B.A.D.D – Vial Uncapping, Filling, and Finishing
Operation and Maintenance Guide

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Overview

Living in today's society it is impossible to ignore the desire to develop fast-paced precision processes. These processes cannot be too complicated however and should be simplified as much as possible while maintaining functionality. With these things in mind, a manufacturing process for uncapping, filling, and recapping was designed. The design that was selected made use of two filling and uncapping stations so that vial replacement could occur while filling a different vial simultaneously.

To initialize the process, power and compressed air must be connected to the system and turned on in order to begin. A tray filled with six empty vials are then placed in a designated location and the process of filling a vial can commence.

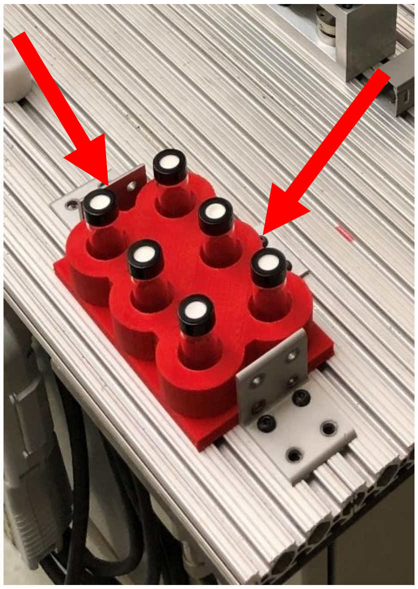
To begin, the location of the pump track and robot are moved to their home positions by pressing the start button. The pump is then primed to make sure no air is in the tube between the fluid reservoir and exit of the tube. This is initialized by pressing the prime button. After these first two initializations are complete, the start button is pressed, and the uncapping portion of the process starts. The robot grabs the first vial, the first filling station opens, and the vial is placed into the first of two filling stations. These filling stations can be opened, closed and spun in order to grip the vial, uncap, then recap. Collets are placed inside each filling station and are connected to springs and pneumatics to allow gripping and un-gripping. They are also connected to two stepper motors to provide the rotation needed. After the vial is secured in station 1, the robot continues to hold the cap while station 1 spins to remove the cap. Next, the robot takes the cap to a temporary cap holder and the pump is moved to station 1 on a track that is controlled by separate stepper motor. Once there the robot grip releases the cap and it is set on the holder. The pump begins running and fills the first vial. While the vial is filling, the robot grabs the second vial and takes it to station 2 where it is uncapped. Once vial 2 is fully uncapped the robot moves to its home position holding the cap from vial 2 and waits for vial 1 to be completely full. After vial 1 is full, the pump is moved to station 2 to begin filling the second vial. At the midway point on the track, a sensor was placed that tells the robot the filling apparatus is clear of station 1 and allows for a recapping of vial 1, The robot moves to station 1, recaps it using the same process as uncapping to recap the vial but in reversed direction. This time a torque sensor, placed on the robot grip, is utilized to ensure an accurate tightness will be applied to the vial cap. Having too much torque can lead to deformities in cap which can lead to unexpected problems. Once the proper torque is applied to capping vial 1, station 1 releases vial 1 and the robot returns the vial to the tray. Then it picks up vial 3, uncaps it and returns home to wait for vial 2 filling to be completed. During the return of vial 1 and retrieving of vial 3, the pump fills vial 2. Once the filling of vial 2 is completed the pump moves back to station 1, tells the robot its clear and begins filling the third vial while the robot recaps vial 2, returns it and replaces it with vial 4 and so on. In the ending sequence the robot removes the second to last vial from its filling station, returns it then grabs the cap at the cap holder instead of grabbing a new vial. Once the last vial is filled, the pump is moved, the last vial is capped and then gets returned to the tray. The robot then moves to its home position and the process waits until a new tray is replaced, and the start button is pressed again.

This process would work theoretically for any specified number of vials in each tray but for this project was simplified to 6. For demonstration purposes, and due to time constraints, the presentation only showed the process through the first 3 vials. This allowed the audience to have a full understanding of how the process worked.

Operation Instructions

Loading

1. Place empty capped vials into the red vial tray.
2. Ensure that the tray is tight against the brackets closest to the robot as indicated by the red arrows in the picture below.

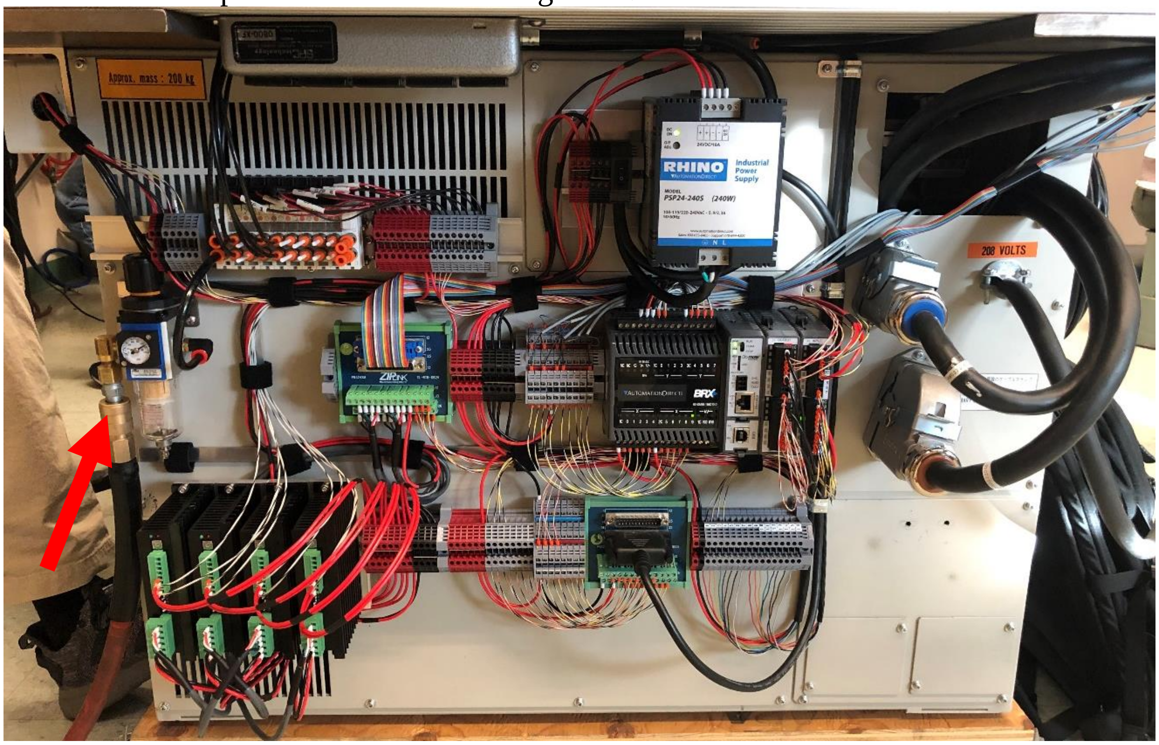


3. Check the water level in the reservoir (water bottle) and add water if necessary.

Machine Start-up

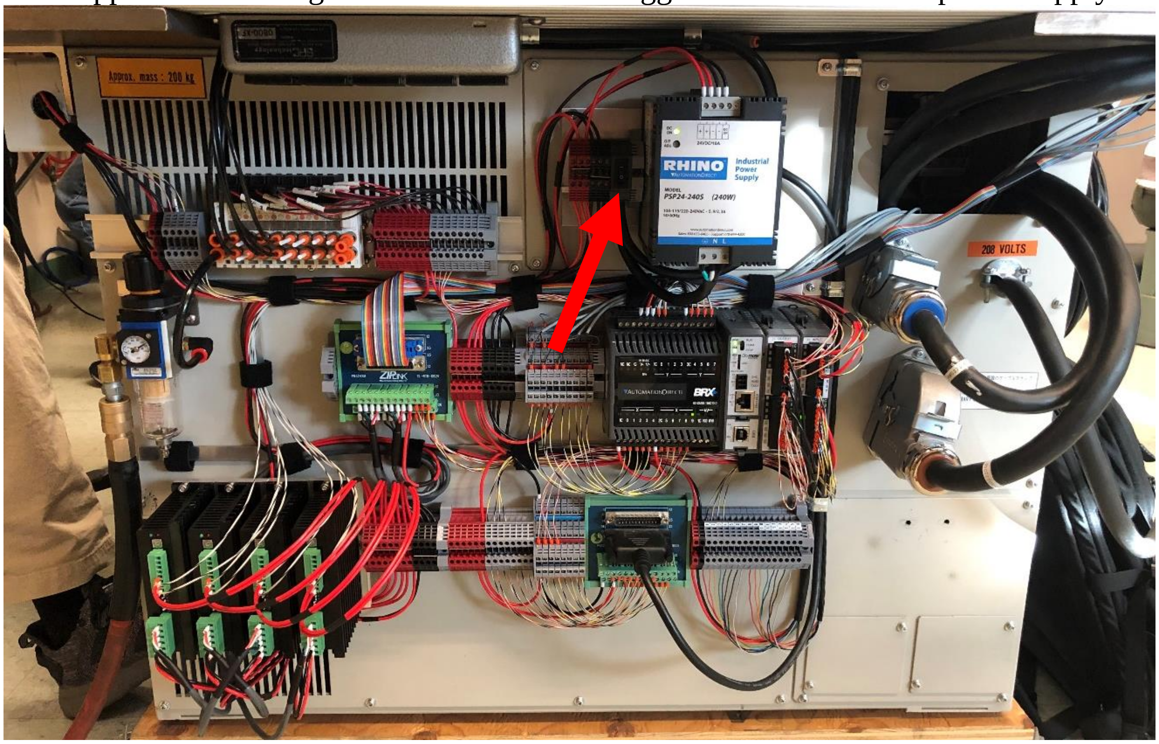
1. Make sure that both the emergency stop button on the robot teach pendant and the machine control panel are off (in the popped-out position).

2. Connect the compressed air hose to the regulator.

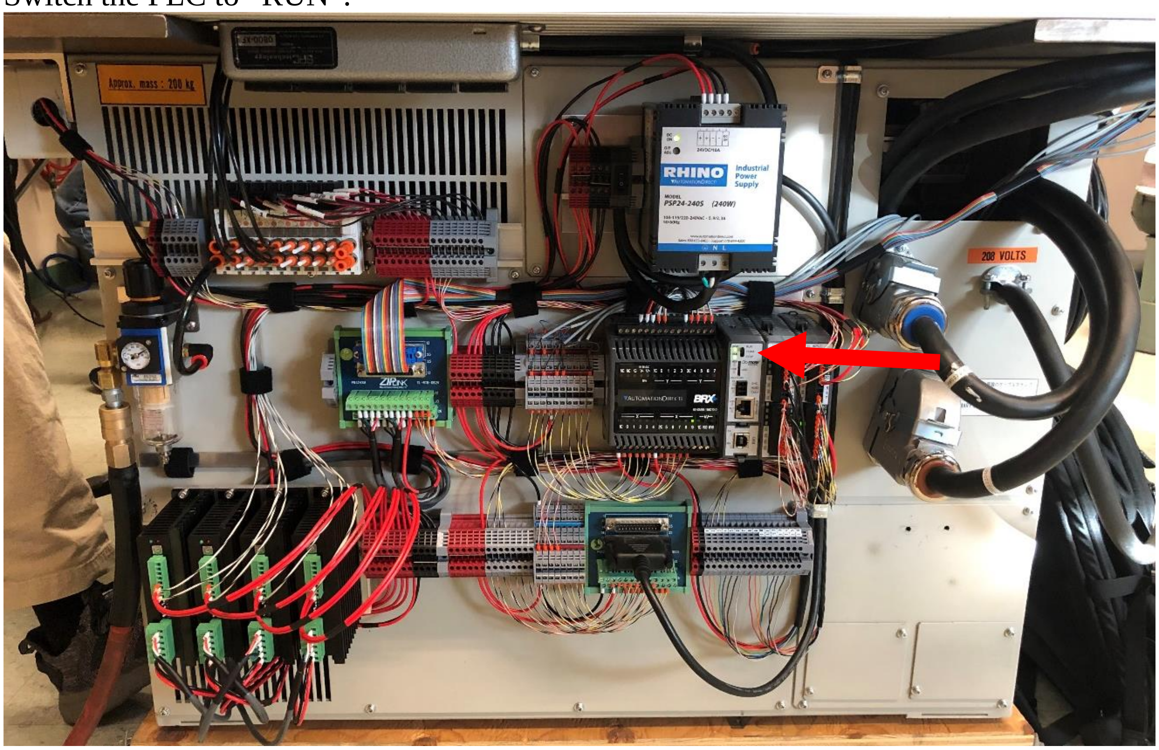


3. Turn on the main power located on the same side of the machine as the teach pendant.

4. While the robot controller is starting up, turn on the power to the PLC, sensors, valves, and stepper motors using the DIN rail mounted toggle switch next to the power supply.



5. Switch the PLC to “RUN”.



6. On the robot teach pendant, turn the key to "TEACH" (1) and use the touchscreen to select "JOB" (2). If the main menu on the left side of the screen is not visible like shown in the picture below, press the "Main Menu" button (3) at the lower left corner of the screen.

7. Press "Select Job"

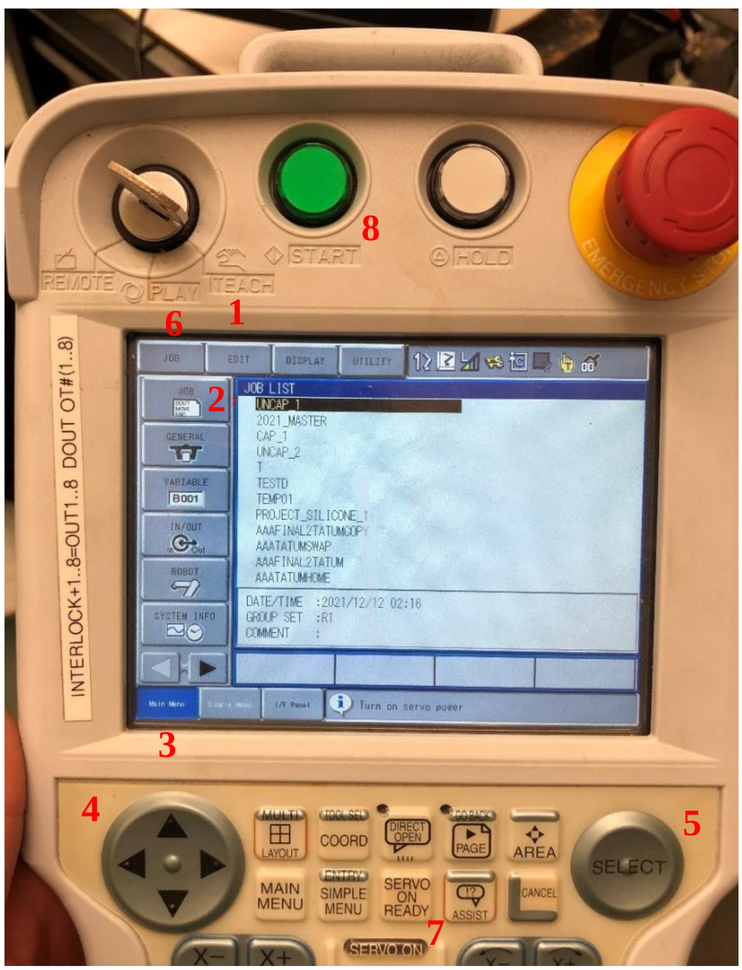
8. Navigate to the job titled "2021_MASTER" using the large button with arrows on it (4) at the top left of the keypad.

9. Press the "SELECT" button (5) on the upper right side of the keypad.

10. Turn the key to "PLAY" (6).

11. Press the "SERVO ON READY" button (7) on the keypad.

12. Press the green "START" (8) button on the top of the pendant, it should light up when pressed.



13. To home the robot and nozzle, press the “Start” button on the control panel shown below. If not already at home, the robot will move there, and the nozzle will position itself over the station farthest from the tray.

14. Using an empty vial or other container, place it under the nozzle. Press and hold the “Pump Primer” button until a steady stream of fluid is dispensed.

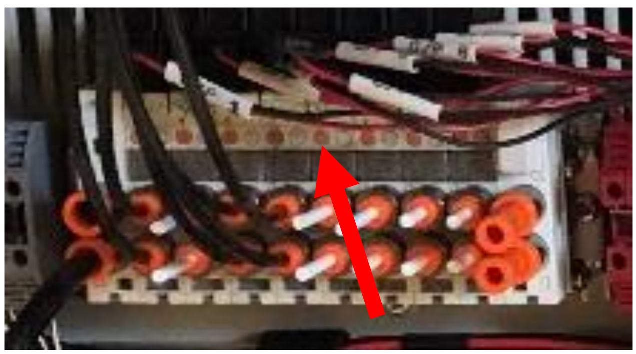
15. Press the “Start” button again to start machine.

