I:1/3
Prox. Sensor
O:2/4
Full Lamp
004
I:1/0
Start - NO
O:2/2
Run Lamp
I:1/1
Stop - NC
O:2/2
Run Lamp
005
END

State table

Name	Meaning	Motor	Valve	Run lamp	Fill lamp	Full lamp
S0	Stop Motor for S1/S2	0	0	0	0	0
S1	Motor Activated	1	0	1	0	0
S2	Filling Activated	0	1	1	1	0
S3	Box Full	0	0	1	0	1
S4	Change Box	1	0	1	0	1
S5	Stop Motor for S4	0	0	0	0	1
S6	Stop Motor for S3	0	0	0	0	1

Moore Diagram



Moore based ladder

Excercise 3.3 - Selectable mode of operation

- When the selector switch is in position "A", the system shall operate in the "Continuous" mode of operation. This is the mode of operation which was used in Exercise 3.1.

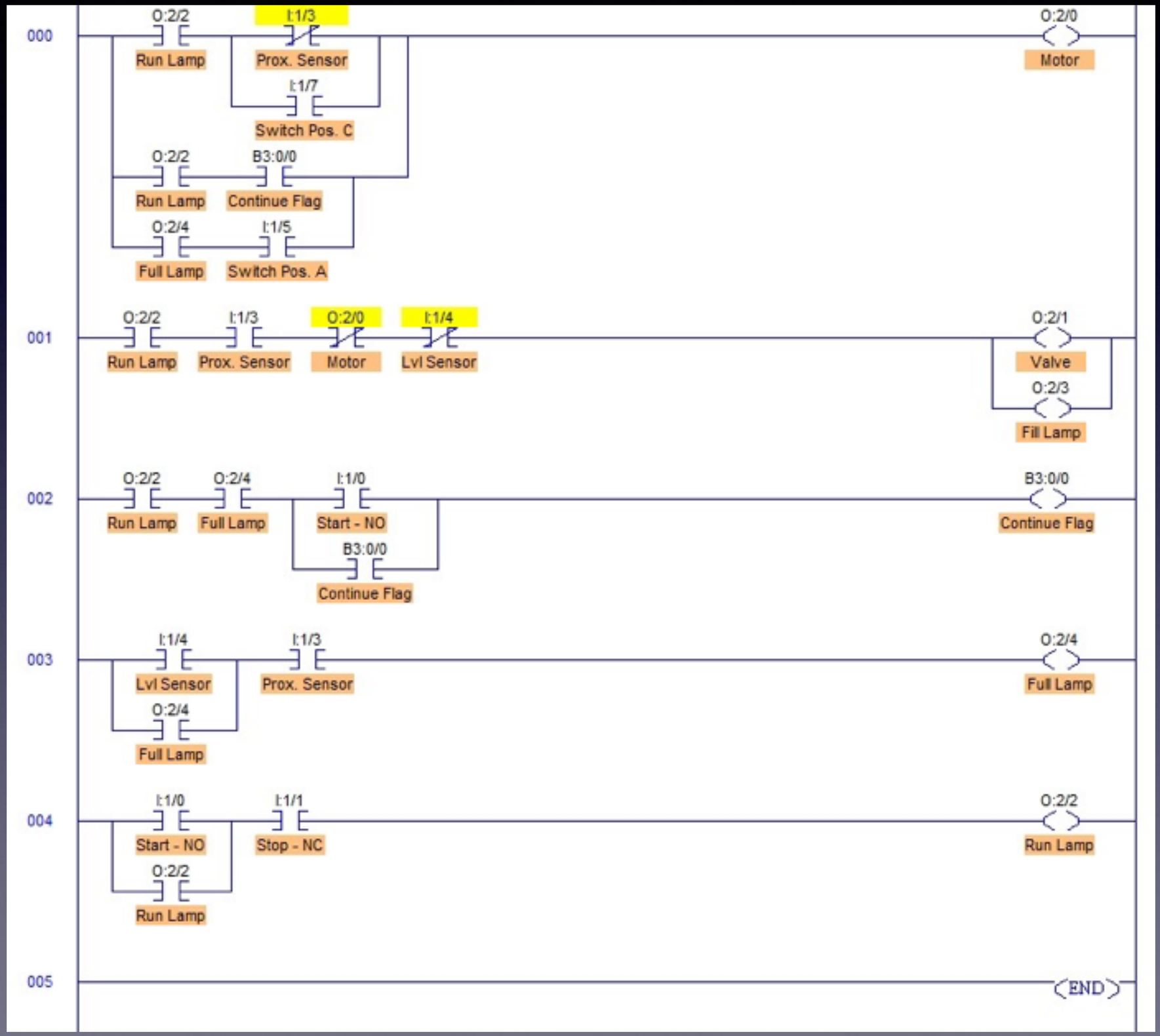
- When the selector switch is in position "B", the system shall operate in the "Manual Restart" mode of operation. This is the mode of operation which was used in Exercise 3.2.

- When the selector switch is in position "C", the system shall operate in the "Fill Bypass" mode of operation. In this mode, the boxes will simply move down the conveyor continuously and bypass the fill operation. As in the other modes, the Start and Stop pushbuttons will control the conveyor motion and the Run Lamp will operate as expected.

Inputs table

Name	Meaning
I:1/0	Start switch
I:1/1	Stop switch
I:1/3	Proximity sensor
I:1/4	Level sensor
I:1/5	Switch position A
I:1/6	Switch position B
I:1/7	Switch position C

