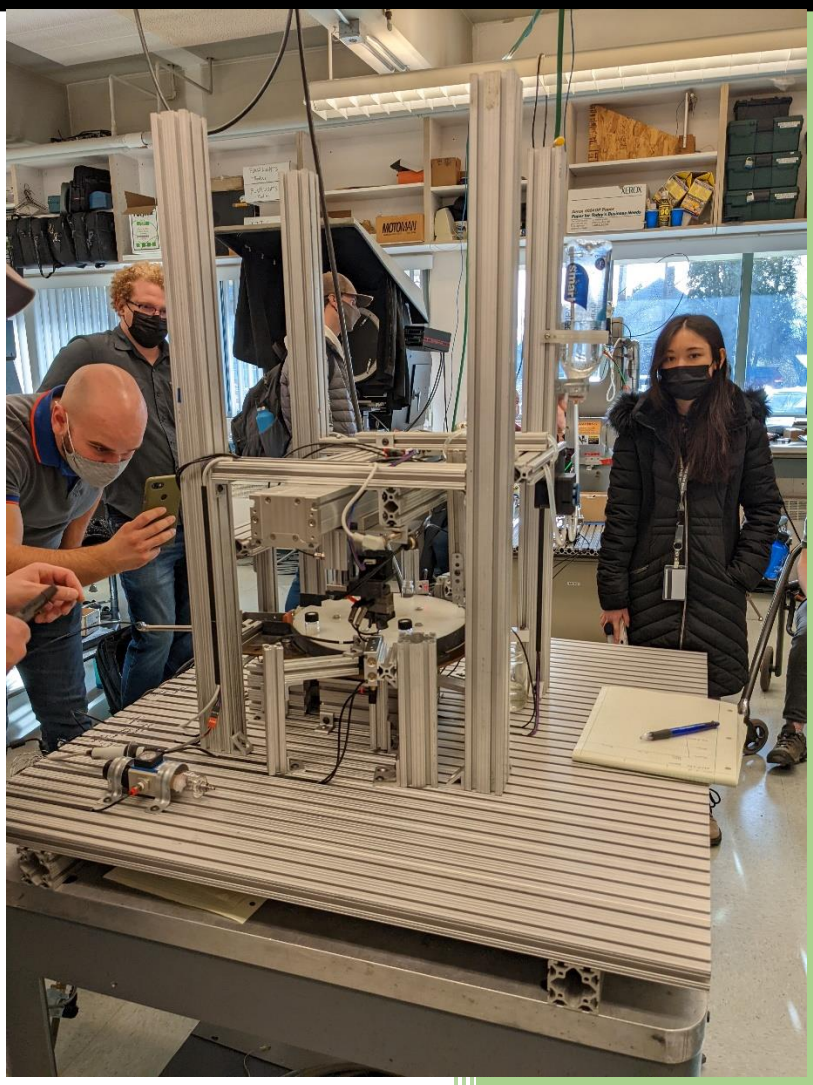
ENGR480

NORobot Operating Manual



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Walla Walla University

It worked until it didn't

Instructions

1. Loading the Machine

Ensure that all power is cut to the system and that all pressure in the pneumatic system is dissipated before reaching into the machine. In order for the system to function properly, a vial needs to be present in 4 out of the 5 stations along the turret. First, place an uncapped vial in the capping turret station after the filling station. Note that this vial will be ejected into the bin, so be ready to sort it from the subsequent filled vials that are ejected. Next, place an empty, uncapped vial in the turret station corresponding to the fill nozzle. Place an empty capped vial in the turret station corresponding to the uncapping station. Place all remaining vials in the queue and ensure that they are capped and empty. Ensure that a vial is present in each of the stations except the outfeed station and that they are appropriately empty or capped. Before starting the machine, make sure that there is sufficient room in the outfeed bin for the number of vials you wish to process.

2. Starting the Machine

To start the machine, first check all power and pneumatic connections. Hook the shop air up to the machine via the 1” grey air hose with a quick connect coupler. Next, check that both power strips on the table are switched on. Check that the PLC is booted, which is indicated by the presence of steady green lights at various locations. Next, turn the red emergency stop button clockwise until the button releases outwards. If the button does not extend outwards, then it was already released and you are good to go. The machine should begin moving now. If the machine does not immediately move, check that the small switch in the top right corner of the PLC is in the “RUN” position, which is all the way to the top. When the switch is in the run position, the machine should start moving.

3. Clearing Jams

If the input jams, stop the machine using the emergency stop button. Remove vials by hand. Replace them one at a time.

If a vial is missing from a turret station, stop the machine using the emergency stop button. Place a vial in the missing position with the appropriate configuration. If the missing vial is in the station corresponding to

- Loading: empty, capped vial
- Uncapping: empty, capped vial
- Filling: empty, uncapped vial
- Capping: full (preferably) uncapped vial

If the output is jammed, determine whether the jam is being caused because the outfeed box is full. If the box is full, remove vials from it. The machine does not have to be stopped to remove vials from the outfeed box. If the jam has occurred on the outfeed chute, immediately stop the machine and remove the obstructing vials/material. Once the chute is cleared, operation can resume.

Descriptions:

1. Station and Component Descriptions

Wheel

The wheel is a central component to the NORobot machine. There are five notches evenly spaced on the edge hold vials and move them between the five stations in the machine: Input, Uncapping, Filling, Recapping, And Output.

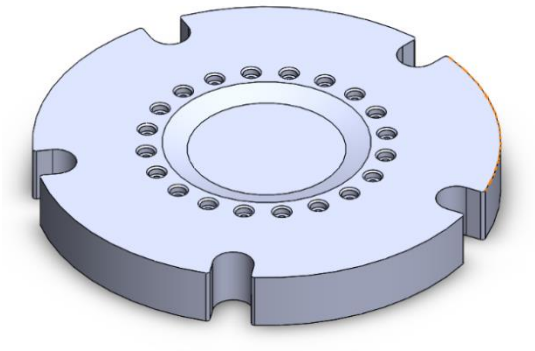


Figure 1: Wheel

Input

Empty capped vials are inserted into the magazine in front of the wheel. The pneumatic actuator with the orange rubber plate puts constant pressure on the end of the line of vials. When the wheel rotates a notch into place, a vial gets pushed in. Since the notch is only large enough for one vial, the system doesn't bind up and the vials are singulated. The vials then go to the uncapping station.

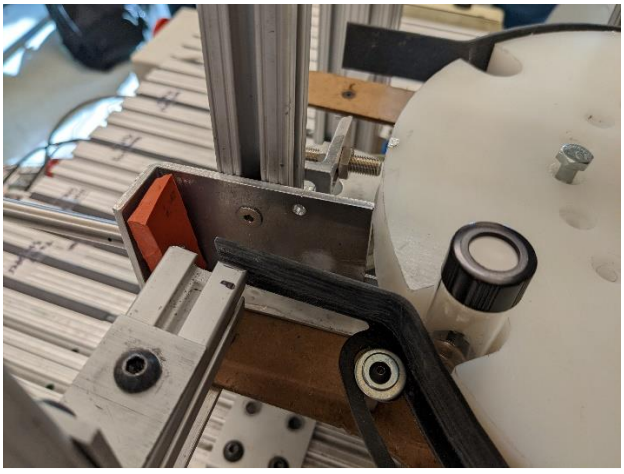


Figure 2: Input

Uncap Vial

When the vial reaches the uncapping station, an inductive proximity sensor senses when the wheel is in the exact position and the wheel stops. An optical proximity sensor senses if a vial is present. The linear slider with the gripper head slides over and stops when it reaches another inductive proximity sensor. Next the side gripper moves in to hold the vial and the gripper head moves down over the vial cap. The gripper head closes around the cap, then turns and removes the cap. The gripper head goes up and moves toward the recapping station. The side gripper retracts and the wheel moves the vial to the filling station.

Figure 3: Inductive Proximity Sensor

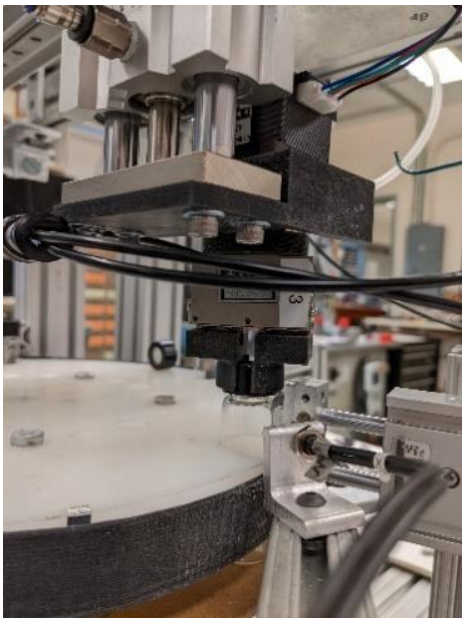


Figure 5: Gripper Head

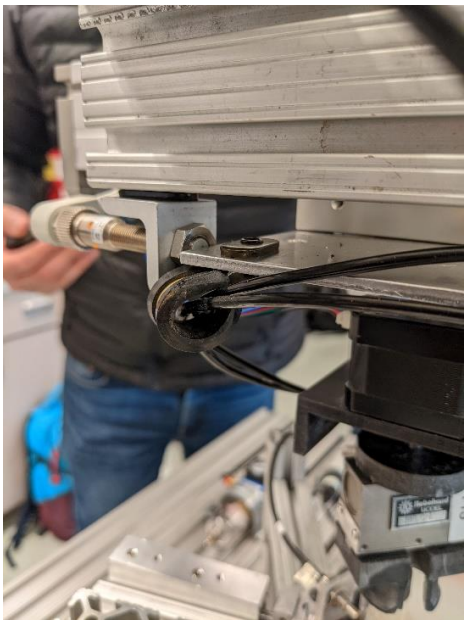


Figure 4: Inductive Proximity Sensor

Figure 6:Side Gripper

Filling

When the vial reaches the filling station, its presence is sensed by the optical sensor. A function generator runs a stepper motor connected to a peristaltic pump. The peristaltic pump pumps fluid from the reservoir through the nozzle filling the vial. If there is no vial present, the pump will not operate. The wheel moves the vial to the recapping station.

