

HND Electrical and Electronic Engineering

PLC's and Control

PLC Assignment 1

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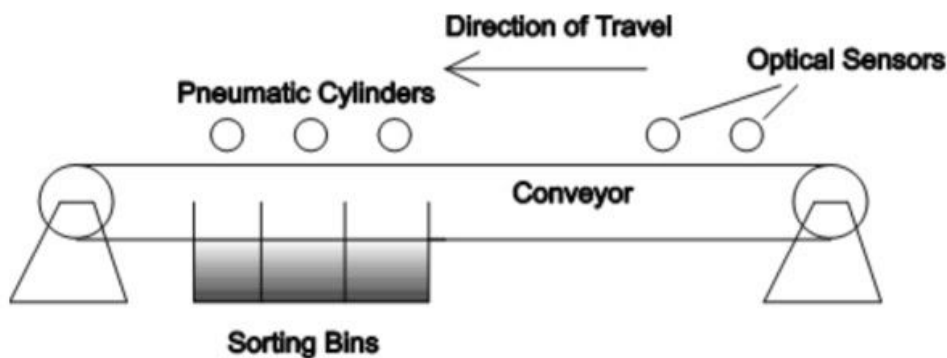
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Task 1 - Sorting Conveyor

Introduction

The report in this task will aim to outline a detailed specification for the operation of an electronic sorting system. The main function of this system will be to eject metal disks that are travelling along a conveyor belt into their correct bins according to their size. The report will also cover the design process and a record of the necessary coding used, along with proof of the system operating in line with its initial requirements. The electronic sorting system is an industrial unit that would be suited to most batch-processing working environments.



Specification

In order for the system to start, the operator must press and hold the green switch for three seconds, during which a green lamp will flash. This initiates the conveyor to run. When the conveyor is running, the green lamp will be on.

The operator can stop the system at any point by pressing the red button. When the conveyor has stopped, the red light will be on.

Items will be placed on the conveyor at the right-hand side in 5 second intervals and will progress along the conveyor past two pairs of optical sensors towards the sorting bins. When reaching the correct bin, a cylinder will operate and eject the item into the required bin.

If the system has not sensed any items for 30 seconds, the conveyor will stop.

System requirements

The system must use a SIMATIC S7-1200 PLC, CPU 1214C DC/DC/DC, 6ES7 214-1AG31-0XB0

The system will start when the user holds the green switch for 3 seconds during which the green lamp will flash.

The system will stop when the user presses the red switch, at any point during the sequence.

The system will automatically stop after 30 seconds of no item detected.

The system's size criteria is; large disk radius (34-36)mm, medium disk radius (24-26)mm, small disk radius (14-16)mm. Reject otherwise.

The system must be able to sort disks that fit the size criteria into 3 sorting bins, at a rate of 1 disk per 5 second.

Design

Inputs

R1 (cylinder 1)

R2 (cylinder 2)

R3 (cylinder 3)

Optical sensor 1

Optical sensor 2

Green switch

Red switch

Outputs

Green light

Red light

Enable conveyor

Cylinder 1

Cylinder 2

Cylinder 3

Code

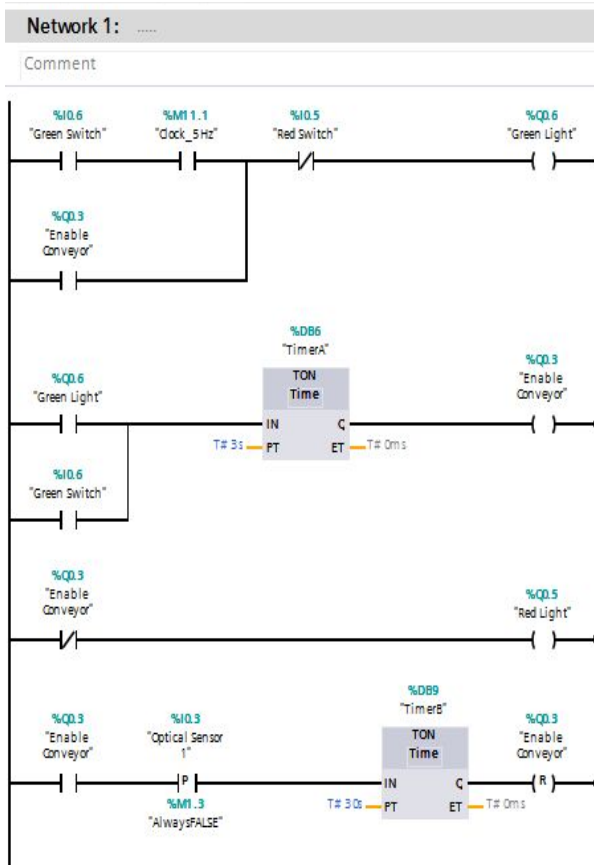
Siemens TIA portal was used to program the PLC, this software uses ladder logic which is a graphical diagram logic (Siemens USA, 2020). Ladder logic enables code to be split into separate networks.

Tag Table

Default tag table							
	Name	Data type	Address	Retain	Acces...	Writa...	Visibl...
1	 R1 (Cylinder1)	Bool	%I0.0	☐	☒	☒	☒
2	 R2 (Cylinder2)	Bool	%I0.1	☐	☒	☒	☒
3	 R3 (Cylinder3)	Bool	%I0.2	☐	☒	☒	☒
4	 Optical Sensor 1	Bool	%I0.3	☐	☒	☒	☒
5	 Optical Sensor 2	Bool	%I0.4	☐	☒	☒	☒
6	 Red Switch	Bool	%I0.5	☐	☒	☒	☒
7	 Green Switch	Bool	%I0.6	☐	☒	☒	☒
8	 Cylinder1	Bool	%Q0.0	☐	☒	☒	☒
9	 Cylinder2	Bool	%Q0.1	☐	☒	☒	☒
10	 Cylinder3	Bool	%Q0.2	☐	☒	☒	☒
11	 Enable Conveyor	Bool	%Q0.3	☐	☒	☒	☒
12	 Red Light	Bool	%Q0.5	☐	☒	☒	☒
13	 Green Light	Bool	%Q0.6	☐	☒	☒	☒
14	 AlwaysTRUE	Bool	%M1.2	☐	☒	☒	☒
15	 AlwaysFALSE	Bool	%M1.3	☐	☒	☒	☒
16	 Clock_Byte	Byte	%MB11	☐	☒	☒	☒
17	 Clock_5Hz	Bool	%M11.1	☐	☒	☒	☒

The tag table for the ladder logic was constructed first. The first 13 tags are the inputs and outputs as listed in the design. All of the inputs and outputs are of the data type Boolean, this is because when using these tags within the code they will either have the state of true or false. Tags 14, 15, 16 and 17 are extra tags that were added during the coding process. Tags 16 and 17, Clock_byte and Clock_5Hz, have been enabled thus solving the problem of making the green lamp flash during the starting sequence.

