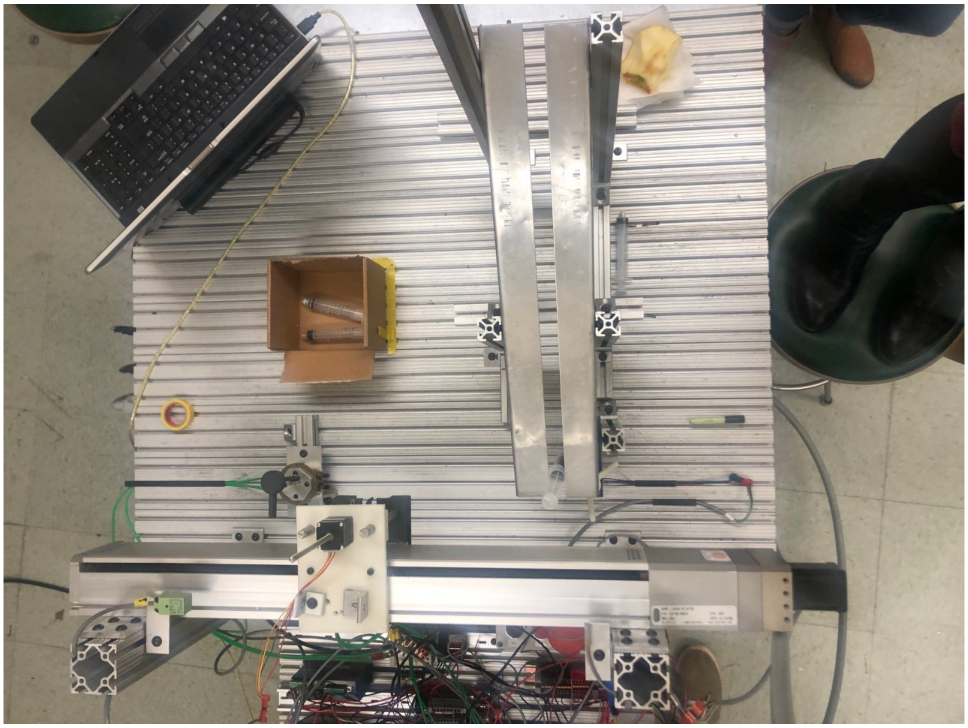
Machine Instructions

Loading Machine

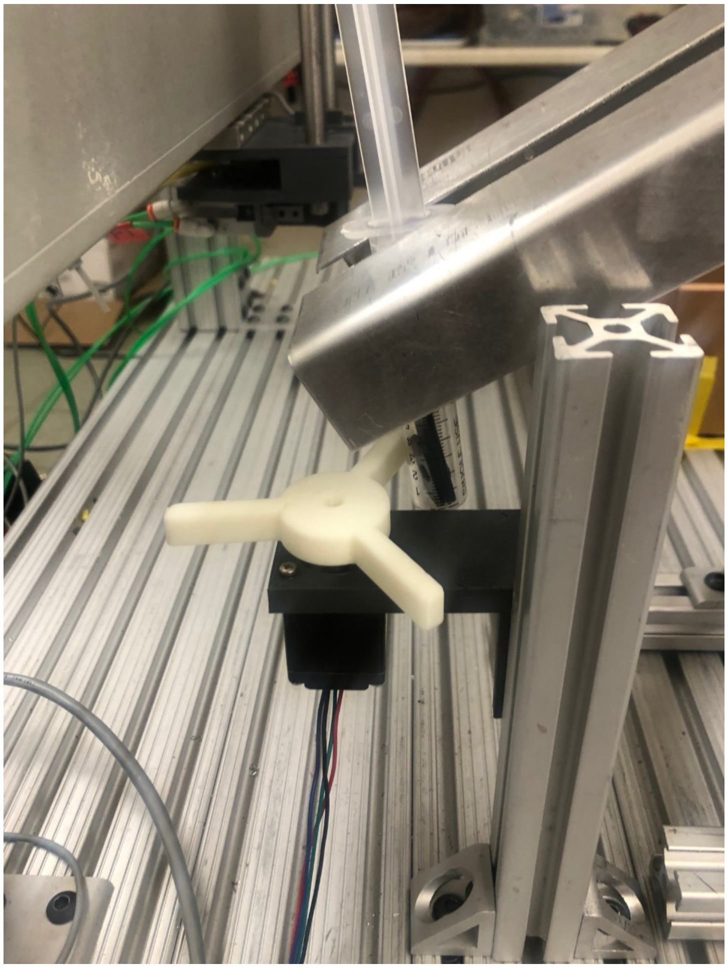
To load the machine, insert standard syringes filled to the 10mL line into the end of the gravity fed track shown on the right side of the figure below. Make sure the syringes reach the end of the track successfully. For best results, ensure the long side of the syringe body is aligned with the tracks of the loading track. Reference figure two if needed.

Figure 1: Aerial view of automatic syringe changer assembly



To hold the syringes in place behind the turnstile, position one of the turnstile arms as shown in figure two. For further clarification, one of the turnstile arms should be positioned perpendicularly in relation to the linear actuator on the main printer body holding the syringe mount.

Figure 2: Turnstile assembly



Starting Machine

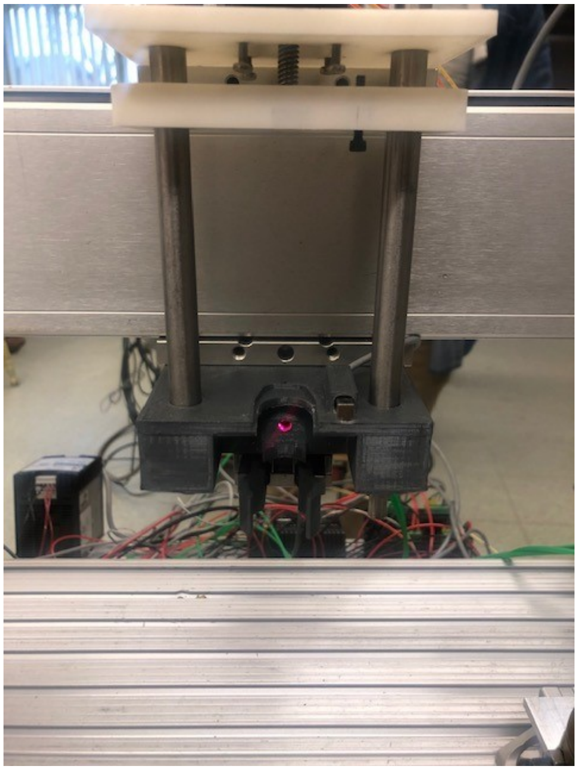
To start the machine, double check the machine is loaded properly. Turn on the main power source using the red switch on the power strip attached to the workbench on which the syringe changer sits. Run the ladder diagram on the provided laptop in DoMore Designer. The machine should home, move the mount to the storage area, activate the turnstile to load the syringe, move the carriage, extrude fully, and finally reject the syringe.