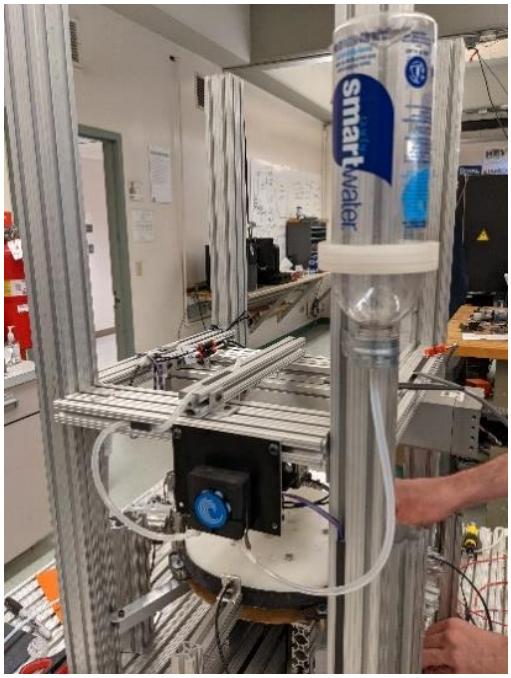


Figure 7: Pump Assembly

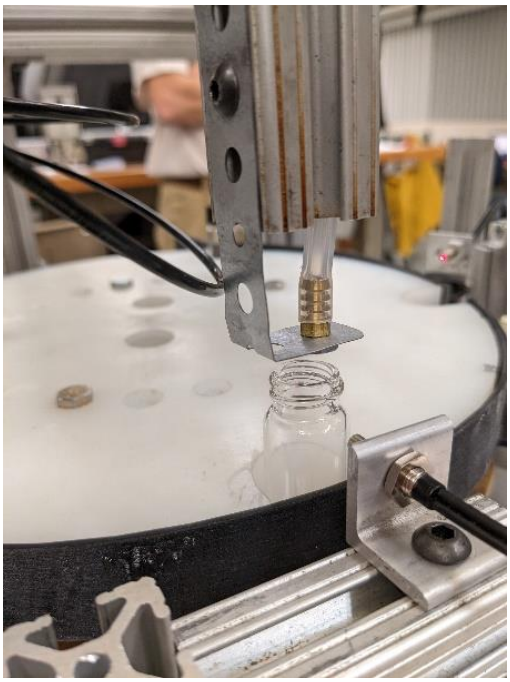


Figure 8: Pump Nozzle

Recap Vial

The recapping station is identical to the uncapping station. When the vial reaches the recapping station, an optical proximity sensor senses if a vial is present. The gripper head holding a cap moves over on the linear slider and stops when it hits a limit switch. The side gripper moves in to hold the vial and the gripper head moves down over the vial. The gripper head rotates and secures the cap on the vial. The gripper head goes up and moves back to the uncapping station while the side gripper retracts. The wheel moves the vial to the output station.

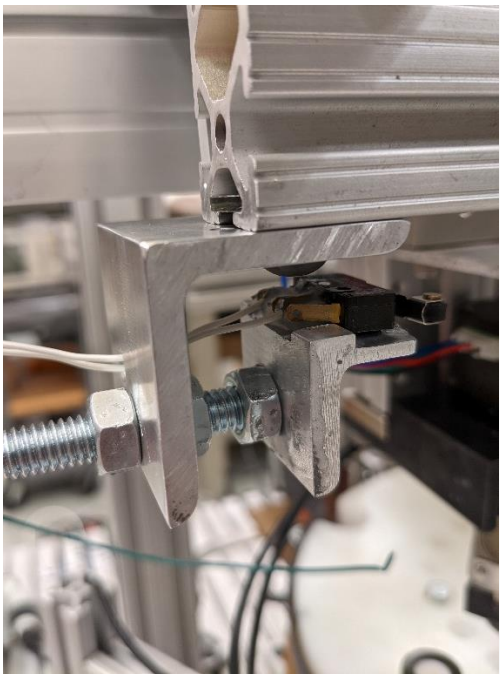


Figure 9: Limit Switch

Output

When the capped vial is moved to the output of the machine, the wheel moves it past the floor plate. The vial falls down the chute and is deposited in the box ready for use.

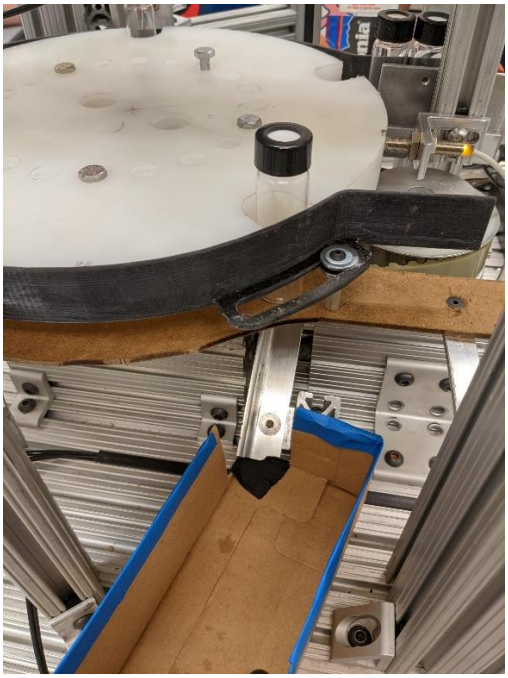


Figure 10: Output Station

Figure 11: Output Shoot

2. Maintenance instructions

Under normal operation, the machine should operate continuously and autonomously. Should the vials shift out of position with the gripper subsystem, it may be necessary to gently adjust the position of the limit switches to realign the end points of the gripper.

The turret may encounter resistance, preventing regular turning. Adjust slack to prevent bearing slip with the belt and the driver bearing.

As vial input is out of sync with a stationary stage, the timing with respect to the stage movement is precise, and any misalignment in time may cause resistance to turret movement or damage to the input system. If input piston is damaged, replace the piston. If input system is causing excessive resistance with respect to the turret movement, decrease input piston pressure. If input piston fails to insert vial, increase input piston pressure.

Vial output may be interrupted by interaction with the driver belt. To prevent this permanently, a belt cover may be manufactured to allow passage over the belt without interaction. Without a driver belt cover, adjust the turret speed to minimize interaction, and adjust chute angle to catch the output vials more easily.

Misaligned grippers may cause fatigue in the floor of the system by applying excessive force through vials. Check that the system floor is level and readjust as needed. If this problem persists unadjusted, destructive interaction between the placement pistons and the stage wall is possible due to the stage wall supports' attachment to the system floor.

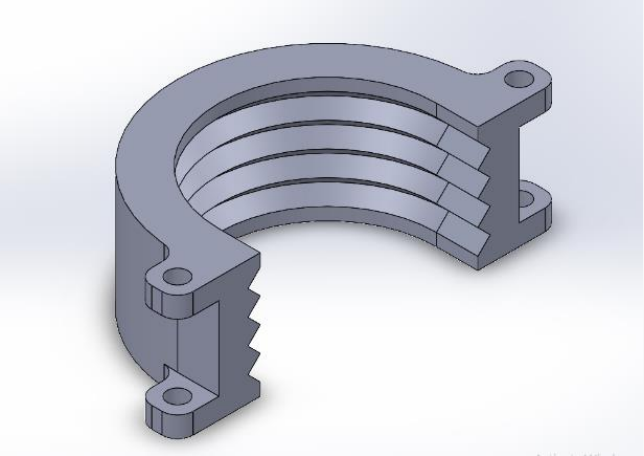
The stage wall is brittle, and may bend or break if stressed by interaction with the placement pistons. A broken or bent stage wall is likely to rub against the main turret, causing resistance. If mending is possible, then take steps to mend the stage wall, if not, manufacture a replacement.

Placement pistons may cause damage as a result of excess force during interactions with either vials, or if misaligned, with the stage wall. If vials are being broken due to excessive force, readjust the expected force for the placement pistons. If vials are being broken due to direct metal -to-glass interaction, add or replace foam insert to face of piston. If placement pistons pin vials at a non-normal contact point, readjust horizontal placement piston position, or adjust trigger time. If the placement piston physically interacts in any way with cap gripper assembly, adjust vertical placement piston position.

3. Suggestions for future improvements

Soft Vial Notches

One improvement for the wheel would be to print soft inserts for the notches. These would help center and stabilize the vial making the uncapping/capping and filling tasks more accurate. We designed a part for this but we were not able to print it when the Eden Poly-jet printer had the flexible material installed.



Capping Mechanism

The most complex component of the machine was the overhead capping/uncapping mechanism. This mechanism used a 4-axis stack that had a lot of play in it and was very hard to calibrate properly. In the future, it would be beneficial to combine some of these axis. In particular, the raising/lowering and the spinning of the gripper could be combined through the use of a lead screw that exactly matched the thread pitch of the vial cap. This part would have to be custom made, but it would result in less play and more accurate capping of the vial.

Needle Valves

The pneumatics could be very violent, especially in the context of handling glass vials. The use of needle valves on each pneumatic system could give the user much more accurate control over the pneumatics. Pistons could extend slower without sacrificing much force.

4. Performance data

Vial filling was the most consistent stage, due to the continuous nature of the peristaltic pump and the forgiving positioning of the vial placement below. This stage needed some adjustment for volumetric control over the amount of fluid dispensed.

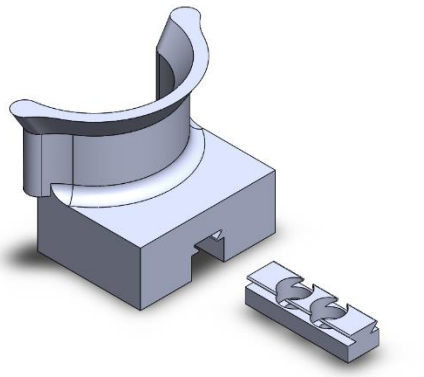
The performance of the overhead multi-axis assembly degraded over time. Heat generated in the stepper motor within the gripper assembly warped the 3D-printed stepper motor mount, causing significant bend to the motion of the gripper below, and a consequential misalignment between the gripper and the vial. This made calibration almost impossible. The axis needs to be made from less temperature sensitive materials, such as aluminum.

Problems with turret positioning came up due to the inexact placement of reflective tape used in tandem with an induction sensor to set stage position. Some turret positions were more precise than others. This led to difficulty in calibration, as settings for one position didn't necessarily apply to another.