Network 1



Network 1 is made up of rungs which control the start and stop functions of the system.

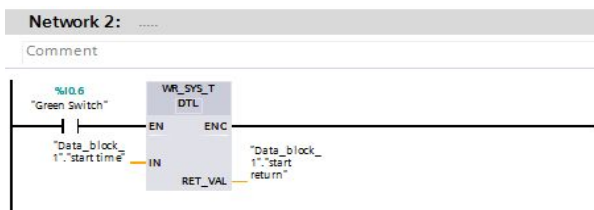
The first rung in this network causes the green light to turn on. This rung is the method used to satisfy the specification point of having the green lamp flash upon the starting sequence. This was achieved by using a 5 Hz system clock as the condition for the switch that is in conjunction with the green switch. When the green switch is pressed it causes the signal to pass through to the 5Hz clock resulting in the signal 'pulsing' to the lamp making it flash. The lamp will flash until the green switch is not pressed or till the conveyor is running, at which point the green light stays on.

The second rung fulfills the specification requirement of a 3 second start up period. This rung uses a 'TON' timer that delays the signal reaching the output for 3 seconds. This 'TON' ensures that the source signal is present for the entire 3 seconds as it does not accumulate the signal so restarts if no signal is present, thus once the 3 seconds has passed the source signal is connected through the green light rather than the green switch.

Rung 4 uses a normally closed switch with the tag enable conveyor, this means that if the conveyor is not running then the switch is closed and turns the red lamp on.

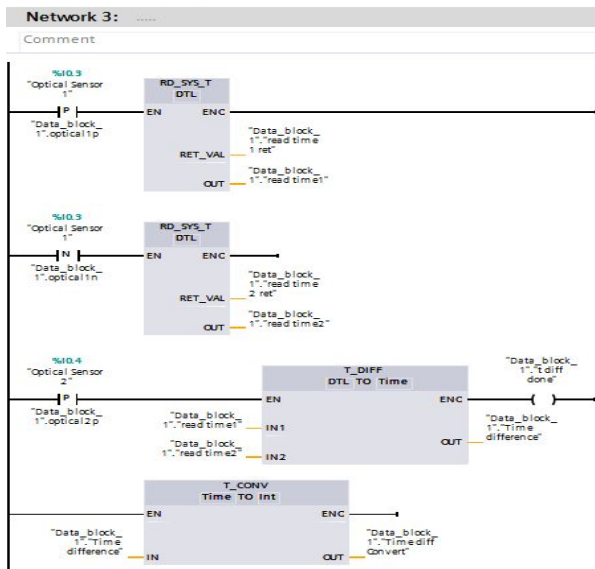
Rung 5 achieves the specification requirement of having the conveyor automatically stop after 30 seconds of inactivity. This rung achieves this by again using a 'TON' timer that has a set time of 30 seconds which is connected to two switches. If both switches are in their closed position for 30 seconds the signal will reach the output which is to reset the enable conveyor. This will cause the enable conveyor switch in rung one to reset to its open position causing a knock-on effect of stopping the entire system.

Network 2



Network 2 uses a 'WR_SYS_T' to store the start time of the system, this is what all other times recorded will be in reference to.

Network 3



Network 3 is used to measure how long each item takes to pass both sensors.

The first rung uses a 'RD_SYS_T' to read the time when the item passes optical sensor 1, making it go positive.

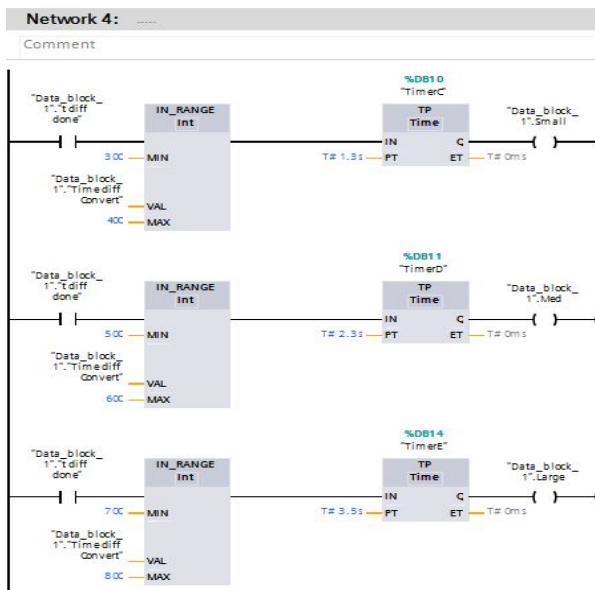
Rung two does the same as rung one but records the time when optical sensor 1 goes negative.

Rung three is triggered when optical sensor 2 goes positive.

It uses a 'T_DIFF' block which calculates the difference between both of the previously recorded times. Then an output of 'tdiffdone' is on.

The fourth rung uses a 'T_CONV' block to convert a time value into an integer. It converts the time difference value into an integer so it can be checked within a range.

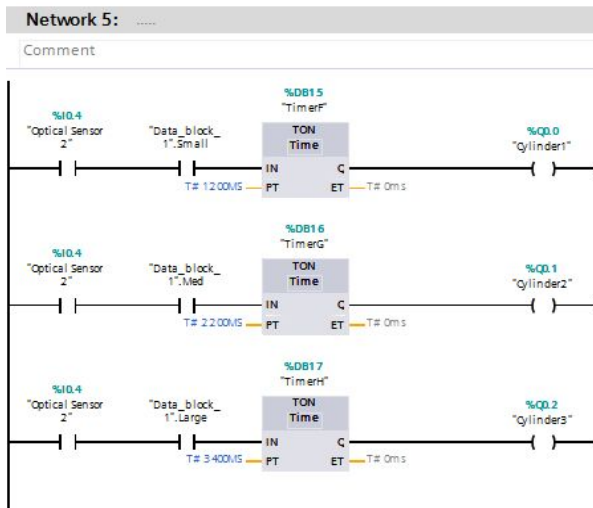
Network 4



Network 4 determines whether the item is small, medium, or large.

Each rung is triggered by the 'Timediffdone' switch and uses an 'IN_RANGE' block to see what range each item fits in. The block takes the time difference value that was converted into an integer and checks to see if it fits in one of the 3 ranges. If it fits in one of the ranges a corresponding pulse signal is generated from a 'TP' block, this pulse then activates the item size output for the given pulse time.

