

PSDE4005 Assignment 2 Adam Bedner

by Adam Bedner

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Assignment 2: Pick And Place Robot

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[0XB0](https://mall.industry.siemens.com/mall/en/WW/Catalog/Product/6ES7214-1AG40-0XB0)

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1. Hardware description

1.1 Sensors and actuators

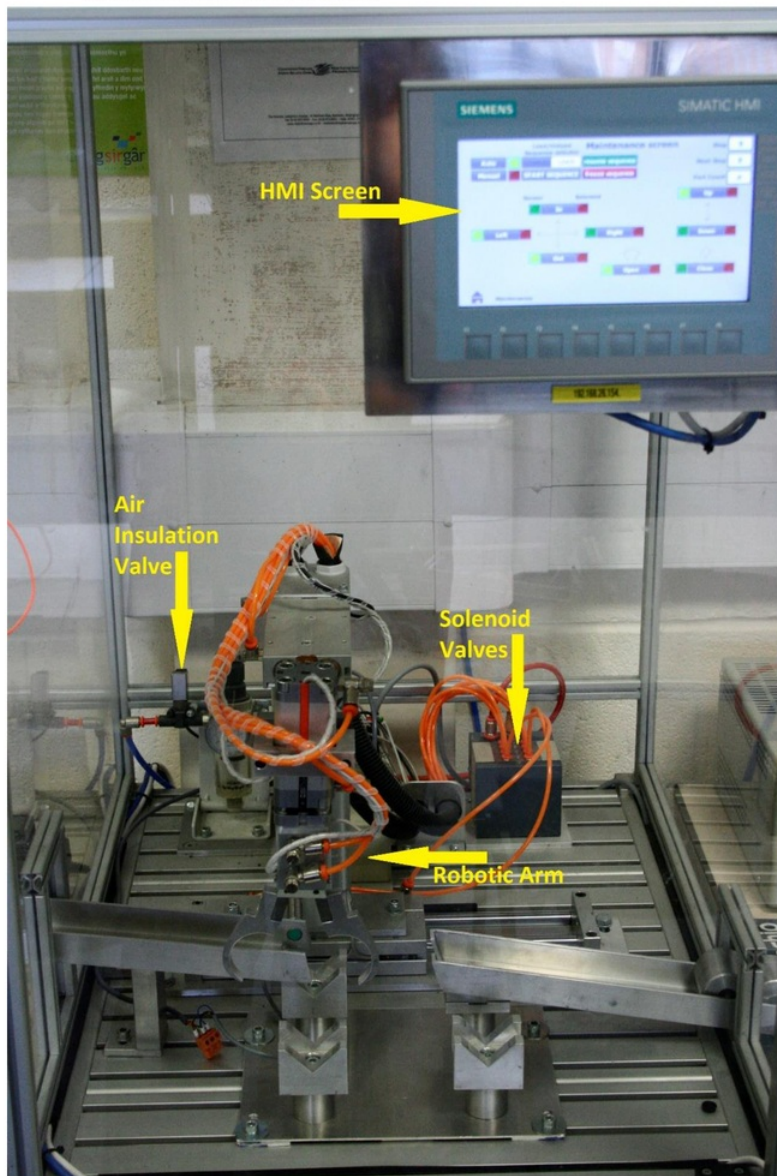


Fig. 1 Pick/Place robot

The hardware shown in Fig. 1 is a pick and place robot which will move material from one chute to another. As shown in Fig. 2 it has a loading chute, unloading chute and 4 stations; station 1 is a loading station, station 2 and 3 are idle stations and station 4 is an unloading station.

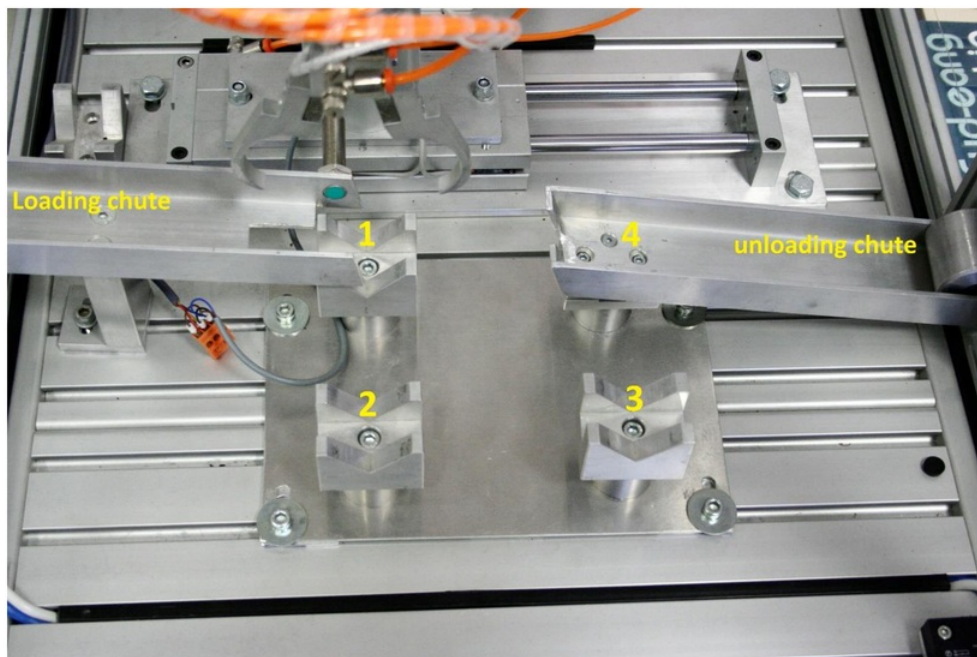


Fig. 2 station layout of the pick and place robot

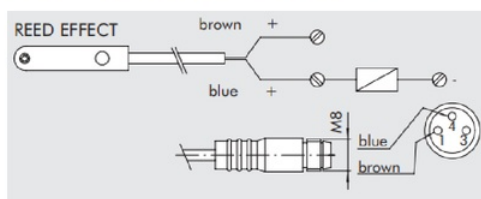


Fig. 3 wiring diagram for reed switch

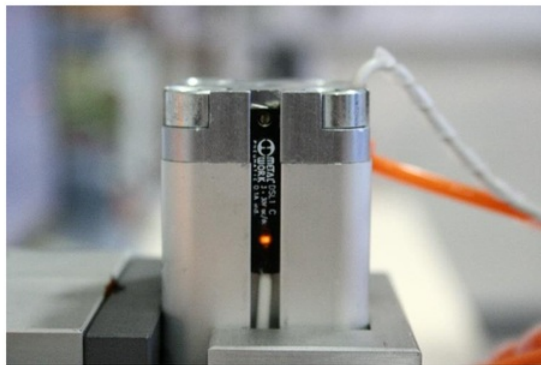


Fig. 4 reed switch in up/down piston

The pick and place robot uses 14 digital inputs and 8 digital outputs. 8 of the inputs are reed switches (MetalWork DSL1 C) mounted on the pistons as shown in Fig. 4, those sensors uses 2 wires (wiring diagram shown Fig. 3) on are Normally open switches which can operate between 3 and 30 VAC/DC with an output current of $\leq 100\text{mA}$, maximum switching frequency of 400 Hz, activation time of $0.5\mu\text{s}$ and average live of 1 million impulses, it has as well a yellow LED which indicate when the switch is closed. (MetalWork, 2008) The pick and place robot uses as well 3 pushbuttons, 2 toggle switches and one

inductive sensor.

All of the outputs are solenoid valves, shown in Fig. 5 (MetalWork NSV F5 SEB 00). There is a total of 8 11mm solenoid valve cartridges, all solenoids are bistable, requires only one impulse to change over, and all are operated by 24VDC. (MetalWork, N/A)

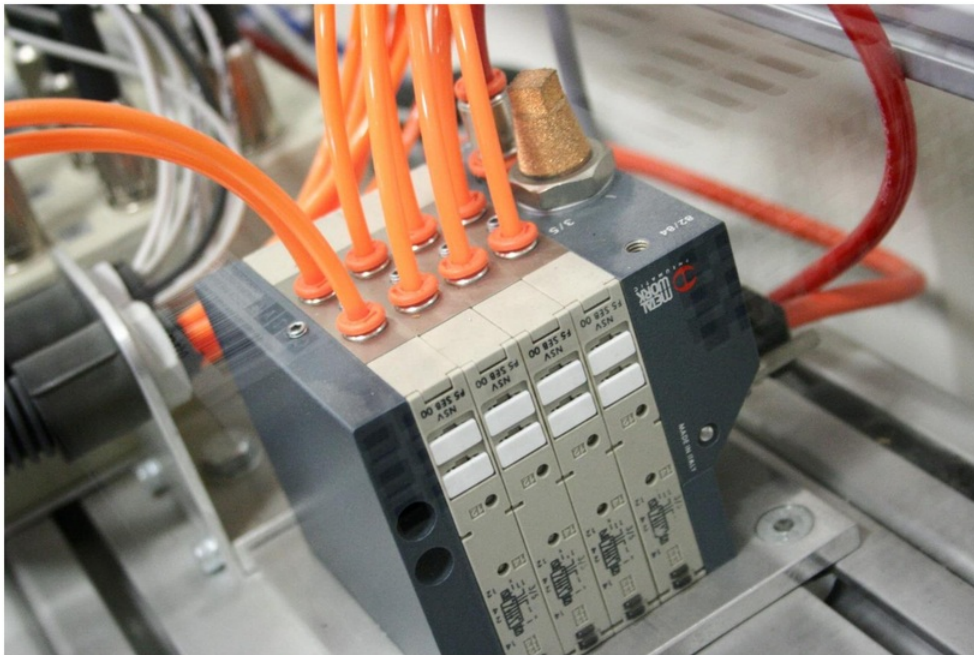


Fig. 5 Bistable solenoid valve package

1.2 Control systems

The PLC used is a Siemens s7-1214c DC/DC/DC supplied by 24VDC. It has 100KB of programable memory, 14 digital inputs, 2 analogue inputs and 10 digital outputs. (Siemens, 2018)

This PLC has the required number of I/O and programable memory therefore no additional modules are required. The wiring diagram for the PLC is shown in drawing 1 and the I/O list in Table 1.