Clearing Jams

The most likely location in our team's experience to experience jams is when the turnstile loads the syringe into the mount. As you can see in figure three, the syringe mount is the dark gray 3D printed part with two guiding rods attached. If the syringe is not aligned correctly in the storage, the turnstile may jam the syringe into the mount in the incorrect position. To correct this, you can adjust the syringe in the mount, so the body matches the cutout area in the mount shown in figure four.

Figure 3: Syringe mount and storage area

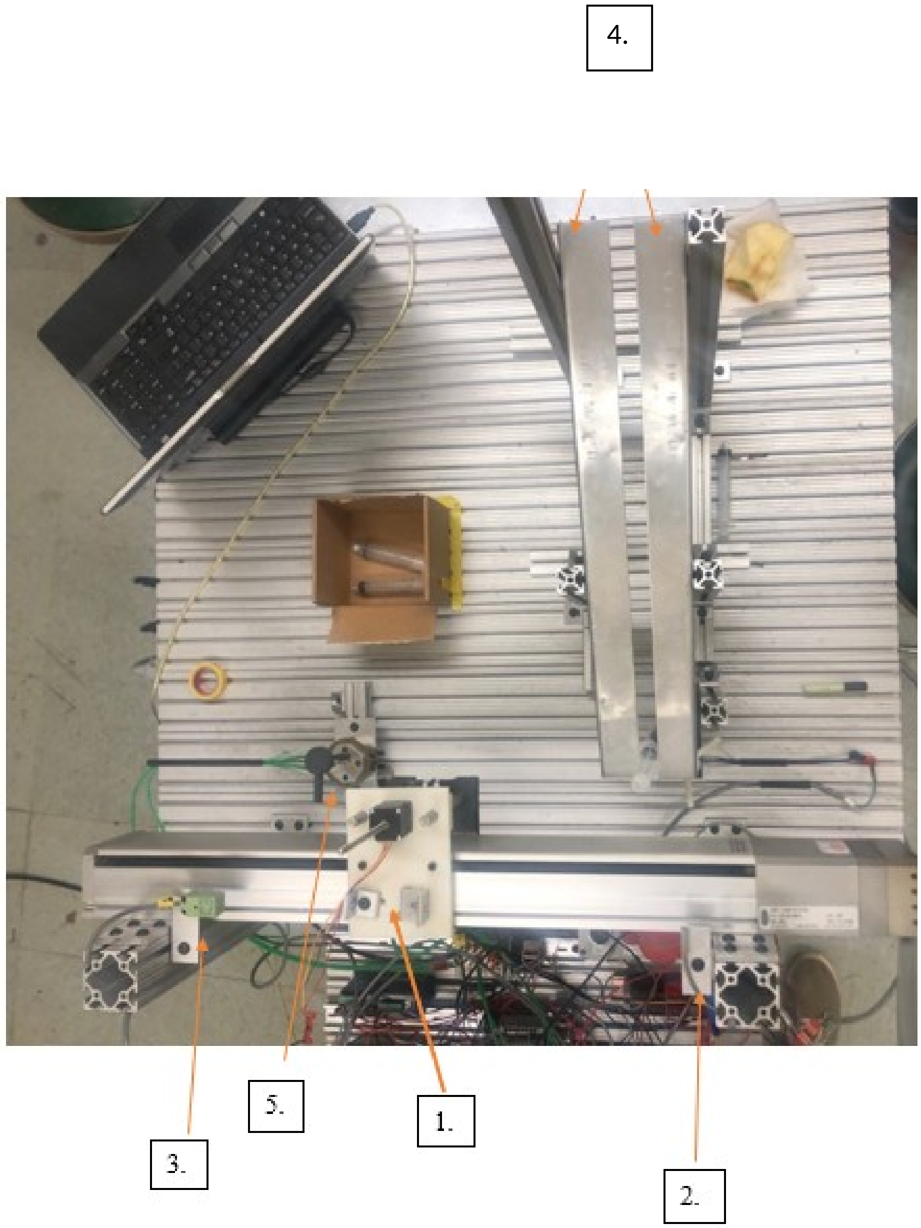
Figure 4: Syringe mount



Diagrams

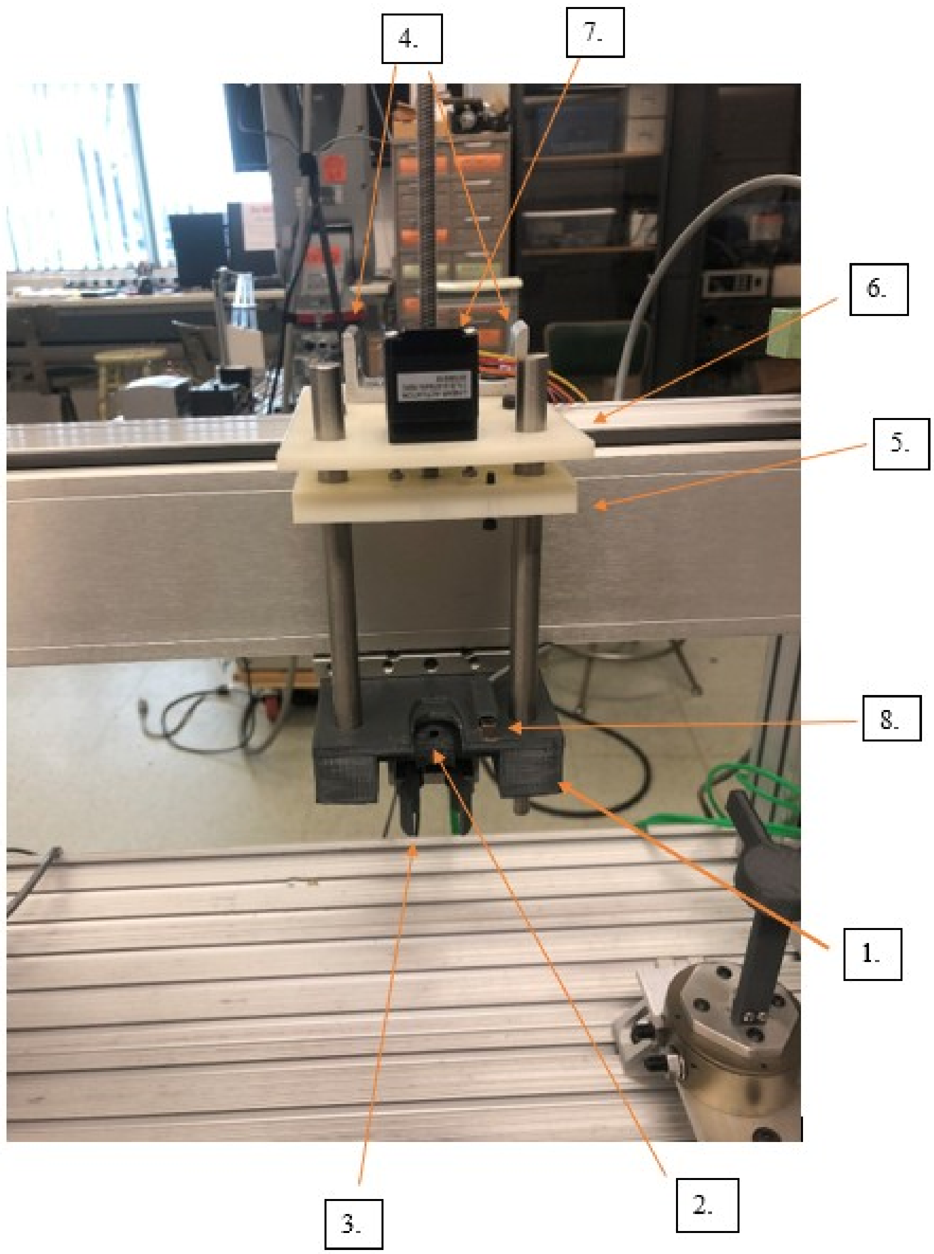
Mechanical Drawings and annotated photos