Network 5



Network 5 controls the operation of the cylinders through two switches and a 'TON' timer. The first switch is triggered from optical sensor 2 meaning that the timings for all sizes are linked to the location of optical sensor 2. Therefore, the timings are staggered with the sizes of the items. The second switch is triggered by network 4s output of the range checked size. When both switches are triggered together the 'TON' timer is activated causing a delay until the signal reaches the cylinder output, this delay has been celebrated to extend as the item reaches the correct cylinder.

Data Block

Data_block_1								
	Name	Data type	Start value	Retain	Accessi...	Writable fr..	Visible in ...	Setpoint
1	Static			☐	☐	☐	☐	☐
2	Conveyor delay	Time	T#3S	☐	☒	☒	☒	☐
3	start time	DTL	DTL# 2020-11-03-13:00:00	☐	☒	☒	☒	☐
4	start return	Int	0	☐	☒	☒	☒	☐
5	optical1p	Bool	false	☐	☒	☒	☒	☐
6	optical1n	Bool	false	☐	☒	☒	☒	☐
7	optical2p	Bool	false	☐	☒	☒	☒	☐
8	optical2n	Bool	false	☐	☒	☒	☒	☐
9	read time 1	DTL	DTL# 2020-11-03-13:00:00	☐	☒	☒	☒	☐
10	read time 1 ret	Int	0	☐	☒	☒	☒	☐
11	read time 2	DTL	DTL# 2020-11-03-13:00:00	☐	☒	☒	☒	☐
12	read time 2 ret	Int	0	☐	☒	☒	☒	☐
13	Time difference	Time	T#0ms	☐	☒	☒	☒	☐
14	t diff done	Bool	false	☐	☒	☒	☒	☐
15	Time diff Convert	Int	0	☐	☒	☒	☒	☐
16	Small	Bool	false	☐	☒	☒	☒	☐
17	Med	Bool	false	☐	☒	☒	☒	☐
18	Large	Bool	false	☐	☒	☒	☒	☐

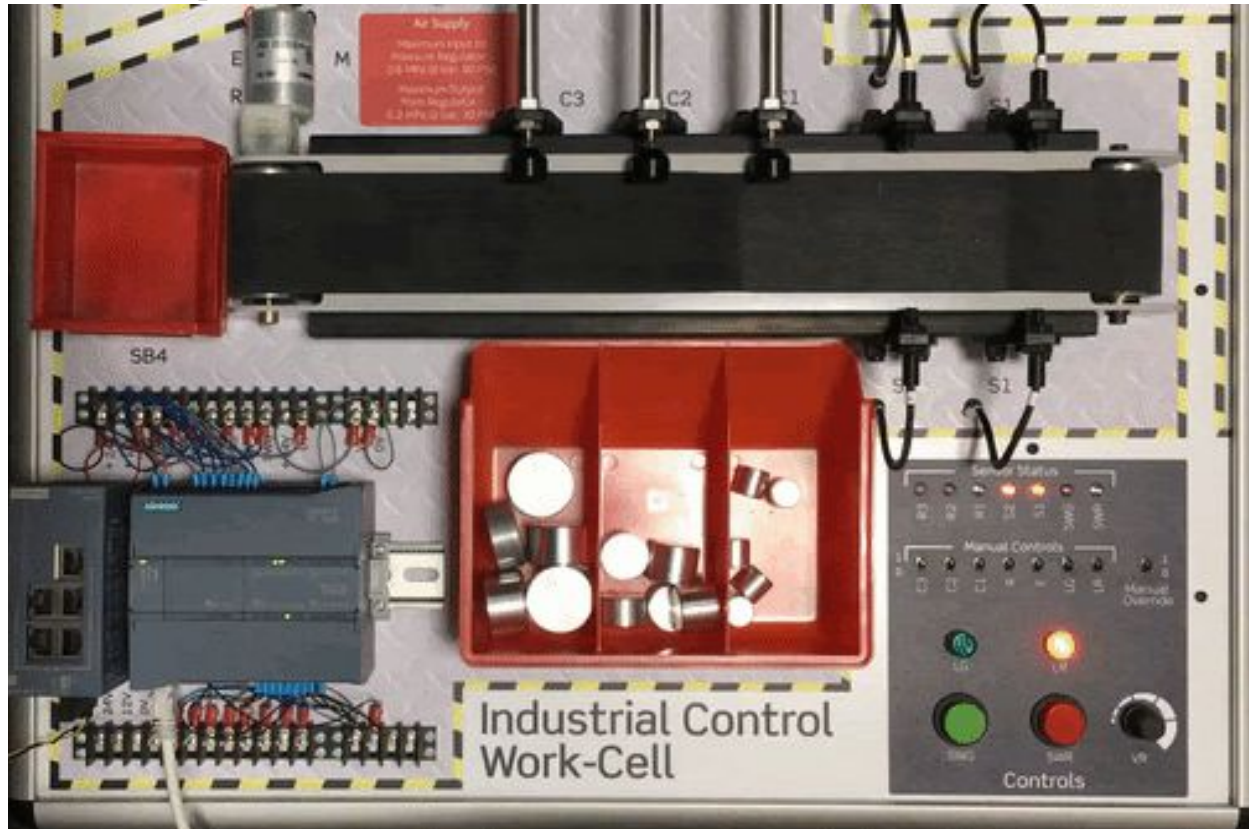
This image shows the storage location of data from the program in the form of a data block. An example of when the data block is implemented is during the calculation of the time difference. In order to calculate this, data that had been saved within the data block was accessed to perform the calculation. The data block is important to the program as there are multiple calculations happening simultaneously. Use of the data block allowed stored values to be variables that could be measured continuously throughout the cycle of the program, rather than fixed quantities.

Testing the system

Test	Expected result	No of tests	Actual result
System on but not running.	Red light on	3	Red light on
Green switch held for 0-3 seconds.	Green light flashes	3	Green light flashes
Green switch held for 3+ seconds.	Green light on. Conveyor runs.	3	Green light on, conveyor runs.
Red switch pressed.	Conveyor stop. Red light on.	3	Conveyor stop. Red light on.
Large disk.	Cylinder 3 moves disk into bin 3.	3	Cylinder 3 moves disk into bin 3.
Medium disk.	Cylinder 2 moves disk into bin 2.	3	Cylinder 2 moves disk into bin 2.
Small disk.	Cylinder 1 moves disk into bin 1.	3	Cylinder 1 moves disk into bin 1.
Foreign item	Goes into the rejection bin.	3	Goes into the rejection bin.
Small Medium Large	All disks into the correct bin.	2	All disks into the correct bin.
Small Large Medium	All disks into the correct bin.	2	All disks into the correct bin.
Medium Small Large	All disks into the correct bin.	2	All disks into the correct bin.
Medium LargeSmall	All disks into the correct bin.	2	All disks into the correct bin.
Large Small Medium	All disks into the correct bin.	2	All disks into the correct bin.
Large Medium Small	All disks into the correct bin.	2	All disks into the correct bin.
Minimum load interval.	No longer than 5 seconds	5	4 seconds
Mid sequence stop	Conveyor stop. Red light on.	3	Conveyor stop. Red light on. Cylinder still extended.