The machine uses as well a Siemens 7" HMI screen (Fig. 6) connected to the PLC and which will be used control the machine. Fig. 7

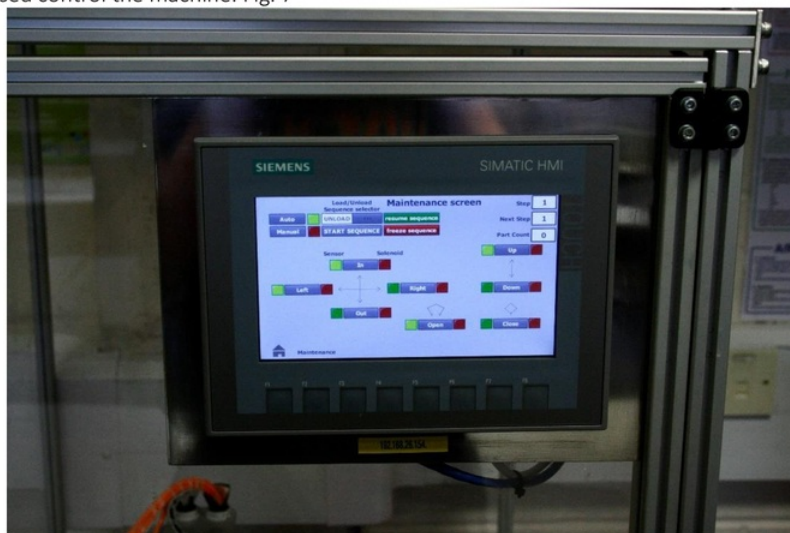
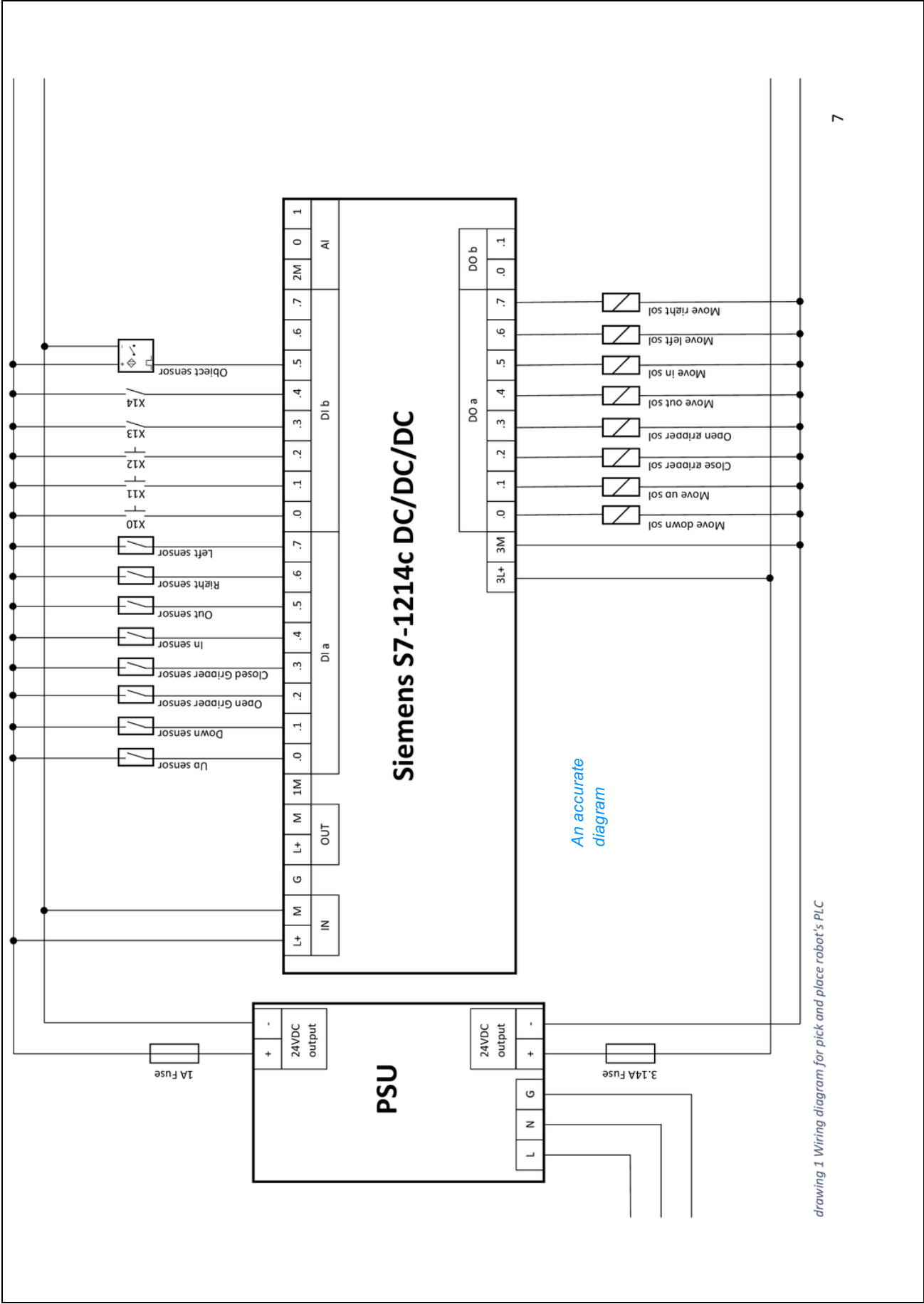


Fig. 6 HMI screen for the pick and place robot



Inputs			Outputs					
Address	Tag name	Type	Description	Address	Tag name	Type	Description	
I0.0	Up sensor	Reed sensor	Up position sensor	Q0.0	Move down solenoid	Bistable solenoid air valve	Moves the arm down	
I0.1	Down sensor		Down position sensor	Q0.1	Move up solenoid		Moves the arm up	
I0.2	Gripper open sensor		Open gripper sensor	Q0.2	Close gripper solenoid		Closes the gripper	
I0.3	Gripper closed sensor		Closed gripper sensor	Q0.3	Open gripper solenoid		Opens the gripper	
I0.4	In sensor		In position sensor	Q0.4	Move out solenoid		Moves the arm out	
I0.5	Our sensor		Out position sensor	Q0.5	Move in solenoid		Moves the arm in	
I0.6	Right sensor		Right position sensor	Q0.6	Move left solenoid		Moves the arm left	
I0.7	Left sensor		Left position sensor	Q0.7	Move right solenoid		Moves the arm right	
I1.0	Pushbutton X10	Push bottom button?	Push bottom X10 on machine's front panel					
I1.1	Pushbutton X11		Push bottom X11 on machine's front panel					
I1.2	Pushbutton X12		Push bottom X12 on machine's front panel					
I1.3	Toggle switch X13	Toggle switch	Toggle switch X13 on machine's front panel					
I1.4	Toggle switch X14		Toggle switch X14 on machine's front panel					
I1.5	Object sensor	Inductive sensor	Inductive sensor on loading chute to detect incoming objects					

Table 1 List of I/O

1.3 Power supplies

The pick and place robot is supplied with 240VAC from the power socket which supplies a PSU which brings the voltage down to 24VDC. The PSU has two 24VDC outputs, both lines are fused. One 24VDC power line is fused with 1A fast-acting fuse and supplies power to the PLC and the sensors, the other 24VDC line is fused with a 3.14A fast-acting fuse and supplies the output section of the PLC together with the solenoid valves. Diagram of the power PSU wiring is seen in drawing 1.

The pick and place robot is supplied as well by 3bar air supply which supplies the arm's pistons. The air supply can be manually insulated by a toggle switch on the front panel of the robot as well as it is automatically insulated if the front door is opened as an safety system.

	Name	Data type	Address	Retain	Acces...	Writa...	Visibl...
1	up sensor	Bool	%I0.0	☐	☒	☒	☒
2	down sensor	Bool	%I0.1	☐	☒	☒	☒
3	grripper open sensor	Bool	%I0.2	☐	☒	☒	☒
4	grripper closed sensor	Bool	%I0.3	☐	☒	☒	☒
5	in sensor	Bool	%I0.4	☐	☒	☒	☒
6	out sensor	Bool	%I0.5	☐	☒	☒	☒
7	right sensor	Bool	%I0.6	☐	☒	☒	☒
8	left sensor	Bool	%I0.7	☐	☒	☒	☒
9	pushbutton X10	Bool	%I1.0	☐	☒	☒	☒
10	pushbutton X11	Bool	%I1.1	☐	☒	☒	☒
11	pushbutton X12	Bool	%I1.2	☐	☒	☒	☒
12	toggle switch X13	Bool	%I1.3	☐	☒	☒	☒
13	toggle switch X14	Bool	%I1.4	☐	☒	☒	☒
14	object sensor	Bool	%I1.5	☐	☒	☒	☒
15	Move down solenoid	Bool	%Q0.0	☐	☒	☒	☒
16	move up solenoid	Bool	%Q0.1	☐	☒	☒	☒
17	close gripper solenoid	Bool	%Q0.2	☐	☒	☒	☒
18	open gripper solenoid	Bool	%Q0.3	☐	☒	☒	☒
19	move out solenoid	Bool	%Q0.4	☐	☒	☒	☒
20	move in solenoid	Bool	%Q0.5	☐	☒	☒	☒
21	move left solenoid	Bool	%Q0.6	☐	☒	☒	☒
22	move right solenoid	Bool	%Q0.7	☐	☒	☒	☒
23	FSP	Bool	%M50.0	☐	☒	☒	☒
24	start sequence	Bool	%M50.1	☐	☒	☒	☒
25	STEP	UInt	%MW120	☐	☒	☒	☒
26	next_STEP	UInt	%MW130	☐	☒	☒	☒
27	Auto	Bool	%M0.0	☐	☒	☒	☒
28	move up man	Bool	%M10.0	☐	☒	☒	☒
29	move down man	Bool	%M10.1	☐	☒	☒	☒
30	move in man	Bool	%M10.2	☐	☒	☒	☒
31	move out man	Bool	%M10.3	☐	☒	☒	☒
32	move left man	Bool	%M10.4	☐	☒	☒	☒
33	move right man	Bool	%M10.5	☐	☒	☒	☒
34	open gripper man	Bool	%M10.6	☐	☒	☒	☒
35	close gripper man	Bool	%M10.7	☐	☒	☒	☒
36	move up REQ	Bool	%M20.0	☐	☒	☒	☒
37	move down REQ	Bool	%M20.1	☐	☒	☒	☒
38	move in REQ	Bool	%M20.2	☐	☒	☒	☒
39	move out REQ	Bool	%M20.3	☐	☒	☒	☒
40	move left REQ	Bool	%M20.4	☐	☒	☒	☒
41	move right REQ	Bool	%M20.5	☐	☒	☒	☒
42	open gripper REQ	Bool	%M20.6	☐	☒	☒	☒
43	close gripper REQ	Bool	%M20.7	☐	☒	☒	☒
44	Load	Bool	%M0.1	☐	☒	☒	☒
45	Unload	Bool	%M0.2	☐	☒	☒	☒
46	HMI Start	Bool	%M0.3	☐	☒	☒	☒
47	Load/Unload selector	Bool	%M0.4	☐	☒	☒	☒
48	freeze	Bool	%M0.5	☐	☒	☒	☒
49	stop	Bool	%M0.6	☐	☒	☒	☒
50	start	Bool	%M0.7	☐	☒	☒	☒
51	auto mode	Bool	%M1.0	☐	☒	☒	☒
52	manual mode	Bool	%M1.1	☐	☒	☒	☒
53	<Add new>			☐	☒	☒	☒

Fig. 8 Tag list

2. Manual Controls and HMI screens

2.1 program for manual operating

In order to operate the robot manually, a program has been written in ladder language, as shown in Fig. 9 and Fig. 10 and the tag list used for the program can be seen on Fig. 8. Those runs already include the selection between automatic and manual mode which will be used later on. It also includes the interlock system which won't allow the arm move down unless it is situated above any of the four stations (Fig. 9: Network 2), move left right, left, in or out unless it is in up position (Fig. 9: Networks 3 and 4; Fig. 10: Networks 5 and 6) and close the gripper unless it is in down position (Fig. 10: Network 8). This interlock system are in place to prevent damage to the system due to faults or misuse.

The program includes power saving features seen on Fig. 9 and Fig. 10. The power saving feature consists of a NC contact labelled as the sensor of the same axis as the valve and put in series with said valve. The solenoid valves, being bistable, only needs one impulse to change over; therefore, even if the solenoid vale is deactivated after the arm reaches the limit, it will stay there.

2.2 HMI screens

There are two HMI screens for the robot in order to allow operation and maintenance of the robot.