Figure 5: Overall Labeled Assembly



1.	Syringe mount assembly
2, 3.	Induction Sensors
4.	Gravity fed track
5.	Rejection assembly

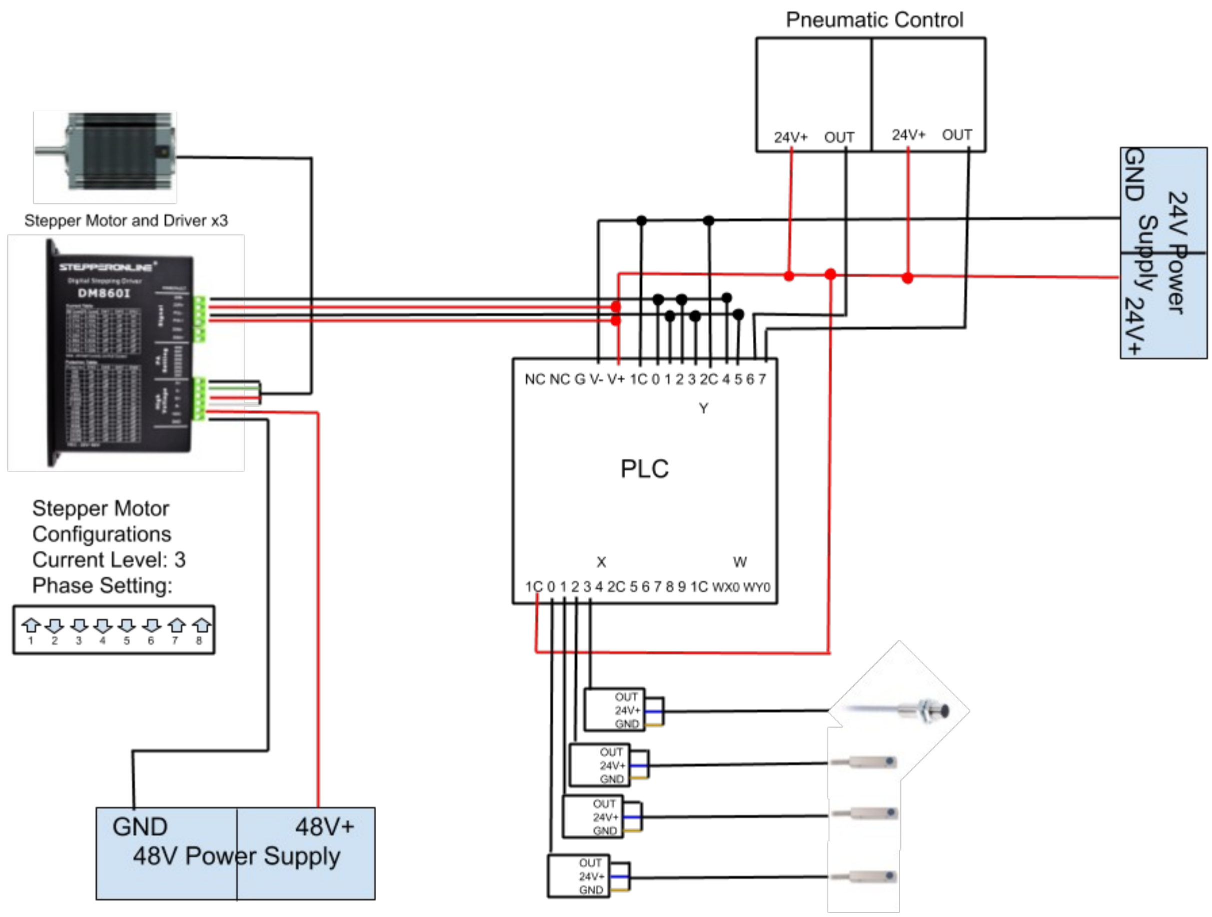
Figure 6: Labeled Extruder Assembly



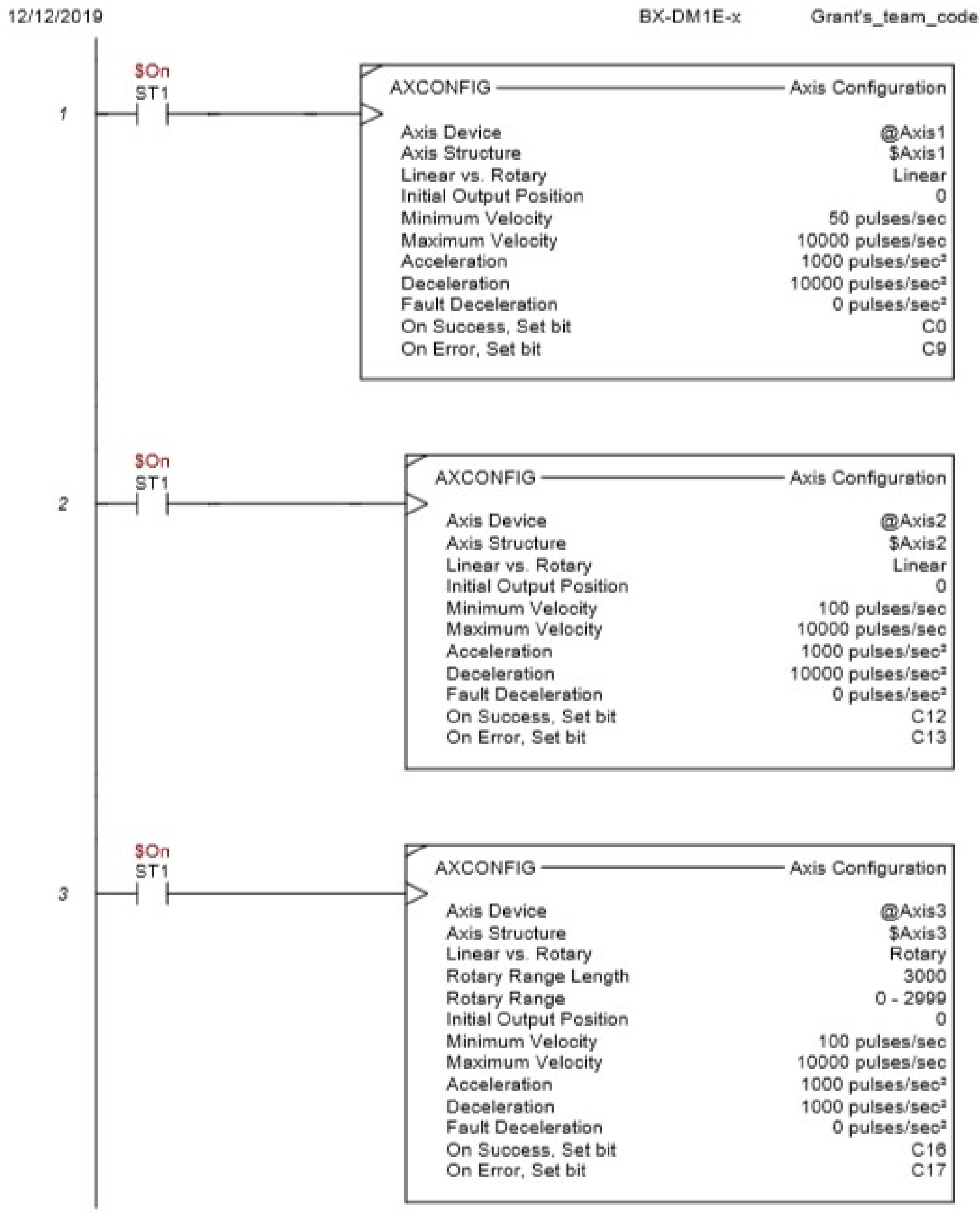
1.	Syringe_mount
2.	Optical Sensor
3.	Pneumatic Gripper
4.	Aluminum end stops
5.	Push_plate

6.	Top_plate
7.	Stepper motor
8.	Induction Sensor

Wiring/Pneumatic Diagram



PLC Code


12/12/2019
BX-DM1E-x
Grant's_team_code
1
$On
ST1
AXCONFIG
Axis Configuration
Axis Device @Axis1
Axis Structure $Axis1
Linear vs. Rotary Linear
Initial Output Position 0
Minimum Velocity 50 pulses/sec
Maximum Velocity 10000 pulses/sec
Acceleration 1000 pulses/sec²
Deceleration 10000 pulses/sec²
Fault Deceleration 0 pulses/sec²
On Success, Set bit C0
On Error, Set bit C9
2
$On
ST1
AXCONFIG
Axis Configuration
Axis Device @Axis2
Axis Structure $Axis2
Linear vs. Rotary Linear
Initial Output Position 0
Minimum Velocity 100 pulses/sec
Maximum Velocity 10000 pulses/sec
Acceleration 1000 pulses/sec²
Deceleration 10000 pulses/sec²
Fault Deceleration 0 pulses/sec²
On Success, Set bit C12
On Error, Set bit C13
3
$On
ST1
AXCONFIG
Axis Configuration
Axis Device @Axis3
Axis Structure $Axis3
Linear vs. Rotary Rotary
Rotary Range Length 3000
Rotary Range 0 - 2999
Initial Output Position 0
Minimum Velocity 100 pulses/sec
Maximum Velocity 10000 pulses/sec
Acceleration 1000 pulses/sec²
Deceleration 1000 pulses/sec²
Fault Deceleration 0 pulses/sec²
On Success, Set bit C16
On Error, Set bit C17