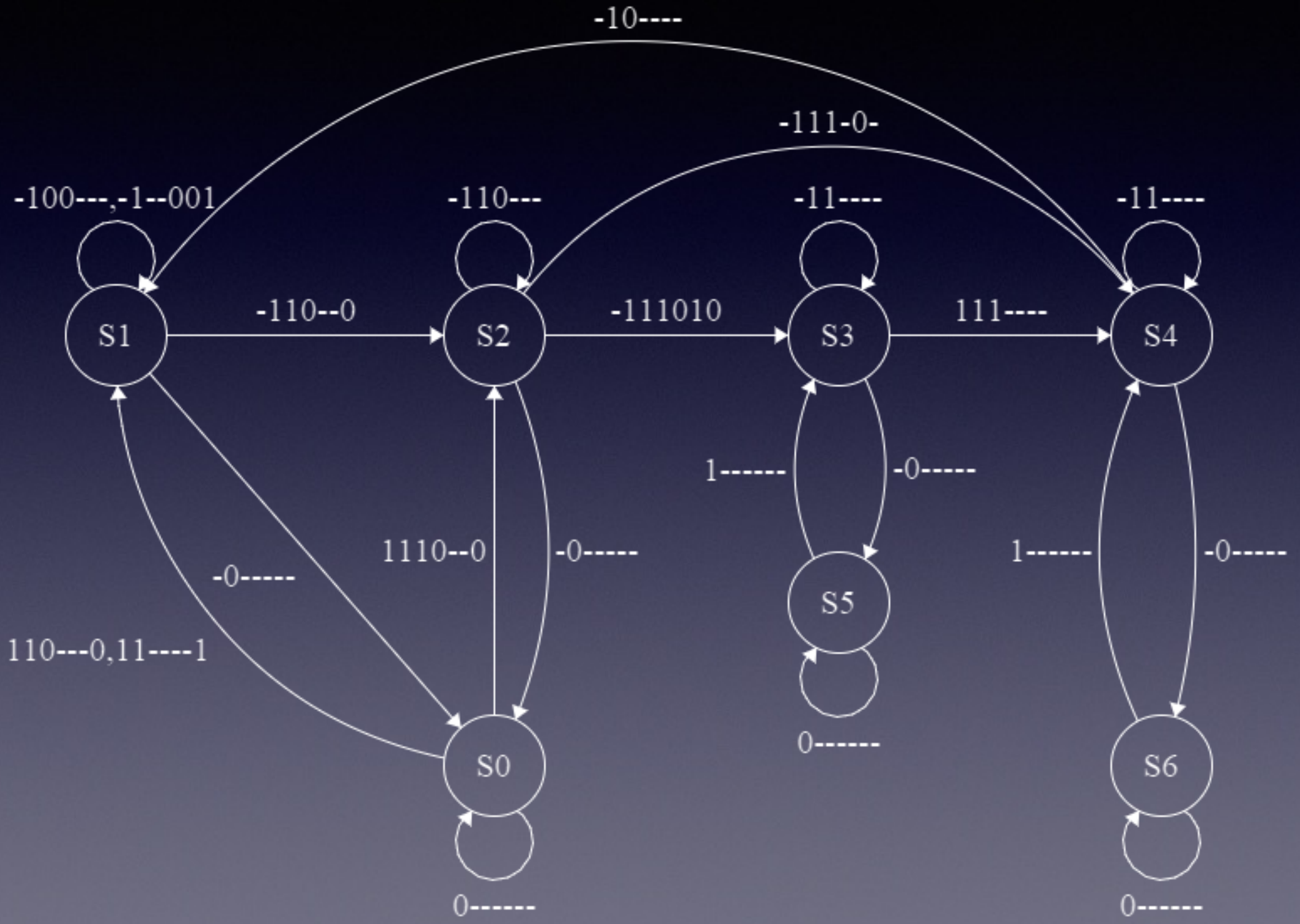
Ladder


000
O:2/2
Run Lamp
I:1/3
Prox. Sensor
I:1/7
Switch Pos. C
O:2/2
Run Lamp
B3:0/0
Continue Flag
O:2/4
Full Lamp
I:1/5
Switch Pos. A
O:2/0
Motor
001
O:2/2
Run Lamp
I:1/3
Prox. Sensor
O:2/0
Motor
I:1/4
Lvl Sensor
O:2/1
Valve
O:2/3
Fill Lamp
002
O:2/2
Run Lamp
O:2/4
Full Lamp
I:1/0
Start - NO
B3:0/0
Continue Flag
B3:0/0
Continue Flag
003
I:1/4
Lvl Sensor
I:1/3
Prox. Sensor
O:2/4
Full Lamp
O:2/4
Full Lamp
004
I:1/0
Start - NO
I:1/1
Stop - NC
O:2/2
Run Lamp
O:2/2
Run Lamp
005
END

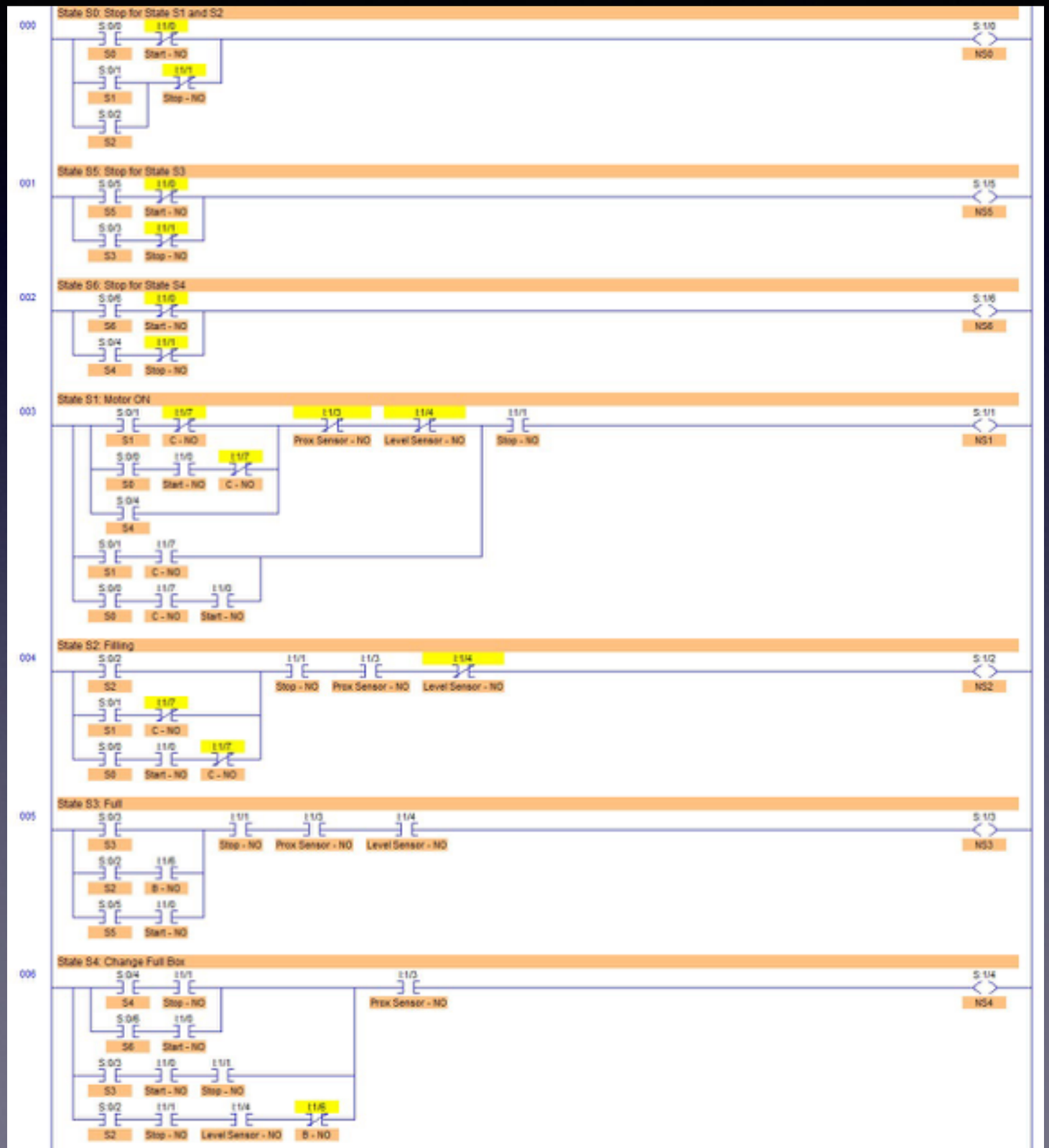
State table

Name	Meaning	Motor	Valve	Run lamp	Fill lamp	Full lamp
S0	Stop Motor for S1/S2	0	0	0	0	0
S1	Motor Activated	1	0	1	0	0
S2	Filling Activated	0	1	1	1	0
S3	Box Full	0	0	1	0	1
S4	Change Box	1	0	1	0	1
S5	Stop Motor for S4	0	0	0	0	1
S6	Stop Motor for S3	0	0	0	0	1