The operator's screen with basic information and controls as seen on Fig. 11, where 1.automatic mode selection; 2. light indicator for automatic mode; 3.manual mode selection; 4.light indicator for manual mode; 5.step number at which the machine is currently on when in automatic mode; 6.number of parts currently in the machine; 7.selector between load and unload sequences; 8.starts the selected sequence when in automatic mode; 9.resumes the sequence after being frozen (note: it will resume from the step it have been frozen at); 10.freezes the sequence; 11.goes to the maintenance's screen.

The maintenance's screen which holds all the information and controls to allow the engineers to maintain and repair the robot as seen on Fig. 12, where 1.automatic mode selector; 2.manual mode selector; 3.load/unload sequence selector; 4.star of the selected sequence; 5.resume of the frozen sequence (note: it will start from the step it was frozen at); 6.freezes the sequence; 7.suence's step the robot is currently at when in automatic mode; 8.sequence's next that the robot will at when in automatic mode; 9.number of parts currently in the robot; 10.manual move up request; 11.manual move down request; 12.manual close gripper request; 13.manual move right request; 14.manual open gripper request; 15.manual move out request; 16.manual move left request; 17.manual move in request; 18.goes back to main (operator) screen; 19.sensors light indicators for the position of the request button those are next to; 20.solenoid valve active light indicator for the movement of the request button those are next to; 21. Automatic mode light indicator; 22. Manual mode light indicator.

For any of the manual request buttons being operational, the robot must be in manual mode, otherwise the robot will be unresponsive to any of the manual request. All the safety interlock work for both, manual and automatic mode as to protect the robot from damage in case of invalid movements (example, moving in when in down position) form both, human errors and possible robot's faults.

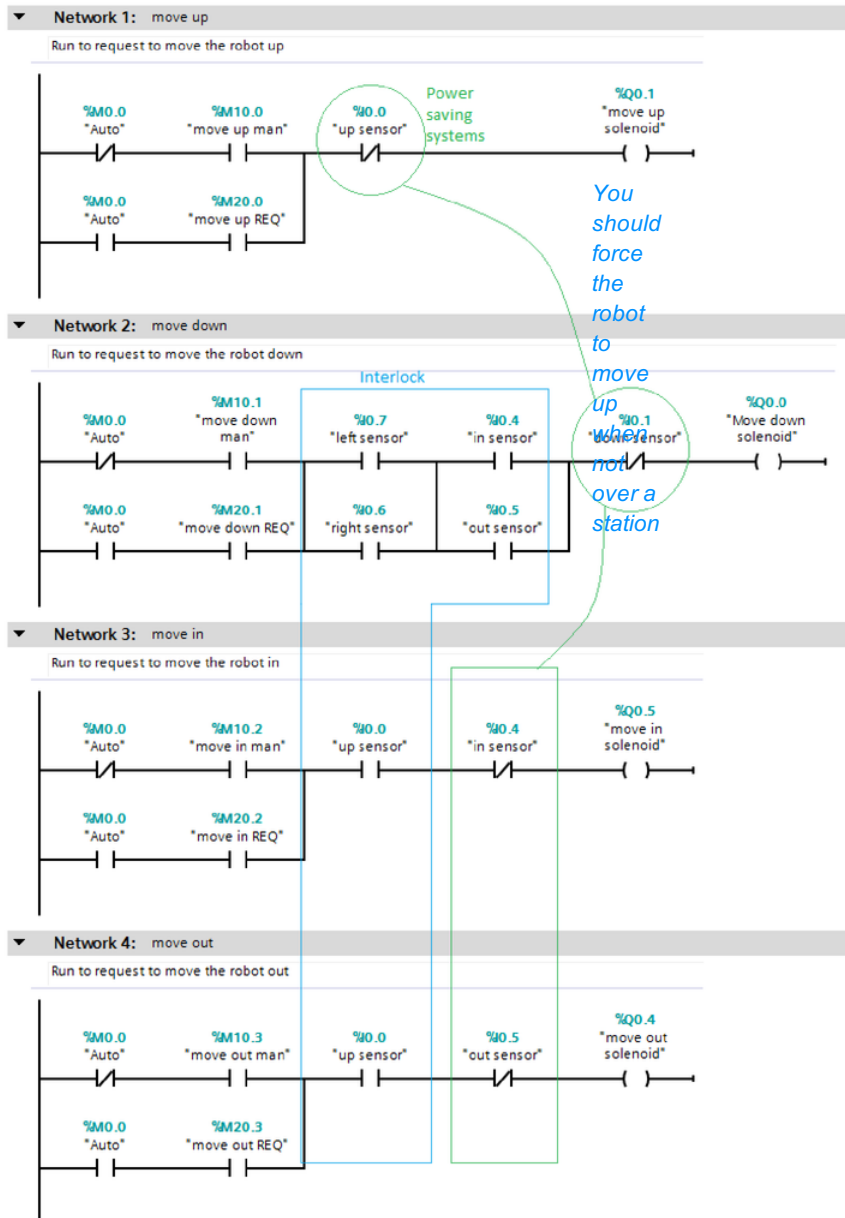


Fig. 9 network runs to move the robotic arm up, down, in and out

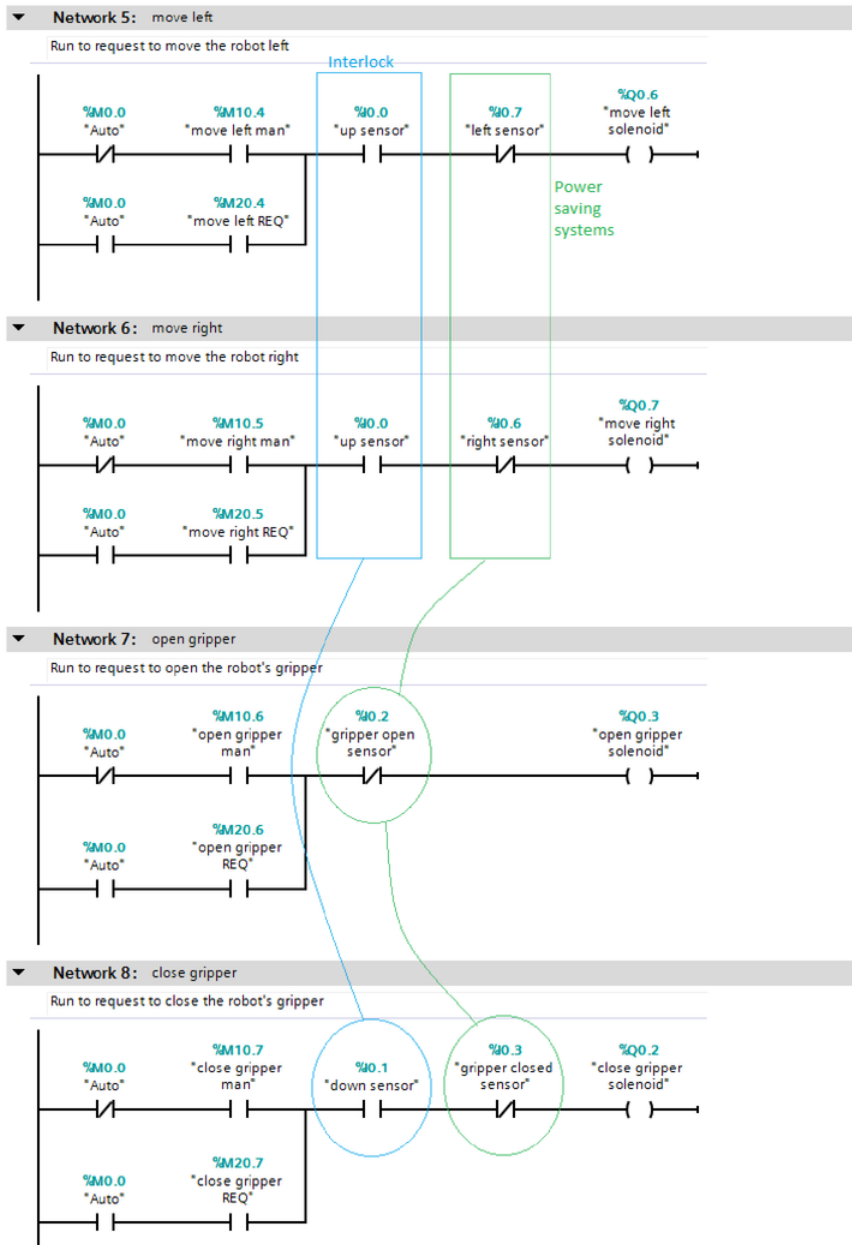


Fig. 10 network runs to move the robotic arm left and right and open and close the gripper

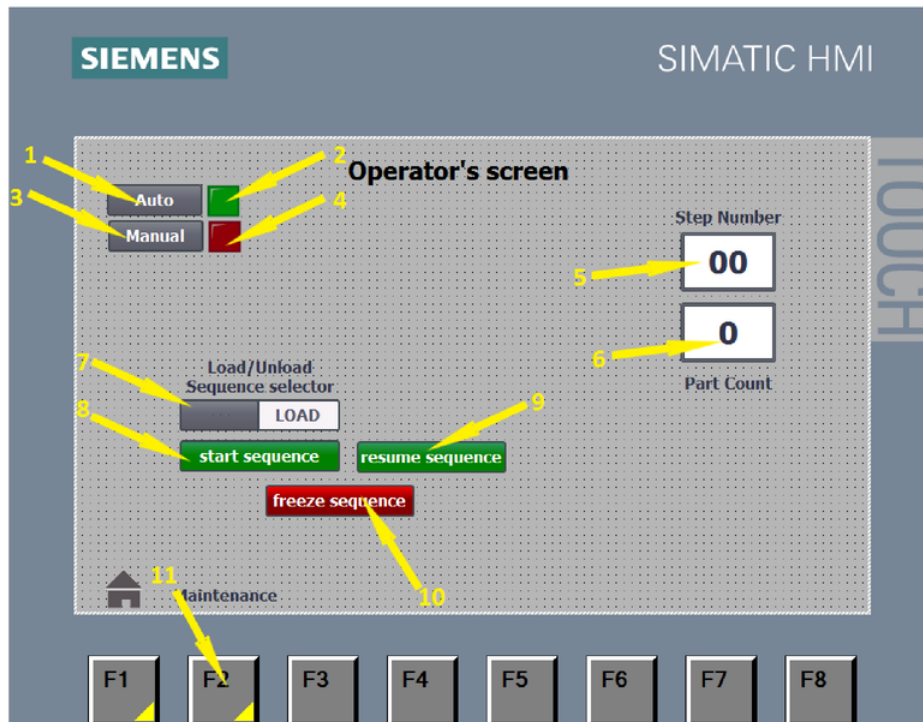


Fig. 11 HMI operator's screen

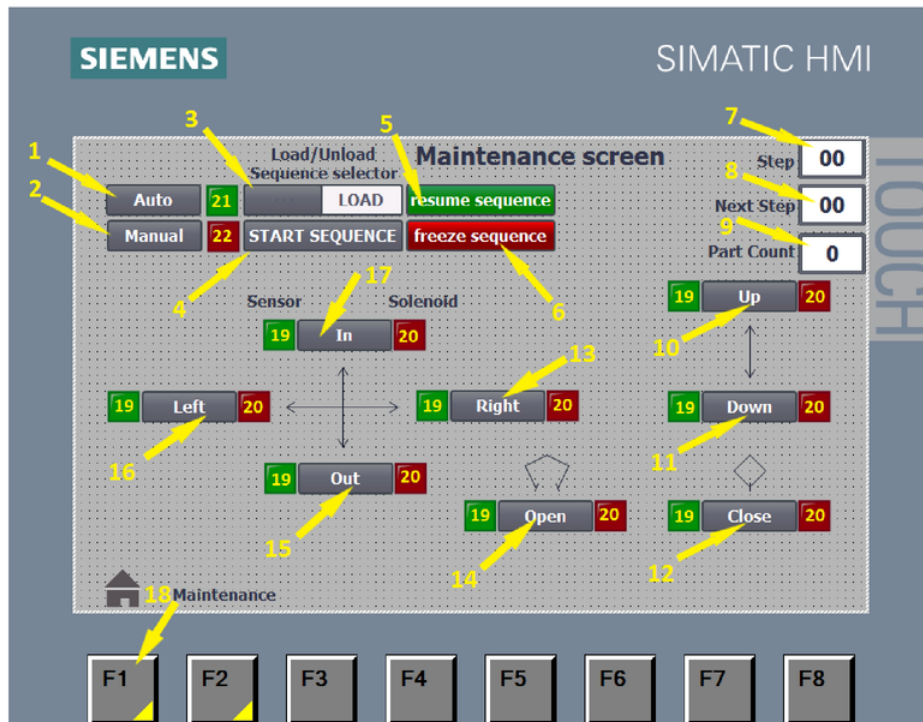


Fig. 12 HMI Maintenance's screen

3. Program description

The robot has an option of automatic mode, where two sequences are used: Load sequence and unload sequence. Those sequences are written in SFC language using main **IF** and **CASE** commands. The SFC map for the program is seen in Fig. 13, Fig. 14 and Fig. 15.