SG — Stage
Home_empty
Stage S2

A

$On
ST1
5

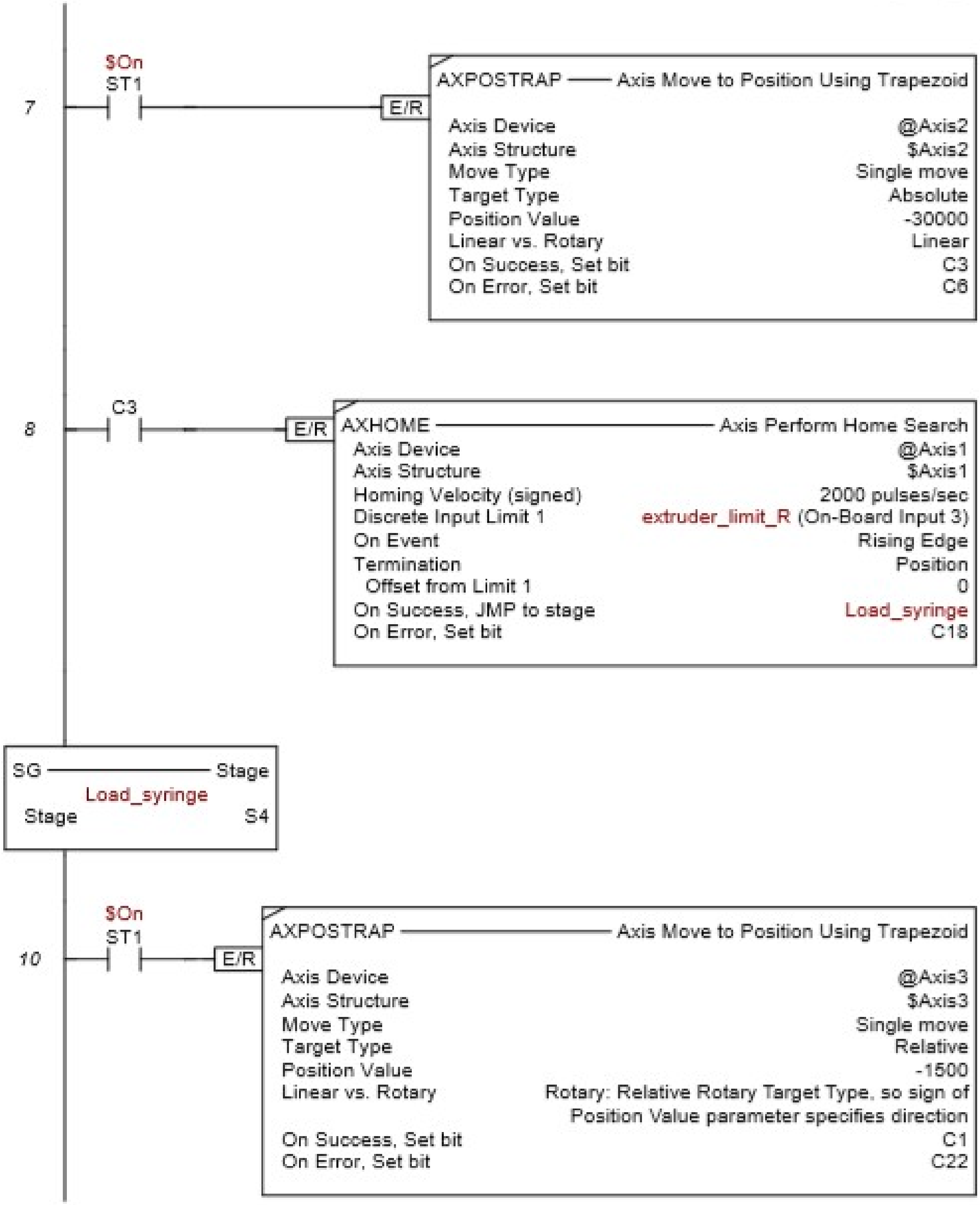
A

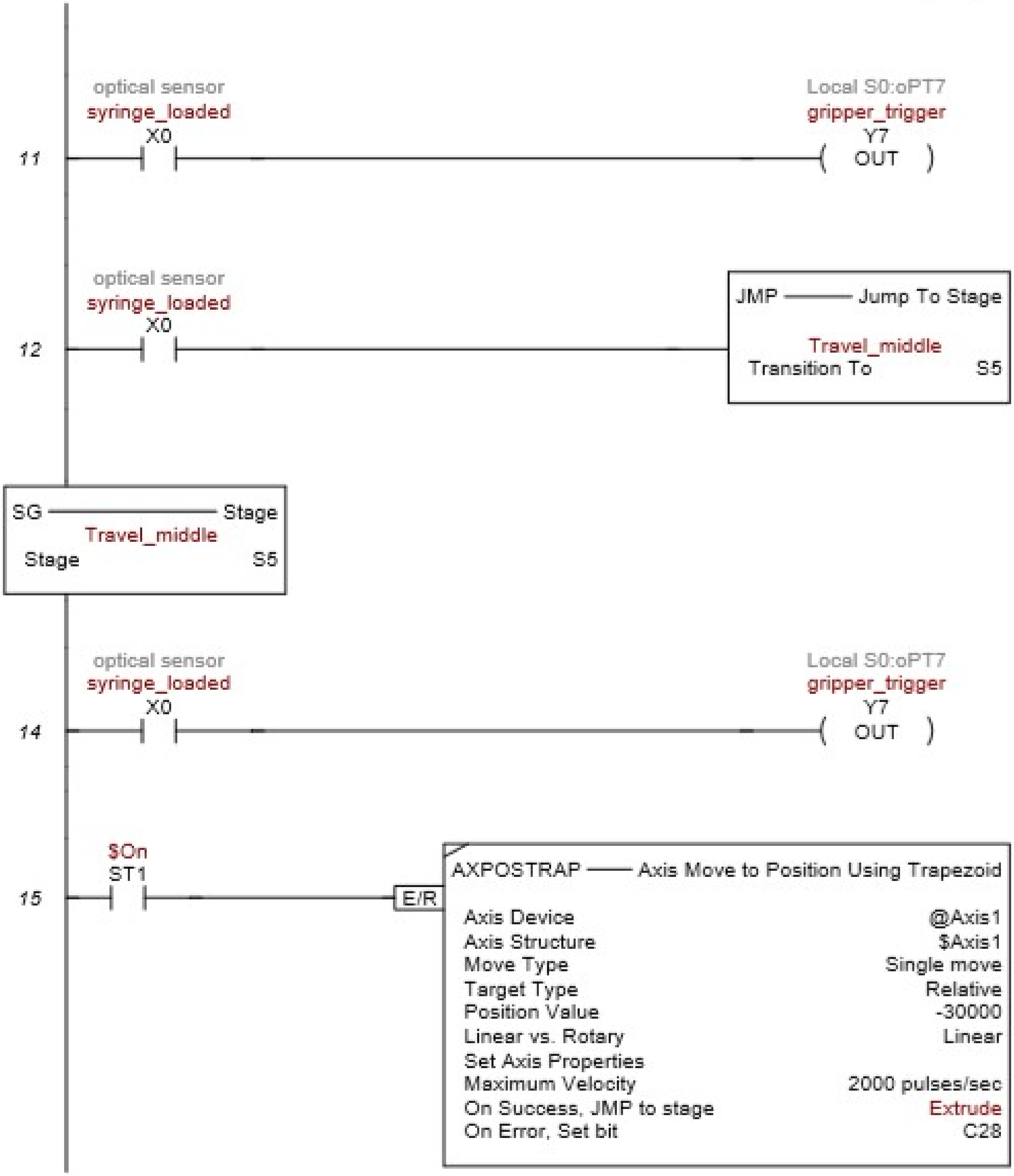
E/R

AXHOME — Axis Perform Home Search

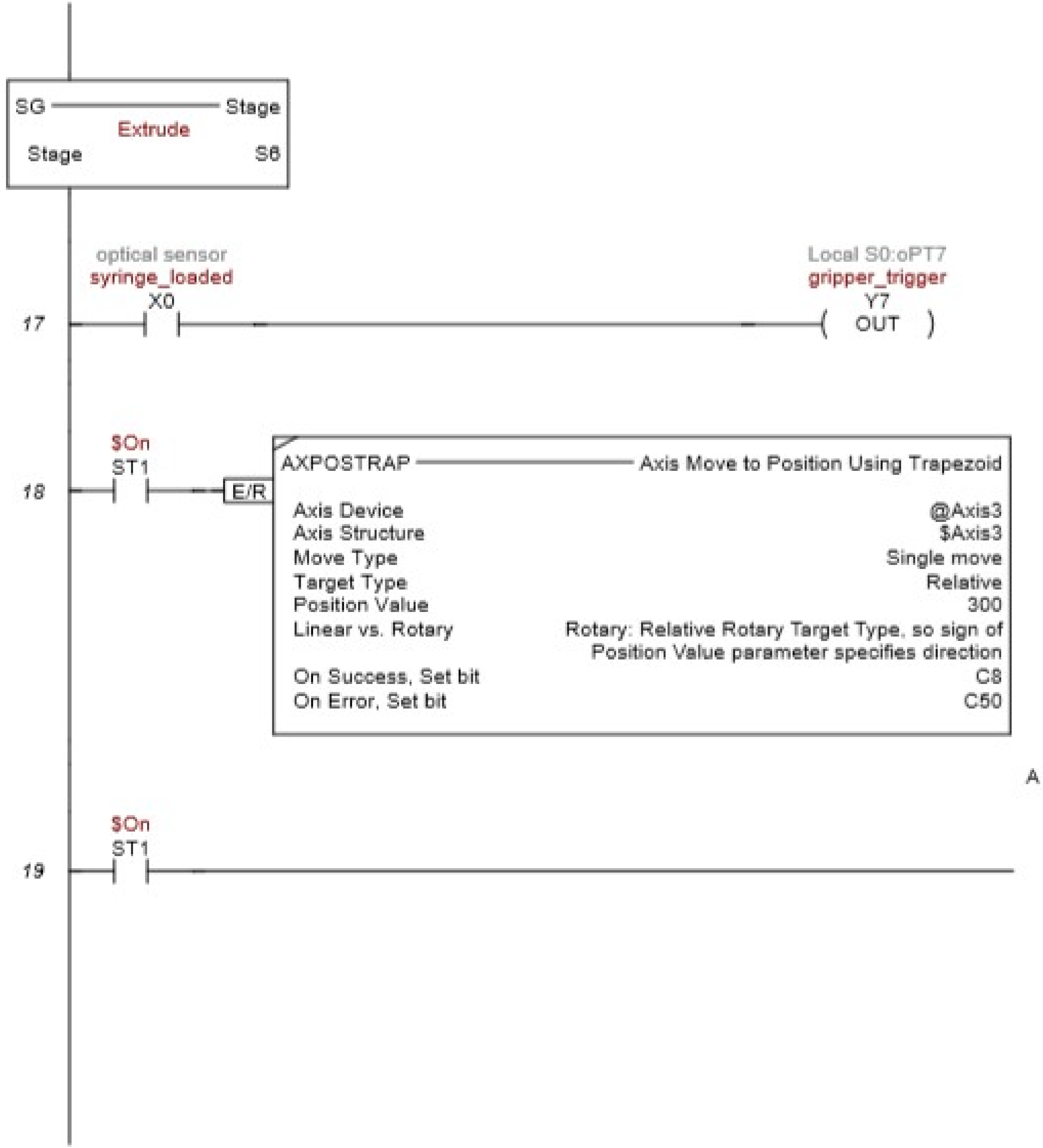
Axis Device	@Axis2
Axis Structure	$Axis2
Homing Velocity (signed)	1000 pulses/sec
Discrete Input Limit 1	syringe_empty (On-Board Input 1)
On Event	Rising Edge
Termination	Position
Offset from Limit 1	0
Zero-out Position At Home / when Done	
On Success, JMP to stage	Home_load
On Error, Set bit	C15

SG — Stage
Home_load
Stage S3


$On
ST1
7
E/R
AXPOSTRAP —— Axis Move to Position Using Trapezoid
Axis Device @Axis2
Axis Structure $Axis2
Move Type Single move
Target Type Absolute
Position Value -30000
Linear vs. Rotary Linear
On Success, Set bit C3
On Error, Set bit C6
C3
8
E/R
AXHOME —— Axis Perform Home Search
Axis Device @Axis1
Axis Structure $Axis1
Homing Velocity (signed) 2000 pulses/sec
Discrete Input Limit 1 extruder_limit_R (On-Board Input 3)
On Event Rising Edge
Termination Position
Offset from Limit 1 0
On Success, JMP to stage Load_syringe
On Error, Set bit C18
SG —— Stage
Load_syringe
Stage S4
$On
ST1
10
E/R
AXPOSTRAP —— Axis Move to Position Using Trapezoid
Axis Device @Axis3
Axis Structure $Axis3
Move Type Single move
Target Type Relative
Position Value -1500
Linear vs. Rotary Rotary: Relative Rotary Target Type, so sign of Position Value parameter specifies direction