Clearing Jams & Resetting Machine

In the rare instance of a failure to cap/uncap, filled vials placed in the tray, or any other reason arises that makes it necessary to pause the machine, the E-stop button on the control panel of the machine can be pressed. This will turn off power to the robot servo motors as well as all of the pneumatic valves and stepper motors. However, both the PLC and robot controller will remain on so that the process can resume once the problem is resolved, if desired. Both the instructions to stop and resume a process as well as stop and restart a process will be presented in this section. Methods for manually actuating the pneumatic valves will also be described so that the cap and vials can be removed from the grippers.

<u>Manually Actuating Pneumatic Valves</u>

If it is required to release any of the grips, the pneumatic valves can be actuated manually by using a small screwdriver to depress the small orange button on the front of the corresponding valve as shown below.



From left to right, the first valve is the robot gripper followed by an unused valve, the rotating grip station nearest to the pump (S2), and the other rotating grip station nearest to the tray (S1).

<u>Pause and Restart</u>

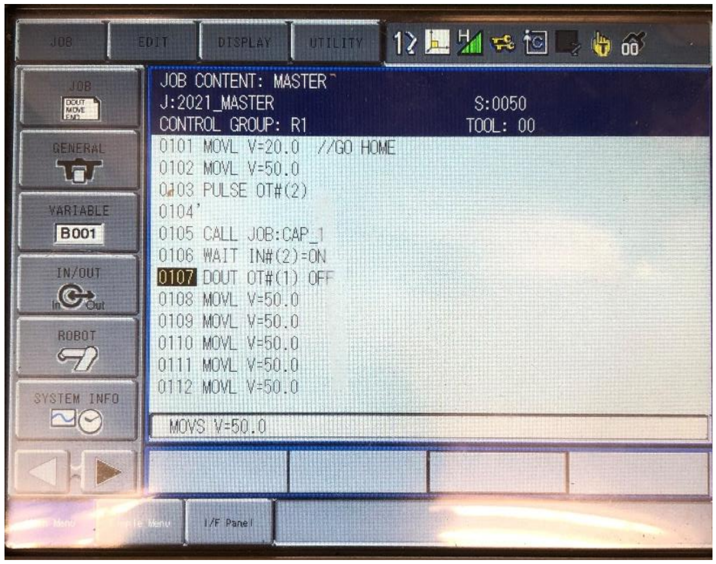
Once the E-stop has been pressed and the issue is resolved, the process can be restarted by:

1. Turn the PLC to “OFF” and then back to “RUN”

2. Release the E-stop button

3. On the robot teach pendant, turn the key to “TEACH” and clear the error by pressing the “RESET” button at the bottom of the touchscreen.

4. Use the button with the large arrows, to navigate to the side of the job where the cursor is highlighting the address side of the job (the step number) as shown below.



5. Use the same button to scroll up to the beginning of the job.

6. Proceed by following steps 10-15 in the previous section entitled **Machine Start-up**

Pause and Resume

Depending on where the robot is in the program, it may be possible to continue from where the process was stopped. This can be done by following steps 2-3 in the above instructions for Pause and Restart followed by steps 10-12 in the previous section entitled **Machine Start-up**. The process will continue immediately after pressing the green "START" button.

Component Descriptions

Yaskawa MotoMan MH5L Robot

A Yaskawa MotoMan MH5L robot was used for transferring the vials between the tray and rotating grip stations. The specific job programs from the DX100 controller are provided on page 35. The end-effector designed to function as both a gripper and a torque sensor for capping the vials is discussed in the subsequent section.

Figure 1 – MotoMan MH5L Robot

<u>Maintenance Instructions</u>

Please refer to the MotoMan MH5L manual for maintenance and troubleshooting instructions.

Torque Sensing Cap Gripper

The end-effector used on the MotoMan MH5L consists of two main parts, a gripper and a torque sensor. The body of the griper is a Robohand DTH-1M-L 3 jaw gripper with a Jaw throw of 4mm. Its primary function is to grip vial caps for transport between the filling stations and box. The torque sensor is an in-house design that uses sprung force and an induction sensor to translate torque into an I/O sensor output. This is used to ensure caps of each finished vial will be installed with a uniform torque. The gripper is mounted to the free side of the torque sensor and the fixed side is mounted to the robot's tool head. A variety of other sensors are fixed to the assembly to return vial present and gripper open/closed signals.

Maintenance Instructions - Gripper

The soft jaws of the gripper are designed to be easily replaced when worn. Each of the three rubber soft jaws is fixed to its rigid internal frame by a single M3 screw (2mm hex key) face opposite the gripping surface. A partially disassembled gripper assembly can be seen for reference in Figure 3 below. To replace one of these rubber inserts, remove the fixing screw and slide the insert off of its frame (this will be in the direction parallel to the central axis of the gripper). Slide the replacement insert back onto the frame in the same way the discarded one was removed and ensure that the insert is fully seated before replacing the fixing screw.

If the frame of one of the jaws needs to be replaced, the rubber insert must be removed from the frame in the way explained above, then the frame can be detached from the assembly by removing the two M3 screws (2mm hex key) holding it in place. The replacement frame can then be installed by replacing the 2 M3 screws and the rubber insert reinstalled.

For any routine or specific maintenance on the Robohand 3 jaw gripper itself, detach the assembly from the torque sensor by removing the M5 screw (3mm hex key) in the base of the photoelectric proximity sensor as well as the 3 M3 screws (2.5mm hex key) fixing the gripper at its base. Next refer to the Robohand DTH series manual for further information. When finished, the gripper can be reinstalled by replacing bolts in the reverse order of removal.

Maintenance Instructions – Torque Sensor

The torque sensor can be easily adjusted without requiring further disassembly or removal from the robot's tool head. The different parts can be seen labeled in the cutaway sketch below (Figure 2). The torque at which the sensor returns positive can be adjusted up or down by rotating the M3 set screw (2mm hex key) in the fixed side of the torque sensor assembly. This assembly can be seen in Figure 4 below. By tightening this screw, the sensor trip plate is pushed closer to the inductive proximity sensor on the free side, resulting in a shorter required throw and a lower torque input. By loosening the screw, the trip plate moves further away from the inductive proximity sensor and increases the throw and the required torque input.

In order to change the torque window of the sensor further, the spring can be swapped out for a stiffer or softer spring if needed. To do this, remove the nut on the end of the M3 screw that passes through the center of the spring and remove it. Then remove the screw (2.5mm hex key) and swap the spring. Reinstall the bolt and fix it in place with the nut.

Thirdly, when the desired torque is achieved, the throw of the sensor can be adjusted by tightening the M3 screw (2.5mm hex key) that passes through the spring. To do this loosen the nut, then loosen or tighten the bolt to its desired location. Tightening the bolt will decrease the throw and loosening it will increase the throw. It is good to make sure that the throw is great enough that the sensor will not accidently be tripped prematurely (a spacing of >1.5mm is recommended between the trip plate and sensor). When the throw is satisfactory, ensure that the adjustment will be fixed by re-tightening the nut.

To replace the bearing in the torque sensor, or to remove the sensor from the robot head further disassembly is required. To replace or service the bearing, first follow the instructions in the previous section for removing the gripper from the torque sensor. Remove the 6 M5 screws (3mm hex key) securing the outer face plate to the free side of the sensor assembly. Next remove the core cap M5 screw that is holding the bearing in place. At this point the bearing should be free to remove. Figure 2 can be used as a reference of how the assembly comes apart.

To remove the whole sensor assembly from the robot tool head, follow all the steps above for removing the bearing, then remove the inductive proximity sensor from the free side of the sensor assembly by removing the 2 small flathead screws. Finally, fold the free side out of the way by allowing it to pivot on the M3 screw passing through the center of the spring so that the 4 M5 screws (3mm hex key) can be removed.

The process for installing or re-installing the torque sensor will be the opposite of uninstalling it in reverse order.

Potential for Future Improvement

Overall, we are quite pleased with the performance of both the gripper and torque sensor used. The design of our gripper jaws is both simple and robust. One idea for future improvement of the gripper would be to make available a library of soft jaw inserts that correspond to varying internal diameters. This would make it a more versatile system that could be used for a variety of future project applications.

If a further iteration of the torque sensor were produced, the use of thrust bearings would potentially increase the overall rigidity of the assembly. Furthermore, milling the parts from aluminum rather than printing them would increase their durability. The poly-jet parts worked well for a proof of concept and for the purposes of this class. However, if a more long-term solution were required, wear on these pieces could result in failure over time

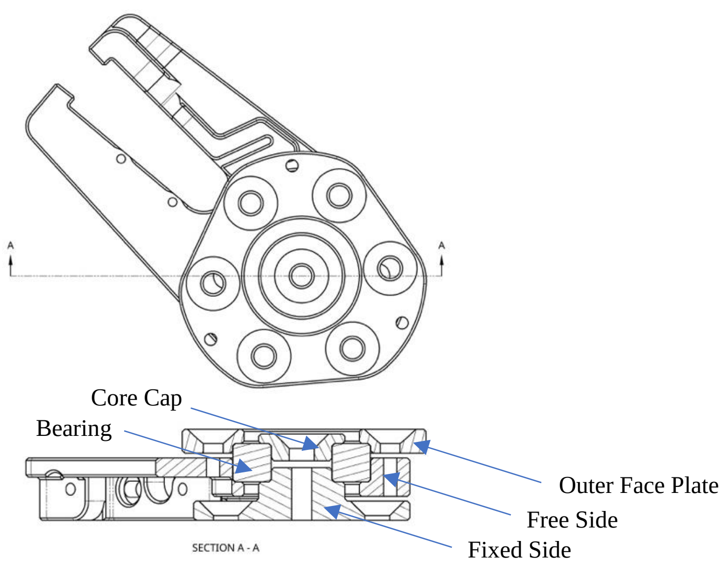


Figure 2 - Torque Sensor Cutaway Sketch

Figure 3 - Soft Jaw Disassembly

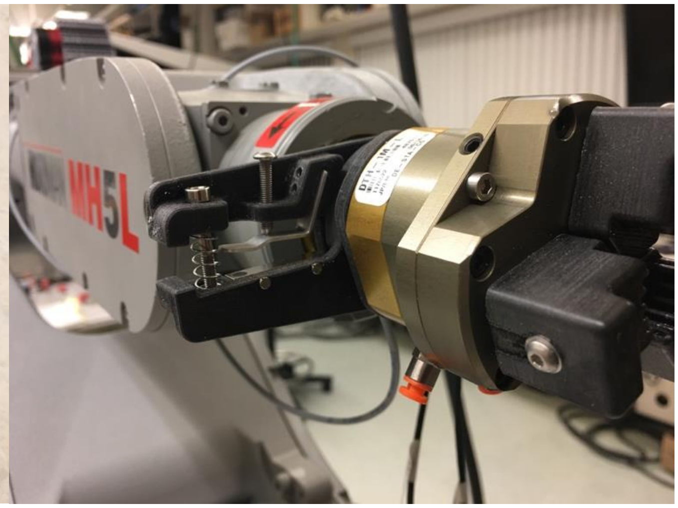


Figure 4 - Torque Sensor Mounted

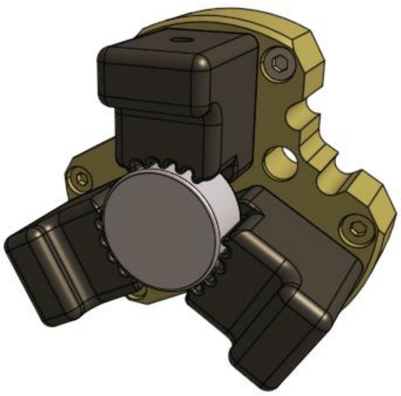


Figure 5 - Soft CAD Model

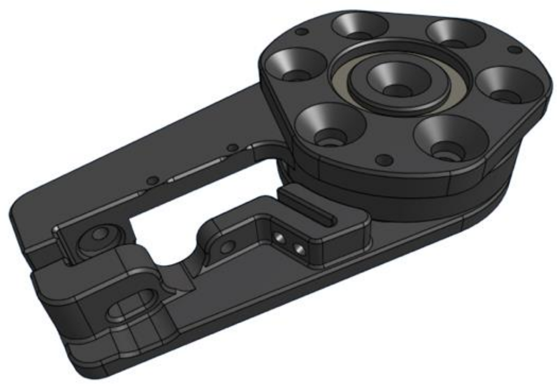


Figure 6 - Torque Sensor CAD Model

Rotating Vial Grip Stations

One of the primary challenges in designing a system to uncap, fill, and recap vials is how to both grip and rotate the caps and/or vials simultaneously without specialized tooling. For this system, the vials are gripped and rotated using NEMA 17 stepper-motor driven collets that are opened using Bimba Flat-1 pneumatic cylinders (FO04025CMT).

A labeled cross-section of the SOLIDWORKS model is shown below in Figure 7. When the pneumatic cylinder is not actuated, the spring inside the spindle draws the collet down into the body. A 10 degree taper angle is used on the collets, which is the same as a regular 5C collet. On the bodies, a 9.75 degree taper is used to encourage the top of the collet to grip tighter.

In order to actuate the cylinders, a minimum operating pressure of 70 psi is required, which supplies three times the necessary force to compress the spring. The additional pressure helps to overcome friction between the surface of the vial and the collet as well as between the collet and collet body.

In order to determine when the collet is open, an inductive proximity sensor is mounted to the base and a small washer is placed under the plunger. Thus, when collet is open, the washer triggers the proximity sensor as shown in Figure 8.

The collet was printed using the Stratasys Eden 500V printer with Stratasys Tango flexible material, which is similar to rubber. The large pulley, bushings, plungers, and retainers were also printed on the Stratasys Eden 500V using a rigid material. Due to cost constraints, the collet body had to be printed as a separate piece on the MakerGear printer.

The spindle and collars were turned from 6061 aluminum using the Mori Seiki Duraturn CNC lathe and finished on the manual mill. The sleeves were also turned on the CNC lathe from acetal. The top plate, where the stepper motor and collet assembly mounts, is also aluminum and was machined on the Mori Seiki NVX-5080 CNC mill.

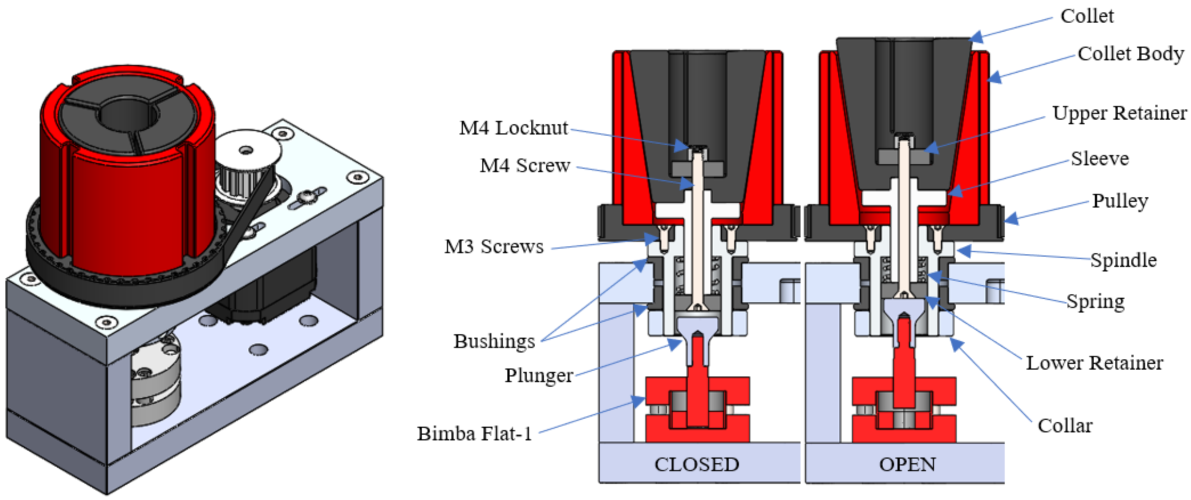


Figure 7 – Rotating Vial Grip Station Assembly and Cross-Section Views

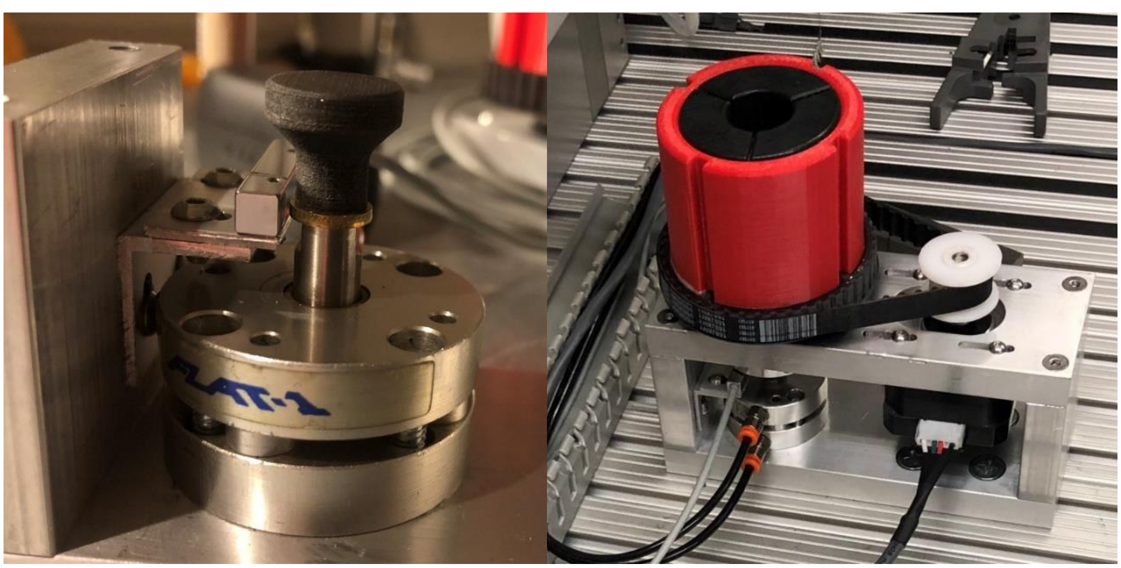


Figure 8 – Inductive Proximity Sensor and Assembled Gripper Station

<u>Maintenance Instructions</u>

Although these stations require minimal routine maintenance, there are four critical areas that can cause issues if not periodically inspected and service, if needed. The first is the timing belt pulley on the stepper motor. The setscrew on this pulley should be checked for tightness before starting the machine. From experience, it has come loose after processing about a dozen vials. This has only occurred on one of the stations so it is likely an issue with the pulley itself, but there are no replacement ones available in the lab so this must be monitored.