Prior to load or unload sequences the program has to initial steps, step 0 and step 1 as shown in Fig. 17, which moves the robotic arm to its home position which is above the station 1 (see Fig. 2), moving it to the up position and setting all the all other solenoid valve's bits to 0; then it is moved in and left and waits for future command of selection between load sequence (moves to step 2) or unload sequence (moves to step 30) as well as the start sequence command which can be activated either from the HMI screen or by the inductive sensor (see Table 1: I1.5).

The load sequence program has 21 steps (step 2 to step 23) seen on Fig. 17, Fig. 18 and Fig. 19 during which the parts will moved from station 1 to station 2, from 2 to 3 and from 3 to 4, the exit chute. The program incorporates a 5 seconds timer (seen on Fig. 16) which makes the robotic arm wait for 5 second in up position with opened gripper after placing the part in station 2 (step 9) and on station 3 (step 17).

The unload sequence program has 21 steps (step 30 to step 51) seen on Fig. 20, Fig. 21 and Fig. 22 during which station 1, 2 and 3 respectively are being unloaded from any possible parts left in the robot to the exit chute. It is recommended to perform this sequence before operating the robot in load sequence mode to prevent any collisions with any possible part left in the machine.

In order to allow the selection between the automatic and manual mode, selection between load and unload sequences, two additional networks have been added to the ladder program as seen on Fig. 23: Network 9 and 11. Both networks uses one NC and one NO contact with the same name tag name and two actuators with "unload" and "load" bits in network 9 and 'auto mode' and "manual mode" bits in network 11. In network 9, the "Load/Unload selector" bit is set and reset with a toggle switch on the HMI screens (see Fig. 11: 7; Fig. 12: 3). In network 11, the "Auto" bit is set by the Auto button on both of the HMI screens (see Fig. 11: 1; Fig. 12: 1) and reset by the Manual button on both of the HMI screens (see Fig. 11: 2; Fig. 12: 2).

The program has as well an option of freezing the sequence at any given step. To enable that an **IF** command have been added to the program, with the condition of "freeze" = 0 to allow the sequence to run and all the sequence program is held within as it can be seen in Fig. 17: line 5 (start of **IF**) and Fig. 22: line 303 (end of **IF**). It is using the "freeze" bit and to control this bit another network in the ladder program has been added (see Fig. 23: network 10) in which two NO contacts are used, one tagged as "stop" to set the freeze set to 1 and the other one tagged as "start" to unfreeze the sequence, The Set bit and reset bit actuators have been used to set and reset the "freeze" bit. Two bottom are used for that in both, operator's and maintenance's screens (freeze Buttons seen on Fig. 11: 10; Fig. 12:6 . Unfreeze Buttons seen Fig. 11: 9; Fig. 12: 5).

The sequence timer (Fig. 16) is written in FBD language using two equal comparator functions for when "step"=9 or "step"=17, an OR logic function for when either comparator is on will activate the time on delay counter for purpose described earlier.

The up/down counter (Fig. 16) is also written in FBD and uses the "object sensor" to count up when a part comes in, an equal comparator function when "step"=23 (end of load sequence) to count down when a part leaves the robot as well as an equal comparator for when "step"=51 to reset the counter to 0 at the end of unload sequence. The counter counts o a maximum of 3, as that is the internal capacity of the robot (station 1,2 and 3).

All the function block of the program are put in the PLC's main function block as seen in Fig. 24.

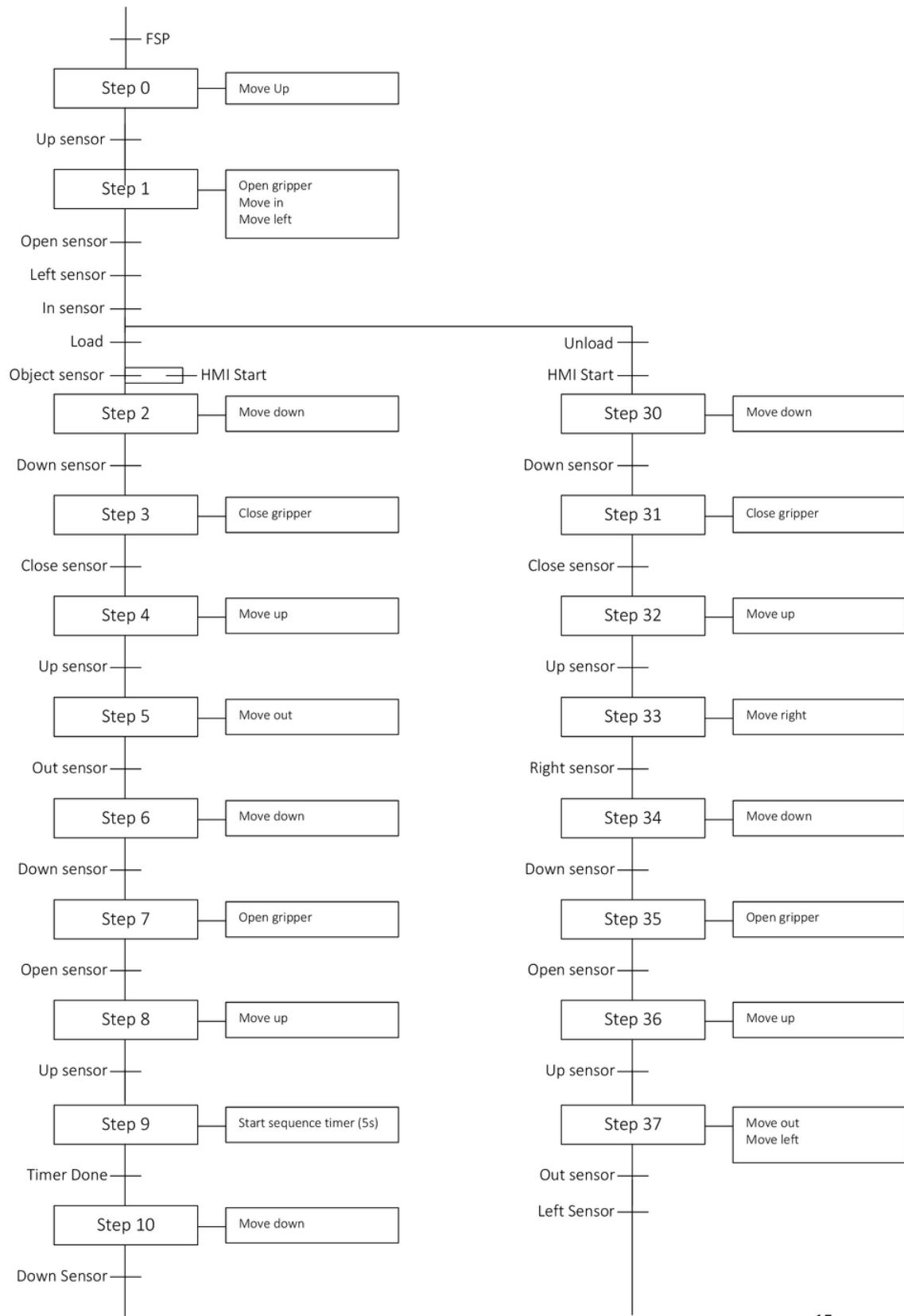


Fig. 13 sequence map steps 0-10/30-37

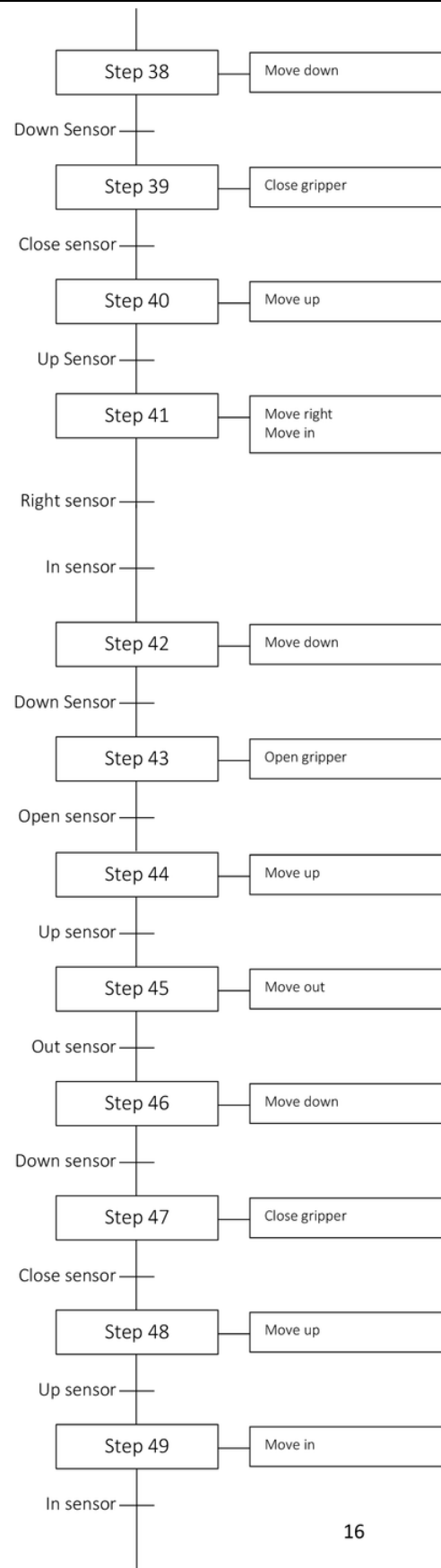
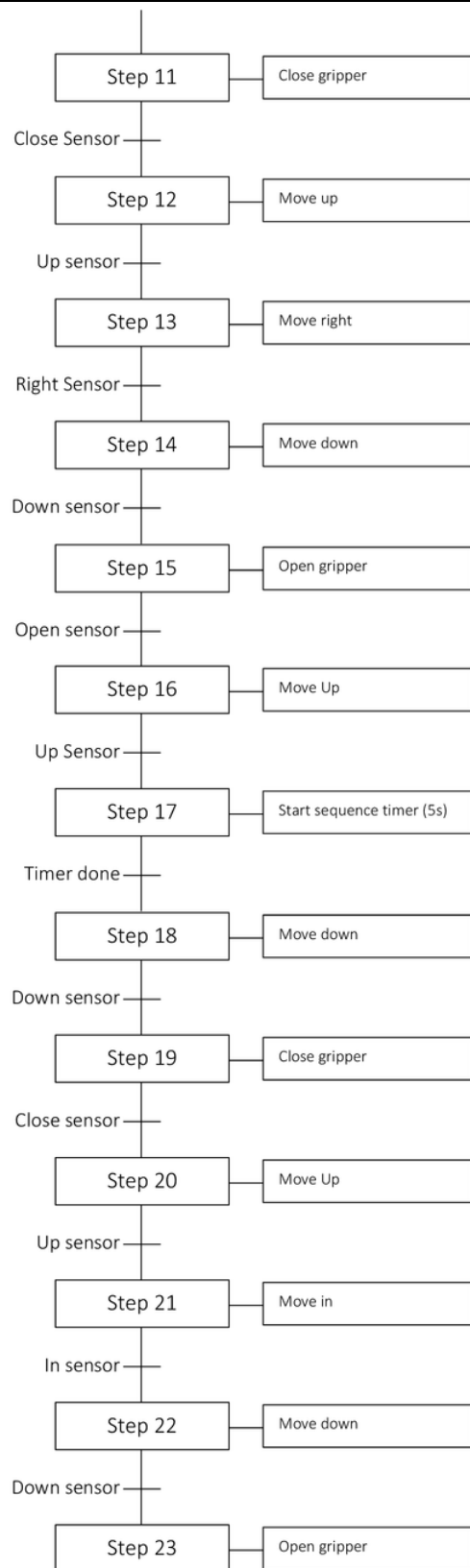