Moore Diagram



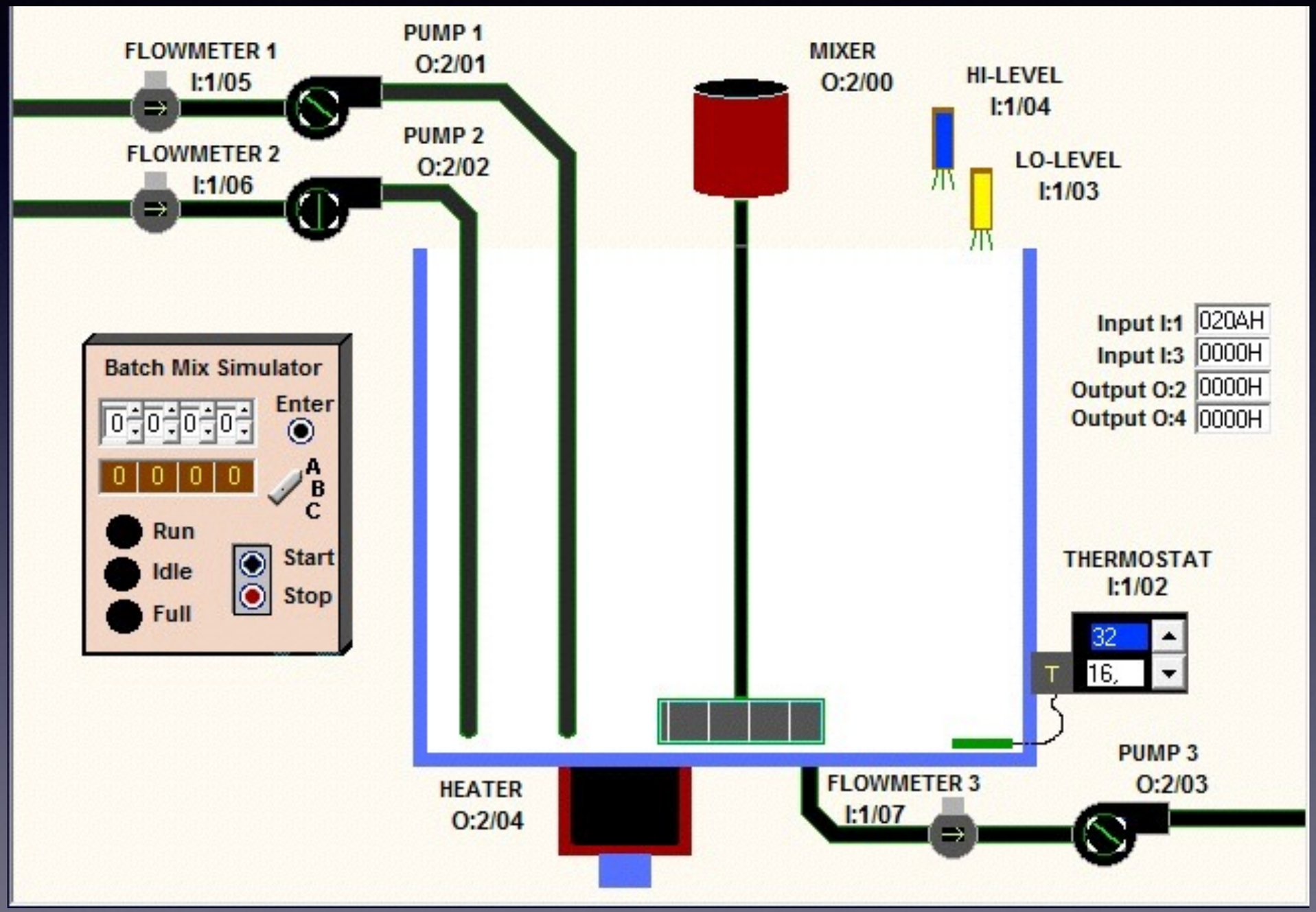
Moore based ladder



Excercise 4

Batch Mixing

System Overview



Excercise 4.1 - Filling the batch mixing tank

- When the Start switch (I:1/0) is pressed, pump P1 will be energized and the tank will start to fill. The pulses generated by Flowmeter 1 should be used to increment a counter.
- When the count reaches a value where the tank is approximately 90% full, the pump is to be shut-off and and the control panels FULL light is to be energized.
- The filling operation is to halt immediately if the stop switch is pressed.
- While testing, utilize the "Reset Simulation" and the "Reset Timers and Counters" entries in the Simulations menu to re-start your program.