On Success, Set bit C1
On Error, Set bit C22



11
optical sensor
syringe_loaded
X0
Local S0:oPT7
gripper_trigger
Y7
OUT
12
optical sensor
syringe_loaded
X0
JMP —— Jump To Stage
Travel_middle
Transition To S5
SG —— Stage
Travel_middle
Stage S5
14
optical sensor
syringe_loaded
X0
Local S0:oPT7
gripper_trigger
Y7
OUT
15
$On
ST1
E/R
AXPOSTRAP —— Axis Move to Position Using Trapezoid
Axis Device @Axis1
Axis Structure $Axis1
Move Type Single move
Target Type Relative
Position Value -30000
Linear vs. Rotary Linear
Set Axis Properties
Maximum Velocity 2000 pulses/sec
On Success, JMP to stage Extrude
On Error, Set bit C28


SG Stage
Extrude
Stage S6
optical sensor
syringe_loaded
X0
17
Local S0:oPT7
gripper_trigger
Y7
OUT
$On
ST1
18
E/R
AXPOSTRAP Axis Move to Position Using Trapezoid
Axis Device @Axis3
Axis Structure $Axis3
Move Type Single move
Target Type Relative
Position Value 300
Linear vs. Rotary Rotary: Relative Rotary Target Type, so sign of Position Value parameter specifies direction
On Success, Set bit C8
On Error, Set bit C50
A
$On
ST1
19

A

E/R

AXHOME — Axis Perform Home Search

Axis Device	@Axis2
Axis Structure	$Axis2
Homing Velocity (signed)	1000 pulses/sec
Discrete Input Limit 1	syringe_empty (On-Board Input 1)
On Event	Rising Edge
Termination	Position
Offset from Limit 1	0
Zero-out Position At Home / when Done	
On Success, JMP to stage	Travel_empty
On Error, Set bit	C15