Fig. 14 sequence map steps 11- 23/38-49

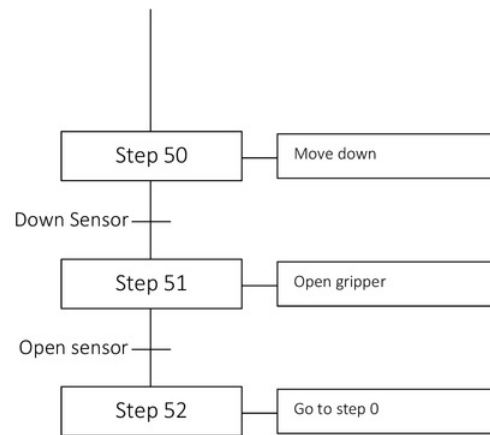
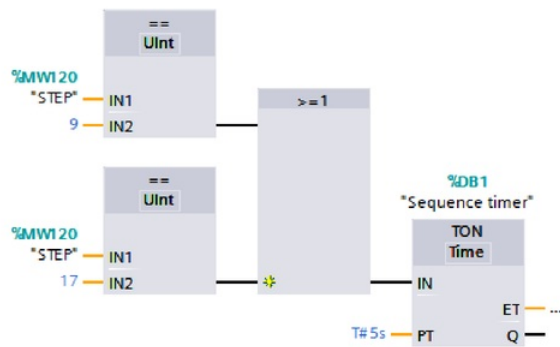


Fig. 15 sequence map steps 50-52

Network 1: sequence timer

5s timer for the sequence's steps 9 and 17.



Network 2: Part counter

up/down counter to count parts coming in and out, with an option of reset when unload sequence is finished.

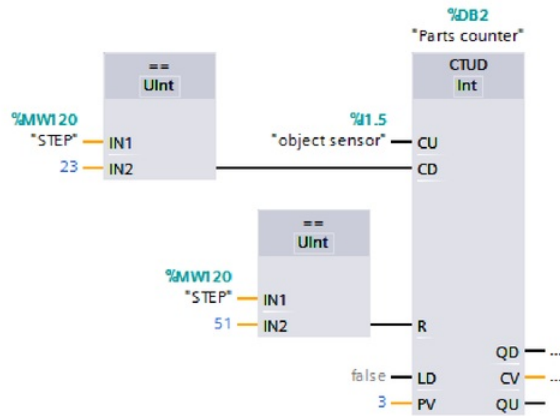


Fig. 16 FBD networks for 5 seconds sequence timer and part counter

```

1 IF "FSP" THEN
2     "STEP" := 0;
3     "next_STEP" := 0;
4 END_IF;
5 IF "freeze" = 0 THEN
6     CASE "STEP" OF
7         0:
8             "move up REQ" := 1;
9             "move down REQ" := 0;
10            "move in REQ" := 0;
11            "move out REQ" := 0;
12            "move right REQ" := 0;
13            "move left REQ" := 0;
14            "close gripper REQ" := 0;
15            "open gripper REQ" := 0;
16            IF "up sensor" = 1 THEN
17                "move up REQ" := 0;
18                "next_STEP" := 1;
19            END_IF;
20        1:
21            "move in REQ" := 1;
22            "move left REQ" := 1;
23            "open gripper REQ" := 1;
24            IF ("in sensor" = 1) AND
25                ("left sensor" = 1) AND
26                ("gripper open sensor" = 1) THEN
27                "move in REQ" := 0;
28                "move left REQ" := 0;
29                "open gripper REQ" := 0;
30                IF (("Load" = 1) AND (("start sequence" = 1) OR ("object sensor" = 1))) THEN
31                    "next_STEP" := 2;
32                END_IF;
33                IF (("Unload" = 1) AND ("start sequence" = 1)) THEN
34                    "next_STEP" := 30;
35                END_IF;
36            END_IF;
37        2:                                //Start of load sequence
38            "move down REQ" := 1;
39            IF "down sensor" = 1 THEN
40                "move down REQ" := 0;
41                "next_STEP" := 3;
42            END_IF;
43        3:
44            "close gripper REQ" := 1;
45            IF "gripper closed sensor" = 1 THEN
46                "close gripper REQ" := 0;
47                "next_STEP" := 4;
48            END_IF;
49        4:
50            "move up REQ" := 1;
51            IF "up sensor" = 1 THEN
52                "move up REQ" := 0;
53                "next_STEP" := 5;
54            END_IF;
55        5:
56            "move out REQ" := 1;
57            IF "out sensor" = 1 THEN
58                "move out REQ" := 0;
59                "next_STEP" := 6;
60            END_IF;

```

Fig. 17 Initial Home position sequence runs: steps 0 and; Load sequence runs: steps 2-5

```

60 |         END_IF;
61 |
62 |     6:
63 |         "move down REQ" := 1;
64 |         IF "down sensor" = 1 THEN
65 |             "move down REQ" := 0;
66 |             "next_STEP" := 7;
67 |         END_IF;
68 |
69 |     7:
70 |         "open gripper REQ" := 1;
71 |         IF "gripper open sensor" = 1 THEN
72 |             "open gripper REQ" := 0;
73 |             "next_STEP" := 8;
74 |         END_IF;
75 |
76 |     8:
77 |         "move up REQ" := 1;
78 |         IF "up sensor" = 1 THEN
79 |             "move up REQ" := 0;
80 |             "next_STEP" := 9;
81 |         END_IF;
82 |
83 |     9:
84 |         IF "Sequence timer".Q = 1 THEN
85 |             "next_STEP" := 10;
86 |         END_IF;
87 |
88 |     10:
89 |         "move down REQ" := 1;
90 |         IF "down sensor" = 1 THEN
91 |             "move down REQ" := 0;
92 |             "next_STEP" := 11;
93 |         END_IF;
94 |
95 |     11:
96 |         "close gripper REQ" := 1;
97 |         IF "gripper closed sensor" = 1 THEN
98 |             "close gripper REQ" := 0;
99 |             "next_STEP" := 12;
100 |         END_IF;
101 |
102 |     12:
103 |         "move up REQ" := 1;
104 |         IF "up sensor" = 1 THEN
105 |             "move up REQ" := 0;
106 |             "next_STEP" := 13;
107 |         END_IF;
108 |
109 |     13:
110 |         "move right REQ" := 1;
111 |         IF "right sensor" = 1 THEN
112 |             "move right REQ" := 0;
113 |             "next_STEP" := 14;
114 |         END_IF;
115 |
116 |     14:
117 |         "move down REQ" := 1;
118 |         IF "down sensor" = 1 THEN
119 |             "move down REQ" := 0;
120 |             "next_STEP" := 15;
121 |         END_IF;
122 |
123 |     15:
124 |         "open gripper REQ" := 1;
125 |         IF "gripper open sensor" = 1 THEN
126 |             "open gripper REQ" := 0;
127 |             "next_STEP" := 16;
128 |         END_IF;

```

Fig. 18 Load sequence runs: steps 6-15

```

119      16:      -
120      "move up REQ" := 1;
121      IF "up sensor" = 1 THEN
122          "move up REQ" := 0;
123          "next_STEP" := 17;
124      END_IF;
125      17:
126      IF "Sequence timer".Q = 1 THEN
127          "next_STEP" := 18;
128      END_IF;
129      18:
130      "move down REQ" := 1;
131      IF "down sensor" = 1 THEN
132          "move down REQ" := 0;
133          "next_STEP" := 19;
134      END_IF;
135      19:
136      "close gripper REQ" := 1;
137      IF "gripper closed sensor" = 1 THEN
138          "close gripper REQ" := 0;
139          "next_STEP" := 20;
140      END_IF;
141      20:
142      "move up REQ" := 1;
143      IF "up sensor" = 1 THEN
144          "move up REQ" := 0;
145          "next_STEP" := 21;
146      END_IF;
147      21:
148      "move in REQ" := 1;
149      IF "in sensor" = 1 THEN
150          "move in REQ" := 0;
151          "next_STEP" := 22;
152      END_IF;
153      22:
154      "move down REQ" := 1;
155      IF "down sensor" = 1 THEN
156          "move down REQ" := 0;
157          "next_STEP" := 23;
158      END_IF;
159      23:
160      "open gripper REQ" := 1;
161      IF "gripper open sensor" = 1 THEN
162          "open gripper REQ" := 0;
163          "next_STEP" := 0;
164      END_IF;                                     //End of load sequence

```

Fig. 19 Load sequence runs: steps 16-23

```

165
166      30:                                     //Start of unload sequence
167      "move down REQ" := 1;
168      IF "down sensor" = 1 THEN
169          "move down REQ" := 0;
170          "next_STEP" := 31;
171      END_IF;
172      31:
173      "close gripper REQ" := 1;
174      IF "gripper closed sensor" = 1 THEN
175          "close gripper REQ" := 0;
176          "next_STEP" := 32;
177      END_IF;