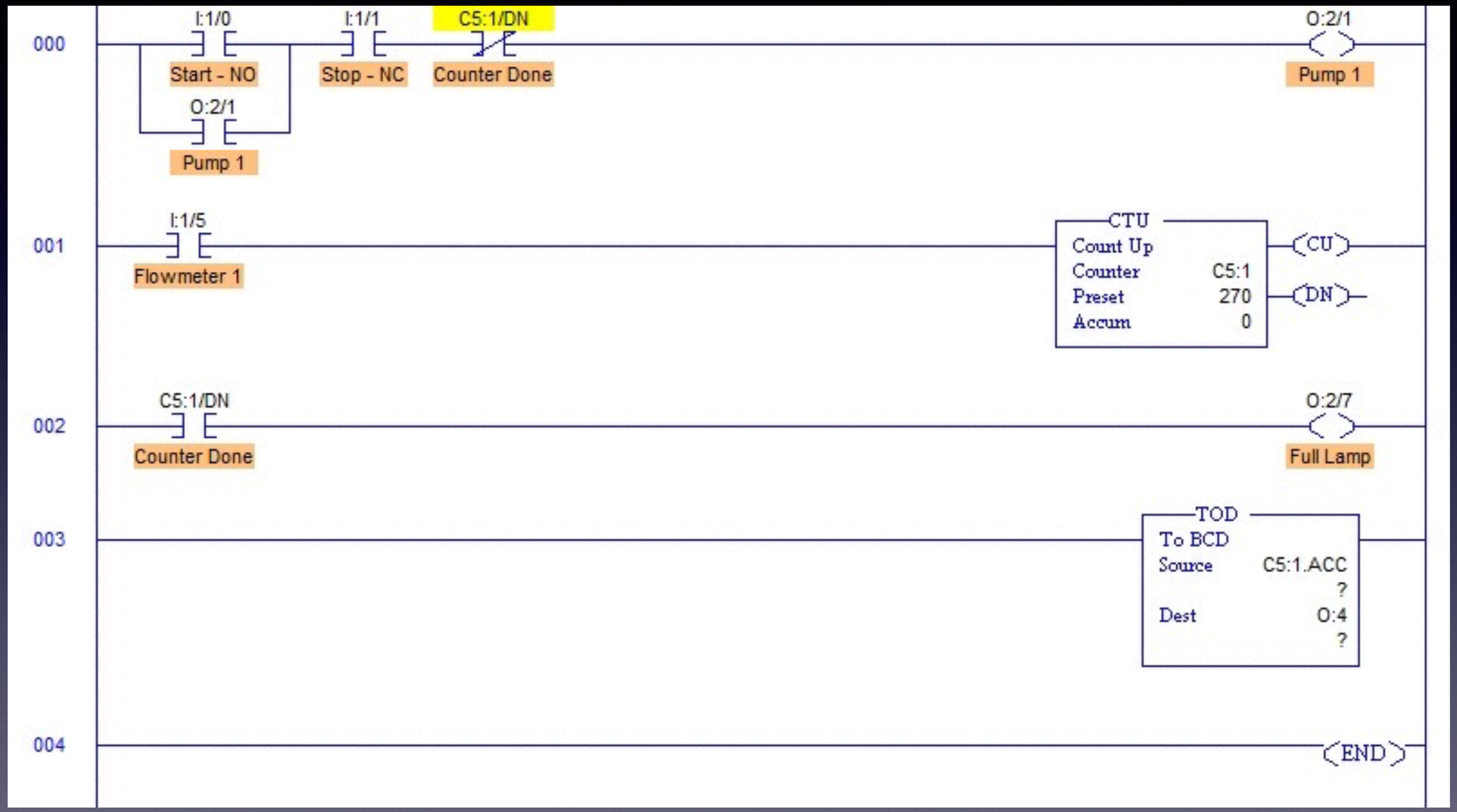
Inputs table

Name	Meaning
I:1/0	Start switch
I:1/1	Stop switch
I:1/5	Flowmeter 1

Outputs table

Name	Meaning
O:2/1	Pump 1
O:2/7	Full lamp

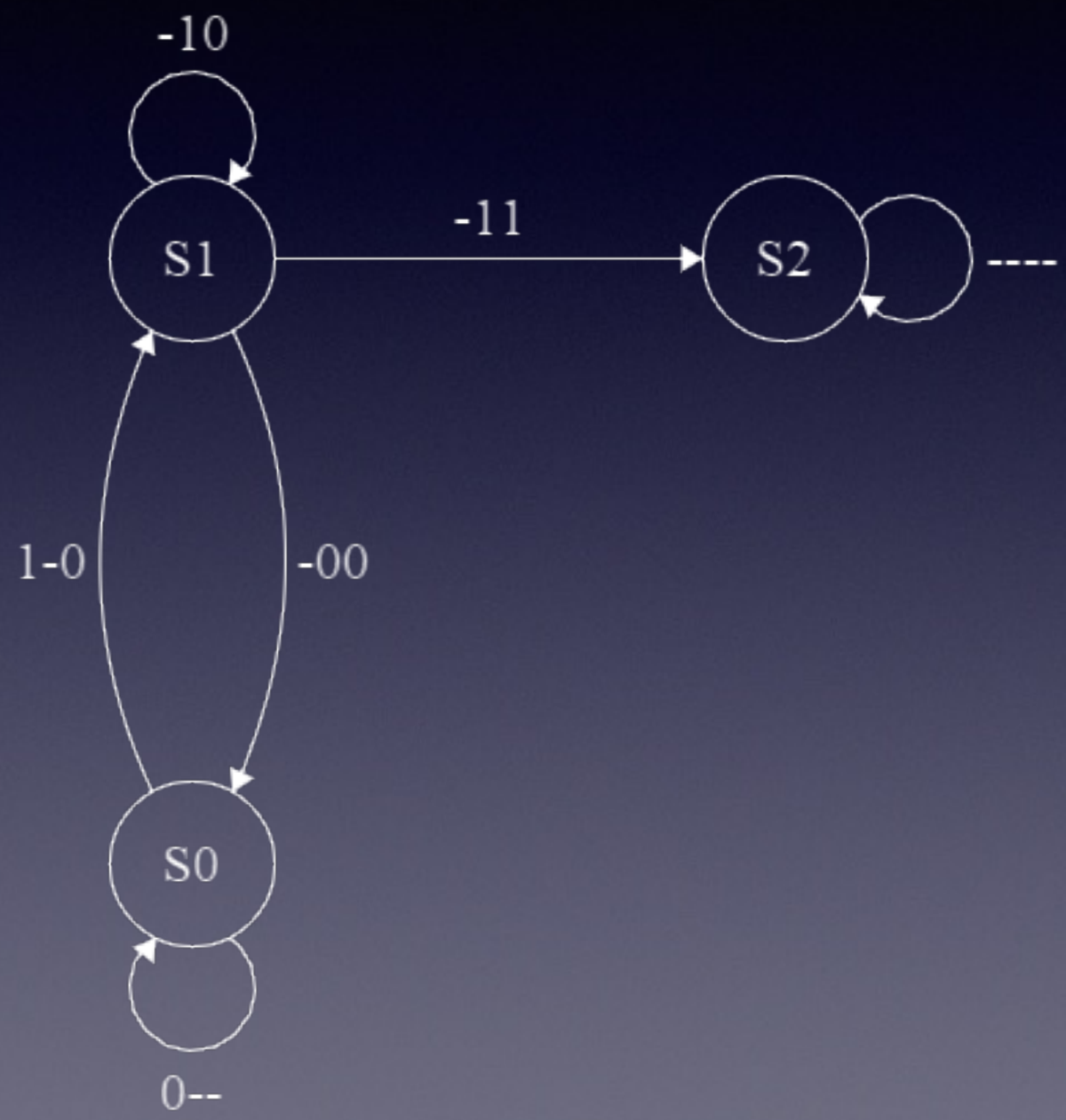
Ladder


000
I:1/0
Start - NO
O:2/1
Pump 1
I:1/1
Stop - NC
C5:1/DN
Counter Done
O:2/1
Pump 1
001
I:1/5
Flowmeter 1
CTU
Count Up
Counter C5:1
Preset 270
Accum 0
CU
DN
002
C5:1/DN
Counter Done
O:2/7
Full Lamp
003
TOD
To BCD
Source C5:1.ACC
?
Dest O:4
?
004
END

State table

Name	Meaning	Pump 1	Full Lamp
S0	Stop Pump	0	0
S1	Pump 1 Activated	**1**	0
S2	Tank Full	0	**1**

Moore Diagram



Moore based ladder

Excercise 4.2 - Emptying the batch mix tank

- The mixer will run for 8 seconds once the tank is full.
- When the mixing is complete, drain pump P3 is to be started and the tank is to be drained. Flowmeter 3 will be employed to decrement the existing counter, and draining will be allowed to continue till the counters accumulator reaches zero.
- Once the tank is empty again, pressing the Start switch will cause the sequence to repeat.