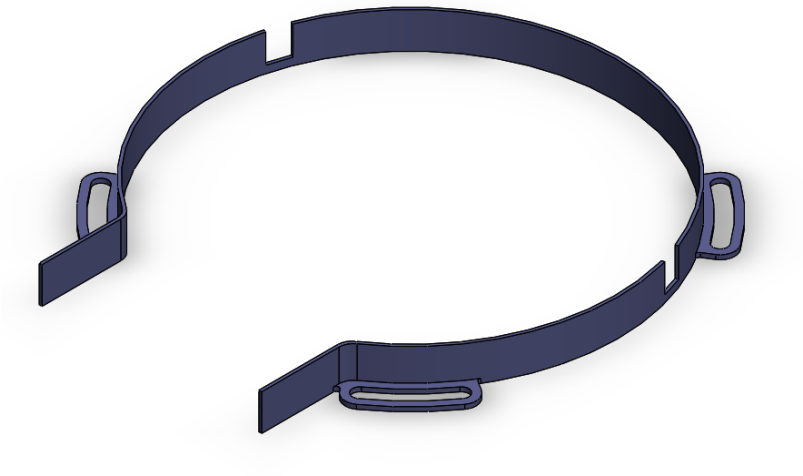
Overall, performance started as semi-reliable, but through heavy fatigue and slight initial inaccuracy, it deteriorates quickly over time.

Diagrams:

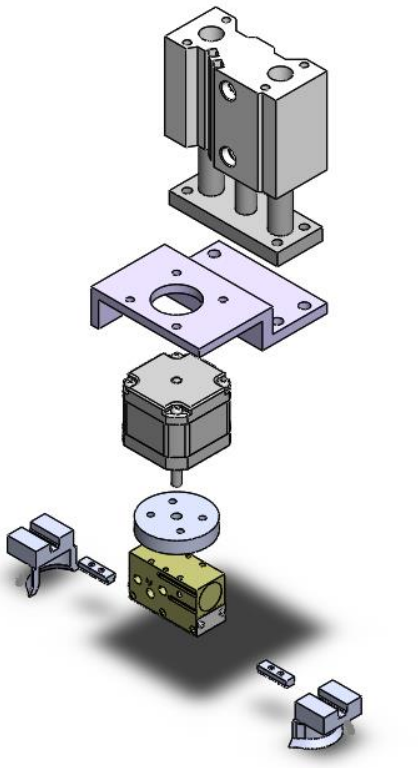
1. mechanical drawings or annotated photos



12 Gripper and Gripper Mount



13 Stage Wall



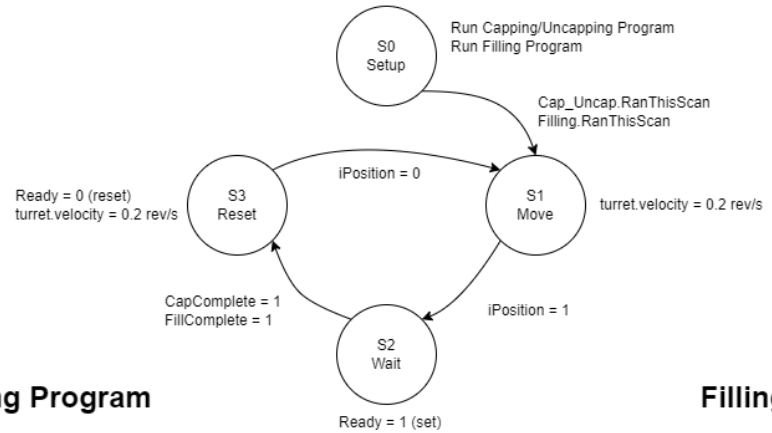
14 Exploded view of Full Gripper Assembly

2. PLC ladder logic (with element labels and rung comments)

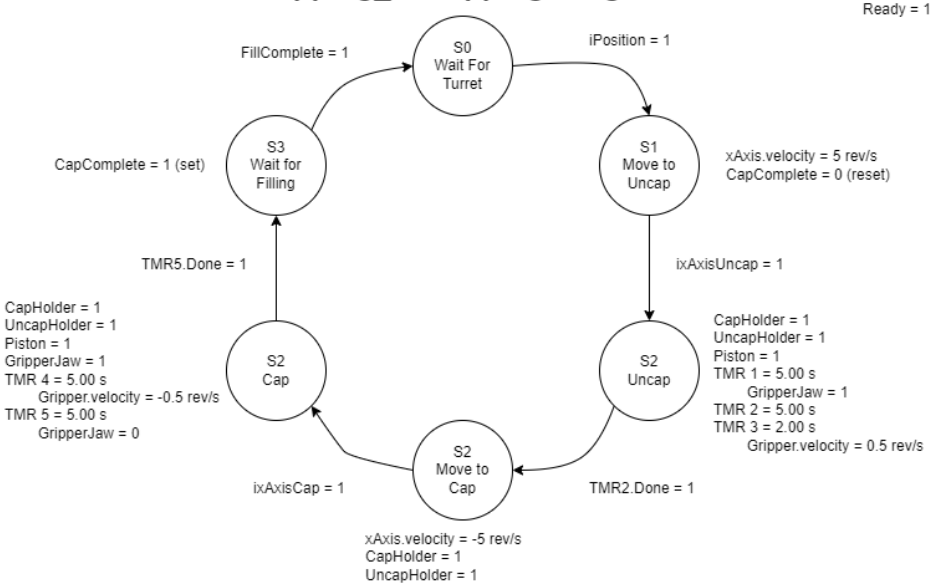
The PLC Ladder Logic was exported from Do-More Designer as a PDF, which is attached at the end of this document.

3. State machine diagram(s)

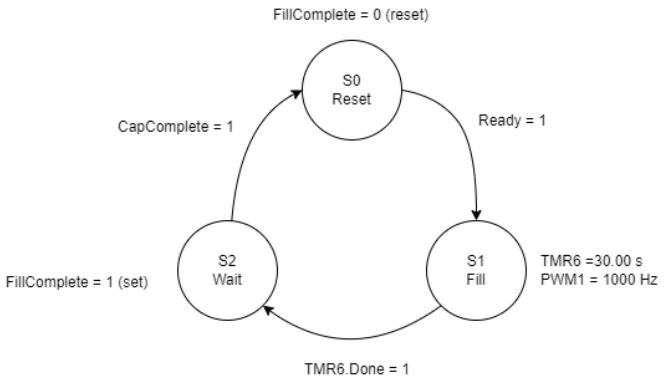
Main



Capping_Uncapping Program



Filling Program



4. Stepper motor drive configuration (if applicable)

Turret Motor – Mode 8

Switch	Position
1	off
2	off
3	off
4	off
5	on
6	on
7	off
8	off

Horizontal Motor – Mode 3

Switch	Position
1	off
2	off
3	off
4	off
5	on
6	on
7	off
8	off

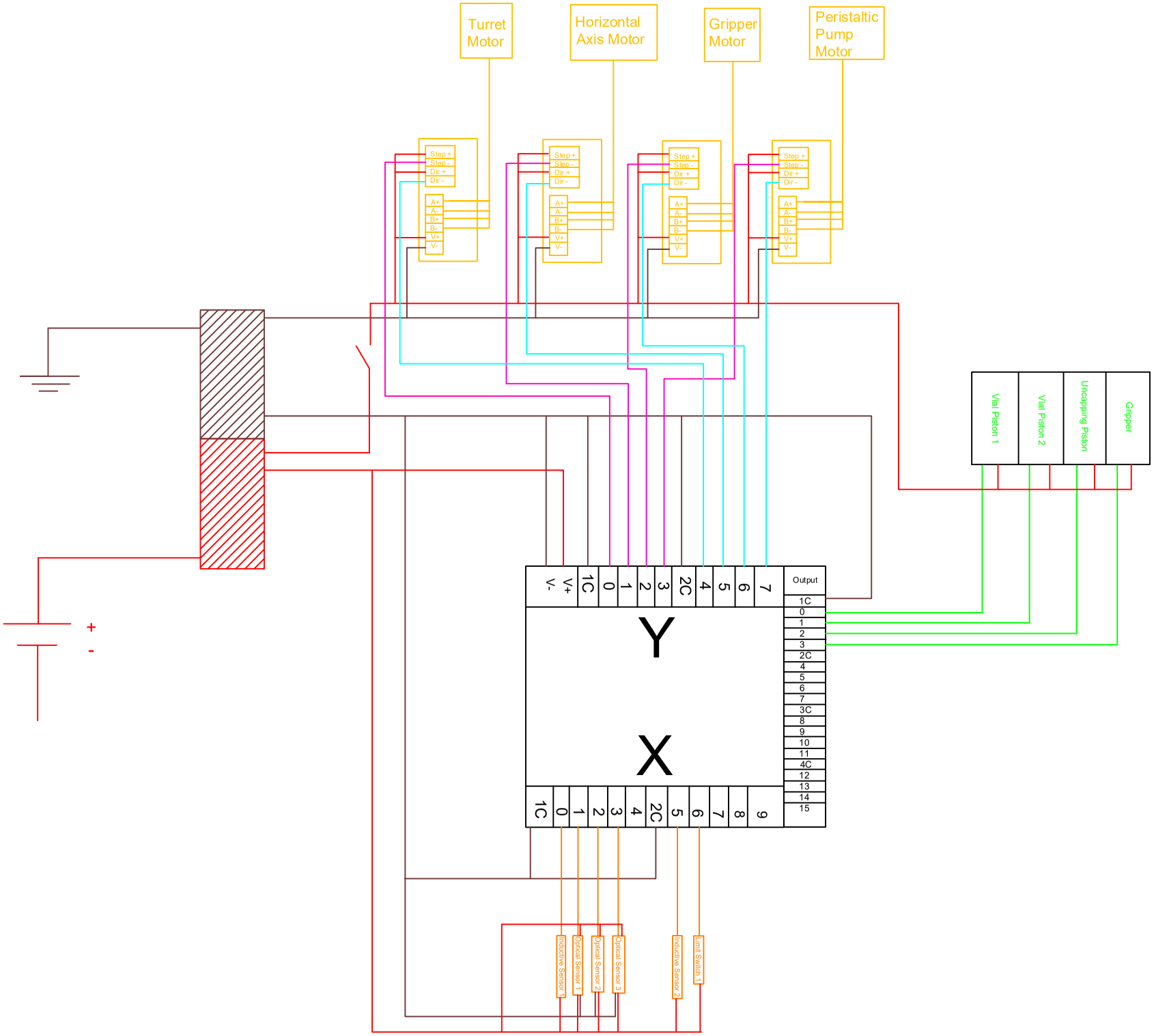
Gripper Motor – Mode 3

Switch	Position
1	off
2	on
3	off
4	on
5	on
6	on
7	off
8	off

Pump Motor – Mode 3

Switch	Position
1	off
2	off
3	off
4	off
5	on
6	on
7	off
8	off

5. Wiring diagram or table, listing all I/O connections between PLC, sensors, pneumatic valves, step motor amplifiers, robot controller, or other devices.