```

Fig. 20 Unload sequence runs: steps 30 and 31

```

178      32:
179          "move up REQ" := 1;
180      IF "up sensor" = 1 THEN
181          "move up REQ" := 0;
182          "next_STEP" := 33;
183      END_IF;
184      33:
185          "move right REQ" := 1;
186      IF "right sensor" = 1 THEN
187          "move right REQ" := 0;
188          "next_STEP" := 34;
189      END_IF;
190      34:
191          "move down REQ" := 1;
192      IF "down sensor" = 1 THEN
193          "move down REQ" := 0;
194          "next_STEP" := 35;
195      END_IF;
196      35:
197          "open gripper REQ" := 1;
198      IF "gripper open sensor" = 1 THEN
199          "open gripper REQ" := 0;
200          "next_STEP" := 36;
201      END_IF;
202      36:
203          "move up REQ" := 1;
204      IF "up sensor" = 1 THEN
205          "move up REQ" := 0;
206          "next_STEP" := 37;
207      END_IF;
208      37:
209          "move out REQ" := 1;
210          "move left REQ" := 1;
211      IF ("out sensor" = 1) AND ("left sensor" = 1) THEN
212          "move out REQ" := 0;
213          "move left REQ" := 0;
214          "next_STEP" := 38;
215      END_IF;
216      38:
217          "move down REQ" := 1;
218      IF "down sensor" = 1 THEN
219          "move down REQ" := 0;
220          "next_STEP" := 39;
221      END_IF;
222      39:
223          "close gripper REQ" := 1;
224      IF "gripper closed sensor" = 1 THEN
225          "close gripper REQ" := 0;
226          "next_STEP" := 40;
227      END_IF;
228      40:
229          "move up REQ" := 1;
230      IF "up sensor" = 1 THEN
231          "move up REQ" := 0;
232          "next_STEP" := 41;
233      END_IF;

```

Fig. 21 Unload sequence runs: steps 32-40

```

234      41:
235      "move right REQ" := 1;
236      "move in REQ" := 1;
237      IF ("right sensor" = 1) AND ("in sensor" = 1) THEN
238          "move right REQ" := 0;
239          "move in REQ" := 0;
240          "next_STEP" := 42;
241      END_IF;
242      42:
243      "move down REQ" := 1;
244      IF "down sensor" = 1 THEN
245          "move down REQ" := 0;
246          "next_STEP" := 43;
247      END_IF;
248      43:
249      "open gripper REQ" := 1;
250      IF "gripper open sensor" = 1 THEN
251          "open gripper REQ" := 0;
252          "next_STEP" := 44;
253      END_IF;
254      44:
255      "move up REQ" := 1;
256      IF "up sensor" THEN
257          "move up REQ" := 0;
258          "next_STEP" := 45;
259      END_IF;
260      45:
261      "move out REQ" := 1;
262      IF "out sensor" = 1 THEN
263          "move out REQ" := 0;
264          "next_STEP" := 46;
265      END_IF;
266      46:
267      "move down REQ" := 1;
268      IF "down sensor" = 1 THEN
269          "move down REQ" := 0;
270          "next_STEP" := 47;
271      END_IF;
272      47:
273      "close gripper REQ" := 1;
274      IF "gripper closed sensor" = 1 THEN
275          "close gripper REQ" := 0;
276          "next_STEP" := 48;
277      END_IF;
278      48:
279      "move up REQ" := 1;
280      IF "up sensor" = 1 THEN
281          "move up REQ" := 0;
282          "next_STEP" := 49;
283      END_IF;
284      49:
285      "move in REQ" := 1;
286      IF "in sensor" = 1 THEN
287          "move in REQ" := 0;
288          "next_STEP" := 50;
289      END_IF;
290      50:
291      "move down REQ" := 1;
292      IF "down sensor" = 1 THEN
293          "move down REQ" := 0;
294          "next_STEP" := 51;
295      END_IF;
296      51:
297      "open gripper REQ" := 1;
298      IF "gripper open sensor" = 1 THEN
299          "open gripper REQ" := 0;
300          "next_STEP" := 0;
301      END_IF;
302      //End of unload sequence
303      END_CASE;
304      "STEP" := "next_STEP";

```

Fig. 22 Unload sequence runs: steps 41-51

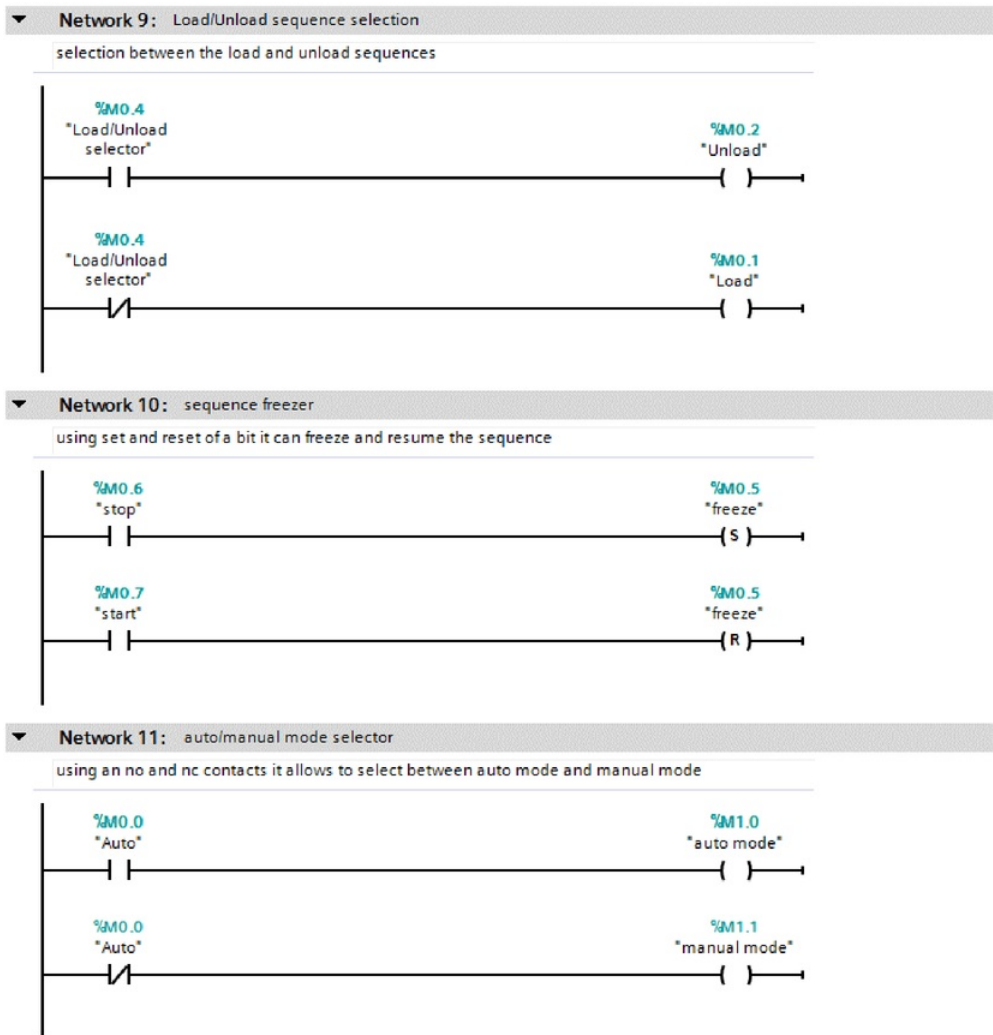


Fig. 23 sequence control networks

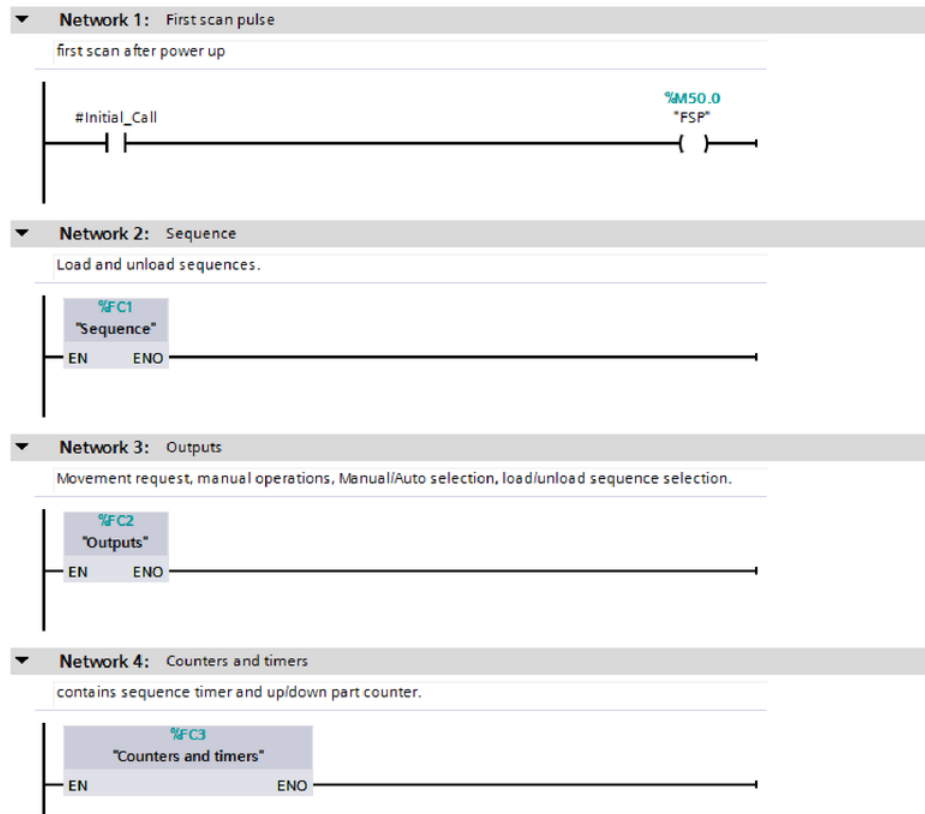


Fig. 24 Main PLC's program block

4. System's testing and evaluation

The system been tested first in manual mode, checking if the robotic arm moves in every required direction as well as the functionality of all of the interlocks. All the interlock behaved as expected to. The robot made successfully all the required movements, the left and right movement can be seen on Fig. 25, up and down movement on Fig. 26, in and out movement on Fig. 27 and the opening and closing gripper on Fig. 28.

After checking that the robot behaves as expected, the sequence modes have been checked, checking that every step does what is programmed for. Mainly checking if it parks in home position when activating automatic mode (Fig. 29).

In load sequence mode mainly the counter in step 9 (Fig. 30) and step 17 (Fig. 31) have been checked.

In unloading sequence the appropriate unloading of the station have been checked. The unloading of the station 2, step 38, can be seen in Fig. 32; the unloading of station 3, step 46 can be seen on Fig. 33 and the finishing of the unload sequence, before opening the griper, step 50, can be seen on Fig. 34.

The freeze option have been checked as well and if the sequence is frozen and then unfrozen from the same spot the robots runs fine, but if the sequence is frozen and then before unfreezing is manually moved to a different position then the sequence latches up and the robot has to be manually moved to home position and "step" and "next step" set manually to 1 in order to unlatch it.