SG — Stage

Travel_empty

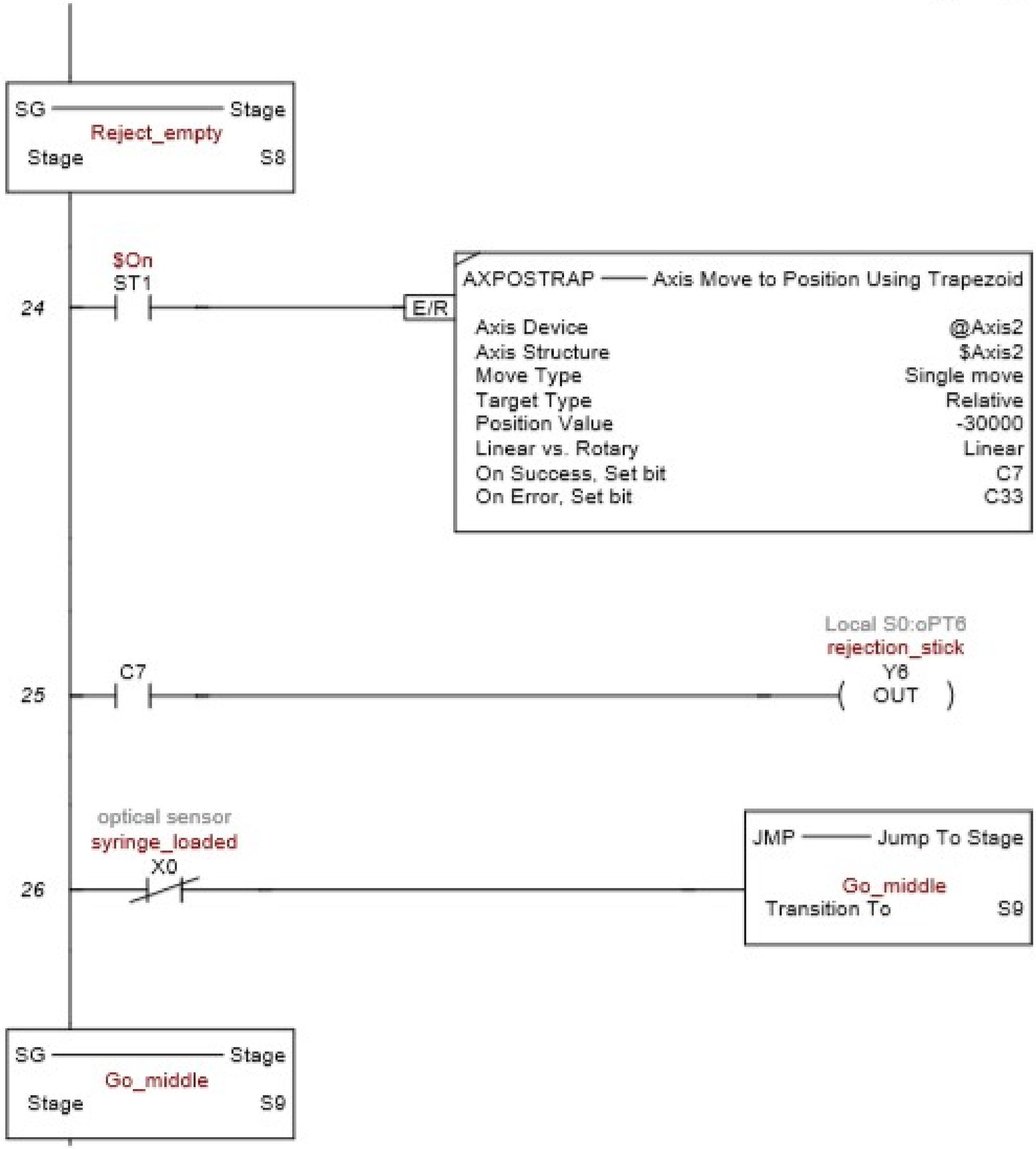
Stage S7

21 optical sensor syringe_loaded X0 — Local S0:oPT7 gripper_trigger Y7 (OUT)

22 $On ST1 — E/R

AXHOME — Axis Perform Home Search

Axis Device	@Axis1
Axis Structure	$Axis1
Homing Velocity (signed)	-2000 pulses/sec
Discrete Input Limit 1	extruder_limit_l (On-Board Input 4)
On Event	Rising Edge
Termination	Position
Offset from Limit 1	0
On Success, JMP to stage	Reject_empty
On Error, Set bit	C18


SG Stage
Reject_empty
Stage S8
24
$On
ST1
E/R
AXPOSTRAP Axis Move to Position Using Trapezoid
Axis Device @Axis2
Axis Structure $Axis2
Move Type Single move
Target Type Relative
Position Value -30000
Linear vs. Rotary Linear
On Success, Set bit C7
On Error, Set bit C33
25
C7
Local S0:oPT6
rejection_stick
Y6
OUT
26
optical sensor
syringe_loaded
X0
JMP Jump To Stage
Go_middle
Transition To S9
SG Stage
Go_middle
Stage S9

28 $On ST1 —| |— [E/R]

AXPOSTRAP — Axis Move to Position Using Trapezoid

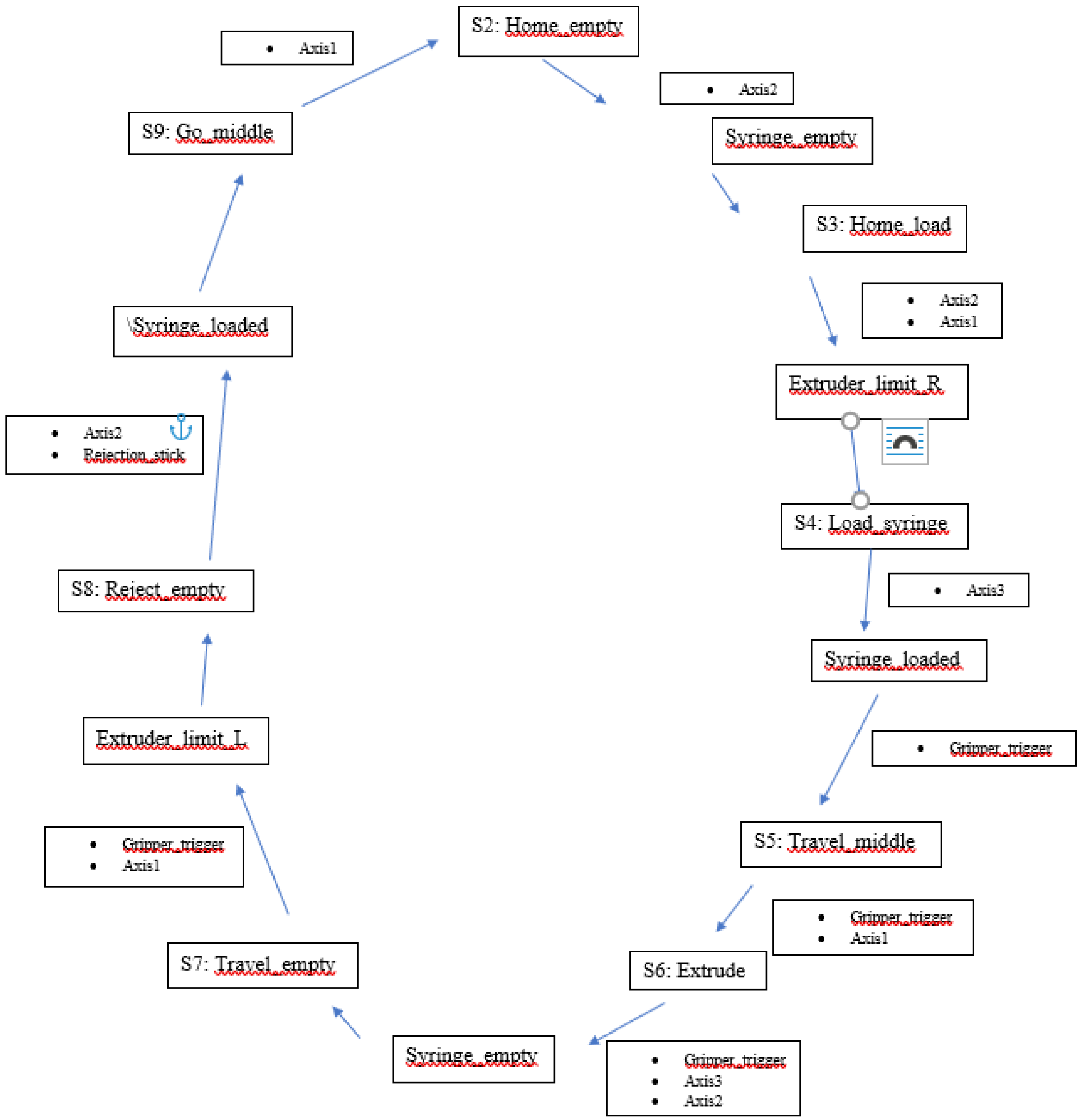
Axis Device	@Axis1
Axis Structure	$Axis1
Move Type	Single move
Target Type	Relative
Position Value	30000
Linear vs. Rotary	Linear
Set Axis Properties	
Maximum Velocity	2000 pulses/sec
On Success, JMP to stage	Home_empty
On Error, Set bit	C5