Next, the M3 screws shown in Figure 9 that attach the collar to the spindle, must be checked for tightness before starting the machine. It is recommended that medium strength thread locking compound be reapplied to these screws if they are removed. When reinstalling the collar, use standard copy paper to make shims that are two pages thick and place them between the collar and bushing to provide proper clearance. This will avoid binding. Additionally, white lithium grease can be used sparingly on the spindle to ensure smooth operation.

Lastly, if the station is disassembled or the grip strength has noticeably decreased, the three pieces of electrical tape on the inside of the collet should be replaced. If this does not fix the issue, the preload on the spring should be checked as overtightening the M4 screw holding the assembly together will negatively impact the collet's ability to grip the vial. The space between the bottom of the spindle and lower retainer (highlighted blue in Figure 9 below) should be $7.9\ mm\ \pm 0.3\ mm$.

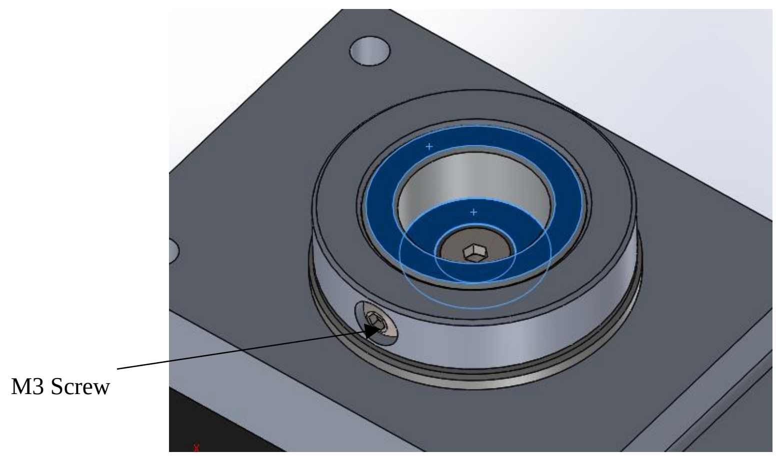


Figure 9 – Measurement Between Blue Surfaces is $7.9\ mm\ \pm 0.3\ mm$.

If it is necessary to replace either the spring or timing belt, both of those are available through McMaster-Carr using the following part numbers:

9657K482 - Compression Spring, 0.75" Long, 0.6" OD, 0.502" ID

6484K221 - XL Series Timing Belt, Trade No. 110Xl037

<u>Potential for Future Improvement</u>

There are six main improvements that could be made to these stations. The first is that the sizes of the collet and collet body could be adjusted further so that they provide more grip without having to use the small pieces of electrical tape on the inner surface of the collet. The collet diameter should be decreased by approximately 0.5 mm and the diameter at the top of the taper on the body could be decreased by approximately 0.3 mm. The body and pulley could also be printed as a single piece.

The second improvement would be to add an upper ledge to the large timing belt pulley so that the belt cannot rise up. This was originally left off to try and avoid having the printer fill all of the grooves with support material. However, it still filled them so having the overhang would not result in any additional support material or labor to clean up the parts.

The third improvement would be to adjust the inside the diameter of the bushings. The original set was too tight once they were pressed into the aluminum and the second set was a little bit too loose so printing a third set that had an inside diameter between these two would be beneficial to minimize play in the assembly.

The fourth improvement would be to use three screws to attach the collar to the spindle. As soon as these start to loosen, the collar can tilt and cause some binding. Adding a third screw and spacing them 120° apart would solve this and further eliminate any binding.

The fifth improvement would be to make the base a little bit longer and move the collet away from the edge so that the screws on that side that secure the top of the base could be easily removed without having to use a modified hex key or remove the collet assembly first.

The last improvement would be to add another module to the PLC so that a fourth high-speed axis could be operated independently. Although the PLC lists four high-speed outputs, it only allowed three of them to be used. Thus, both of the stepper motor drivers for these stations had to be wired in parallel, so the motors would always spin together. This was not an issue because the other station was just filling while the other was spinning to uncap/cap, but it would be preferable to operate these independently.

Although there are several improvements that could be made, these gripping stations performed reliably and provided enough grip to install the caps to the desired torque.

Pump and Moving Nozzle Assemblies

The pump system is comprised of two major pieces. There is the peristaltic pump itself, and a nozzle assembly. The pump nozzle is fixed to Destaco SLA90 linear motion device via an adjustable arm. This linear motion device allows the nozzle to move from uncapping station one to uncapping station two. The nozzle arm is adjustable so that the nozzle can be precisely positioned above each station. The pump is a peristaltic pump that is run by a stepper motor. The stepper motor is programmed to rotate for a set amount of time in order to fill the vial.

<u>Maintenance Instructions</u>

There is minimal maintenance required for these components of the machine. The first thing that needs to be maintained is the pump and its reservoir. The reservoir needs to be refilled so that the surgical tubing doesn’t get any air in it. The pump needs to be occasionally checked to make sure the hose fittings aren’t coming apart. If the fittings come apart the pump sprays fluid everywhere and makes a mess. The nozzle tip sometimes can vibrate loose and become misaligned. It is important that the nozzle tip is maintained in the correct position. Lastly, the SLA90 needs to be kept clean and the path that it follows needs to remain clear.

<u>Suggestions for Future Improvement</u>

There are a couple of improvements that could be made to these components. First of all, the nozzle arm could now be made in a more permanent manner. The original design needed to be adjustable so that it would properly mate with the other components of the system. Now that the system is finalized, the nozzle arm could be manufactured in a more aesthetically pleasing way. The next improvement would be to change the nozzle tip design. The current design is just a hose connector which has a very small hole in it which limits the flow of the fluid. If glycerin were to be used this small hole would make for a very slow sill time. Lastly, the peristaltic pump could be improved with a bigger and more accurate pump. This would allow for more accuracy and would allow the system to operate at a faster rate.

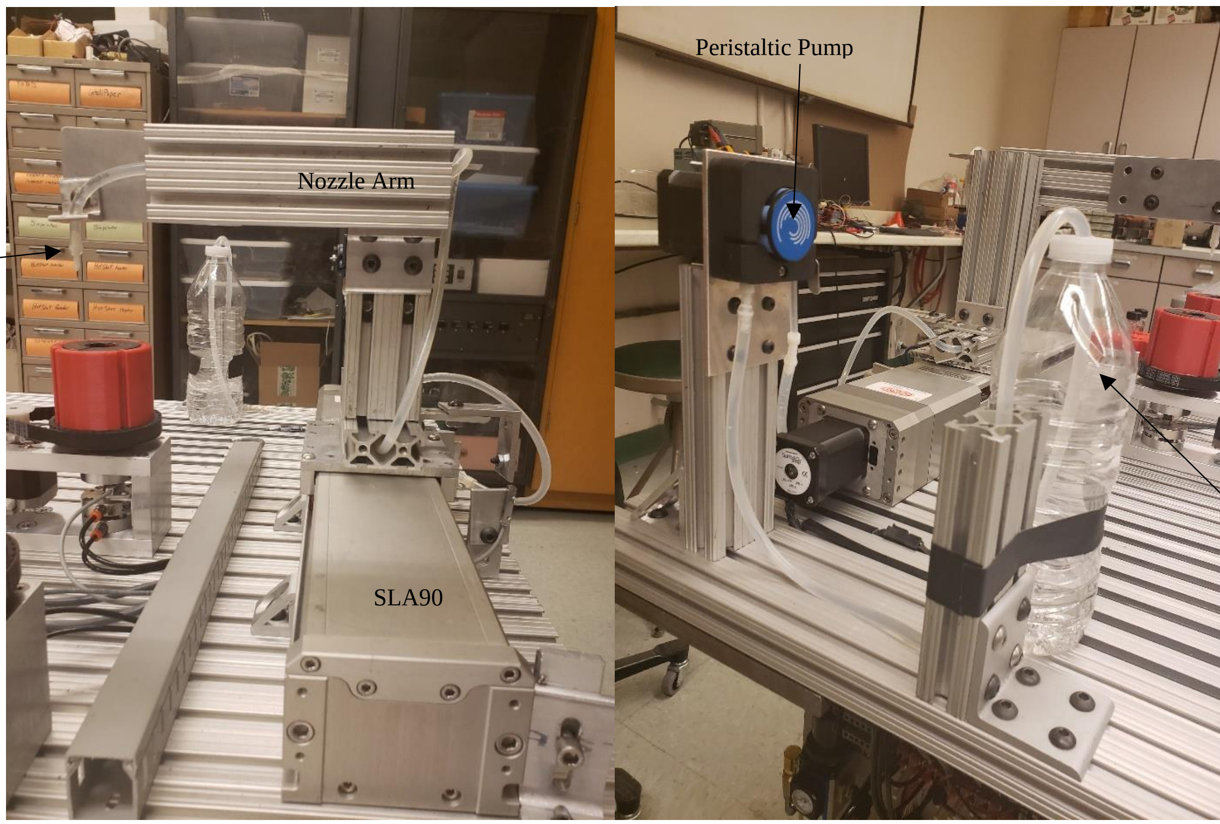


Figure 10 -Pump and Moving Nozzle Assemblies

Vial Tray

The vial tray was chosen instead of a singulation process using a conveyor belt. This was chosen because it was assumed if this process was applied within a manufacturing company a larger tray could be made, containing more vials. This is convenient because it is convenient to grab vials, fill them and replace them back in the same location where the tray could then be removed and replaced with a tray containing empty vials. The tray that was constructed for this project was 3D printed using hard plastic. For this component there were two requirements. First, the tray had to be designed to allow enough clearance between the vials to allow the robot grip to pick up a single vial without running into the others next to it. The other requirement was to allow enough vertical distance of exposed vial to avoid the same problem. Rounded corners around the vials, excluding the base, were used to conserve material and reduce printing time.

Figure 11 – Vial Tray

Cap Holder

As part of the start-up sequence, the cap from the first vial must be stored until it is picked up to use on the last vial processed. The cap holder shown in Figure 12 below was turned from acetal using the manual lathe. It is secured with a button head screw in the center and a t-slot nut.

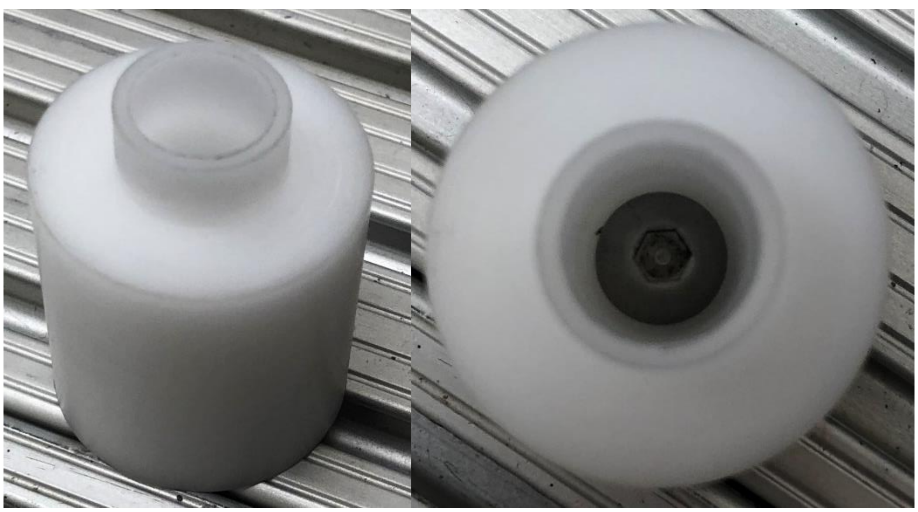


Figure 12 – Cap Holder

Robot Case Electrical Notes

There were several notable changes that were made within the robot controller for future technicians to be aware of. The first is regarding the E-stop. In the control panel on the side of the robot case, the E-stop button has 2 switches mounted to it. One kills power to all the mechanical elements run by the PLC and the other triggers the second external E-stop for the robot. If the control panel needs to be removed, it is crucial that the jumper bridging ports 21 and

22 on the MTX panel on the left side of the din rail mounted to the inside of the robot controller door. The jumper is taped to the door below the MTX panel for safe keeping. This is shown by the arrow in Figure 13 below.

The second modification we made was to use the auxiliary power output from the robot controller to power the power supply for our PLC as well as a power strip mounted to the bottom of the deck above the PLC side of the robot controller. If the power to the PLC side of the case doesn’t turn on, it is possible that the fuse for the auxiliary power has blown. The fuse is located on the left side of the din rail on the floor of the robot case just inside the door. The fuse holder is denoted by the arrow in Figure 14 below as well as the auxiliary power ports directly next to it.

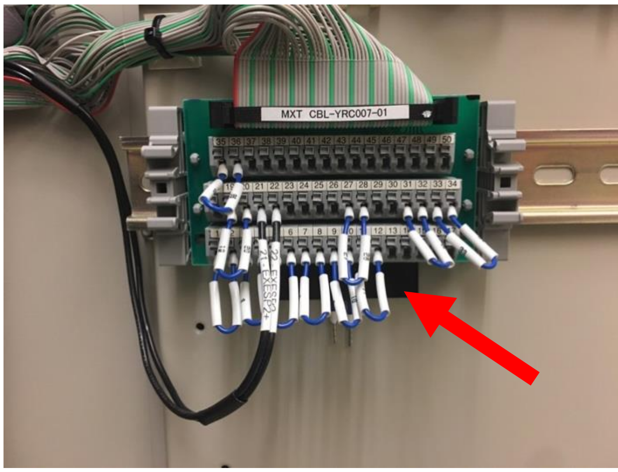


Figure 13 - Robot Controller MTX Board

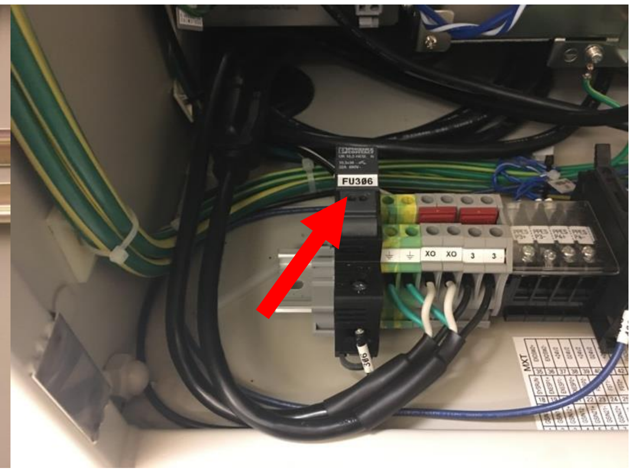


Figure 14 - Auxiliary Power Fuse Location

Performance Data

Capacity

The time to process three vials including the start-up and ending sequences was three minutes and twenty seconds, which is approximately 67 seconds per vial. However, there is potential for this to be significantly reduced as the robot speed could be increased so it could cap a vial, return it to the tray, pick up an empty vial, place it into the rotating grip station and uncap it in a time that was much closer to the time it takes to fill the other vial. Currently, the other vial is already filled before the robot picks up the next empty vial.

Additionally, the times within the process such as where the filling begins, or the nozzle begins moving from one station to the other could be optimized so that the time that each sub-system is waiting for another one to complete its task is minimized.