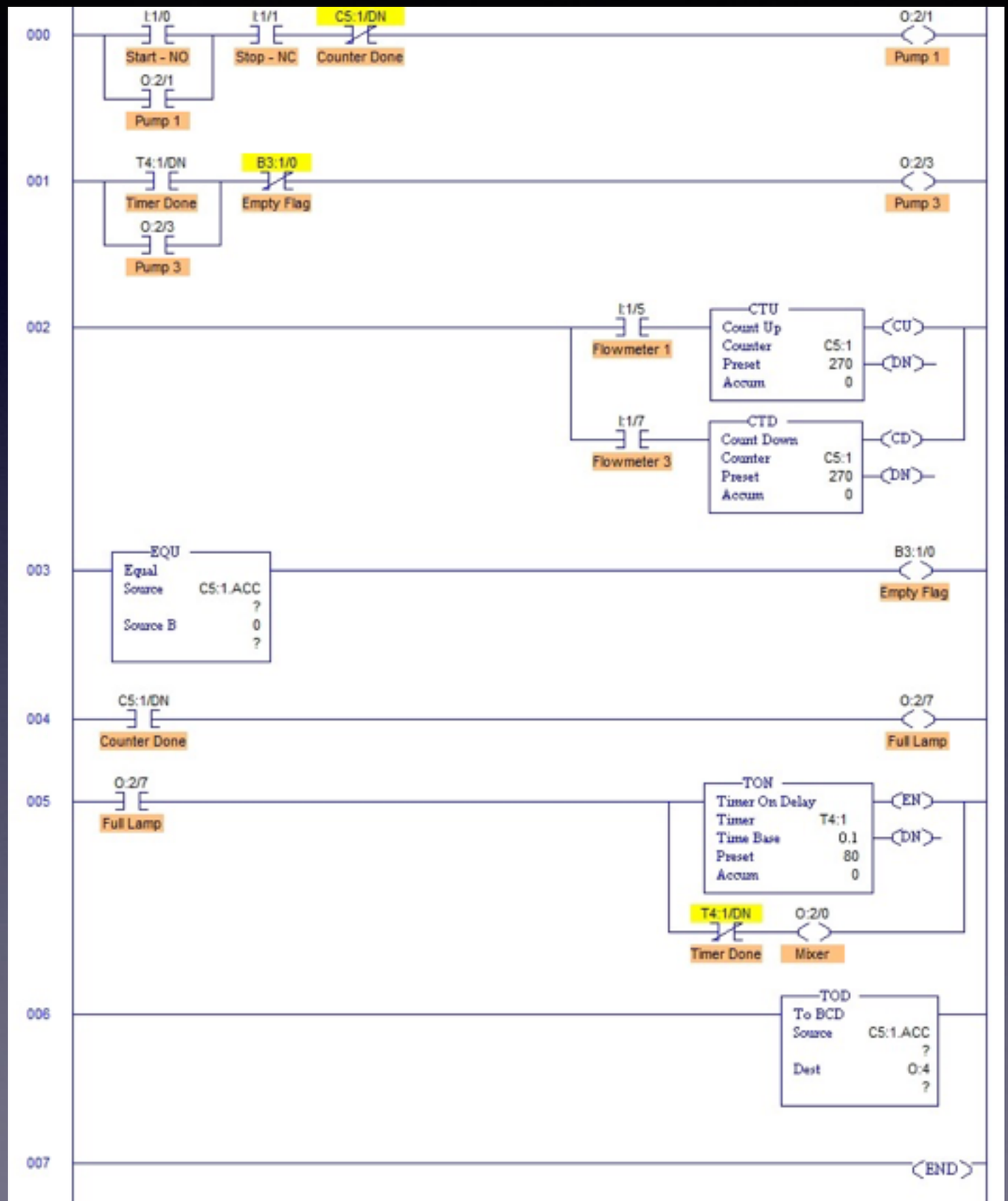
Inputs table

Name	Meaning
I:1/0	Start switch
I:1/1	Stop switch
I:1/5	Flowmeter 1
I:1/7	Flowmeter 3