System operating

Start and Stop



This clip shows the start sequence which consists of the green switch being pressed for 3 seconds by the user and the green light flashing simultaneously. Once the 3 seconds has passed, the conveyor starts and the green light stays on. The user then demonstrates that pushing the red switch immediately stops the conveyor causing the red light to turn on and the green light to turn off.

Start-reject



This clip shows what happens when the user loads the conveyor. The user loads the first 3 items with a time gap of under 5 seconds. The system correctly recognises these items and responds with the correct output, this means the system meets specification of being able to sort at a rate of at least 1 disk per 5 seconds, it also sorts them into their correct bins thus meeting the size criteria. The fourth item is recognised by the system and does not fit any of the size criteria, therefore it is rejected.

Emergency stop



This clip shows the system response when the red switch is pressed mid sequence. The system is initiated with the start sequence and is loaded with an item. The user presses the red switch when the item is mid-way down the conveyor. This causes the conveyor to correctly stop. However, moments after the conveyor stops, cylinder C3 partially extends. Even though the stop sequence has met the specifications criteria of stopping the conveyor, C3 or any of the cylinders extending during a potential emergency stop could pose a serious hazard.

30s stop



This clip shows the user restart the system after it was stopped. From when the user presses the green switch a timer starts to count down from 30 seconds as part of the starting sequence. As nothing is present for the system to detect the timer runs out, resulting in the system automatically stopping. This aspect of the system achieves two things, firstly it is a great way to conserve energy, keeping running costs low and helping the environment. Secondly this is a way to help mitigate and prevent potential working area hazards.

Rapid fire

This clip shows what happens when the systems limits are pushed. As you can see 8 disks were loaded onto the conveyor in quick succession, the 1st, 3rd and 4th disks were rejected by the system. This was an interesting result as 5 of the disks were correctly sorted and only 3 were incorrectly rejected. This is a limitation of the program's design, but the required criteria for the load time interval has been exceeded in this example. The reason for the 3 rejections is believed to be a data storage issue. When disks trigger the optical sensors, a time is read and stored in the data block. If the time interval of the same sized object is too small, then the previous trigger time gets re-written. This causes the initial disk to be forgotten about and as a result wrongly rejected.

Compare final system to initial requirements

Overall, the final system achieves everything that the initial requirements requested. The system is compatible with the *SIMATIC S7-1200 PLC*, it follows the specified start and stopping sequences. It correctly detects disks of the required size criteria and it exceeds the required sorting rate of 5 seconds by approximately a whole second. Therefore, this system is fit for purpose.

Reflecting on the functionality of the system there are improvements that would be valid and necessary. A necessary improvement would be to stop any cylinder movement if the red stop switch is pressed. This is extremely important as any contact with a moving cylinder could cause serious injury or system malfunction. A possible way to achieve this would be to ensure that engagement of the red switch opens the connections to any rung with a cylinder as the output. An improvement that could be a valid option would be to include a counter for each bin, displaying how many of each item has been sorted. One way to achieve this would be to have an additional optical sensor at each collection bin that would detect each item as it travels into the bin. Another way to achieve this would be to count the number of times each cylinder is signaled to extend, giving a number of each item sorted.

Specification

Key operating requirements.

System must operate safely.

User has the ability to stop the process at any stage.

System must be fully automated.

Key measurements from leading edge

Length of bracket	230mm
Drill POS 1	10mm
Drill POS 2	30mm
Drill POS 3	50mm
Drill line 1	15mm
Drill line 2	50mm
Drill line 3	165mm
Drill line 4	195mm
Bend point	120mm

Design

Operating sequence

For the system to start the user must initiate the system with an input. Pressing and holding the start button for 3 seconds causes a green light to flash. After the 3 seconds, the green light is on and conveyor 1 starts, driving the source of the steel bar past Measuring device 1 and towards the Cut Off Saw.

Once Measuring device 1 measures 230mm a signal (*Measure1*) is sent that stops conveyor 1, clamps the source material with Clamping device 1 and starts the Cut Off Saw.

When Conveyor 1 has stopped, Clamping device 1 has clamped the steel bar before the Cut Off Saw and the Cut Off Saw has started. This produces a signal (*LowerSaw*) which starts to lower the saw through the 5mm steel bar along the Y axis towards the maximum cut point.

Once the saw's blade has reached the max cut point a signal (*LiftSaw*) is produced causing the saw to stop and lift out of the way. Leaving the first stage of the steel bracket a 230mm steel bar.

Once the saw has been lifted a signal (*Conveyor2*) is sent to start conveyor 2, moving the 230mm bar past Measuring device 2 and towards the Drill.

When Measuring device 2 measures 15mm a signal (*Measure2.1*) is sent that stops Conveyor 2 and clamps the material past the Drill with Clamping device 2.

When both Conveyor 2 has stopped and Clamping device 2 has clamped the steel which has passed the Drill, a signal (*DrillSequenceStart*) will trigger the Drill to start its drilling sequence. The signal will trigger the Drill to start and move to POS 1, 10mm in from the side along the Z axis.

Once in POS 1 and running, the signal (*LowerDrill*) will cause the drill to be lowered through the 5mm steel along the Y axis and towards a maximum drill point. Once the drillbit has reached the maximum drill point the signal (*LiftDrill*) will cause the drill to lift back to its starting height.

When the drill is back at its starting height a signal (*MovePOS2*) will cause the Drill to move to POS 2, a further 20mm along the Z axis.

With the drill now in the middle of the width of the bar, 30mm from the leading edge, the signal (*LowerDrill*) will cause the drill to be lowered through the 5mm steel along the Y axis and towards a maximum drill point. Once the drillbit has reached the maximum drill point the signal (*LiftDrill*) will cause the drill to lift back to its starting height.

When the drill is back at its starting height a signal (*MovePOS3*) will cause the Drill to move to POS 3, a further 20mm along the Z axis.

With the drill now 10mm from the other side the signal (*LowerDrill*) will cause the drill to be lowered through the 5mm steel along the Y axis and towards a maximum drill point. Once the

drillbit has reached the maximum drill point the signal (*LiftDrill*) will cause the drill to lift back to its starting height.

When the drill is back at its starting height a signal (*MovePOS1*) will cause the Drill to stop and to move to back to POS 1, producing a signal (*DrillSequenceEnd*).