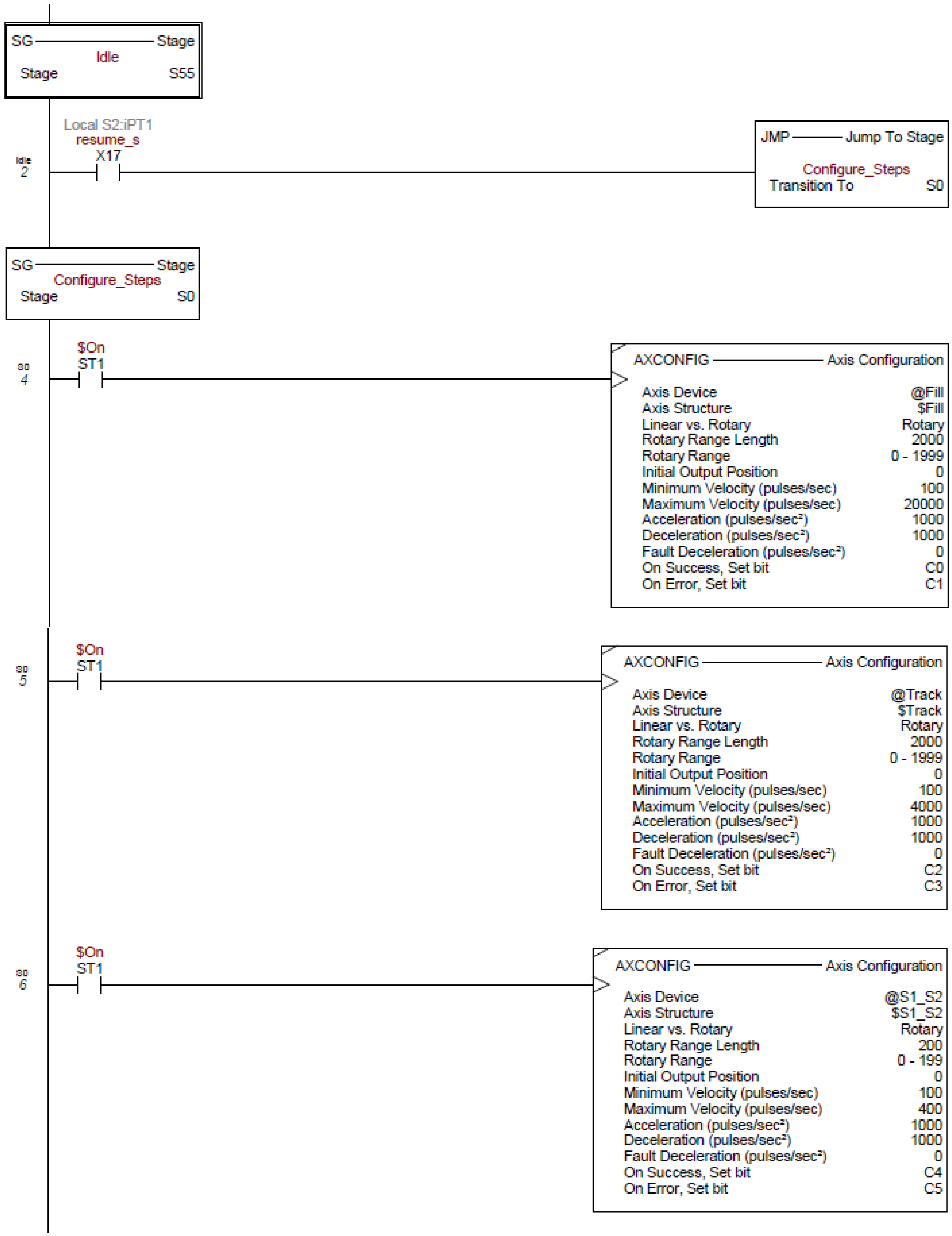
Overall, there is a lot of potential to drastically reduce the processing time per vial given the time to optimize the speeds and coordinate the timing of each state in the process.

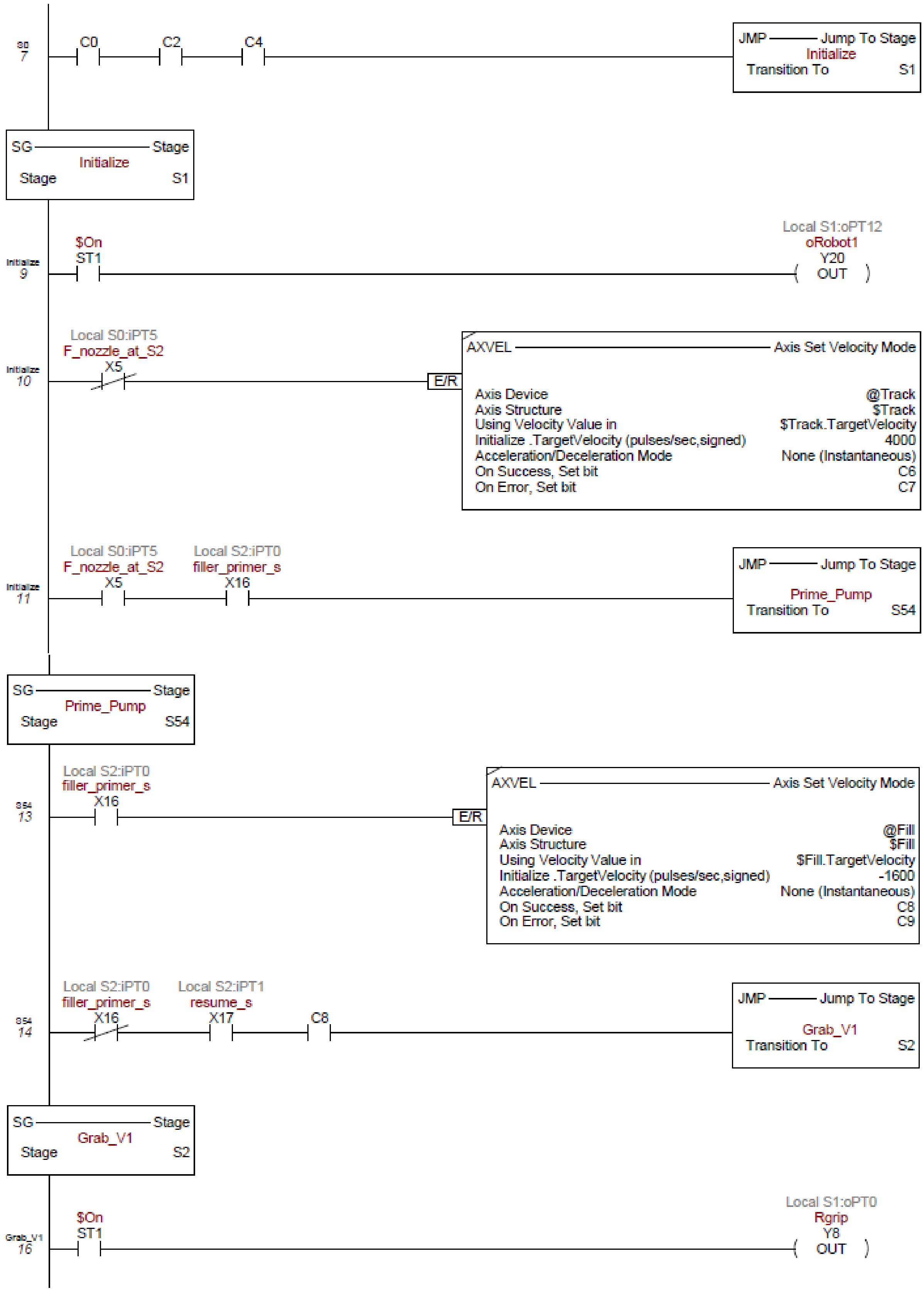
Accuracy

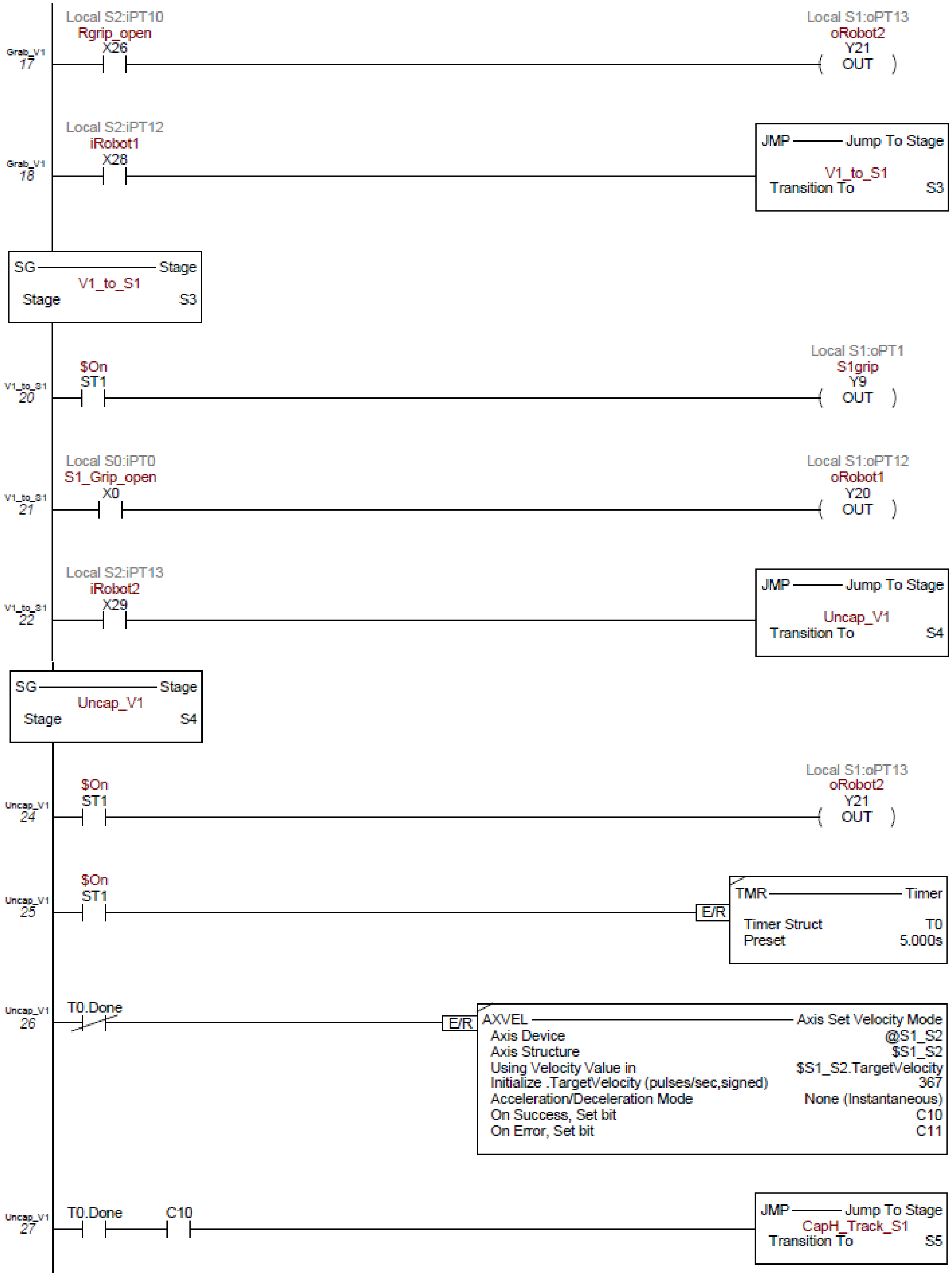
In order to evaluate the accuracy of the machine in filling the vials to a specified level, three vials were labeled and weighed before and after filling. A pumping time of ten seconds was chosen for this test. The net weight of the water in each vial was 11.30 g, 11.36 g, and 11.31 g, respectively. Thus, assuming an average of 11.32 g, the maximum error is approximately 0.3%. These results correspond to a standard deviation of only 0.03, which is very good considering the quality of pump being used with a simple timer on the PLC.