Outputs table

Name	Meaning
O:2/0	Mixer
O:2/1	Pump 1
O:2/3	Pump 3
O:2/7	Full lamp

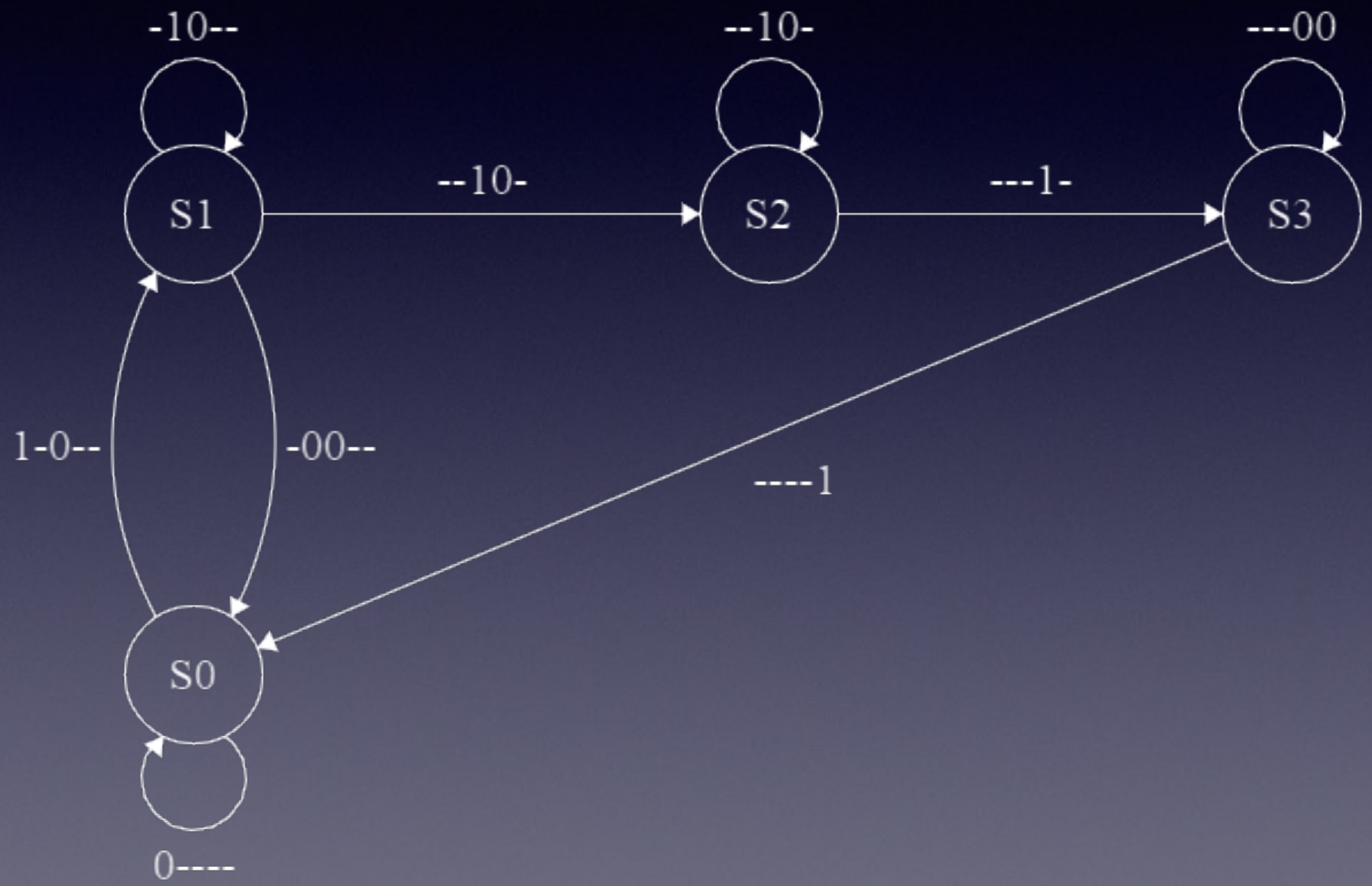
Ladder


000
I:1/0
Start - NO
O:2/1
Pump 1
I:1/1
Stop - NC
C5:1/DN
Counter Done
O:2/1
Pump 1
001
T4:1/DN
Timer Done
O:2/3
Pump 3
B3:1/0
Empty Flag
O:2/3
Pump 3
002
I:1/5
Flowmeter 1
CTU
Count Up
Counter C5:1
Preset 270
Accum 0
CU
DN
I:1/7
Flowmeter 3
CTD
Count Down
Counter C5:1
Preset 270
Accum 0
CD
DN
003
EQU
Equal
Source C5:1.ACC
?
Source B 0
?
B3:1/0
Empty Flag
004
C5:1/DN
Counter Done
O:2/7
Full Lamp
005
O:2/7
Full Lamp
TON
Timer On Delay
Timer T4:1
Time Base 0.1
Preset 80
Accum 0
EN
DN
T4:1/DN
Timer Done
O:2/0
Mixer
006
TOD
To BCD
Source C5:1.ACC
?
Dest O:4
?
007
END

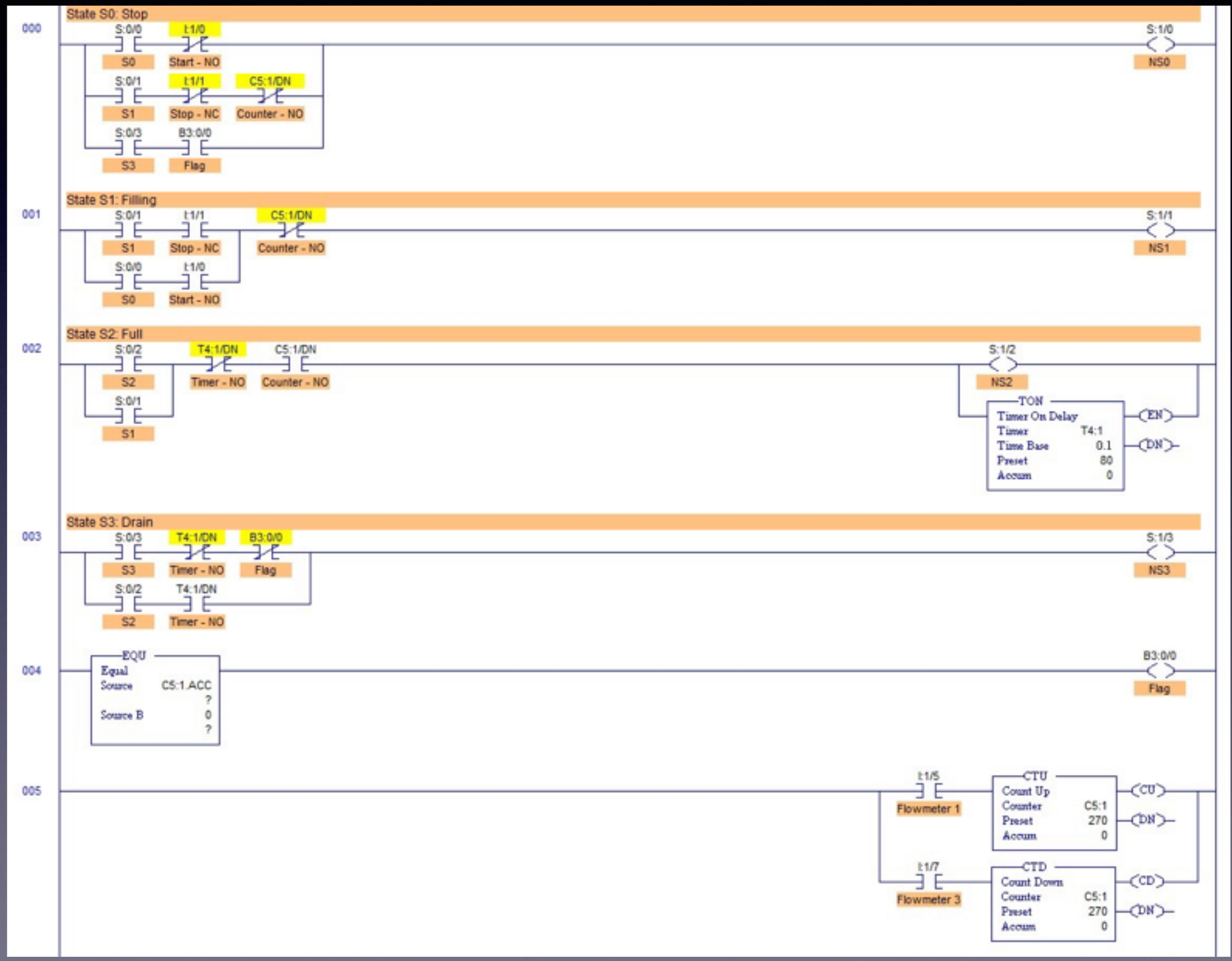
State table

Name	Meaning	Mixer	Pump 1	Pump 3	Full Lamp
S0	Stop Pump 1	0	0	0	0
S1	Pump 1 Activated	0	**1**	0	**0**
S2	Tank Full and Mixer Activated	**1**	0	0	**1**
S3	Tank Draining	0	0	**1**	0