This signal un-clamps Clamping device 2 and enables Conveyor 2, driving the steel bar past Measuring device 2.

When Measuring device 2 measures 35mm a signal (*Measure2.2*) is sent that stops Conveyor 2 and clamps the material past the Drill with Clamping device 2.

When both Conveyor 2 has stopped and Clamping device 2 has clamped the steel which has passed the Drill, a signal (*DrillSequenceStart*) will trigger the Drill to start its drilling sequence.

When the drilling sequence has finished a signal is produced (*DrillSequenceEnd*).

This signal un-clamps Clamping device 2 and enables Conveyor 2, driving the steel bar past Measuring device 2.

When Measuring device 2 measures 115mm a signal (*Measure2.3*) is sent that stops Conveyor 2 and clamps the material past the Drill with Clamping device 2.

When both Conveyor 2 has stopped and Clamping device 2 has clamped the steel which has passed the Drill, a signal (*DrillSequenceStart*) will trigger the Drill to start its drilling sequence.

When the drilling sequence has finished a signal is produced (*DrillSequenceEnd*).

This signal un-clamps Clamping device 2 and enables Conveyor 2, driving the steel bar past Measuring device 2.

When Measuring device 2 measures 30mm a signal (*Measure2.4*) is sent that stops Conveyor 2 and clamps the material past the Drill with Clamping device 2.

When both Conveyor 2 has stopped and Clamping device 2 has clamped the steel which has passed the Drill, a signal (*FinalDrillSequenceStart*) will trigger the Drill to start its drilling sequence.

When the drilling sequence has finished a signal is produced (*FinalDrillSequenceEnd*).

This signal un-clamps Clamping device 2 and enables Conveyor 3, as that was the last of the drilling sequences. There is now enough material on the Conveyor 3 for it to move the bar.

Conveyor 3 drives the bar past Measuring device 3 and towards the Clamping and Bending Device. When measuring device 3 measures 120mm a signal (*Measure3*) causes Conveyor 3 to stop and Clamping device 3 to clamp the bar just before the bending point, 120mm from the leading edge.

Conveyor 3 stopping and Clamping device 3 clamping produces a signal (*ClampAndBendStart*) causing the Clamping and Bending Device to Clamp the leading edge of the 230mm bar, bend it 90 degrees into a right-angled bracket shape and then un-clamp.

Once the bend has been completed, a signal (*ClampAndBendEnd*) causes Clamping device 3 to unclamp and Robot 1 to transfer the item to the Welding station.

When the welding station has received the item a signal (*Transfer1*) is produced, causing Clamping devices 4a and 4b to clamp the item in position.

When both Clamping devices 4a and 4b have clamped the item a signal (*WeldStart*) initiates the automated welding sequence.

When the welding sequence is complete a signal (*WeldComplete*) will be produced, causing both Clamping devices 4a and 4b to unclamp and Robot 2 to transfer the item to the Pickling station, an acid pickling bath.

Once the item has finished pickling a signal (*Transfer2*) causes Conveyor 4 to start and Robot 2 to transfer the item to Conveyor 4. When the item has been transferred a signal (*Open1*) opens Door 1 to Heater 1. Once the item is inside a signal (*StopClose*) causes Conveyor 4 to stop and Door 1 to close. When the conveyor has stopped and the door has closed, a signal (*PaintingStart*) causes the painting sequence to start. During the painting sequence the system will modulate the temperature inside Heater 1, keeping it at $28^{\circ}\text{C} \pm 2^{\circ}\text{C}$. When the painting sequence is done a signal (*PaintingDone*) will be produced causing Door 2 of Heater 1 to open and Conveyor 4 to drive the item out of Heater 1 and through the Heat treatment area.

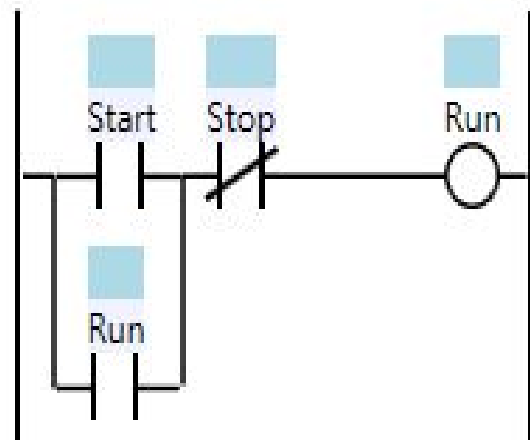
When the item has left Heater 1 a signal (*Door2*) will cause Door 2 of Heater 1 to close, this signal will also activate the Heat treatment area, by modulating its heat at $35^{\circ}\text{C} \pm 2^{\circ}\text{C}$. This is the final step in the sequence. After this the process will repeat.

Systems safety

During the operation of this automated system there are multiple hazardous operations. Ensuring the safety of these operations is extremely important as every output must be performed correctly, otherwise production will fail and an injury could occur. The design tackles this issue of safely performing an operation in two ways, firstly by having each operation separated into smaller segments. Secondly, by having at least 1 condition before a signal is sent, which triggers an output. For example, to cut the source material, the operation is split into 3 parts: starting the saw, lowering the saw and stopping the saw whilst lifting it. Measuring device 1 must have measured 230mm for the saw to start. Conveyor 1 must have stopped, Clamping device 1 must have clamped the material and the saw must be running for the saw to be lowered. The saw must have reached its maximum cut point for the saw to be stopped and lifted.

User control

To achieve the second of the specification's key operating requirements (user has the ability to stop the process at any stage), a latching function should be used, as depicted. Latching should be used where the output must be activated even after the entry ceases. (Latching in PLC – Instrumentation and Control Engineering, 2020) So, for our design this means that once the user has started the system by holding a switch for 3 seconds, they can release the switch and the system will continue to run. As well as triggering the system to perform its automated sequence, the latch also means that if the stop button is pressed it will open the normally closed switch breaking the connection to the output, thus stopping the system mid sequence.