Diagrams

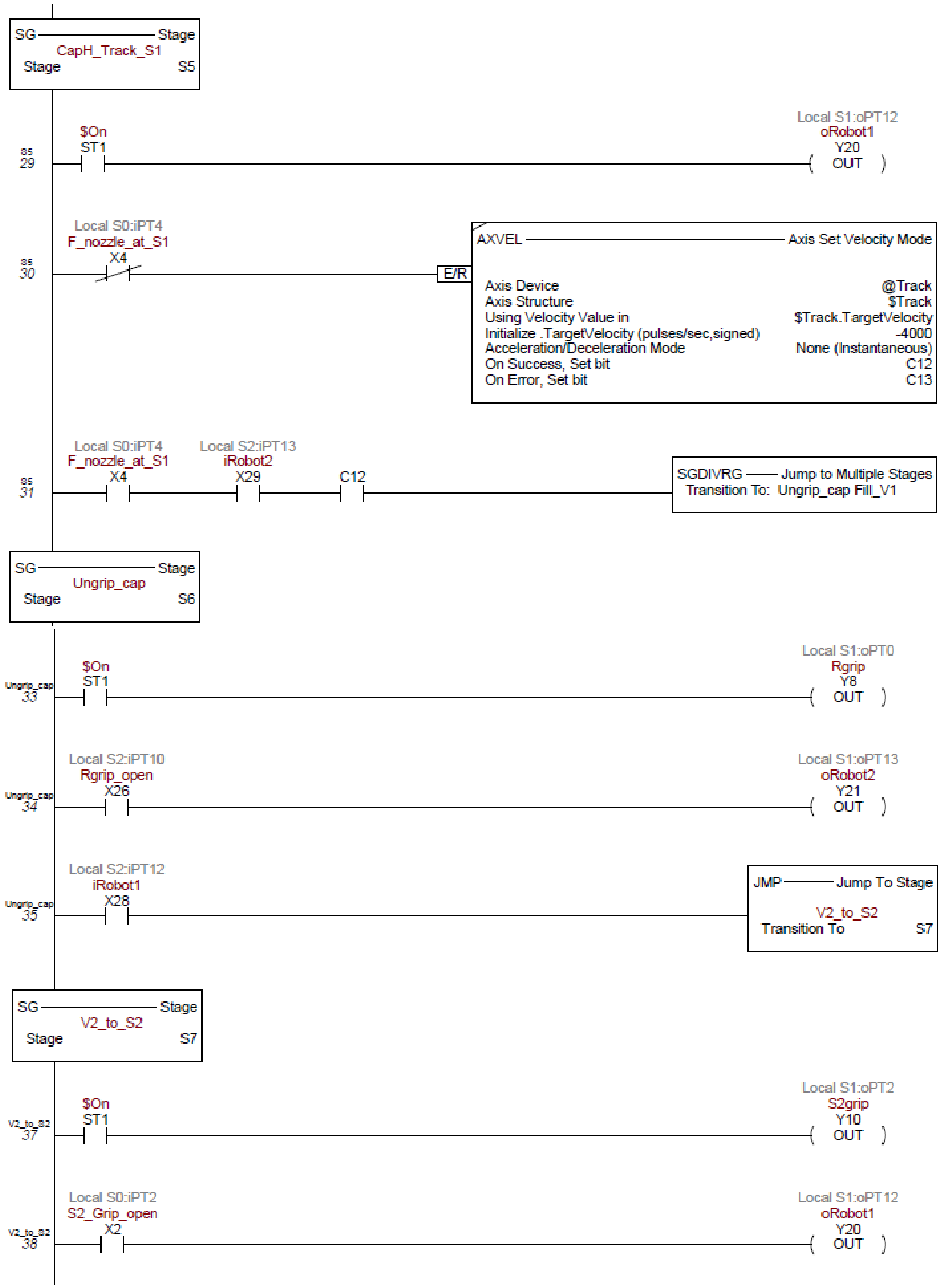
PLC Ladder Logic

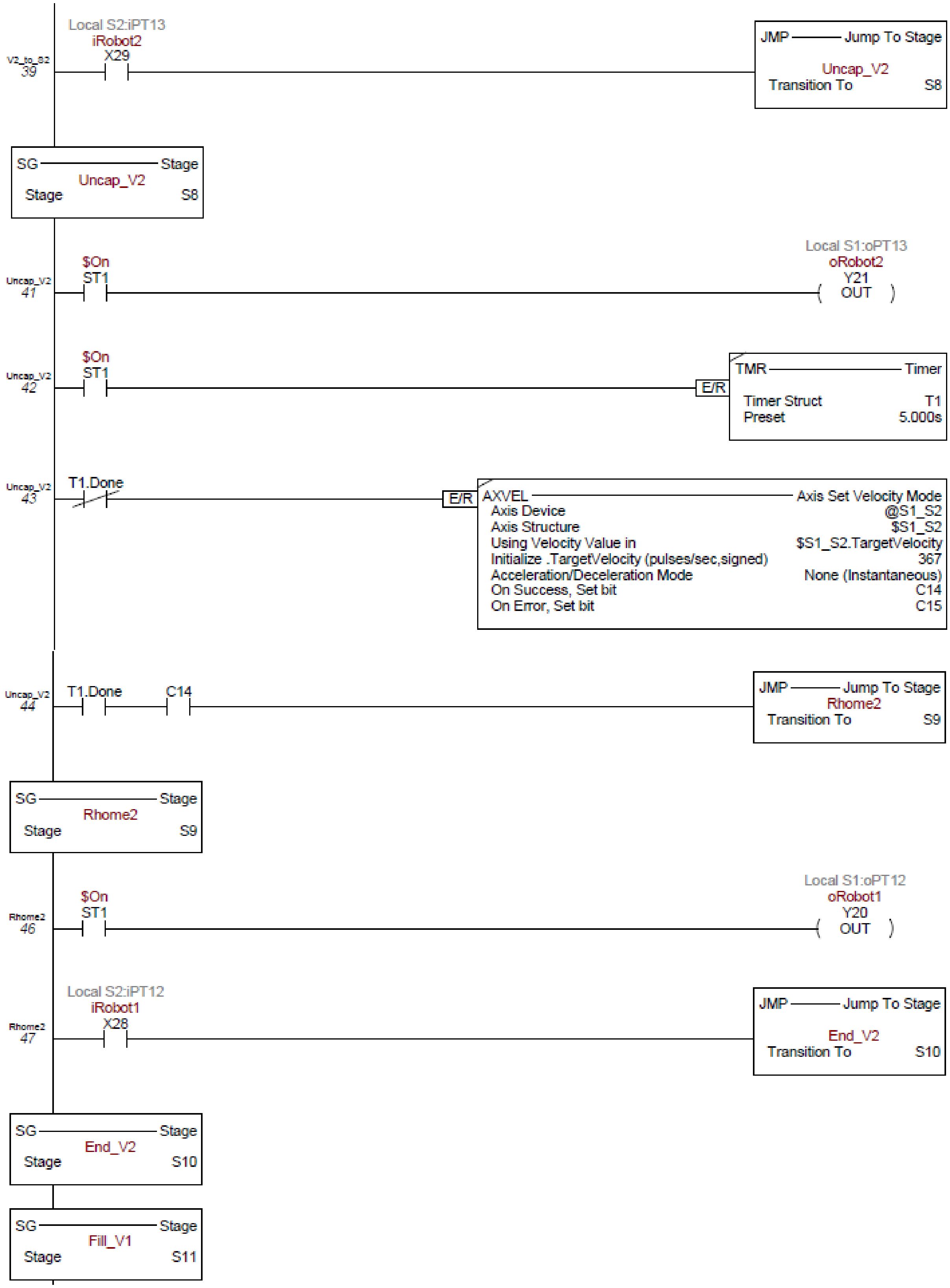


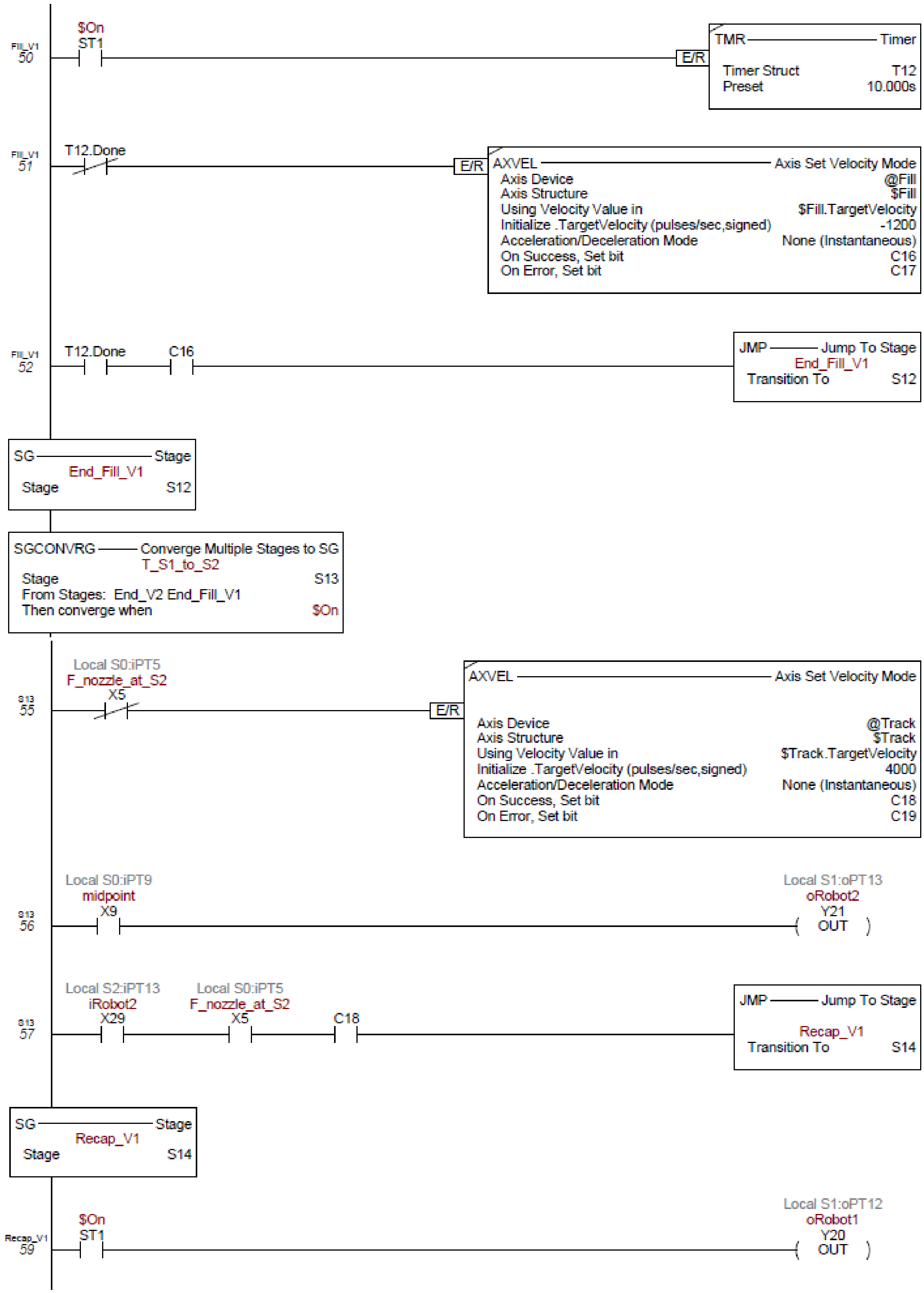

S0
7
C0
C2
C4
JMP Jump To Stage
Initialize
Transition To S1
SG Stage
Initialize
Stage S1
Initialize
9
$On
ST1
Local S1:oPT12
oRobot1
Y20
OUT
Initialize
10
Local S0:iPT5
F_nozzle_at_S2
X5
E/R
AXVEL Axis Set Velocity Mode
Axis Device @Track
Axis Structure $Track
Using Velocity Value in $Track.TargetVelocity
Initialize .TargetVelocity (pulses/sec,signed) 4000
Acceleration/Deceleration Mode None (Instantaneous)
On Success, Set bit C6
On Error, Set bit C7
Initialize
11
Local S0:iPT5
F_nozzle_at_S2
X5
Local S2:iPT0
filler_primer_s
X16
JMP Jump To Stage
Prime_Pump
Transition To S54
SG Stage
Prime_Pump
Stage S54
S54
13
Local S2:iPT0
filler_primer_s
X16
E/R
AXVEL Axis Set Velocity Mode
Axis Device @Fill
Axis Structure $Fill
Using Velocity Value in $Fill.TargetVelocity
Initialize .TargetVelocity (pulses/sec,signed) -1600
Acceleration/Deceleration Mode None (Instantaneous)
On Success, Set bit C8
On Error, Set bit C9
S54
14
Local S2:iPT0
filler_primer_s
X16
Local S2:iPT1
resume_s
X17
C8
JMP Jump To Stage
Grab_V1
Transition To S2
SG Stage
Grab_V1
Stage S2
Grab_V1
16
$On
ST1
Local S1:oPT0
Rgrip
Y8
OUT

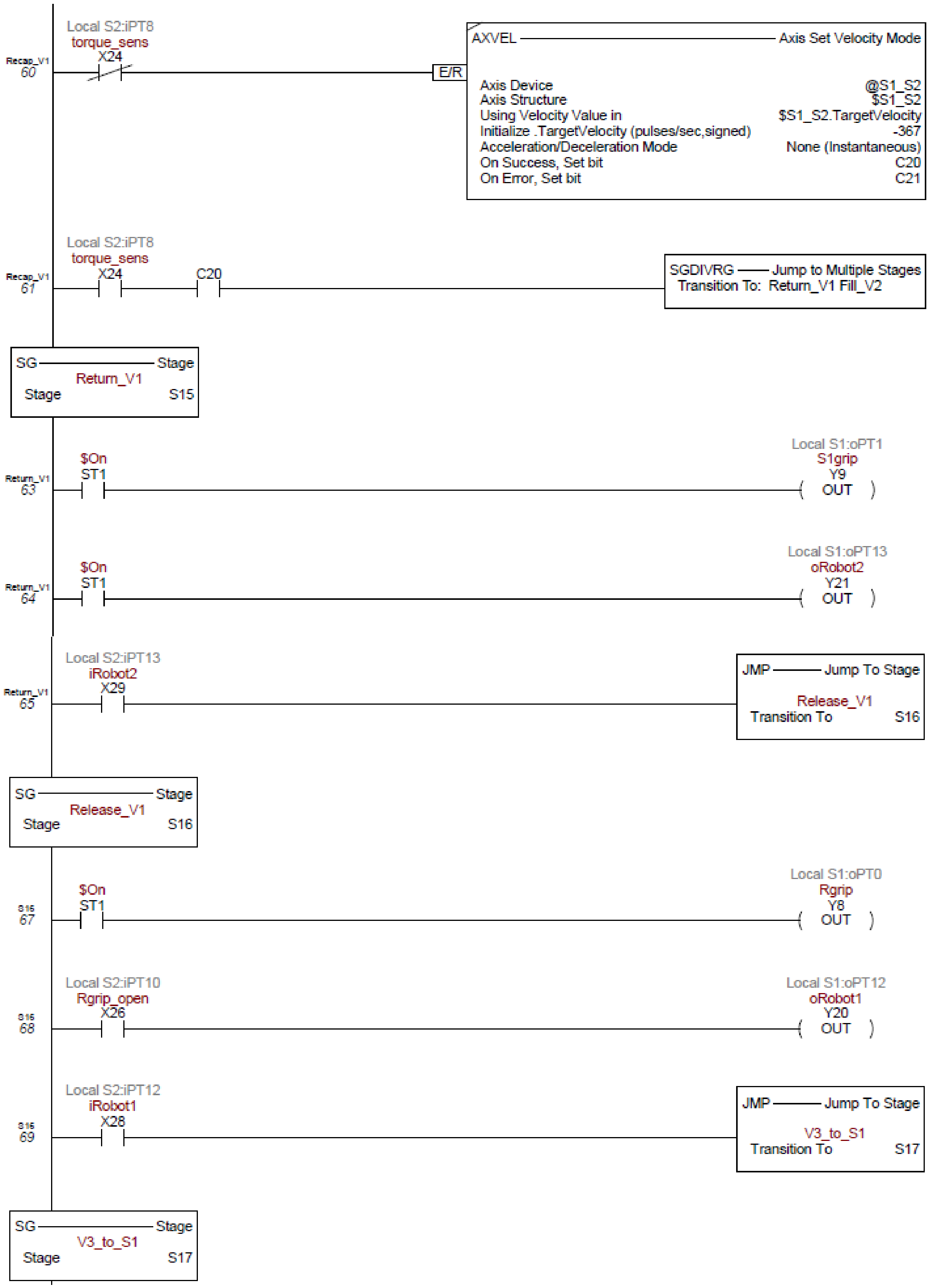


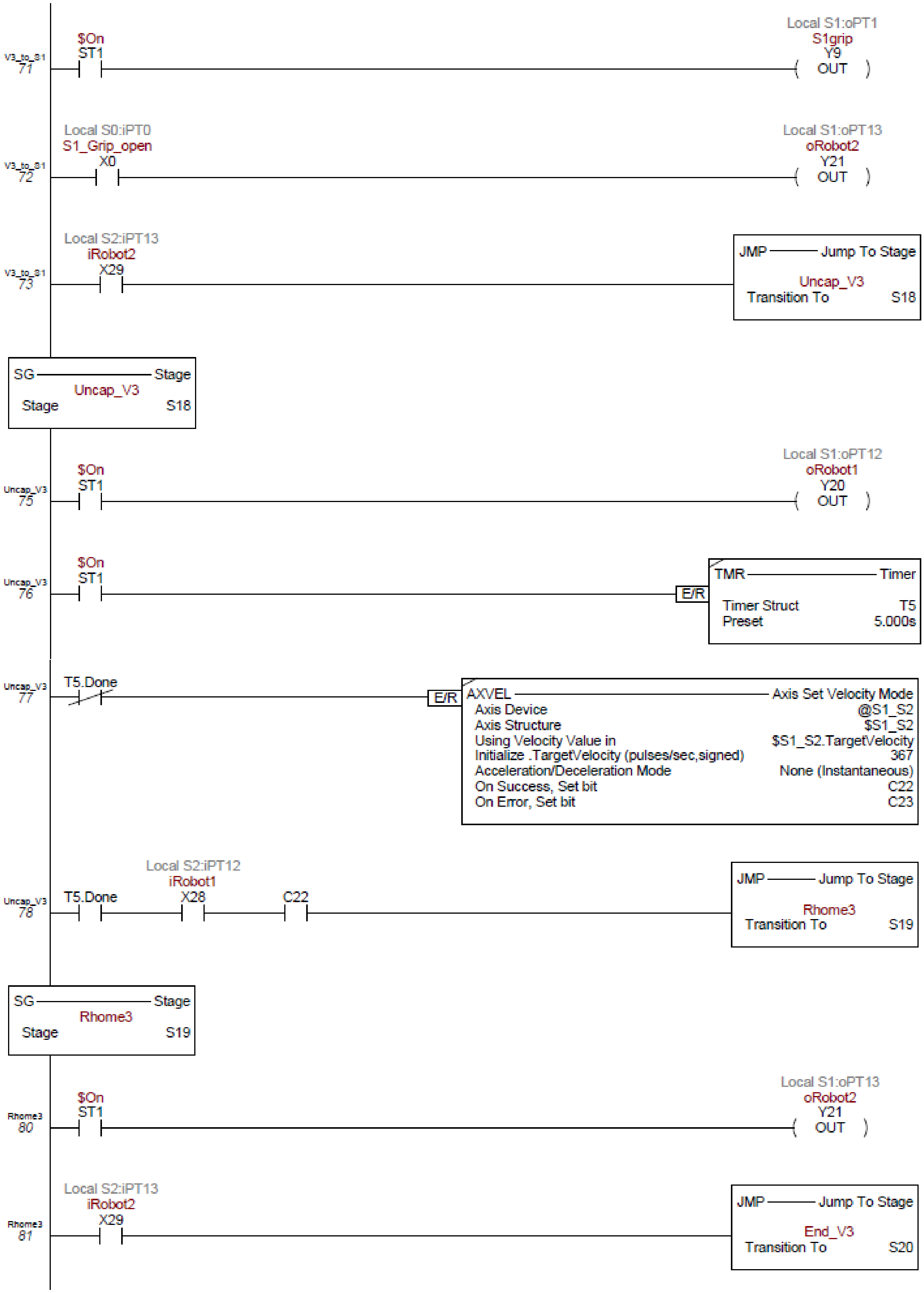
Grab_V1 17
Local S2:iPT10
Rgrip_open
X26
Local S1:oPT13
oRobot2
Y21
OUT
Grab_V1 18
Local S2:iPT12
iRobot1
X28
JMP Jump To Stage
V1_to_S1
Transition To S3
SG Stage
V1_to_S1
Stage S3
V1_to_S1 20
$On
ST1
Local S1:oPT1
S1grip
Y9
OUT
V1_to_S1 21
Local S0:iPT0
S1_Grip_open
X0
Local S1:oPT12
oRobot1
Y20
OUT
V1_to_S1 22
Local S2:iPT13
iRobot2
X29
JMP Jump To Stage
Uncap_V1
Transition To S4
SG Stage
Uncap_V1
Stage S4
Uncap_V1 24
$On
ST1
Local S1:oPT13
oRobot2
Y21
OUT
Uncap_V1 25
$On
ST1
E/R
TMR Timer
Timer Struct T0
Preset 5.000s
Uncap_V1 26
T0.Done
E/R
AXVEL Axis Set Velocity Mode
Axis Device @S1_S2
Axis Structure $S1_S2
Using Velocity Value in $S1_S2.TargetVelocity
Initialize .TargetVelocity (pulses/sec,signed) 367
Acceleration/Deceleration Mode None (Instantaneous)
On Success, Set bit C10
On Error, Set bit C11
Uncap_V1 27
T0.Done
C10
JMP Jump To Stage
CapH_Track_S1
Transition To S5