Test#	Description		Expected output	Actual output
1	Manual operations	In manual mode, move down	Move down	Moved down
2		In manual mode, move up	Move up	Moved up
3		In manual mode, move in	Move in	Moved in
4		In manual mode, move down	Move out	Moved out
5		In manual mode, move right	Move right	Moved right
6		In manual mode, move left	Move left	Moved left
7		In manual mode, open gripper	Open gripper	Opened gripper
8		In manual mode, close gripper	Close gripper	Closed gripper
9	Interlock	Move up and left at the same time	Move only up	Moved only up
10		Move up and right at the same time		
11		Move up and in at the same time		
12		Move up and out at the same time		
13		Move down and left at the same time	Move only down	Moved only down
14		Move down and right at the same time		
15		Move down and in at the same time		
16		Move down and out at the same time		
17		Close gripper when in up position	The gripper will not close	The gripper did not close
18	Auto/ manual and load/ unload sequence selection	Change to auto mode	Move to home position and wait for start command	Moved to home position and waited for start command
19		Chose unload sequence and press start sequence	Unload sequence will start	Unload sequence have started
20		Chose load sequence and press start sequence	Load sequence will start	Load sequence have started
21	FSP	Power up the machine	Move up (step 0)	Moved up
22		Up sensor met (step 0 complete)	Move left and in (step 1)	Moved left and in
23	Load Sequence	Select load sequence and start the sequence. Up, left	Move down (step 2)	Moved down

		and in sensors met (step 1 complete)		
24		Down sensor met (step 2 complete)	Close gripper (step 3)	Closed gripper
25		Close gripper met (step 3 complete)	Move up (step 4)	Moved up
26		Up sensor met (step 4 complete)	Move out (step 5)	Moved out
27		Out sensor met (step 5 complete)	Move down (step 6)	Moved down
28		Down sensor met (step 6 complete)	Open gripper (step 7)	Opened gripper
29		Open gripper met (step 7 complete)	Move up (step 8)	Moved up
30		Up sensor met (step 8 complete)	Start a 5s on delay timer(step 9)	Started 5s on delay timer
31		5s count down finished (step 9 complete)	Move down (step 10)	Moved down
32		Down sensor met (step 10 complete)	Close gripper (step 11)	Closed gripper
33		Close gripper sensor met (step 11 complete)	Move up (step 12)	Moved up
34	Load Sequence	Up sensor met (step 12 complete)	Move right (step 13)	Moved right
35		Right sensor met (step 13 complete)	Move down (step 14)	Moved down
36		Down sensor met (step 14 complete)	Open gripper (step 15)	Opened gripper
37		Open gripper sensor met (step 15 complete)	Move up (step 16)	Moved up
38		Up sensor met (step 16 complete)	Start 5s on delay timer(step 17)	Started 5s on delay timer
39		5s count down finished (step 17 completed)	Move down (step 18)	Moved down
40		Down sensor met (step 18 completed)	Close gripper (step 19)	Closed gripper
41		Close gripper sensor met (step 19 completed)	Move up (step 20)	Moved up
42		Up sensor met (step 20 completed)	Move in (step 21)	Move in
43		In sensor met (step 21 completed)	Move down (step 22)	Moved down
44		Down sensor met (step 22 completed)	Open gripper (step 23)	Opened gripper
45		Open gripper sensor met (step 23 complete)	Move up (step 0)	Moved up
46		Up sensor met (step 0 complete)	Move left and wait for commands (step 1)	Moved left and waited for commands

47	Unload Sequence	Unload sequence selected and start sequence pressed up, left and in sensors met (step 1 complete)	Move down (step 30)	Moved down
48		Down sensor met (step 30 complete)	Close gripper (step 31)	Closed gripper
49		Close gripper sensor met (step 31 complete)	Move up (step 32)	Moved up
50		Up sensor met (step 32 complete)	Move right (step 33)	Moved right
51		Right sensor met (step 33 complete)	Move down (step 34)	Moved down
52		Down sensor met (step 34 complete)	Open gripper (step 35)	Opened gripper
53		Open gripper sensor met (step 35 complete)	Move up (step 36)	Moved up
54		Up sensor met (step 36 complete)	Move out and left (step 37)	Moved out and left
55		Out and left sensor met (step 37 complete)	Move down (step 38)	Moved down
56		Down sensor met (step 38 complete)	Close gripper (step 39)	Closed gripper
57		Close gripper met (step 39 complete)	Move up (step 40)	Moved up
58		Up sensor met (step 40 complete)	Move right and in (step 41)	Moved right and in
59		Right and in sensor met (step 41 complete)	Move down (step 42)	Moved down
60		Down sensor met (step 42 complete)	Open gripper (step 43)	Opened gripper
61		Open gripper sensor met (step 43 complete)	Move up (step 44)	Moved up
62		Up sensor met (step 44 complete)	Move out (step 45)	Moved out
63		Out sensor met (step 45 complete)	Move down (step 46)	Moved down
64		Down sensor met (step 46 complete)	Close gripper (step 47)	Closed gripper
65		Close gripper sensor met (step 47 complete)	Move up (step 48)	Moved up
66		Up sensor met (step 48 complete)	Move in (step 49)	Moved in
67		In sensor met (step 49 complete)	Move down (step 50)	Moved down
68		Down sensor met (step 50 complete)	Open gripper (step 51)	Opened gripper
69		Open gripper sensor met (step 51 complete)	Move up (step 0)	Moved up
70		Up sensor met (step 0 complete)	Move left (step 1)	Moved left

71	Unload Sequence	Up, in and left sensors met (step 1 ready)	Wait for commands (step 1)	Waited for commands
72	Freezing the sequence	The "stop" bottom is pressed	The sequence will freeze	The sequence have frozen
73		The "start" bottom is pressed	The sequence will restart	The sequence have restarted
74	Counter	Part is place on the entrance chute	Counter count one up	Counter counted one up*
75		Part leaves the machine (load sequence step 23)	Counter count one down	Counter counted one down*
76		Unload sequence is activated (unload sequence step 51)	Counter reset	Counter reseted
77	Object sensor	Object is pushed down the entrance chute and load sequence and auto mode is activated	Start the load sequence	Started the load sequence
78	Step Counter	Current step display	Show current step	Showed current step
79		Next step display	Show next step	Showed next step

Table 2 testing table of the pick and place robot

*Counter not always behaves as it should, that is due to lack of a object sensor on the exit chute and the counter relies on the sequence's end step, which, if the robot's loading sequence been started manually being empty will latch as it will try to count negative, that is the reason for the "#" in the parts count seen on Fig. 30Fig. 34.

The robot is starting the load sequence (if selected) automatically when a part is placed on entrance chute and in those conditions the counter works as expected. If the sequence is started manually then the counter can latch up as described above.