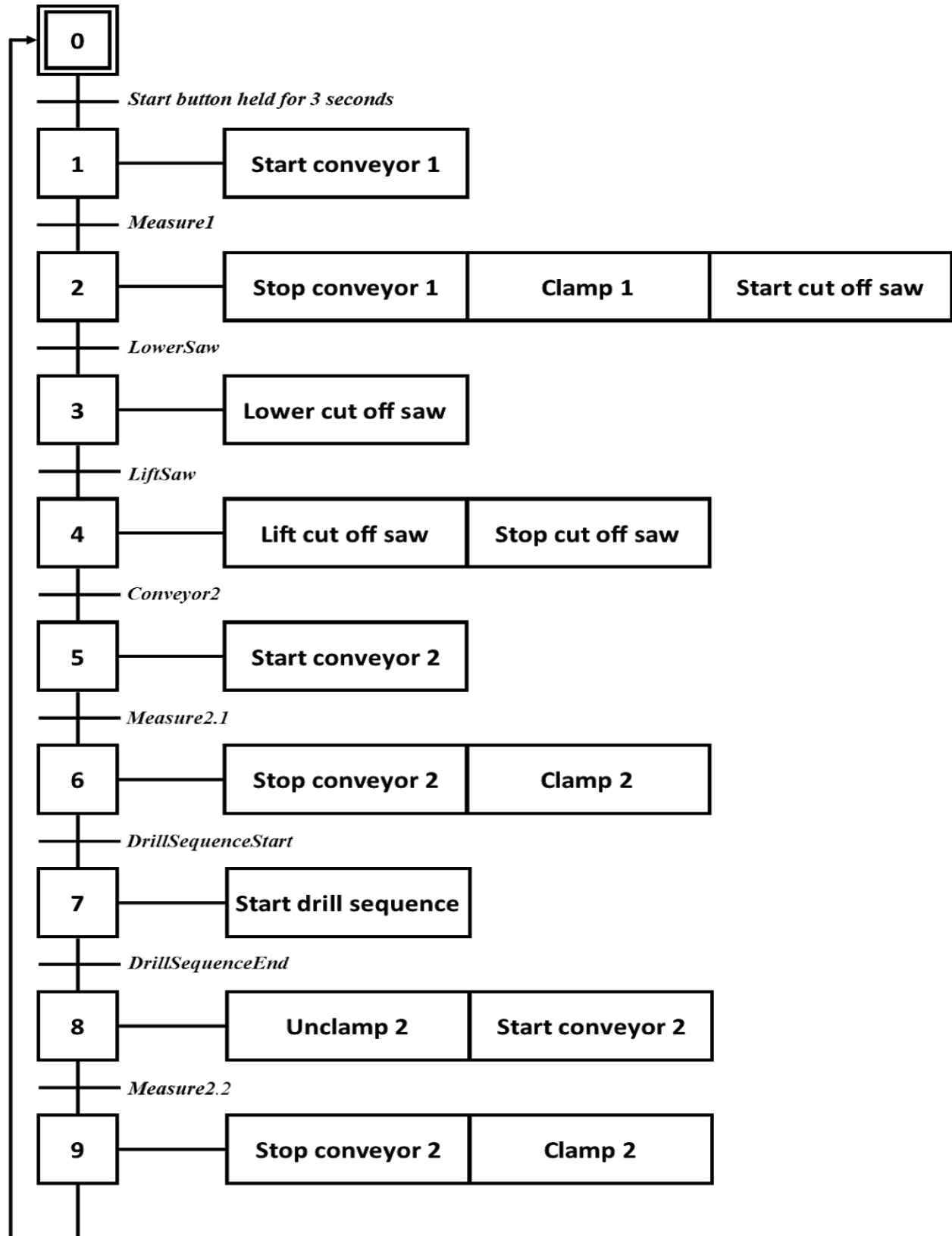
Fully automated system

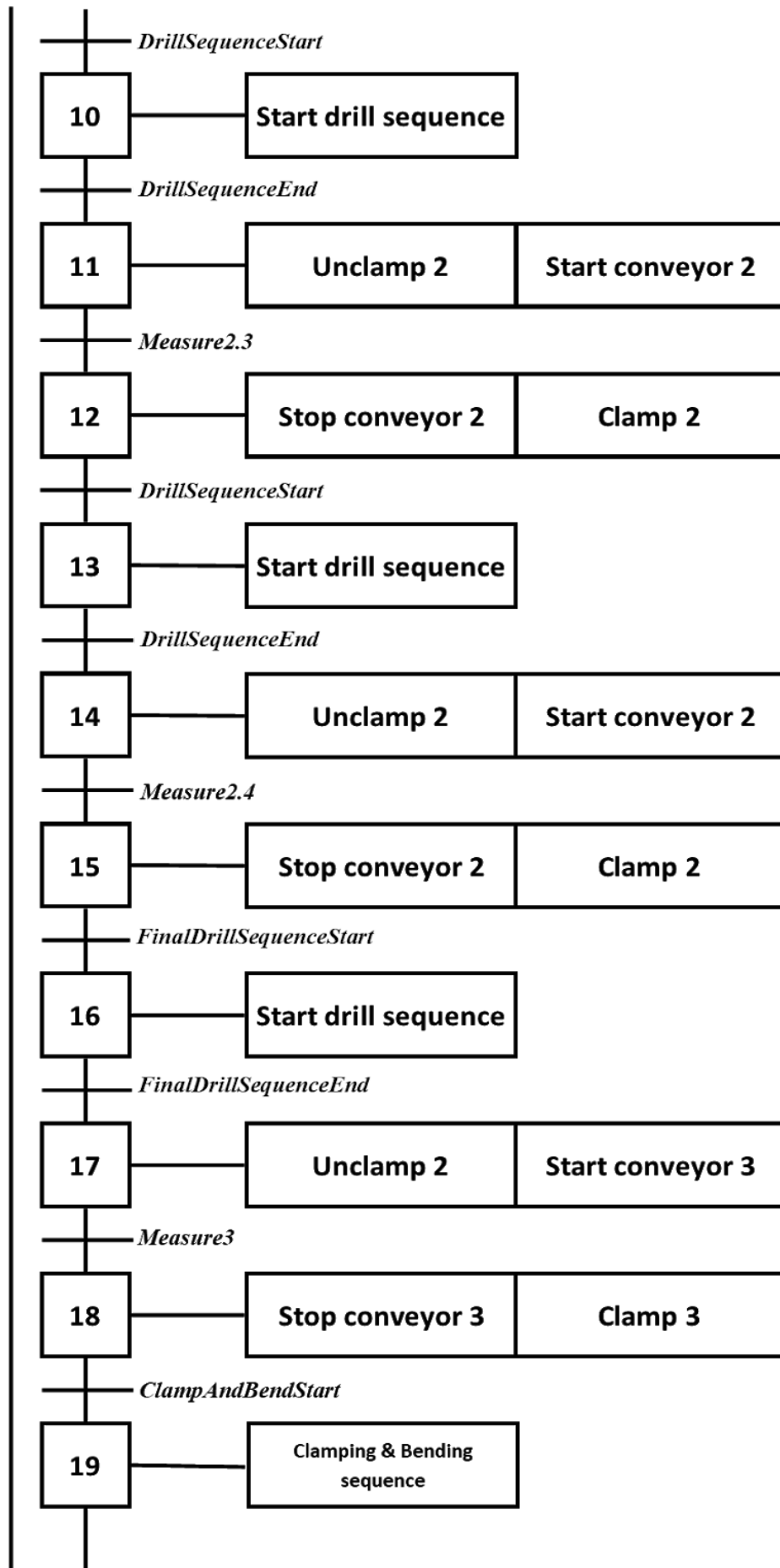
The automation of the system is dependent on using the systems activity as conditions for every output. Use of these conditions enable the system to self-synchronize, as an output can only occur when the required conditions have been met. Below is a list of every output along with their signal and conditions.