Turret Motor
Horizontal Axis Motor
Gripper Motor
Peristaltic Pump Motor
Step +
Step -
Dir +
Dir -
A+
A-
B+
B-
V+
V-
Vial Piston 1
Vial Piston 2
Uncapping Piston
Gripper
V- V+ 1C 0 1 2 3 2C 4 5 6 7
Output
1C 0 1 2 3 2C 4 5 6 7 3C 8 9 10 11 4C 12 13 14 15
Y
X
1C 0 1 2 3 4 2C 5 6 7 8 9
Inductive Sensor 1
Optical Sensor 1
Optical Sensor 2
Optical Sensor 3
Inductive Sensor 2
Limit Switch 1
+
-

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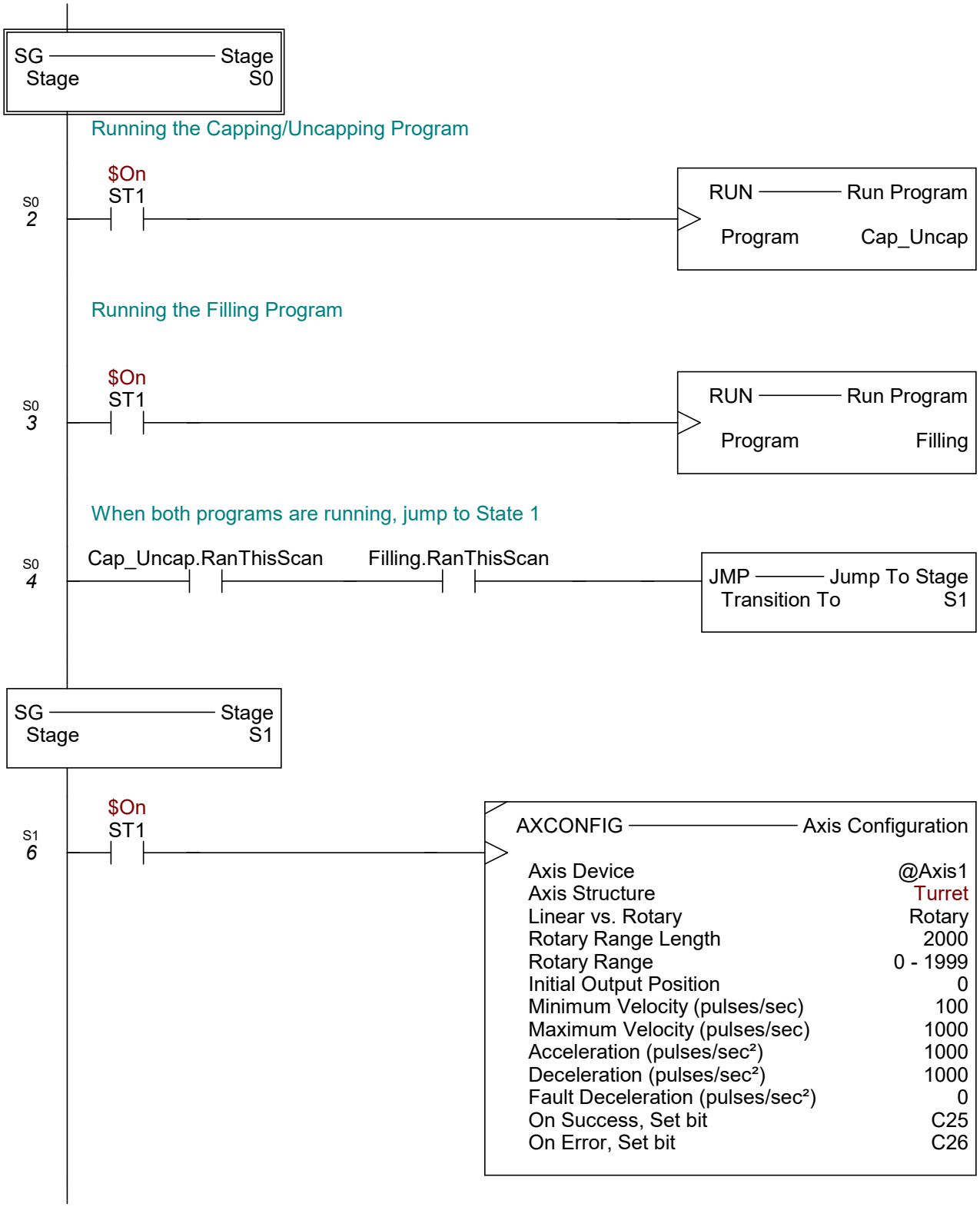
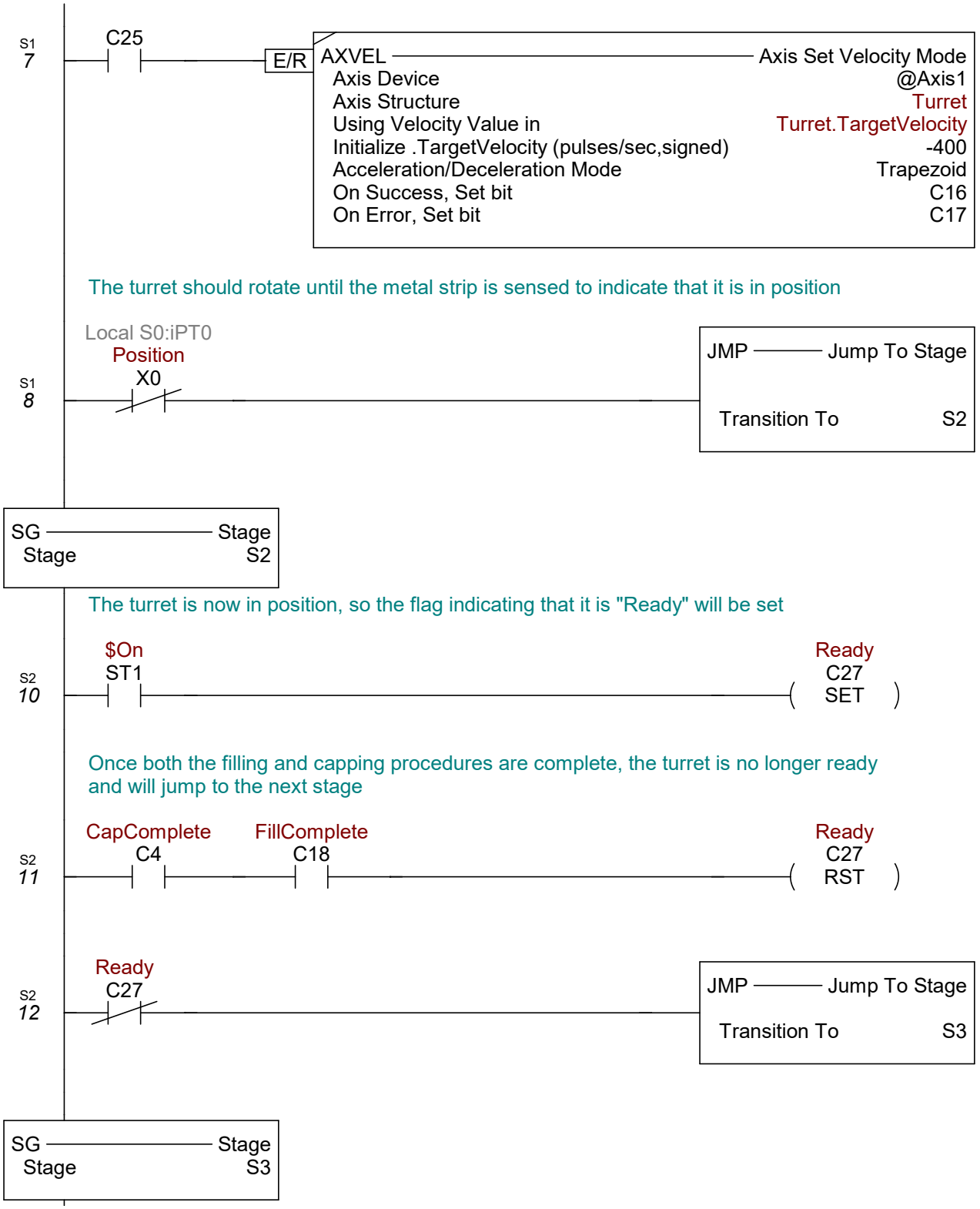
Link Name:
Do-more Technology Version: 2.8
Description:
Version:
Company:
Department:
Programmer:


SG
Stage
Stage
S0
Running the Capping/Uncapping Program
S0
2
$On
ST1
RUN
Run Program
Program
Cap_Uncap
Running the Filling Program
S0
3
$On
ST1
RUN
Run Program
Program
Filling
When both programs are running, jump to State 1
S0
4
Cap_Uncap.RanThisScan
Filling.RanThisScan
JMP
Jump To Stage
Transition To
S1
SG
Stage
Stage
S1
S1
6
$On
ST1
AXCONFIG
Axis Configuration
Axis Device @Axis1
Axis Structure Turret
Linear vs. Rotary Rotary
Rotary Range Length 2000
Rotary Range 0 - 1999
Initial Output Position 0
Minimum Velocity (pulses/sec) 100
Maximum Velocity (pulses/sec) 1000
Acceleration (pulses/sec²) 1000
Deceleration (pulses/sec²) 1000
Fault Deceleration (pulses/sec²) 0
On Success, Set bit C25
On Error, Set bit C26


S1
7
C25
E/R
AXVEL
Axis Set Velocity Mode
Axis Device
@Axis1
Axis Structure
Turret
Using Velocity Value in
Turret.TargetVelocity
Initialize .TargetVelocity (pulses/sec,signed)
-400
Acceleration/Deceleration Mode
Trapezoid
On Success, Set bit
C16
On Error, Set bit
C17
The turret should rotate until the metal strip is sensed to indicate that it is in position
Local S0:iPT0
Position
X0
S1
8
JMP
Jump To Stage
Transition To
S2
SG
Stage
Stage
S2
The turret is now in position, so the flag indicating that it is "Ready" will be set
$On
ST1
S2
10
Ready
C27
SET
Once both the filling and capping procedures are complete, the turret is no longer ready
and will jump to the next stage
CapComplete
C4
FillComplete
C18
S2
11
Ready
C27
RST
Ready
C27
S2
12
JMP
Jump To Stage
Transition To
S3
SG
Stage
Stage
S3

Once both completion flags are reset, the turret will move until it is no longer in position, then jump back to stage 1