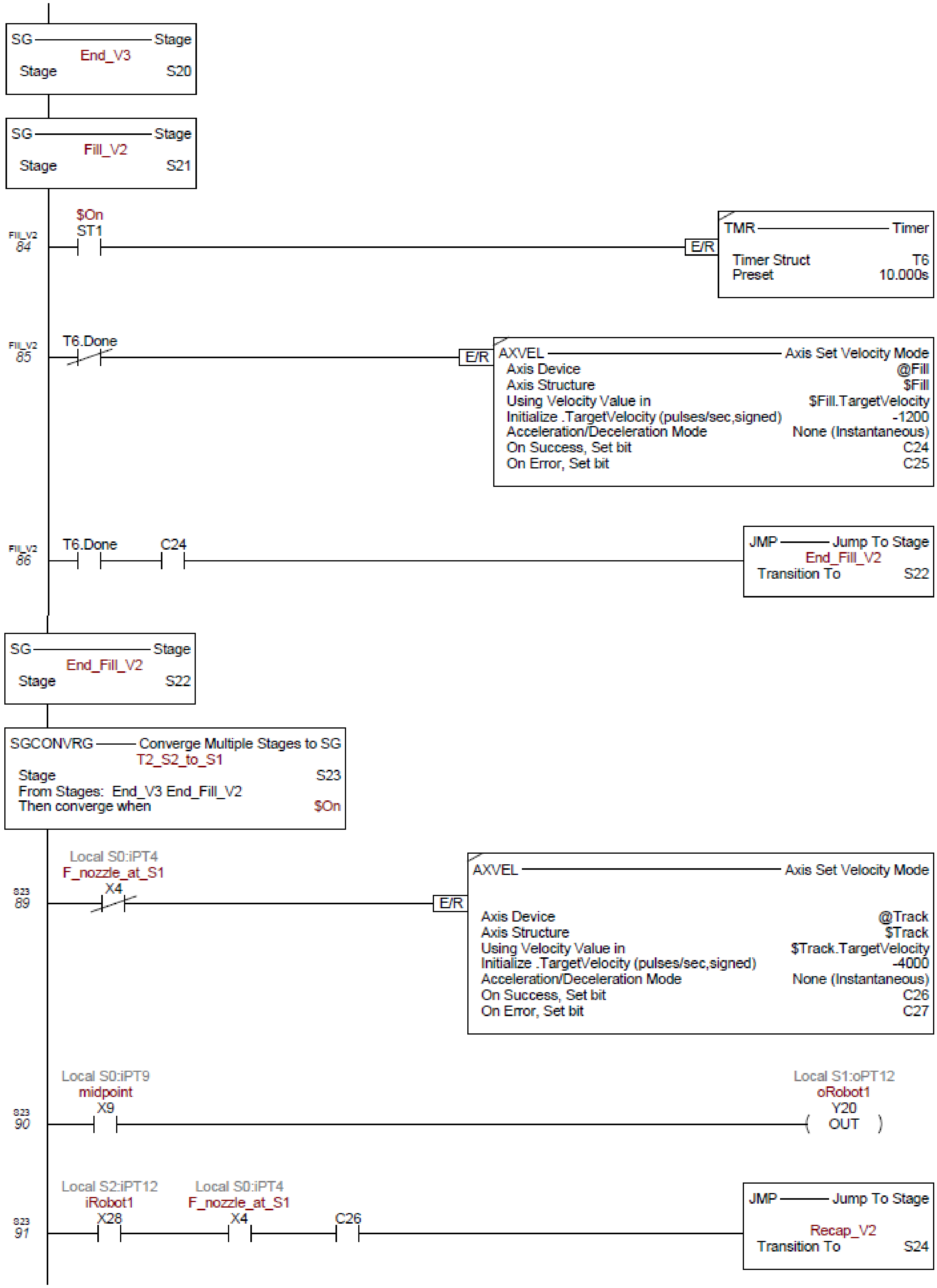

SG Stage
CapH_Track_S1
Stage S5
29
$On
ST1
Local S1:oPT12
oRobot1
Y20
OUT
30
Local S0:iPT4
F_nozzle_at_S1
X4
E/R
AXVEL Axis Set Velocity Mode
Axis Device @Track
Axis Structure $Track
Using Velocity Value in $Track.TargetVelocity
Initialize .TargetVelocity (pulses/sec,signed) -4000
Acceleration/Deceleration Mode None (Instantaneous)
On Success, Set bit C12
On Error, Set bit C13
31
Local S0:iPT4
F_nozzle_at_S1
X4
Local S2:iPT13
iRobot2
X29
C12
SGDIVRG Jump to Multiple Stages
Transition To: Ungrip_cap Fill_V1
SG Stage
Ungrip_cap
Stage S6
33
$On
ST1
Local S1:oPT0
Rgrip
Y8
OUT
34
Local S2:iPT10
Rgrip_open
X26
Local S1:oPT13
oRobot2
Y21
OUT
35
Local S2:iPT12
iRobot1
X28
JMP Jump To Stage
V2_to_S2
Transition To S7
SG Stage
V2_to_S2
Stage S7
37
$On
ST1
Local S1:oPT2
S2grip
Y10
OUT
38
Local S0:iPT2
S2_Grip_open
X2
Local S1:oPT12
oRobot1
Y20
OUT

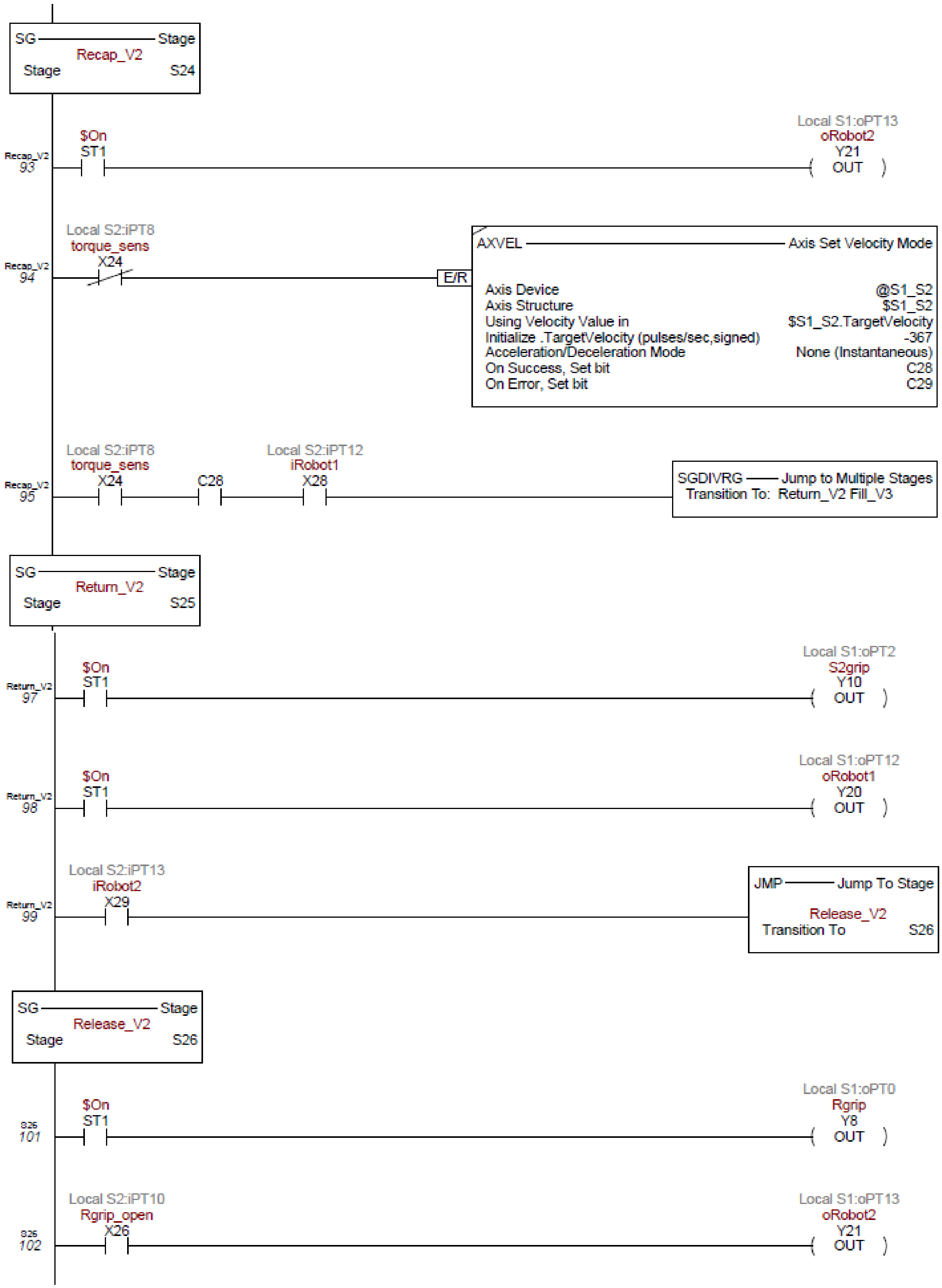

V2_to_S2
39
Local S2:iPT13
iRobot2
X29
JMP Jump To Stage
Uncap_V2
Transition To S8
SG Stage
Uncap_V2
Stage S8
Uncap_V2
41
$On
ST1
Local S1:oPT13
oRobot2
Y21
OUT
Uncap_V2
42
$On
ST1
E/R
TMR Timer
Timer Struct T1
Preset 5.000s
Uncap_V2
43
T1.Done
E/R
AXVEL Axis Set Velocity Mode
Axis Device @S1_S2
Axis Structure $S1_S2
Using Velocity Value in $S1_S2.TargetVelocity
Initialize .TargetVelocity (pulses/sec,signed) 367
Acceleration/Deceleration Mode None (Instantaneous)
On Success, Set bit C14
On Error, Set bit C15
Uncap_V2
44
T1.Done
C14
JMP Jump To Stage
Rhome2
Transition To S9
SG Stage
Rhome2
Stage S9
Rhome2
46
$On
ST1
Local S1:oPT12
oRobot1
Y20
OUT
Rhome2
47
Local S2:iPT12
iRobot1
X28
JMP Jump To Stage
End_V2
Transition To S10
SG Stage
End_V2
Stage S10
SG Stage
Fill_V1
Stage S11

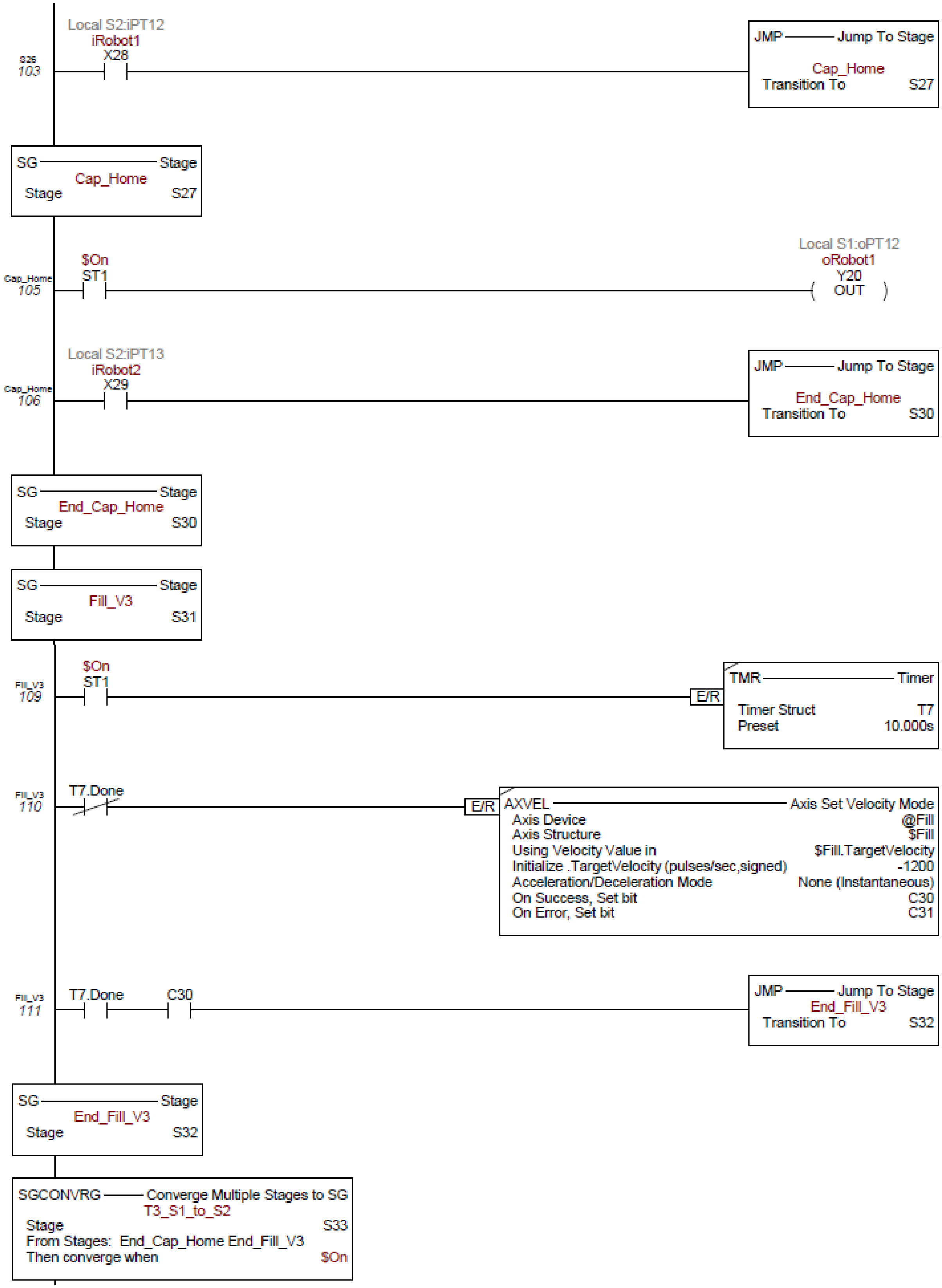

Fill_V1 50
$On
ST1
E/R
TMR Timer
Timer Struct T12
Preset 10.000s
Fill_V1 51
T12.Done
E/R
AXVEL Axis Set Velocity Mode
Axis Device @Fill
Axis Structure $Fill
Using Velocity Value in $Fill.TargetVelocity
Initialize .TargetVelocity (pulses/sec,signed) -1200
Acceleration/Deceleration Mode None (Instantaneous)
On Success, Set bit C16
On Error, Set bit C17
Fill_V1 52
T12.Done
C16
JMP Jump To Stage
End_Fill_V1
Transition To S12
SG Stage
End_Fill_V1
Stage S12
SGCONVRG Converge Multiple Stages to SG
T_S1_to_S2
Stage S13
From Stages: End_V2 End_Fill_V1
Then converge when $On
S13 55
Local S0:iPT5
F_nozzle_at_S2
X5
E/R
AXVEL Axis Set Velocity Mode
Axis Device @Track
Axis Structure $Track
Using Velocity Value in $Track.TargetVelocity
Initialize .TargetVelocity (pulses/sec,signed) 4000
Acceleration/Deceleration Mode None (Instantaneous)
On Success, Set bit C18
On Error, Set bit C19
S13 56
Local S0:iPT9
midpoint
X9
Local S1:oPT13
oRobot2
Y21
OUT
S13 57
Local S2:iPT13
iRobot2
X29
Local S0:iPT5
F_nozzle_at_S2
X5
C18
JMP Jump To Stage
Recap_V1
Transition To S14
SG Stage
Recap_V1
Stage S14
Recap_V1 59
$On
ST1
Local S1:oPT12
oRobot1
Y20
OUT