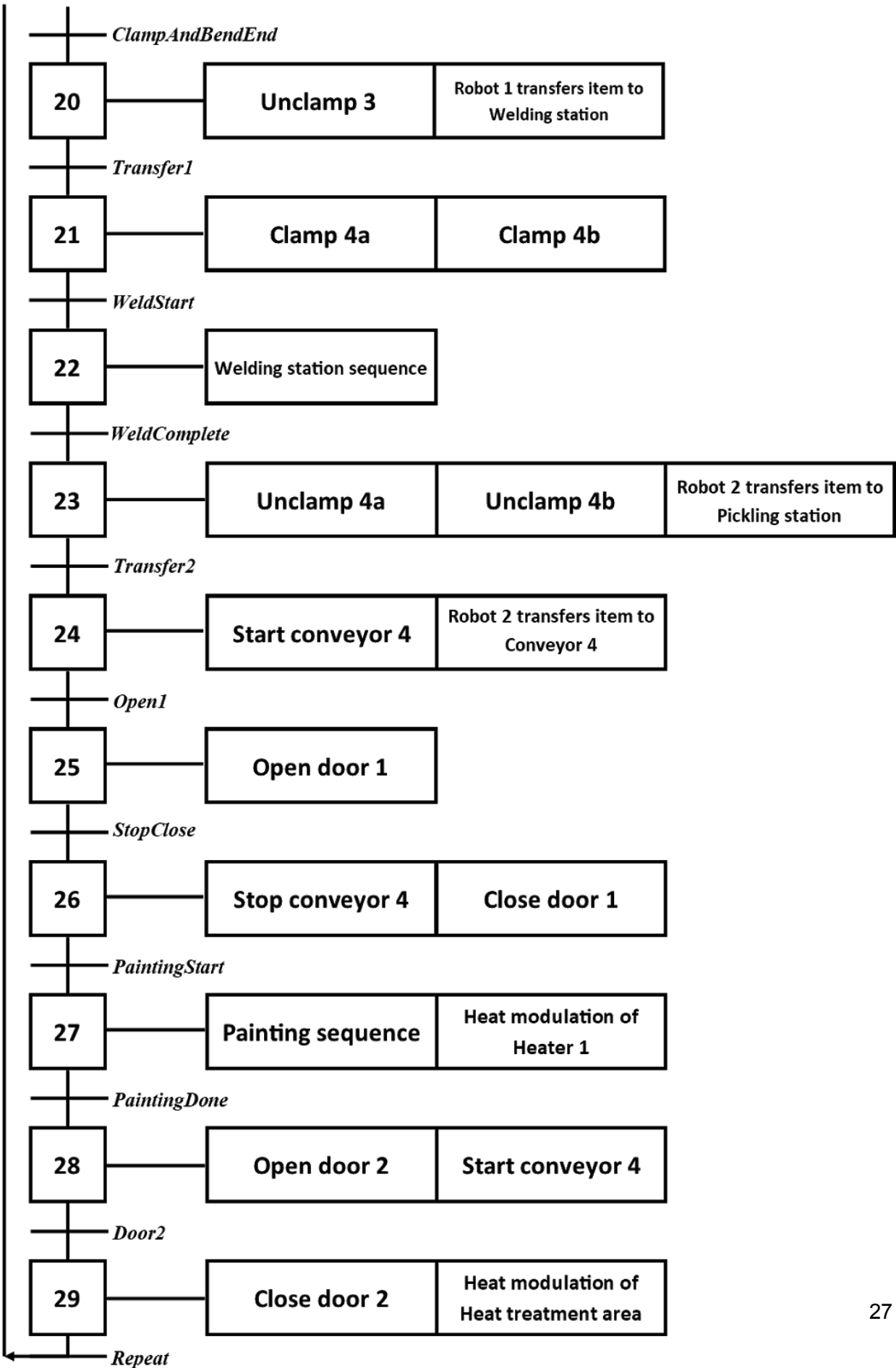
Condition	Signal	Output
1. Stop button pressed	Stop	1. Stops entire system
1. Start button held for 3 seconds	Start	1. System begins automated sequence
1. Measuring device 1 measures 230mm	Measure1	1. Conveyor 1 stops 2. Clamping device 1 clamps 3. Cut Off Saw starts
1. Conveyor 1 stopped 2. Clamping device 1 clamped 3. Cut Off Saw started	LowerSaw	1. Cut Off Saw lowers
1. Cut Off Saw at max cut point	LiftSaw	1. Cut Off Saw stops 2. Cut Off Saw lifts
1. Cut Off Saw lifted	Conveyor2	1. Conveyor 2 starts
1. Measuring device 2 measures 15mm	Measure2.1	1. Conveyor 2 stops 2. Clamping device 2 clamps
1. Conveyor 2 stopped 2. Clamping device 2 clamped	DrillSequenceStart	1. Drill starts 2. Drill moves to POS1
1. Drill in POS1 2. Drill running	LowerDrill	1. Drill lowers
1. Drill lowered	LiftDrill	1. Drill lifts
1. Drill lifted	MovePOS2	1. Drill moves to POS2
1. Drill in POS2	LowerDrill	1. Drill lowers
1. Drill lowered	LiftDrill	1. Drill lifts
1. Drill lifted	MovePOS3	1. Drill moves to POS3
1. Drill in POS2	LowerDrill	1. Drill lowers
1. Drill lowered	LiftDrill	1. Drill lifts
1. Drill lifted	MovePOS1	1. Drill stops 2. Drill moves to POS1
1. Drill stopped 2. Drill in POS1	DrillSequenceEnd	1. Clamping device 2 unclamps 2. Conveyor 2 starts
1. Measuring device 2 measures 35mm	Measure2.2	1. Conveyor 2 stops 2. Clamping device 2 clamps