Moore Diagram



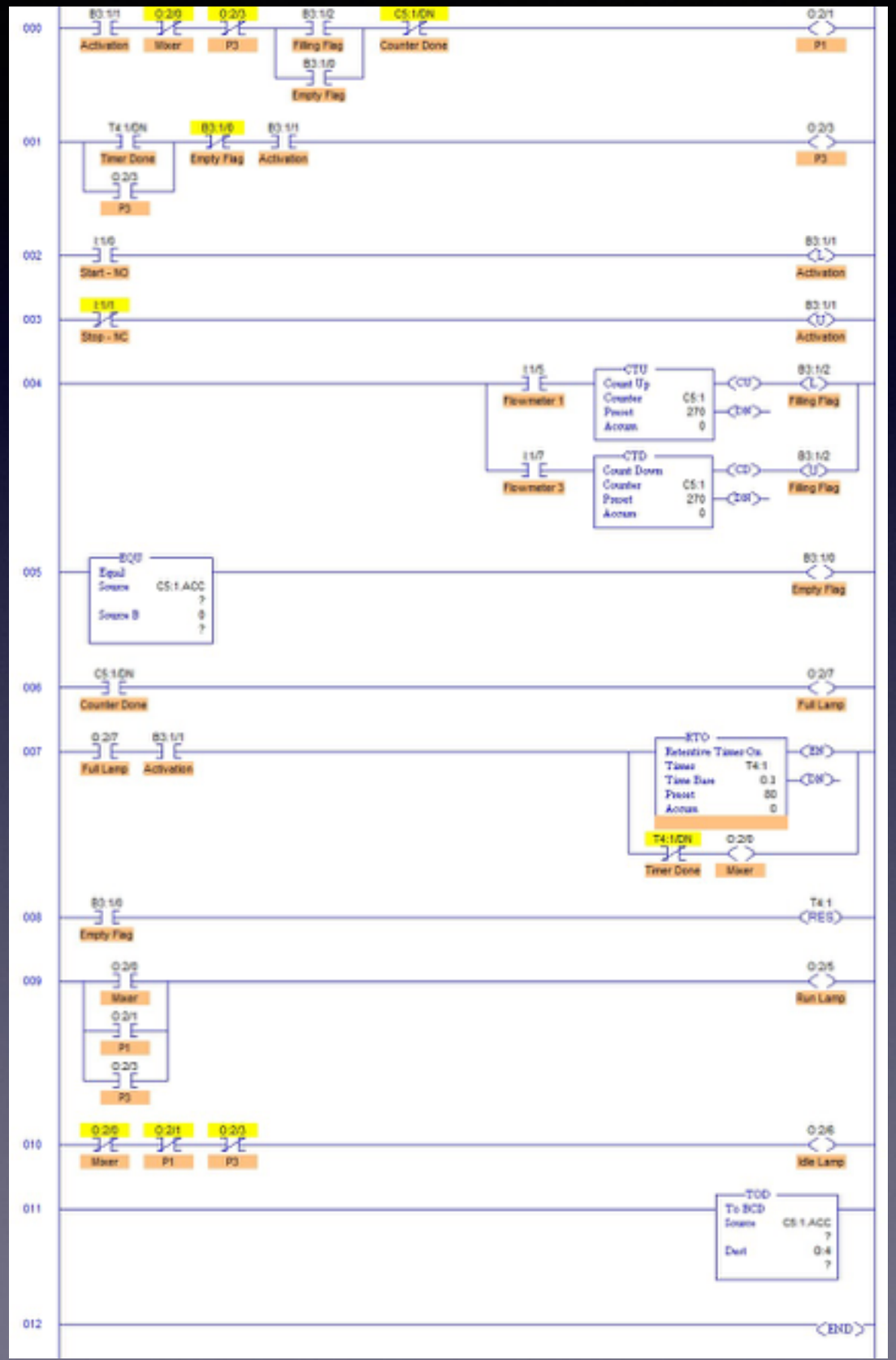
Moore based ladder



Excercise 4.3 - Continuous operation

- Ensure that the RUN light is energized when the mixer or either pump is running.
- The STANDBY light should light and the process should halt when the Stop button is pressed.
- The process should restart where it left off if the the Start button is pressed following a Stop.