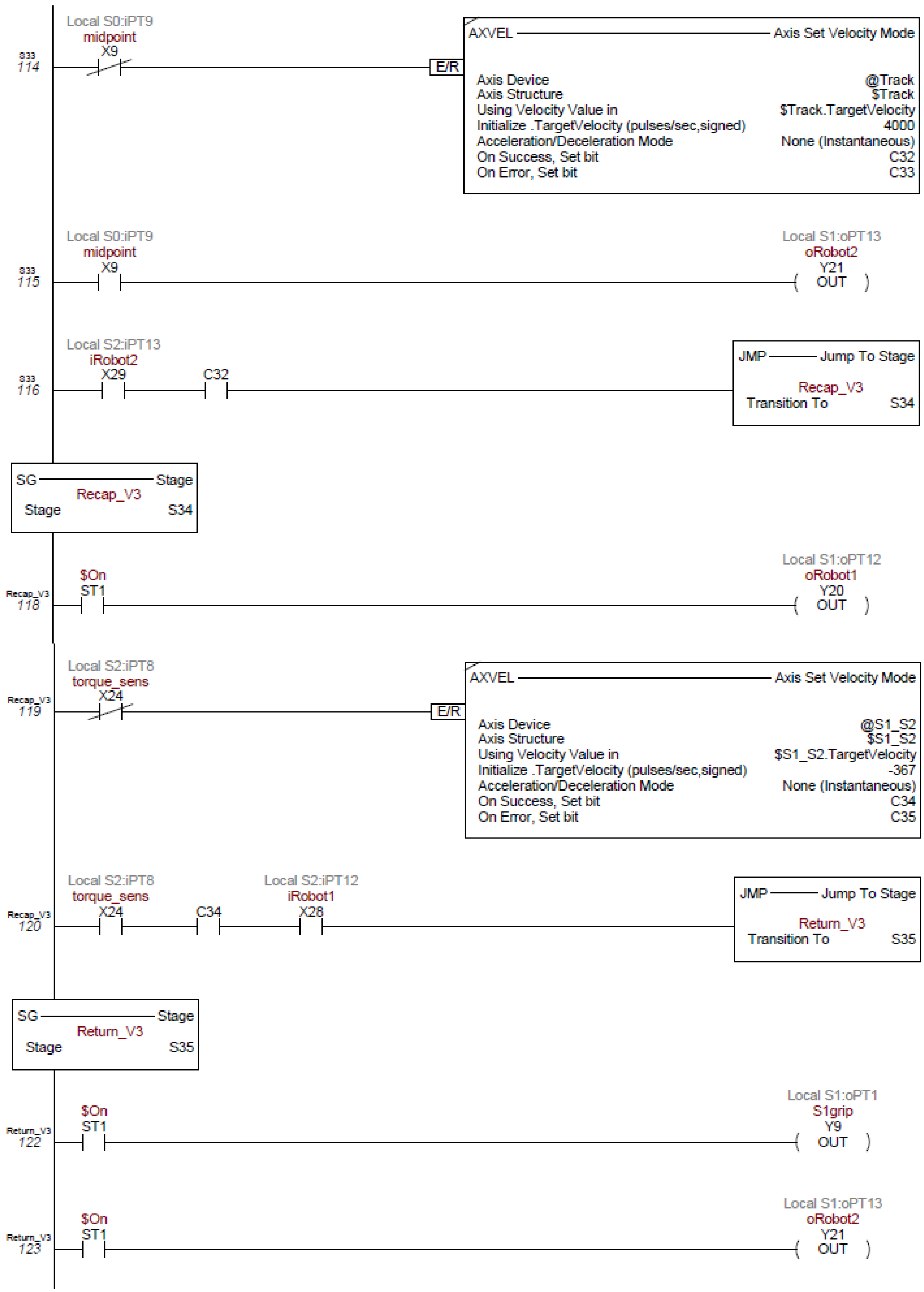

Recap_V1
60
Local S2:iPT8
torque_sens
X24
E/R
AXVEL Axis Set Velocity Mode
Axis Device @S1_S2
Axis Structure $S1_S2
Using Velocity Value in $S1_S2.TargetVelocity
Initialize .TargetVelocity (pulses/sec,signed) -367
Acceleration/Deceleration Mode None (Instantaneous)
On Success, Set bit C20
On Error, Set bit C21
Recap_V1
61
Local S2:iPT8
torque_sens
X24
C20
SGDIVRG Jump to Multiple Stages
Transition To: Return_V1 Fill_V2
SG Stage
Return_V1
Stage S15
Return_V1
63
$On
ST1
Local S1:oPT1
S1grip
Y9
OUT
Return_V1
64
$On
ST1
Local S1:oPT13
oRobot2
Y21
OUT
Return_V1
65
Local S2:iPT13
iRobot2
X29
JMP Jump To Stage
Release_V1
Transition To S16
SG Stage
Release_V1
Stage S16
S16
67
$On
ST1
Local S1:oPT0
Rgrip
Y8
OUT
S16
68
Local S2:iPT10
Rgrip_open
X26
Local S1:oPT12
oRobot1
Y20
OUT
S16
69
Local S2:iPT12
iRobot1
X28
JMP Jump To Stage
V3_to_S1
Transition To S17
SG Stage
V3_to_S1
Stage S17


V3_to_S1
71
$On
ST1
Local S1:oPT1
S1grip
Y9
OUT
V3_to_S1
72
Local S0:iPT0
S1_Grip_open
X0
Local S1:oPT13
oRobot2
Y21
OUT
V3_to_S1
73
Local S2:iPT13
iRobot2
X29
JMP Jump To Stage
Uncap_V3
Transition To S18
SG Stage
Uncap_V3
Stage S18
Uncap_V3
75
$On
ST1
Local S1:oPT12
oRobot1
Y20
OUT
Uncap_V3
76
$On
ST1
E/R
TMR Timer
Timer Struct T5
Preset 5.000s
Uncap_V3
77
T5.Done
E/R
AXVEL Axis Set Velocity Mode
Axis Device @S1_S2
Axis Structure $S1_S2
Using Velocity Value in $S1_S2.TargetVelocity
Initialize .TargetVelocity (pulses/sec,signed) 367
Acceleration/Deceleration Mode None (Instantaneous)
On Success, Set bit C22
On Error, Set bit C23
Uncap_V3
78
T5.Done
Local S2:iPT12
iRobot1
X28
C22
JMP Jump To Stage
Rhome3
Transition To S19
SG Stage
Rhome3
Stage S19
Rhome3
80
$On
ST1
Local S1:oPT13
oRobot2
Y21
OUT
Rhome3
81
Local S2:iPT13
iRobot2
X29
JMP Jump To Stage
End_V3
Transition To S20

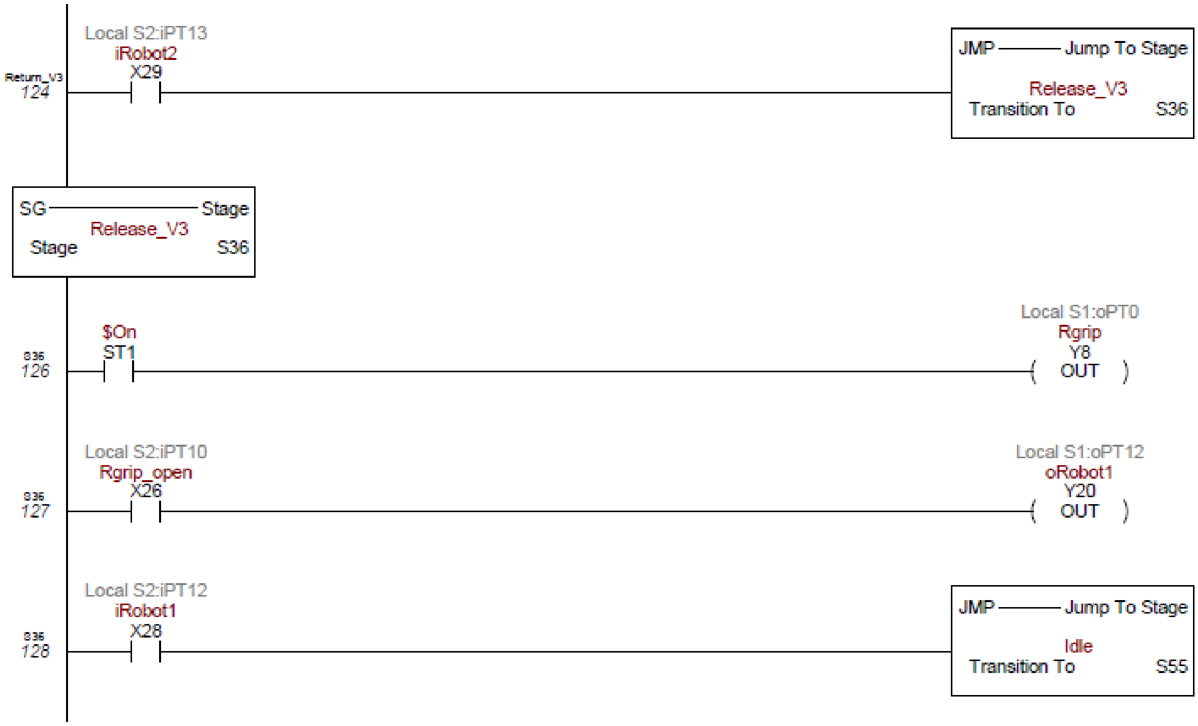

SG Stage
End_V3
Stage S20
SG Stage
Fill_V2
Stage S21
Fill_V2
84
$On
ST1
E/R
TMR Timer
Timer Struct T6
Preset 10.000s
Fill_V2
85
T6.Done
E/R
AXVEL Axis Set Velocity Mode
Axis Device @Fill
Axis Structure $Fill
Using Velocity Value in $Fill.TargetVelocity
Initialize .TargetVelocity (pulses/sec,signed) -1200
Acceleration/Deceleration Mode None (Instantaneous)
On Success, Set bit C24
On Error, Set bit C25
Fill_V2
86
T6.Done
C24
JMP Jump To Stage
End_Fill_V2
Transition To S22
SG Stage
End_Fill_V2
Stage S22
SGCONVRG Converge Multiple Stages to SG
T2_S2_to_S1
Stage S23
From Stages: End_V3 End_Fill_V2
Then converge when $On
S23
89
Local S0:iPT4
F_nozzle_at_S1
X4
E/R
AXVEL Axis Set Velocity Mode
Axis Device @Track
Axis Structure $Track
Using Velocity Value in $Track.TargetVelocity
Initialize .TargetVelocity (pulses/sec,signed) -4000
Acceleration/Deceleration Mode None (Instantaneous)
On Success, Set bit C26
On Error, Set bit C27
S23
90
Local S0:iPT9
midpoint
X9
Local S1:oPT12
oRobot1
Y20
OUT
S23
91
Local S2:iPT12
iRobot1
X28
Local S0:iPT4
F_nozzle_at_S1
X4
C26
JMP Jump To Stage
Recap_V2
Transition To S24


SG Stage
Recap_V2
Stage S24
Recap_V2 93
$On
ST1
Local S1:oPT13
oRobot2
Y21
OUT
Recap_V2 94
Local S2:iPT8
torque_sens
X24
E/R
AXVEL Axis Set Velocity Mode
Axis Device @S1_S2
Axis Structure $S1_S2
Using Velocity Value in $S1_S2.TargetVelocity
Initialize .TargetVelocity (pulses/sec,signed) -367
Acceleration/Deceleration Mode None (Instantaneous)
On Success, Set bit C28
On Error, Set bit C29
Recap_V2 95
Local S2:iPT8
torque_sens
X24
C28
Local S2:iPT12
iRobot1
X28
SGDIVRG Jump to Multiple Stages
Transition To: Return_V2 Fill_V3
SG Stage
Return_V2
Stage S25
Return_V2 97
$On
ST1
Local S1:oPT2
S2grip
Y10
OUT
Return_V2 98
$On
ST1
Local S1:oPT12
oRobot1
Y20
OUT
Return_V2 99
Local S2:iPT13
iRobot2
X29
JMP Jump To Stage
Release_V2
Transition To S26
SG Stage
Release_V2
Stage S26
S26 101
$On
ST1
Local S1:oPT0
Rgrip
Y8
OUT
S26 102
Local S2:iPT10
Rgrip_open
X26
Local S1:oPT13
oRobot2
Y21
OUT

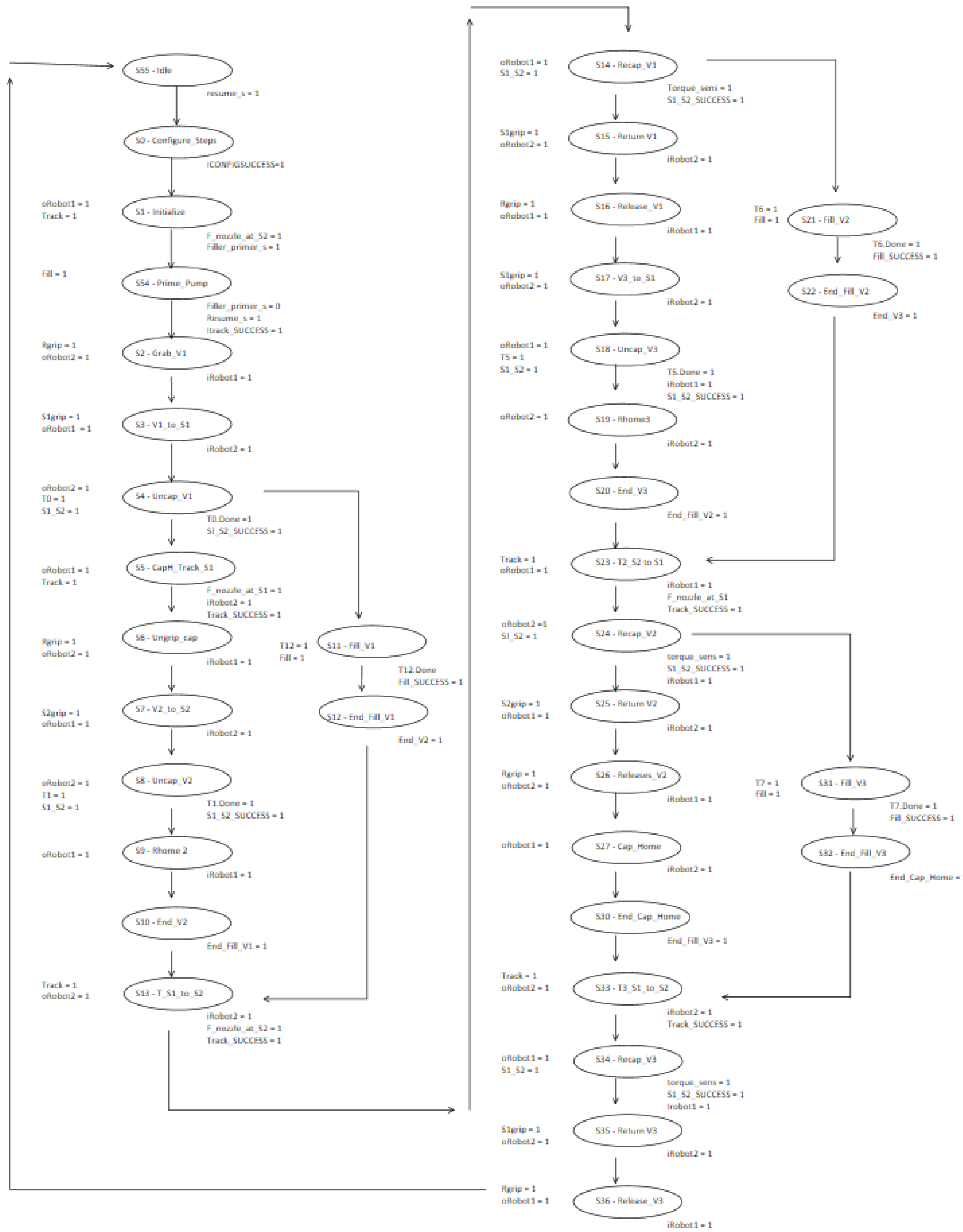

S26
103
Local S2:iPT12
iRobot1
X28
JMP Jump To Stage
Cap_Home
Transition To S27
SG Stage
Cap_Home
Stage S27
Cap_Home
105
$On
ST1
Local S1:oPT12
oRobot1
Y20
OUT
Cap_Home
106
Local S2:iPT13
iRobot2
X29
JMP Jump To Stage
End_Cap_Home
Transition To S30
SG Stage
End_Cap_Home
Stage S30
SG Stage
Fill_V3
Stage S31
Fill_V3
109
$On
ST1
E/R
TMR Timer
Timer Struct T7
Preset 10.000s
Fill_V3
110
T7.Done
E/R
AXVEL Axis Set Velocity Mode
Axis Device @Fill
Axis Structure $Fill
Using Velocity Value in $Fill.TargetVelocity
Initialize .TargetVelocity (pulses/sec,signed) -1200
Acceleration/Deceleration Mode None (Instantaneous)
On Success, Set bit C30
On Error, Set bit C31
Fill_V3
111
T7.Done
C30
JMP Jump To Stage
End_Fill_V3
Transition To S32
SG Stage
End_Fill_V3
Stage S32
SGCONVRG Converge Multiple Stages to SG
T3_S1_to_S2
Stage S33
From Stages: End_Cap_Home End_Fill_V3
Then converge when $On