S3
14

CapComplete
C4

FillComplete
C18

AXCONFIG — Axis Configuration

Axis Device	@Axis1
Axis Structure	Turret
Linear vs. Rotary	Rotary
Rotary Range Length	2000
Rotary Range	0 - 1999
Initial Output Position	0
Minimum Velocity (pulses/sec)	100
Maximum Velocity (pulses/sec)	1000
Acceleration (pulses/sec²)	1000
Deceleration (pulses/sec²)	1000
Fault Deceleration (pulses/sec²)	0
On Success, Set bit	C22
On Error, Set bit	C28

S3
15

C22

E/R

AXVEL — Axis Set Velocity Mode

Axis Device	@Axis1
Axis Structure	Turret
Using Velocity Value in	Turret.TargetVelocity
Initialize .TargetVelocity (pulses/sec,signed)	-400
Acceleration/Deceleration Mode	Trapezoid
On Success, Set bit	C29
On Error, Set bit	C30

S3
16

Local S0:iPT0
Position
X0

JMP — Jump To Stage

Transition To S1

S3
17

NOP

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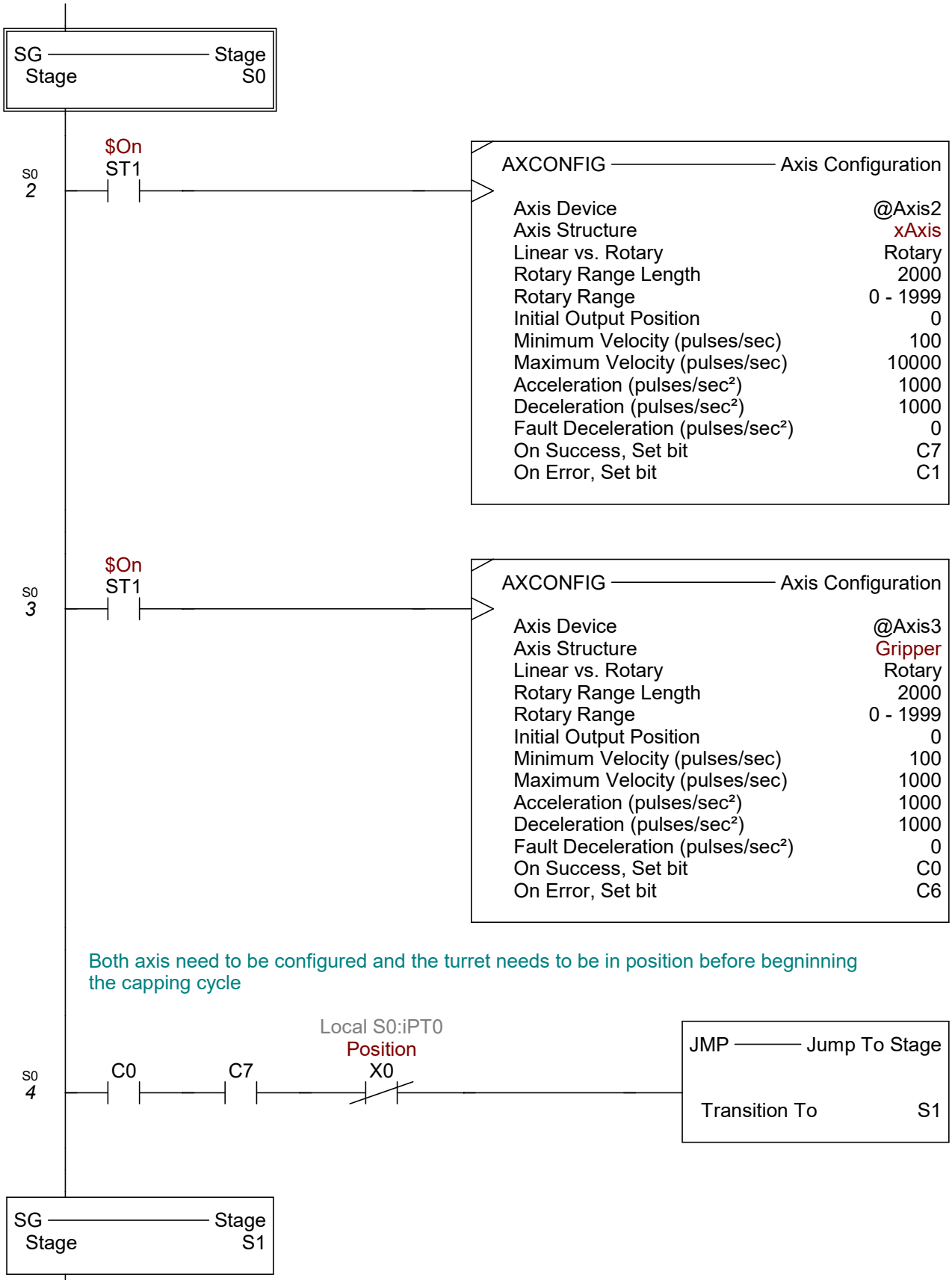
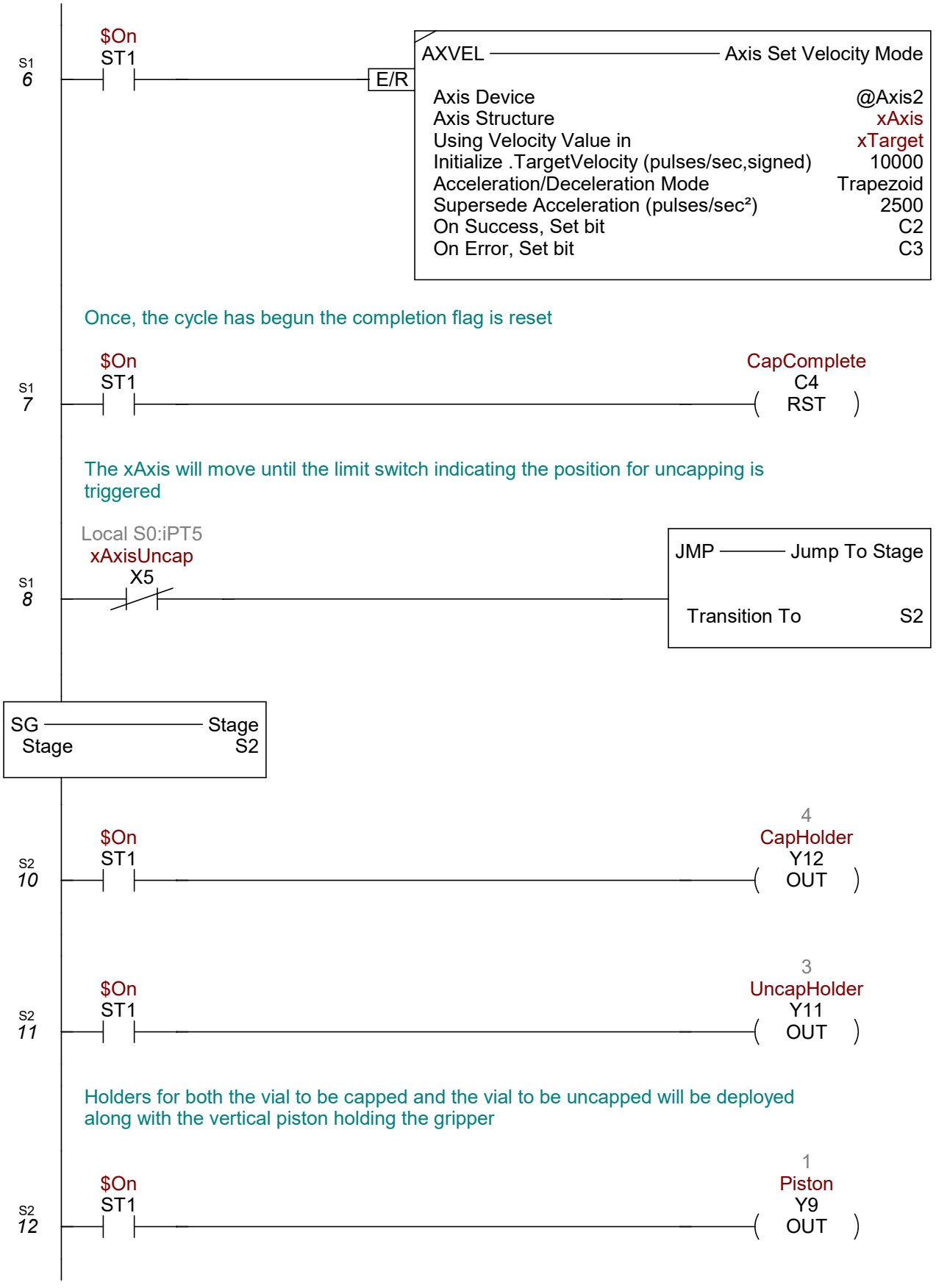
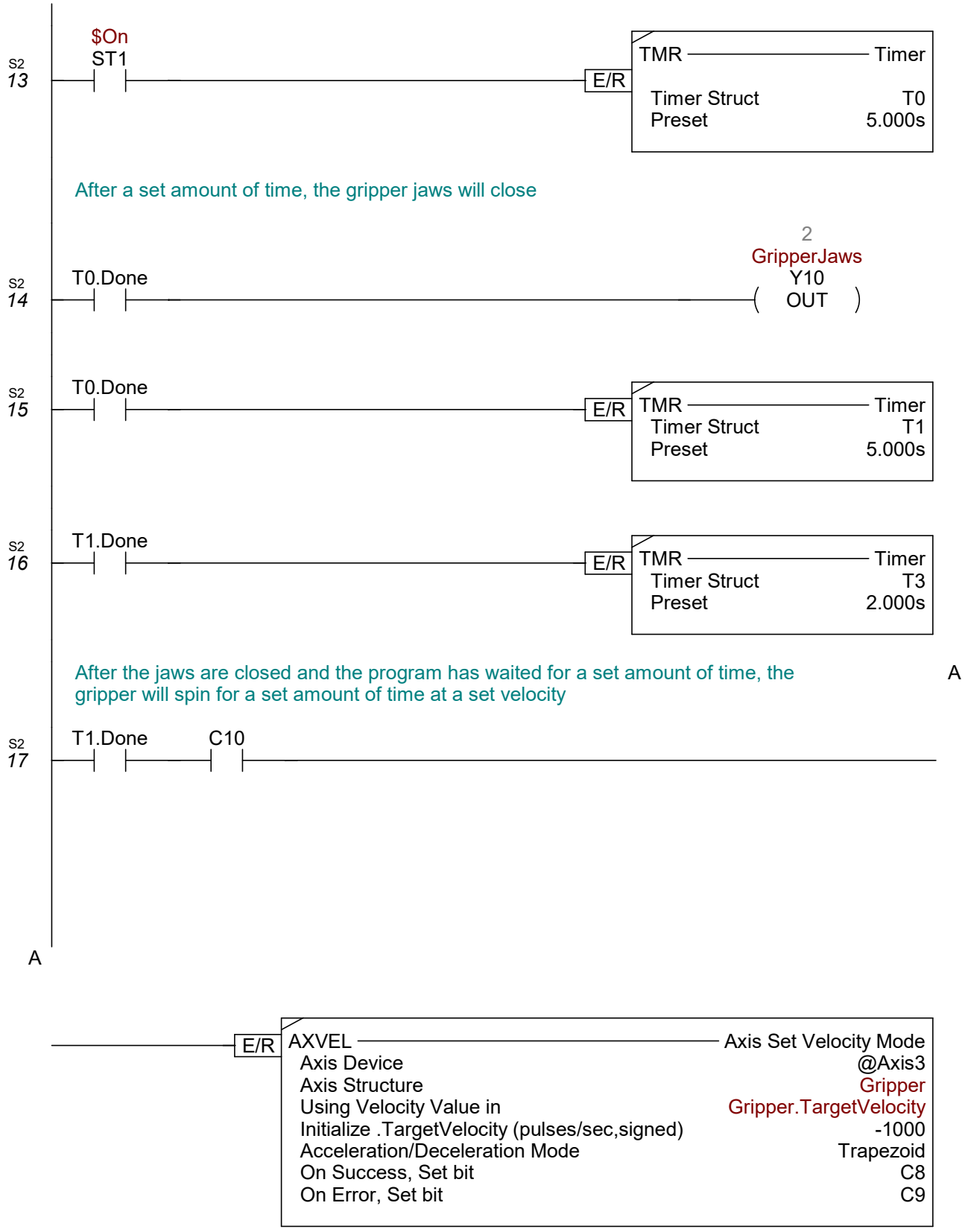
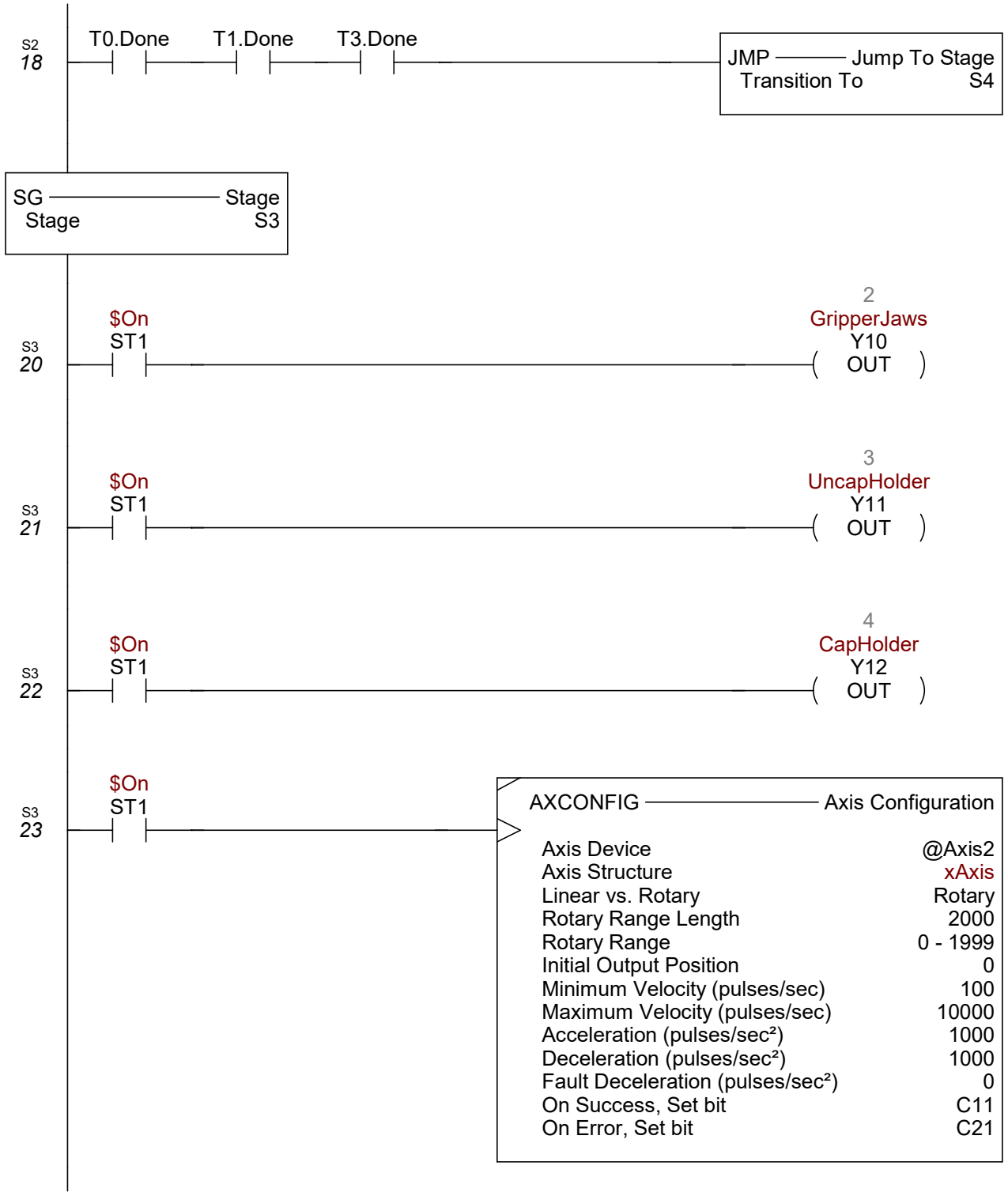
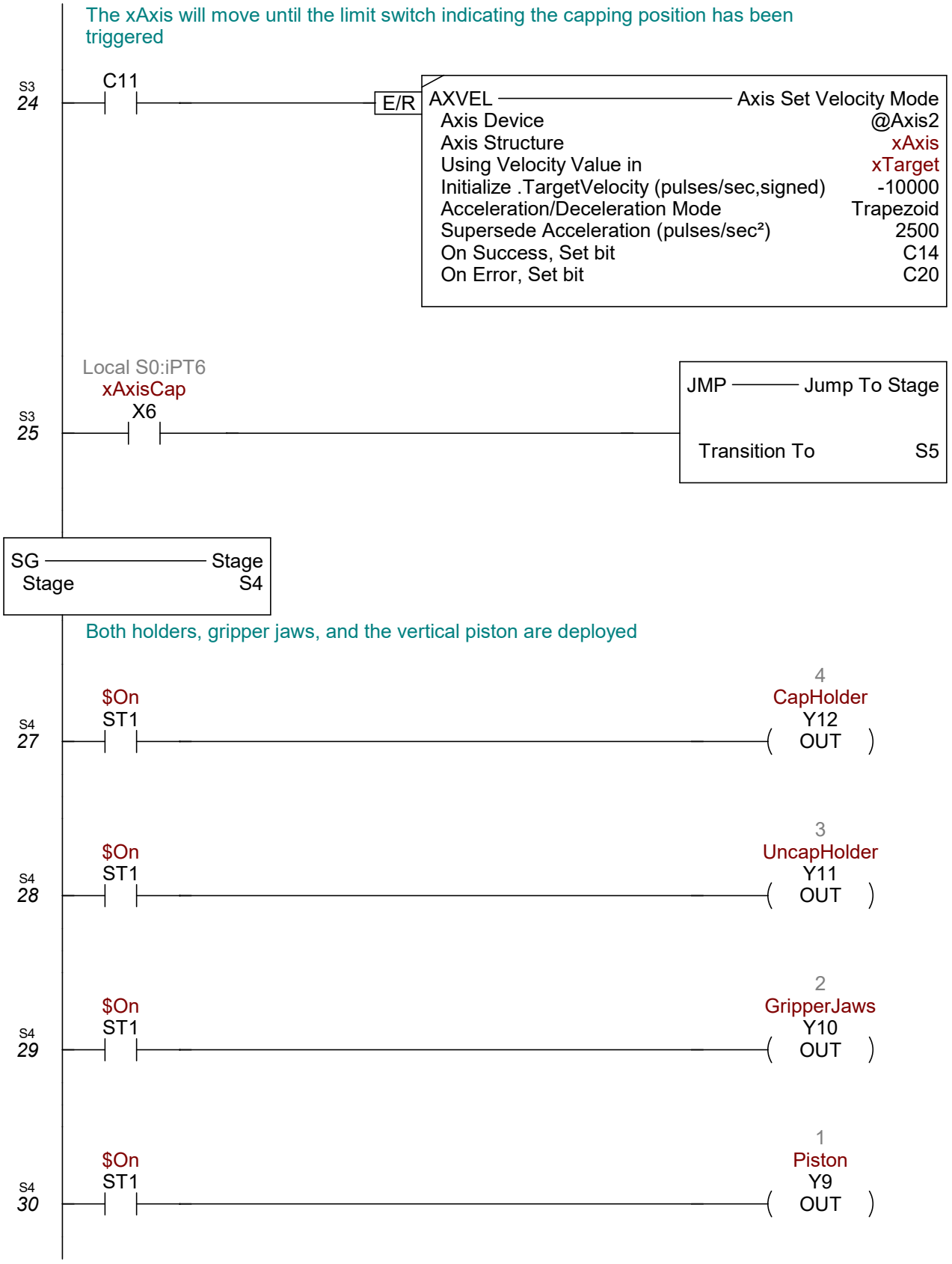
Link Name:
Do-more Technology Version: 2.8
Description:
Version:
Company:
Department:
Programmer:

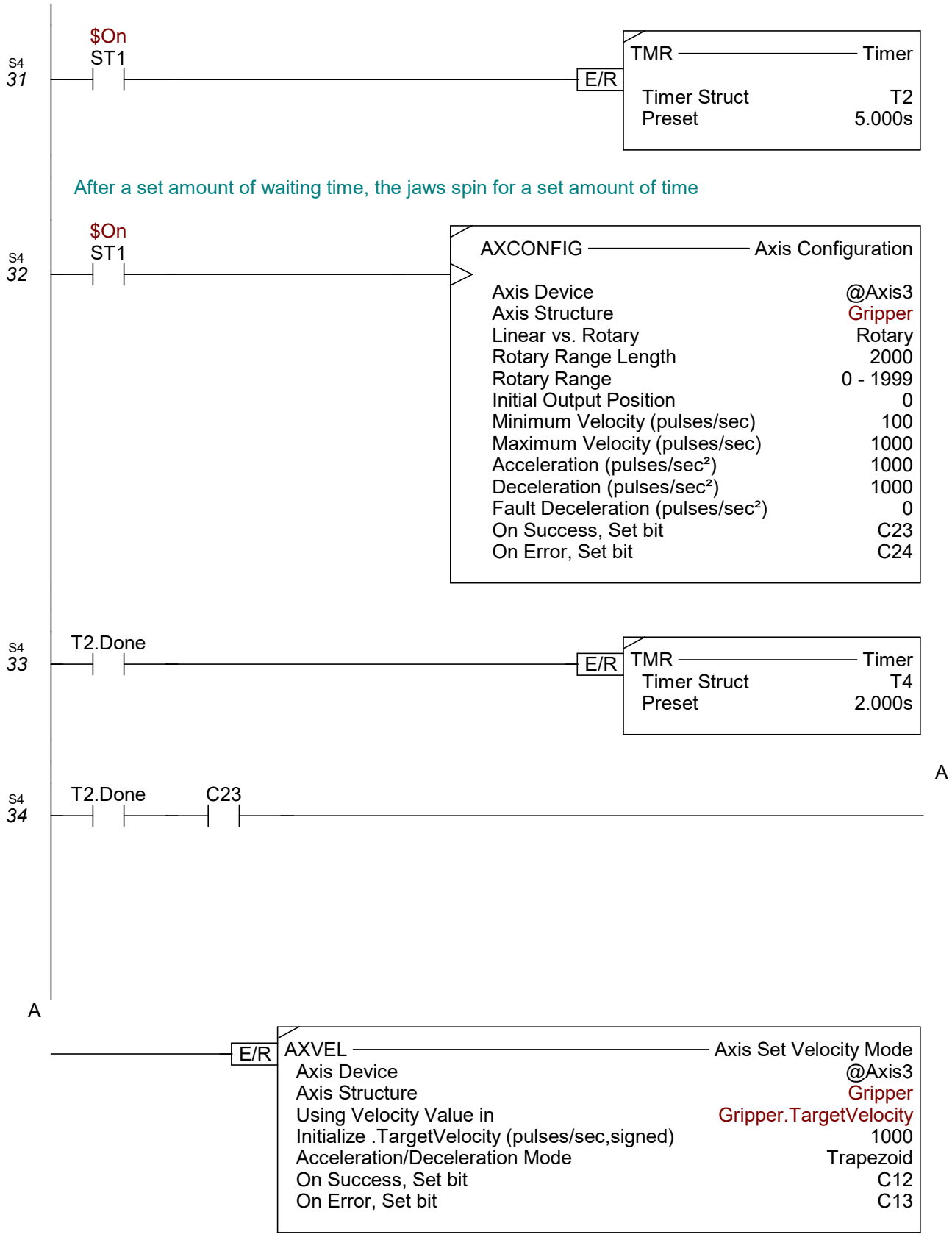

SG
Stage
Stage
S0
$On
ST1
S0
2
AXCONFIG
Axis Configuration
Axis Device @Axis2
Axis Structure xAxis
Linear vs. Rotary Rotary
Rotary Range Length 2000
Rotary Range 0 - 1999
Initial Output Position 0
Minimum Velocity (pulses/sec) 100
Maximum Velocity (pulses/sec) 10000
Acceleration (pulses/sec²) 1000
Deceleration (pulses/sec²) 1000
Fault Deceleration (pulses/sec²) 0
On Success, Set bit C7
On Error, Set bit C1
$On
ST1
S0
3
AXCONFIG
Axis Configuration
Axis Device @Axis3
Axis Structure Gripper
Linear vs. Rotary Rotary
Rotary Range Length 2000
Rotary Range 0 - 1999
Initial Output Position 0
Minimum Velocity (pulses/sec) 100
Maximum Velocity (pulses/sec) 1000
Acceleration (pulses/sec²) 1000
Deceleration (pulses/sec²) 1000
Fault Deceleration (pulses/sec²) 0
On Success, Set bit C0
On Error, Set bit C6
Both axis need to be configured and the turret needs to be in position before begninning the capping cycle
Local S0:iPT0
Position
S0
4
C0
C7
X0
JMP
Jump To Stage
Transition To S1
SG
Stage
Stage
S1

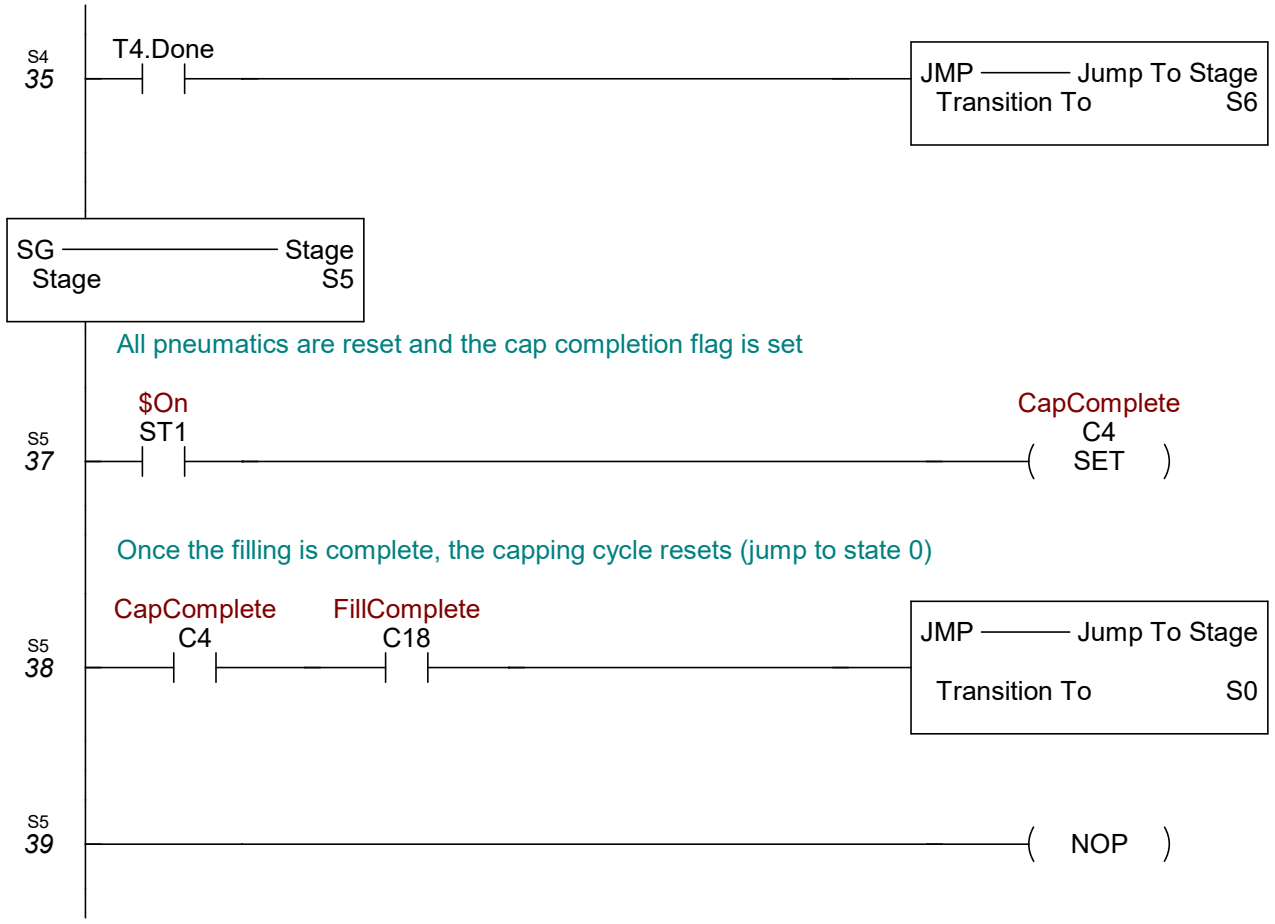

S1
6
$On
ST1
E/R
AXVEL — Axis Set Velocity Mode
Axis Device @Axis2
Axis Structure xAxis
Using Velocity Value in xTarget
Initialize .TargetVelocity (pulses/sec,signed) 10000
Acceleration/Deceleration Mode Trapezoid
Supersede Acceleration (pulses/sec²) 2500
On Success, Set bit C2
On Error, Set bit C3
Once, the cycle has begun the completion flag is reset
S1
7
$On
ST1
CapComplete
C4
RST
The xAxis will move until the limit switch indicating the position for uncapping is triggered
Local S0:iPT5
xAxisUncap
X5
S1
8
JMP — Jump To Stage
Transition To S2
SG — Stage
Stage S2
S2
10
$On
ST1
4
CapHolder
Y12
OUT
S2
11
$On
ST1
3
UncapHolder
Y11
OUT
Holders for both the vial to be capped and the vial to be uncapped will be deployed along with the vertical piston holding the gripper
S2
12
$On
ST1
1
Piston
Y9
OUT


$On
ST1
S2
13
E/R
TMR
Timer
Timer Struct
T0
Preset
5.000s
After a set amount of time, the gripper jaws will close
2
GripperJaws
Y10
OUT
S2
14
T0.Done
S2
15
T0.Done
E/R
TMR
Timer
Timer Struct
T1
Preset
5.000s
S2
16
T1.Done
E/R
TMR
Timer
Timer Struct
T3
Preset
2.000s
After the jaws are closed and the program has waited for a set amount of time, the gripper will spin for a set amount of time at a set velocity
A
S2
17
T1.Done
C10
A
E/R
AXVEL
Axis Set Velocity Mode
Axis Device
@Axis3
Axis Structure
Gripper
Using Velocity Value in
Gripper.TargetVelocity
Initialize .TargetVelocity (pulses/sec,signed)
-1000
Acceleration/Deceleration Mode
Trapezoid
On Success, Set bit
C8
On Error, Set bit
C9