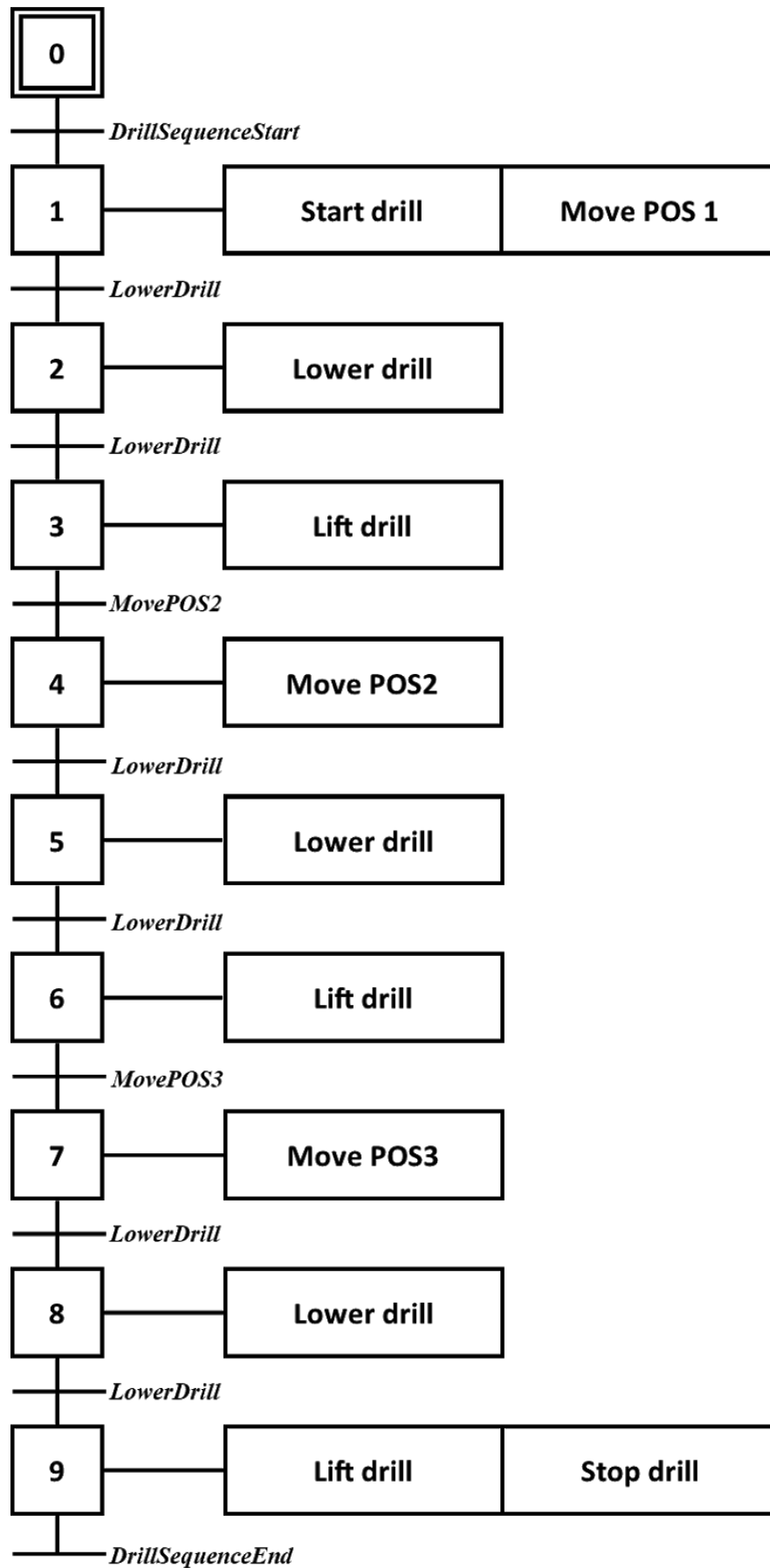
1. Conveyor 2 stopped 2. Clamping device 2 clamped	DrillSequenceStart	1. Drill sequence starts
1. Drill sequence complete	DrillSequenceEnd	1. Clamping device 2 unclamps 2. Conveyor 2 starts
1. Measuring device 2 measures 115mm	Measure2.3	1. Conveyor 2 stops 2. Clamping device 2 clamps
1. Conveyor 2 stopped 2. Clamping device 2 clamped	DrillSequenceStart	1. Drill sequence starts
1. Drill sequence complete	DrillSequenceEnd	1. Clamping device 2 unclamps 2. Conveyor 2 starts
1. Measuring device 2 measures 30mm	Measure2.4	1. Conveyor 2 stops 2. Clamping device 2 clamps
1. Conveyor 2 stopped 2. Clamping device 2 clamped	FinalDrillSequenceStart	1. Drill sequence starts
1. Drill sequence complete	FinalDrillSequenceEnd	1. Clamping device 2 unclamps 2. Conveyor 3 starts
1. Measuring device 3 measures 120mm	Measure3	1. Conveyor 3 stops 2. Clamping device 3 clamps
1. Conveyor 3 stopped 2. Clamping device 3 clamped	ClampAndBendStart	1. Clamp and Bend sequence starts
1. Clamp and Bend sequence complete	ClampAndBendEnd	1. Clamping device 3 unclamps 2. Robot 1 transfers item to Welding station
1. Welding station received item	Transfer1	1. Clamping device 4a and 4b clamps
1. Clamping device 4a and 4b clamped	WeldStart	1. Welding sequence starts
1. Welding sequence complete	WeldComplete	1. Clamping device 4a and 4b unclamps 2. Robot 2 transfers item to Pickling station
1. Pickling complete	Transfer2	1. Conveyor 4 starts 2. Robot 2 transfers item to Conveyor 4
1. Item transferred	Open1	1. Door 1 opens
1. Item inside Heater 1	StopClose	1. Conveyor 4 stops 2. Door 1 closes
1. Conveyor 4 stopped 2. Door 1 closed	PaintingStart	1. Painting sequence starts 2. Temperature modulation
1. Painting sequence complete	PaintingDone	1. Door 2 open 2. Conveyor 4 starts
1. Item out of Heater 1	Door2	1. Door 2 closes 2. Temperature modulation

Grafcet Diagram









Analysis

Overall \,this design specification meets all of the key objectives. The design for the system includes output conditions which ensure the safety of the operating sequence. A latching function has been highlighted as a way to start the system and provides the user the ability to stop the system at any point. As well as safety, using output conditions which are dependent on the systems activity means that operation is fully automated.

After reviewing the functionality of the systems, it is apparent that however functional this design is, there is room for improvement. One way to improve the system would be to increase its efficiency, by having multiple items worked on at once. The current design starts the production of one item and only starts on the second once the first has finished, by simply increasing this production would improve. This would need to be fault tested to ensure that the system would still run smoothly without any collisions, possibly including delays or even item waiting sections as some processes will naturally take longer than others. Nonetheless, being able to produce an increased amount per cycle rather than 1 per cycle is a step towards better efficiency and greater production.

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