Local S0:iPT9
midpoint
X9
S33
114
E/R
AXVEL
Axis Set Velocity Mode
Axis Device @Track
Axis Structure $Track
Using Velocity Value in $Track.TargetVelocity
Initialize .TargetVelocity (pulses/sec,signed) 4000
Acceleration/Deceleration Mode None (Instantaneous)
On Success, Set bit C32
On Error, Set bit C33
Local S0:iPT9
midpoint
X9
S33
115
Local S1:oPT13
oRobot2
Y21
OUT
Local S2:iPT13
iRobot2
X29
C32
S33
116
JMP
Jump To Stage
Recap_V3
Transition To S34
SG
Stage
Recap_V3
Stage S34
$On
ST1
Recap_V3
118
Local S1:oPT12
oRobot1
Y20
OUT
Local S2:iPT8
torque_sens
X24
Recap_V3
119
E/R
AXVEL
Axis Set Velocity Mode
Axis Device @S1_S2
Axis Structure $S1_S2
Using Velocity Value in $S1_S2.TargetVelocity
Initialize .TargetVelocity (pulses/sec,signed) -367
Acceleration/Deceleration Mode None (Instantaneous)
On Success, Set bit C34
On Error, Set bit C35
Local S2:iPT8
torque_sens
X24
C34
Local S2:iPT12
iRobot1
X28
Recap_V3
120
JMP
Jump To Stage
Return_V3
Transition To S35
SG
Stage
Return_V3
Stage S35
$On
ST1
Return_V3
122
Local S1:oPT1
S1grip
Y9
OUT
$On
ST1
Return_V3
123
Local S1:oPT13
oRobot2
Y21
OUT


Return_V3
124
Local S2:iPT13
iRobot2
X29
JMP Jump To Stage
Release_V3
Transition To S36
SG Stage
Release_V3
Stage S36
S36
126
$On
ST1
Local S1:oPT0
Rgrip
Y8
OUT
S36
127
Local S2:iPT10
Rgrip_open
X26
Local S1:oPT12
oRobot1
Y20
OUT
S36
128
Local S2:iPT12
iRobot1
X28
JMP Jump To Stage
Idle
Transition To S55

State Machine Diagram



MotoMan Job Programs

Main Program

```
/JOB
//NAME 2021_MASTER
//POS
///NPOS 58,0,0,0,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
C00000=-39371,7427,-76894,1406,-22199,15828
C00001=-53057,83435,656,971,-32413,21399
C00002=-53057,86576,1381,1012,-31042,21371
C00003=-53057,80534,103,943,-33789,21429
C00004=-53056,73908,-611,867,-37278,21489
C00005=-41229,54520,-25481,1038,-31043,16818
C00006=-25512,33100,-43493,1031,-31046,10773
C00007=-25512,43365,-44337,1291,-24238,10586
C00008=-25511,42730,-44329,1274,-24630,10599
C00009=-25195,39339,-44190,1176,-26773,10550
C00010=-39371,7427,-76894,1406,-22199,15828
C00011=-67224,73306,-37619,2605,-10728,25720
C00012=-67224,75356,-37084,2818,-9902,25582
C00013=-67224,70994,-38221,2387,-11713,25860
C00014=-57311,69964,-27607,1477,-20081,22666
C00015=-47897,79215,-6670,1069,-29733,19352
C00016=-47852,82845,-5756,1122,-28204,19299
C00017=-47852,73796,-7385,991,-32497,19396
C00018=-39371,7427,-76894,1406,-22199,15828
C00019=-11950,1265,-82542,1389,-22017,5309
C00020=10104,29638,-47914,953,-30130,-2866
C00021=10051,40464,-48751,1222,-22988,-3038
C00022=10050,39790,-48738,1203,-23402,-3025
```

C00023=10425,36880,-48511,1112,-25328,-3104

C00024=-11950,1265,-82542,1389,-22017,5309

C00025=-39371,7427,-76894,1406,-22199,15828

C00026=-25421,33239,-43119,1028,-31267,10754

C00027=-25418,33240,-43120,1029,-31269,10753

C00028=-41229,54520,-25481,1038,-31043,16818

C00029=-53056,73908,-611,867,-37278,21489

C00030=-53058,86279,1291,1014,-31176,21378

C00031=-53057,83598,671,983,-32348,21404

C00032=-49779,89563,12328,883,-37222,20237

C00033=-49779,93079,13164,910,-35767,20215

C00034=-49779,84079,11379,835,-39852,20277

C00035=-49027,72574,603,853,-39002,19969

C00036=-41229,54520,-25481,1038,-31043,16818

C00037=-25636,33781,-43492,1043,-30639,10814

C00038=-25636,44056,-44248,1308,-23886,10623

C00039=10275,30070,-47514,950,-30172,-2927

C00040=-11950,1265,-82542,1389,-22017,5309

C00041=-39371,7427,-76894,1406,-22199,15828

C00042=-47852,73796,-7385,991,-32497,19396

C00043=-47853,82601,-5824,1123,-28317,19300

C00044=-47852,80002,-6403,1084,-29466,19330

C00045=-57112,69747,-26635,1462,-20939,22617

C00046=-67010,73368,-37435,2687,-10860,25613

C00047=-67011,75937,-36739,2970,-9818,25435

C00048=-67010,73403,-37431,2693,-10847,25613

C00049=-39371,7427,-76894,1406,-22199,15828

C00050=-25421,33723,-43198,1039,-30925,10751

C00051=-39331,56053,-15235,898,-37621,16218

C00052=-46581,74799,5639,836,-41431,19057

C00053=-49291,78935,10946,813,-42715,20123

C00054=-49459,91749,12720,928,-36251,20090

```
C00055=-49459,89712,12222,912,-37124,20103
C00056=-42505,48712,-37610,1254,-25821,17174
C00057=-39371,7427,-76894,1406,-22199,15828
//INST
///DATE 2021/12/14 03:17
///ATTR SC,RW
///GROUP1 RB1
NOP
*START
'START UP
WAIT IN#(1)=ON
DOUT OT#(1) OFF
DOUT OT#(2) OFF
MOVL C00000 V=75.0  //GO HOME
'
'PICK UP V1
WAIT IN#(2)=ON
MOVL C00001 V=50.0  //V1
MOVL C00002 V=20.0
PULSE OT#(1)
'
WAIT IN#(1)=ON
MOVL C00003 V=20.0  //V1 TO F1
MOVS C00004 V=50.0
MOVS C00005 V=50.0
MOVS C00006 V=50.0
MOVL C00007 V=20.0
PULSE OT#(2)
'
WAIT IN#(2)=ON
TIMER T=1.00
MOVL C00008 V=1.5  //MOVE UP AS CAP IS UNSCREWED
```

```
'
WAIT IN#(1)=ON
MOVL C00009 V=20.0  //MOVE TO CAP HOLDER
MOVL C00010 V=50.0
MOVL C00011 V=50.0
MOVL C00012 V=20.0
DOUT OT#(2) ON
'
WAIT IN#(2)=ON
DOUT OT#(2) OFF
MOVS C00013 V=20.0  //V2
MOVS C00014 V=50.0
MOVS C00015 V=50.0
MOVL C00016 V=20.0
PULSE OT#(1)
'
WAIT IN#(1)=ON
MOVL C00017 V=20.0  //V2 TO S2
MOVL C00018 V=50.0
MOVL C00019 V=50.0
MOVL C00020 V=50.0
MOVL C00021 V=20.0
PULSE OT#(2)
'
WAIT IN#(2)=ON
TIMER T=1.00
MOVL C00022 V=1.5  //MOVE UP AS CAP IS UNSCREWED
'
WAIT IN#(1)=ON
MOVL C00023 V=20.0  //GO HOME
MOVL C00024 V=50.0
MOVL C00025 V=50.0
```

```
PULSE OT#(1)
'
CALL JOB:CAP_1
'
WAIT IN#(2)=ON
DOUT OT#(1) OFF
MOVL C00026 V=20.0
MOVS C00027 V=50.0
MOVS C00028 V=50.0
MOVS C00029 V=50.0
MOVL C00030 V=20.0  //V1 TO F1
PULSE OT#(2)
'
MOVL C00031 V=50.0
MOVL C00032 V=50.0
MOVL C00033 V=20.0
PULSE OT#(1)
WAIT IN#(1)=ON
MOVL C00034 V=20.0
MOVS C00035 V=50.0
MOVS C00036 V=50.0
MOVS C00037 V=50.0
MOVL C00038 V=20.0
PULSE OT#(2)
CALL JOB:UNCAP_1
CALL JOB:CAP_2
'
WAIT IN#(1)=ON
DOUT OT#(1) OFF
MOVL C00039 V=50.0  //RETURN V2
MOVL C00040 V=50.0
MOVL C00041 V=50.0
```

```
MOVL C00042 V=50.0
MOVL C00043 V=20.0
PULSE OT#(2)
'
WAIT IN#(2)=ON
MOVS C00044 V=50.0
MOVS C00045 V=50.0
MOVS C00046 V=50.0
MOVL C00047 V=20.0
PULSE OT#(1)
'
WAIT IN#(1)=ON
MOVL C00048 V=20.0  //GO HOME
MOVL C00049 V=50.0
PULSE OT#(2)
'
CALL JOB:CAP_1
WAIT IN#(2)=ON
DOUT OT#(1) OFF
MOVL C00050 V=50.0
MOVL C00051 V=50.0
MOVL C00052 V=50.0
MOVL C00053 V=50.0
MOVL C00054 V=50.0
PULSE OT#(2)
'
WAIT IN#(1)=ON
MOVS C00055 V=50.0
MOVS C00056 V=50.0
MOVS C00057 V=50.0
PULSE OT#(1)
PULSE OT#(1)
```

```
JUMP *START
END
```

Station 1 – Uncapping

```
/JOB
//NAME UNCAP_1
//POS
///NPOS 3,0,0,0,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
C00000=-25636,43438,-44243,1290,-24263,10638
C00001=-25195,39339,-44190,1176,-26773,10550
C00002=-39371,7427,-76894,1406,-22199,15828
//INST
///DATE 2021/12/12 02:16
///ATTR SC,RW
///GROUP1 RB1
NOP
WAIT IN#(1)=ON
TIMER T=1.00
MOVL C00000 V=1.5  //MOVE UP AS CAP IS UNSCREWED
DOUT OT#(1) ON
'
WAIT IN#(2)=ON
DOUT OT#(1) OFF
MOVL C00001 V=20.0
MOVL C00002 V=50.0  //GO HOME
PULSE OT#(2)
END
```

Station 2 – Uncapping

This program was not created since only three vials were processed in this project and the first two uncapping sequences are coded into the main program since they are unique.

Station 1 – Capping

```
/JOB
//NAME CAP_1
//POS
///NPOS 3,0,0,0,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
C00000=-25421,41444,-43899,1225,-25728,10611
C00001=-25421,42891,-43953,1266,-24822,10582
C00002=-25421,43959,-43981,1298,-24171,10560
//INST
///DATE 2021/12/14 02:31
///ATTR SC,RW
///GROUP1 RB1
NOP
WAIT IN#(2)=ON
MOVL C00000 V=50.0
MOVL C00001 V=20.0
DOUT OT#(2) ON
'
WAIT IN#(1)=ON
DOUT OT#(2) OFF
TIMER T=1.00
MOVL C00002 V=1.5
DOUT OT#(1) ON
END
```

Station 2 – Capping

```
/JOB
//NAME CAP_2
//POS
///NPOS 4,0,0,0,0,0
///TOOL 0
///POSTYPE PULSE
///PULSE
C00000=-11950,1265,-82542,1389,-22017,5309
C00001=10276,39338,-48324,1170,-23978,-3089
C00002=10275,40203,-48352,1195,-23435,-3107
C00003=10275,40961,-48370,1218,-22970,-3121
//INST
///DATE 2021/12/13 20:33
///ATTR SC,RW
///GROUP1 RB1
NOP
WAIT IN#(1)=ON
MOVL C00000 V=50.0
MOVL C00001 V=50.0
MOVL C00002 V=20.0
DOUT OT#(1) ON
'
WAIT IN#(2)=ON
DOUT OT#(1) OFF
TIMER T=1.00
MOVL C00003 V=1.5
DOUT OT#(1) ON
END
```

Stepper Motor Driver Configurations

Four Automation Direct Sure Step STP-DRV-6575 stepper motor drivers control the stepper motors for the rotating grip stations, moving nozzle, and pump.

<u>Rotating Grip Stations:</u>

Motor Details

Model – ANYCUBIC Model 42HD4027-01

Step Angle – 1.8°

Rated Current – 1.5 A

Voltage – 3.3 VDC

Driver Configuration

Motor Current = 100% (SW 1 and SW 2 OFF)

Load Inertia = 0-4X (SW 3 OFF)

Idle Current = 50% (SW 4 ON)

Steps/Rev = 200 SMOOTH (SW 5 OFF, SW 6 and SW 7 ON)

Motor = Custom NEMA 17, 1.3 A (Motor Selector Position 3)

<u>Pump:</u>

Motor Details

Step Angle – 1.8°

Rated Current – 2.0 A

Driver Configuration

Motor Current = 100% (SW 1 and SW 2 OFF)

Load Inertia = 0-4X (SW 3 OFF)

Idle Current = 50% (SW 4 ON)

Steps/Rev = 200 SMOOTH (SW 5 OFF, SW 6 and SW 7 ON)

Motor = STP-MTR-17048(D), 2.0 A (Motor Selector Position 7)

<u>Moving Nozzle:</u>

Motor Details

Step Angle – 1.8°

Rated Current – 2.0 A

Driver Configuration

Motor Current = 100% (SW 1 and SW 2 OFF)

Load Inertia = 0-4X (SW 3 OFF)

Idle Current = 50% (SW 4 ON)

Steps/Rev = 2000 (SW 5 and SW 6 ON, SW 7 OFF)

Motor = STP-MTR-17048(D), 2.0 A (Motor Selector Position 7)

Miscellaneous Electrical Diagrams

PLC Inputs

PLC Body		Expansion	
0	S1 Gripper Open Sensor (NPN)	0	E-stop Switch (NC)
1	S1 Vial Present Sensor (NPN)	1	Move Away/Return Switch (NO)
2	S2 Gripper Open Sensor (NPN)	2	Resume Switch (NO)
3	S2 Vial Present Sensor (NPN)	3	Filler Primer Switch (NO)
4	F Nozzle at S1 Sensor (NPN)	4	
5	F Nozzle at S2 Sensor (NPN)	5	
6	F Nozzle Raised Sensor (NPN)	6	B1 Box Present Sensor (NPN)
7	F Nozzle Lowered Sensor (NPN)	7	B2 Box Present Sensor (NPN)
8	F Vial Full Sensor (NPN)	8	R Torque Sensor (NPN)
9	F Nozzle at Middle Sensor (NPN)	9	R Vial Present Sensor (NPN)
		10	R Gripper Open Sensor (NPN)
		11	R Gripper Closed Sensor (NPN)
		12	Input from Robot 1
		13	Input from Robot 2
		14	Input from Robot 3
		15	Input from Robot 4

Black Indicates Channels in Use

Red Indicates Un-implemented Channels

PLC Outputs

PLC Body		Expansion	
0	S1/S2 Motor Step-	0	R Gripper Pneumatic Controller
1	S1/S2 Motor Dir-	1	S1 Release Pneumatic Controller
2	S2 Motor Step-	2	S2 Release Pneumatic Controller
3	S2 Motor Dir-	3	F Raise Pneumatic Controller
4	F Fill Motor Step-	4	E-stop Engaged Indicator Light
5	F Fill Motor Dir-	5	
6	F Track Motor Step-	6	B1 Indicator Light Red
7	F Track Motor Dir-	7	B1 Indicator Light Yellow
		8	B1 Indicator Light Green
		9	B2 Indicator Light Red
		10	B2 Indicator Light Yellow
		11	B2 Indicator Light Green
		12	Output to Robot 1
		13	Output to Robot 2
		14	Output to Robot 3
		15	Output to Robot 4

Black Indicates Channels in Use

Red Indicates Un-implemented Channels

Zip Link Channels			
Top		Bottom	
SH		14	S1 Motor A+
2	F Fill Motor A+	15	S1 Motor A-
3	F Fill Motor A-	16	S1 Motor B+
4	F Fill Motor B+	17	S1 Motor B-
5	F Fill Motor B-	18	S2 Motor A+
6	F Track Motor A+	19	S2 Motor A-
7	F Track Motor A-	20	S2 Motor B+
8	F Track Motor B+	21	S2 Motor B-
9	F Track Motor B-	22	24V-
10	24V+	23	
11	B2 Indicator Light Red	24	B1 Indicator Light Red
12	B2 Indicator Light Yellow	25	B1 Indicator Light Yellow
13	B2 Indicator Light Green	26	B1 Indicator Light Green

Black Indicates Channels in Use

Red Indicates Un-implemented Channels

PLC Side Power Supply Distribution

Through E-stop		Around E-stop	
1	PLC Channels	1	PLC Power
2	Pneumatic Drivers	2	
3	Stepper Motor Drivers		
4	Zip Link 24V+/- Terminal Blocks		
5	Robot Top 24V+/- Terminal Blocks		
6	Control Panel Start/Pump Primer		
7			
8			

Robot Controller Wiring

MTX Panel		Aux 110V AC	
21	E-stop Switch 24V+	G	PLC Side 24V Power Supply Ground
22	E-stop Switch 24V-	G	PLC Side Aux Power Strip Ground
		X0	PLC Side 24V Power Supply Neutral
		X0	PLC Side Aux Power Strip Neutral
		3	PLC Side 24V Power Supply Line
		3	PLC Side Aux Power Strip Line