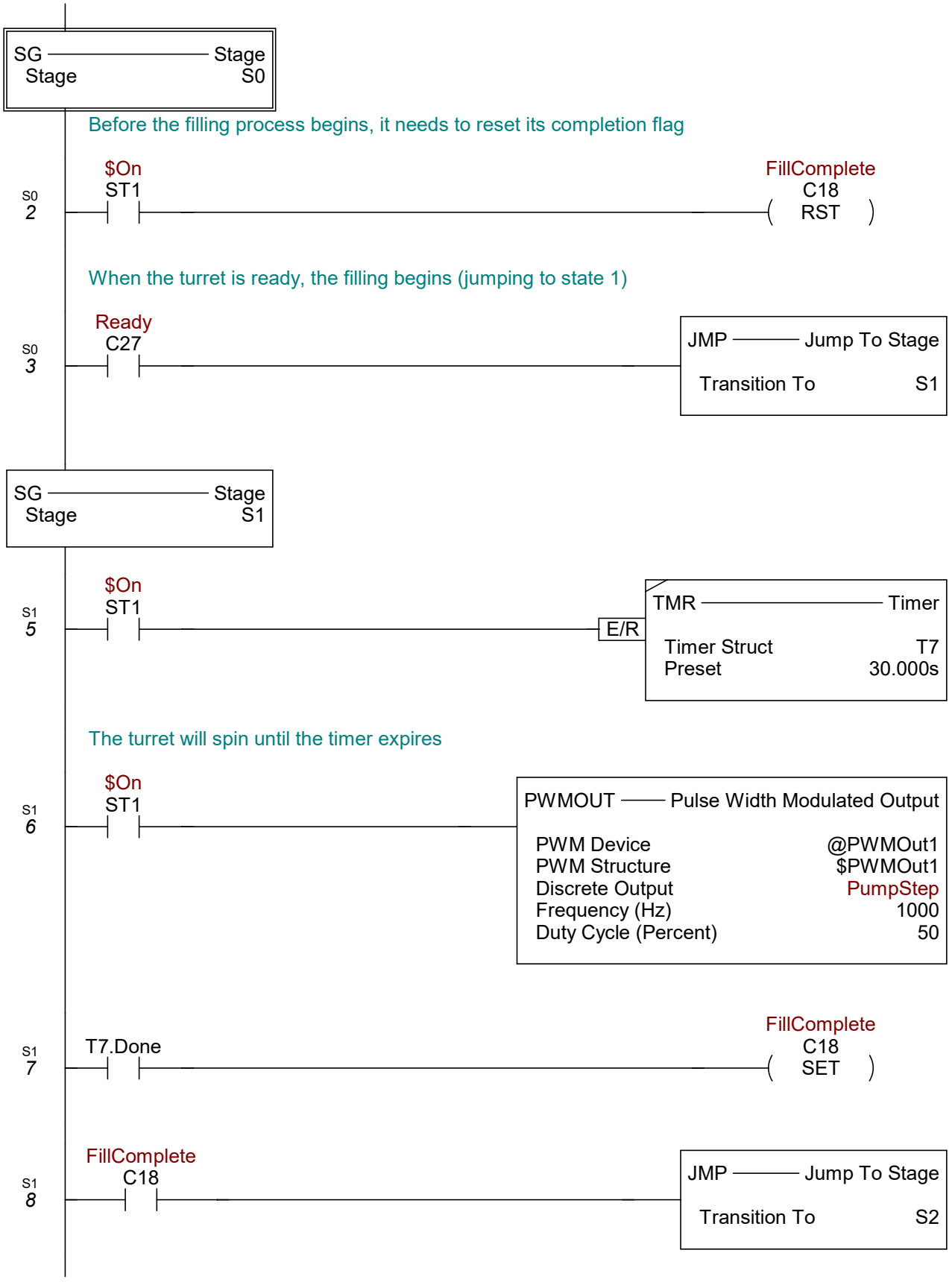

S2
18
T0.Done
T1.Done
T3.Done
JMP
Jump To Stage
Transition To
S4
SG
Stage
Stage
S3
S3
20
$On
ST1
2
GripperJaws
Y10
OUT
S3
21
$On
ST1
3
UncapHolder
Y11
OUT
S3
22
$On
ST1
4
CapHolder
Y12
OUT
S3
23
$On
ST1
AXCONFIG
Axis Configuration
Axis Device @Axis2
Axis Structure xAxis
Linear vs. Rotary Rotary
Rotary Range Length 2000
Rotary Range 0 - 1999
Initial Output Position 0
Minimum Velocity (pulses/sec) 100
Maximum Velocity (pulses/sec) 10000
Acceleration (pulses/sec²) 1000
Deceleration (pulses/sec²) 1000
Fault Deceleration (pulses/sec²) 0
On Success, Set bit C11
On Error, Set bit C21

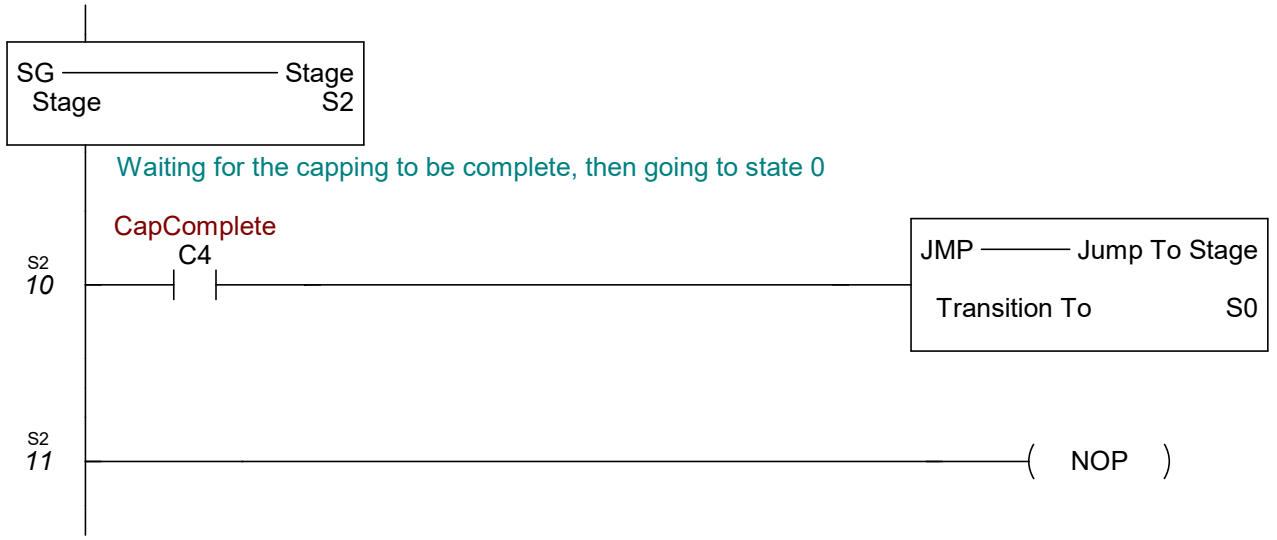

The xAxis will move until the limit switch indicating the capping position has been triggered
S3
24
C11
E/R
AXVEL
Axis Set Velocity Mode
Axis Device
@Axis2
Axis Structure
xAxis
Using Velocity Value in
xTarget
Initialize .TargetVelocity (pulses/sec,signed)
-10000
Acceleration/Deceleration Mode
Trapezoid
Supersede Acceleration (pulses/sec²)
2500
On Success, Set bit
C14
On Error, Set bit
C20
Local S0:iPT6
xAxisCap
S3
25
X6
JMP
Jump To Stage
Transition To
S5
SG
Stage
Stage
S4
Both holders, gripper jaws, and the vertical piston are deployed
4
CapHolder
Y12
S4
27
$On
ST1
OUT
3
UncapHolder
Y11
S4
28
$On
ST1
OUT
2
GripperJaws
Y10
S4
29
$On
ST1
OUT
1
Piston
Y9
S4
30
$On
ST1
OUT


S4
31
$On
ST1
E/R
TMR
Timer
Timer Struct
T2
Preset
5.000s
After a set amount of waiting time, the jaws spin for a set amount of time
S4
32
$On
ST1
AXCONFIG
Axis Configuration
Axis Device
@Axis3
Axis Structure
Gripper
Linear vs. Rotary
Rotary
Rotary Range Length
2000
Rotary Range
0 - 1999
Initial Output Position
0
Minimum Velocity (pulses/sec)
100
Maximum Velocity (pulses/sec)
1000
Acceleration (pulses/sec²)
1000
Deceleration (pulses/sec²)
1000
Fault Deceleration (pulses/sec²)
0
On Success, Set bit
C23
On Error, Set bit
C24
S4
33
T2.Done
E/R
TMR
Timer
Timer Struct
T4
Preset
2.000s
A
S4
34
T2.Done
C23
A
E/R
AXVEL
Axis Set Velocity Mode
Axis Device
@Axis3
Axis Structure
Gripper
Using Velocity Value in
Gripper.TargetVelocity
Initialize .TargetVelocity (pulses/sec,signed)
1000
Acceleration/Deceleration Mode
Trapezoid
On Success, Set bit
C12
On Error, Set bit
C13


S4
35
T4.Done
JMP
Jump To Stage
Transition To
S6
SG
Stage
Stage
S5
All pneumatics are reset and the cap completion flag is set
S5
37
$On
ST1
CapComplete
C4
SET
Once the filling is complete, the capping cycle resets (jump to state 0)
S5
38
CapComplete
C4
FillComplete
C18
JMP
Jump To Stage
Transition To
S0
S5
39
NOP

Project Path: C:\Users\Public\Documents\Do-more\Designer2_8\Projects\ENGR480_V1.dmd
Save Date: 12/14/21 21:09:22
Creation Date: 12/02/21 15:29:17
PLC Type: BX-DM1E-x
Class ID: Do-more BRX Series
Link Name:
Do-more Technology Version: 2.8
Description:
Version:
Company:
Department:
Programmer:


SG
Stage
Stage
S0
Before the filling process begins, it needs to reset its completion flag
S0
2
$On
ST1
FillComplete
C18
RST
When the turret is ready, the filling begins (jumping to state 1)
S0
3
Ready
C27
JMP
Jump To Stage
Transition To
S1
SG
Stage
Stage
S1
S1
5
$On
ST1
E/R
TMR
Timer
Timer Struct
T7
Preset
30.000s
The turret will spin until the timer expires
S1
6
$On
ST1
PWMOUT
Pulse Width Modulated Output
PWM Device
@PWMOut1
PWM Structure
$PWMOut1
Discrete Output
PumpStep
Frequency (Hz)
1000
Duty Cycle (Percent)
50
S1
7
T7.Done
FillComplete
C18
SET
S1
8
FillComplete
C18
JMP
Jump To Stage
Transition To
S2


SG
Stage
Stage
S2
Waiting for the capping to be complete, then going to state 0
CapComplete
C4
S2
10
JMP
Jump To Stage
Transition To
S0
S2
11
NOP