29 (END)

30 (NOP)

31 (NOP)

State Machine Diagram



Descriptions

This mechanism is to be used to load Syringes into a 3-D printer that prints scaffolds for biomaterials to grow on. The design consists of three major parts, the loading, extruding and the unloading portions. The main components include a gravity fed track, a turn style, three stepper motors, a plate to extrude the material from the syringe, a carriage with pneumatic grippers, a box, and a whacker arm that is powered by pneumatics.

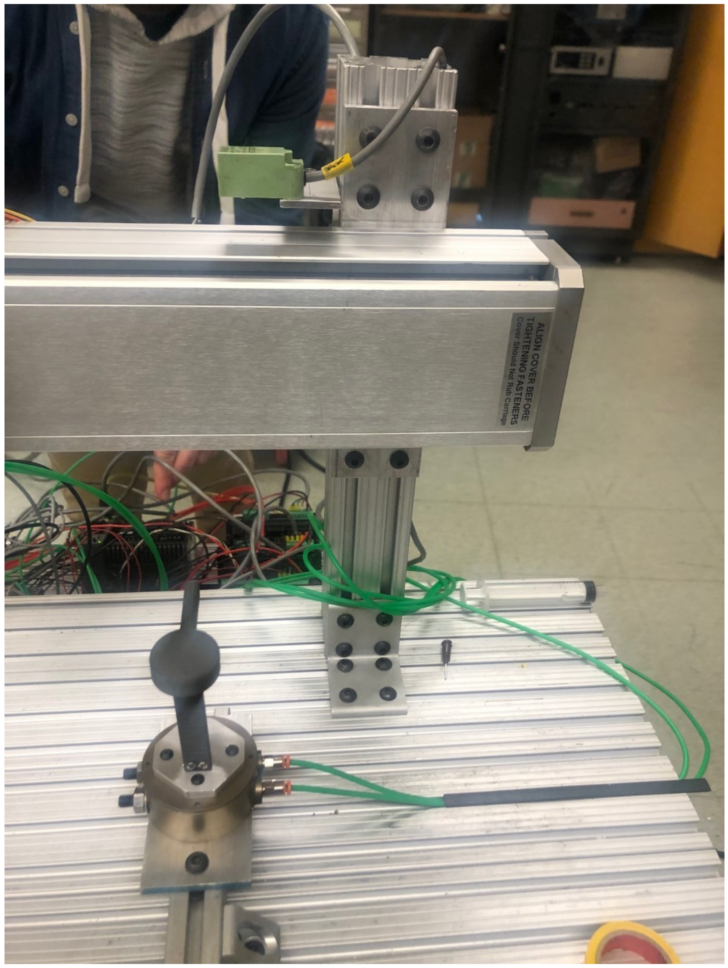
Operation of each major section

The loading portion of the mechanism consists of the gravity fed track as well as one stepper motor and a turnstile as shown in figure four. The syringes are loaded into the gravity fed track and travel down the track to the turnstile where they are pushed into the grippers one at a time as the machine goes through the logic ladder.

The printing portion of the mechanism consists of the grippers, which are powered by a pneumatic and controlled by an optical sensor which identifies when a syringe is loaded into the grippers (see figure four). When the sensor is tripped, the grippers close and the carriage moves down its track. The carriage is powered by another stepper motor. When the carriage reaches a certain point on the carriage path, it begins to extrude the contents of the syringe by running another stepper motor which causes a plate to apply pressure to the plunger of the syringe. When the syringe is empty, an inductive sensor attached above the grippers on the carriage is tripped and the plate begins to rise as the stepper motor rotates.

The ejection portion of the mechanism consists of a whacker arm that is powered by a 180-degree pneumatic and is in use when the extruding plate is at the top of its range of motion. This is visually depicted in figure five. The grippers open and then the pneumatic turns on and causes the whacker arm to rotate and knock the syringe out of the grippers. A box has been placed on the work surface to collect the discarded syringes.

Figure 7: Pneumatic rejection assembly



Maintenance Instructions

This mechanism relies heavily on alignment because it is gravity fed. It is important that the gravity fed tracks are aligned with the grippers for proper loading of the syringes. The inductance sensors require full contact with the metal pieces attached to the top of the carriage so the location and orientation of those needs to be monitored and adjusted as needed. The wiring and pneumatics must be connected correctly for the mechanism to operate as it is intended so those should not be moved or changed from their original connections. The part that connects the carriage and the extrusion stepper motor is a printed part that needs to be monitored and checked for damage periodically because it may not be able to withstand repeated use for long periods of time.

Suggestions for future improvements

Future modifications could be made to this mechanism to improve its performance. The inductance sensors on the carriage should be attached with something better than electrical tape. The turn style does not consistently rotate as it is intended to after loading the syringe into the carriage. The stepper motor responsible for extruding the fluid from the syringe is attached to the carriage with screws that are too long and so it does not do a very consistent job of extruding the fluid, it needs to be able to apply more pressure to the plate so that the syringe plunger can be pushed with greater force. We were unable to get a steady extrusion from the syringe with the needle attached. Some design modifications would likely be able to solve that problem.

Performance data

The loading portion of the mechanism has about an 80% success rate and the ejecting portion has about a 95% success rate. The extrusion portion will require some more design modifications before it can really be considered as an option for use with the bio-printer because it does not perform well.