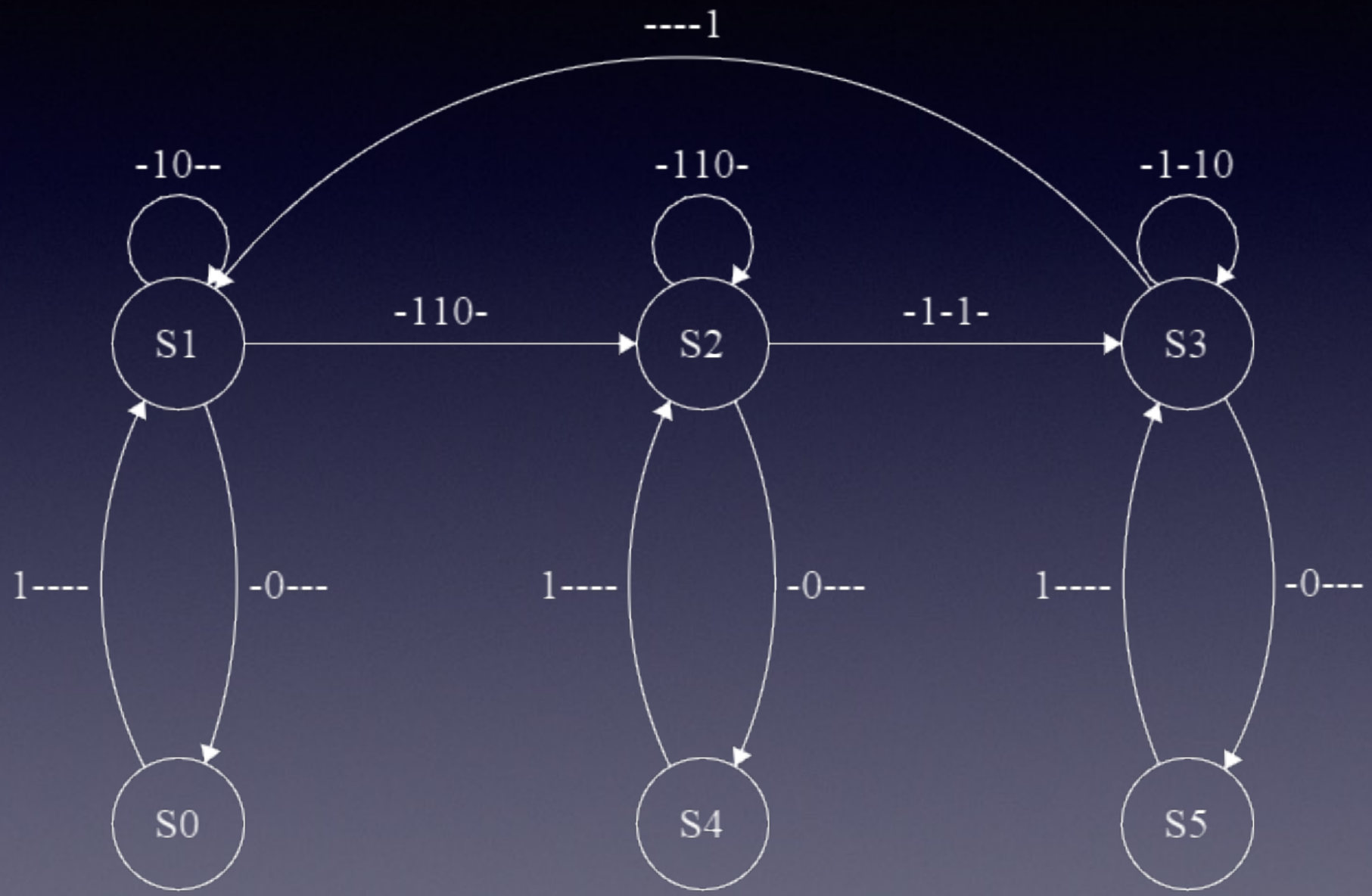
Ladder


000
B3:1/1
Activation
O:2/0
Mixer
O:2/3
P3
B3:1/2
Filling Flag
B3:1/0
Empty Flag
C5:1/DN
Counter Done
O:2/1
P1
001
T4:1/DN
Timer Done
B3:1/0
Empty Flag
B3:1/1
Activation
O:2/3
P3
O:2/3
P3
002
I:1/0
Start - NO
B3:1/1
Activation
003
I:1/1
Stop - NC
B3:1/1
Activation
004
I:1/5
Flowmeter 1
CTU
Count Up
Counter C5:1
Preset 270
Accum 0
CU
CD
B3:1/2
Filling Flag
I:1/7
Flowmeter 3
CTD
Count Down
Counter C5:1
Preset 270
Accum 0
CU
CD
B3:1/2
Filling Flag
005
BCD
Equal
Source C5:1.ACC
?
Source B 0
?
B3:1/0
Empty Flag
006
C5:1/DN
Counter Done
O:2/7
Full Lamp
007
O:2/7
Full Lamp
B3:1/1
Activation
RTO
Retentive Timer On
Timer T4:1
Time Base 0.1
Preset 50
Accum 0
EN
DN
T4:1/DN
Timer Done
O:2/0
Mixer
008
B3:1/0
Empty Flag
T4:1
RES
009
O:2/0
Mixer
O:2/1
P1
O:2/3
P3
O:2/5
Run Lamp
010
O:2/0
Mixer
O:2/1
P1
O:2/3
P3
O:2/6
Idle Lamp
011
TOD
To BCD
Source C5:1.ACC
?
Dest O:4
?
012
END

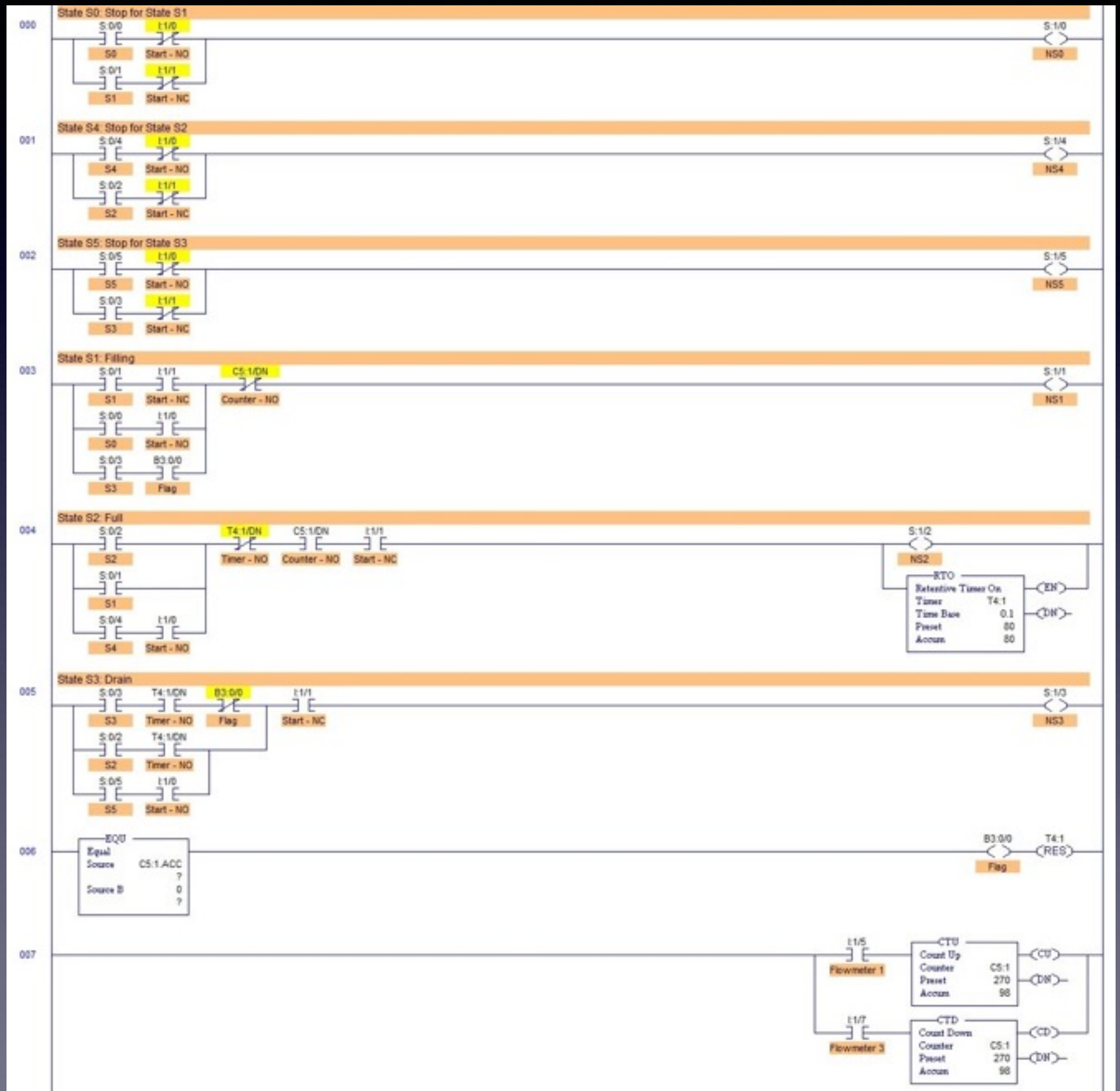
State table

Name	Meaning	Mixer	Pump 1	Pump 3	Run Lamp	Idle Lamp	Full Lamp
S0	Stop Pump 1	0	0	0	0	**1**	0
S1	Pump 1 Activate	0	**1**	0	**1**	0	0
S2	Tank Full and Mixer Activated	**1**	0	0	**1**	0	**1**
S3	Tank Draining	0	0	**1**	**1**	0	0
S4	Mixer Stop	0	0	0	0	**1**	0
S5	Stop Pump 3	0	0	0	0	**1**	0

Moore Diagram



Moore based ladder



Final words

Output based approach

- suitable for simple systems
- generally less rungs
- useful when input/output identify a state of the system
- poor maintainability

FSA based approach

- suitable for complex systems
- formal and systematic
- useful when input/output doesn’t identify a state of the system
- great maintainability

Thank you