Fig. 25 left and right movement of the robotic arm

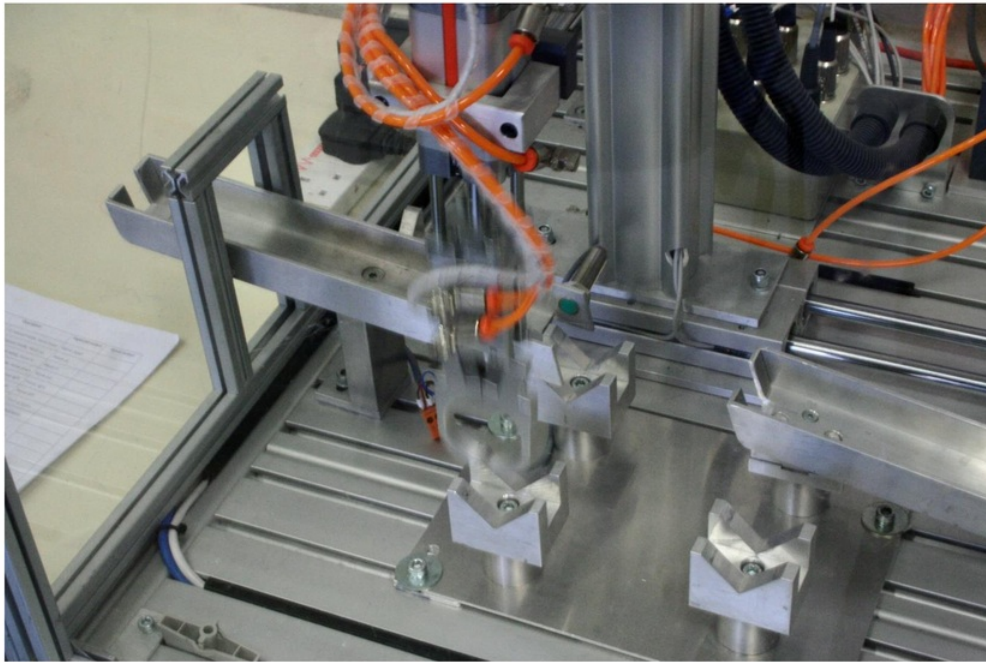


Fig. 26 up and down movement of the robotic arm

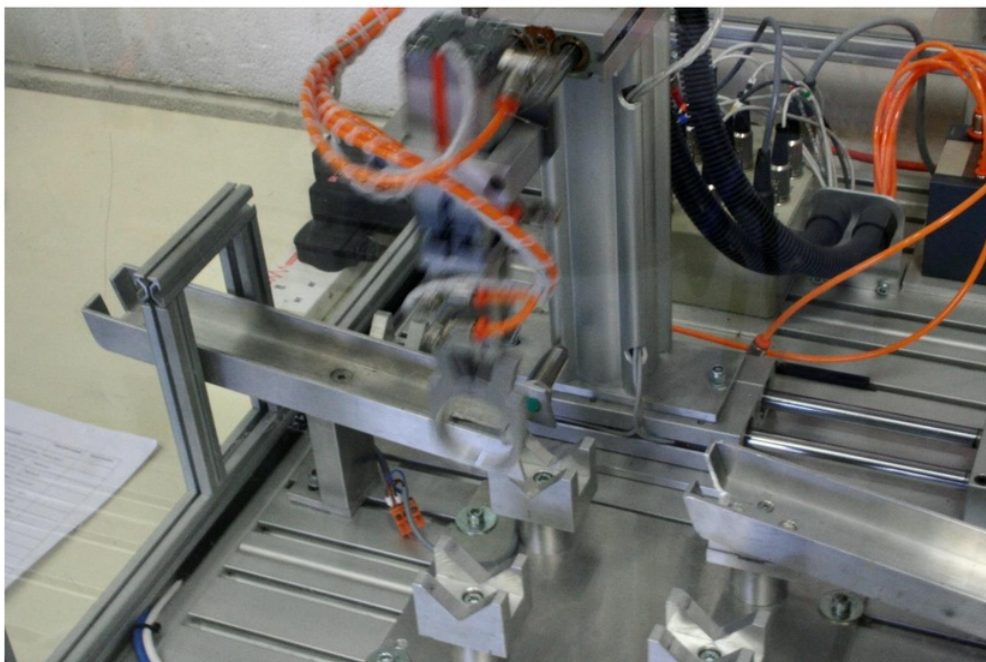


Fig. 27 in and out movement of the robotic arm

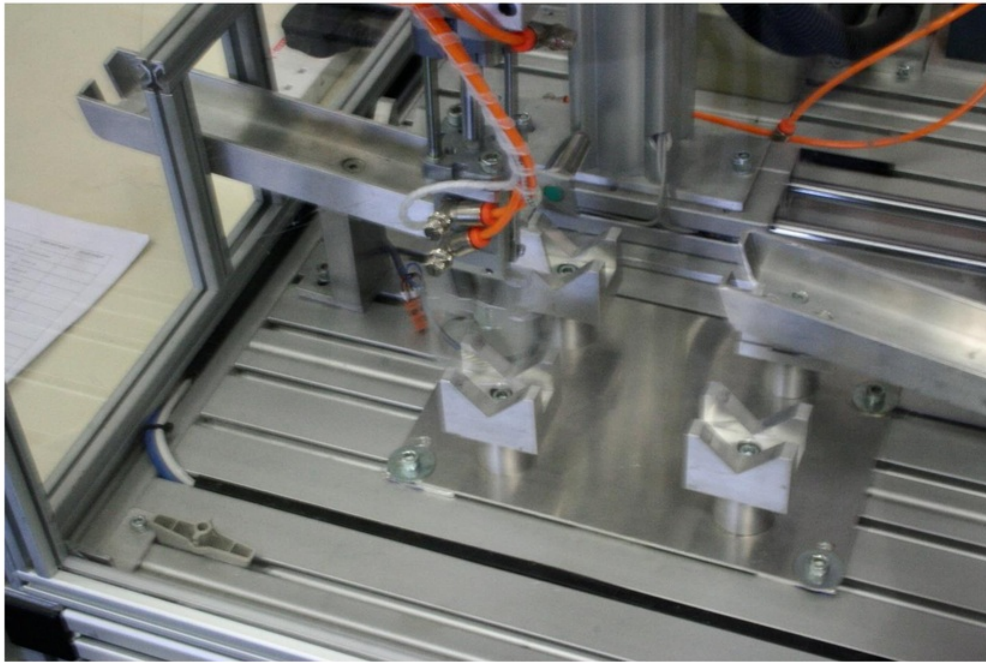


Fig. 28 gripper opening and closing

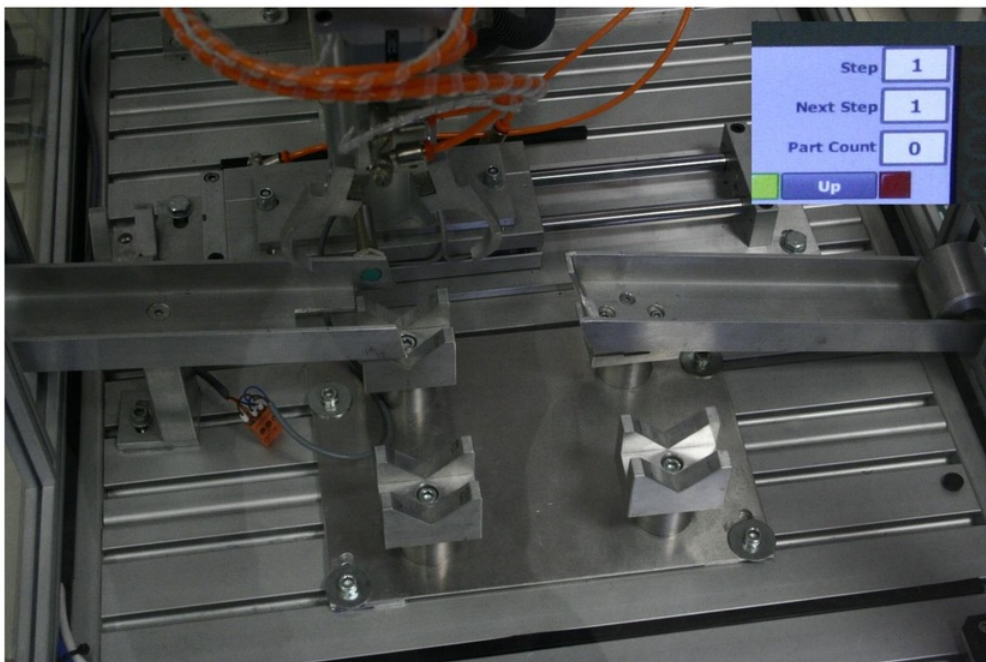


Fig. 29 gripper in home position, step 1

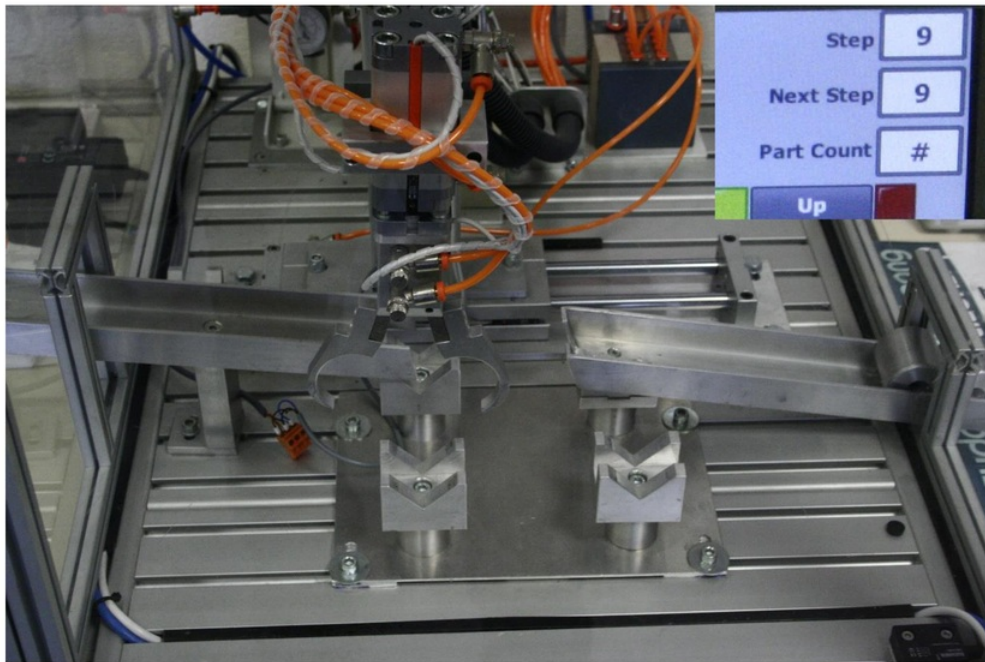


Fig. 30 robot on the 5s wait above station 2, step 9

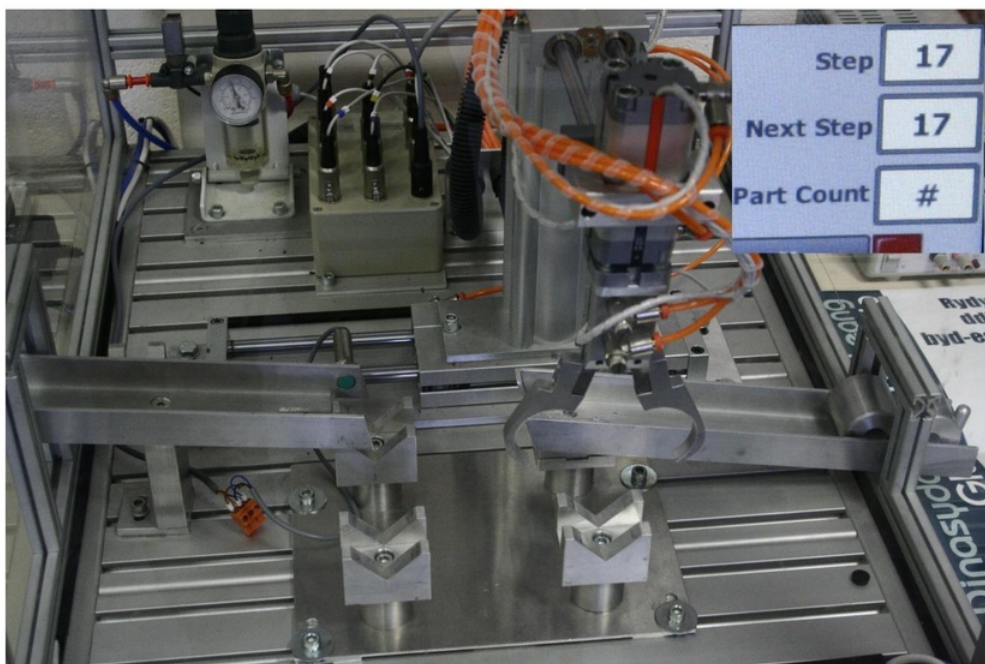


Fig. 31 robot on the 5s wait above station 3, step 17

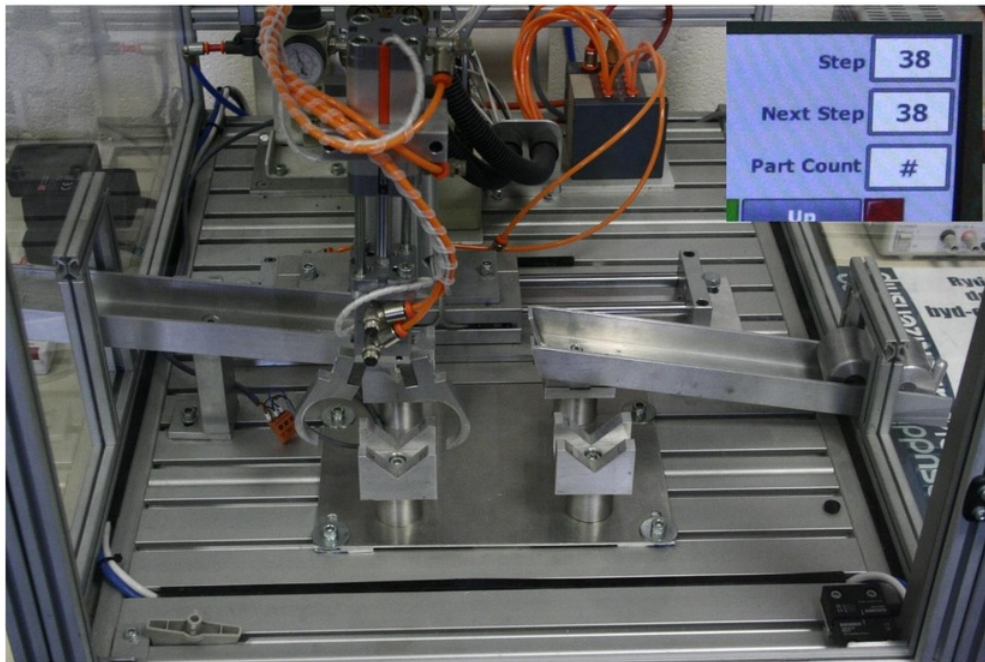


Fig. 32 robot unloading station 2, step 38

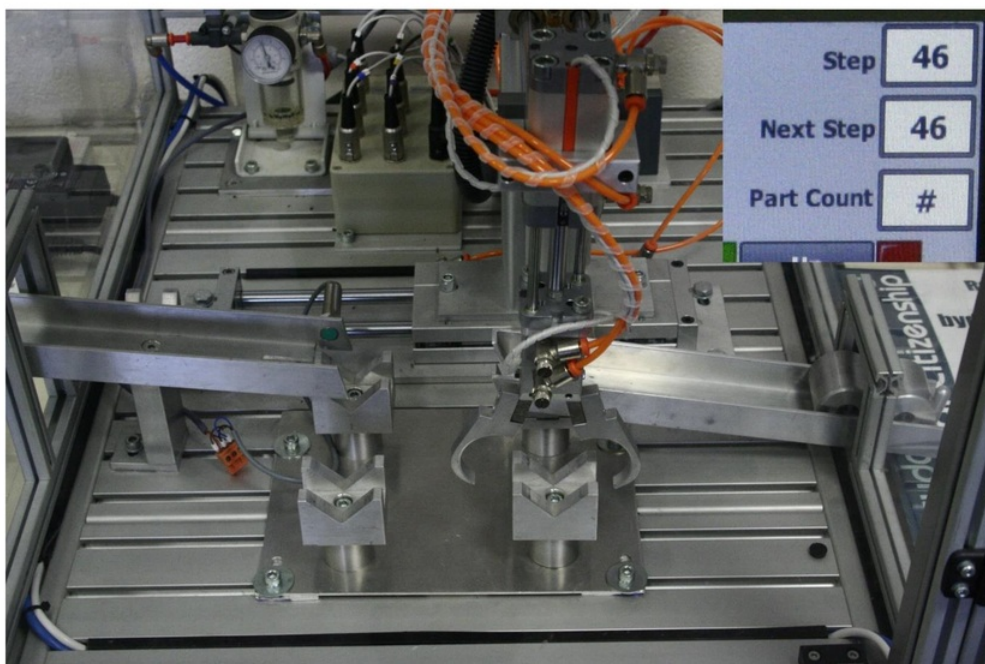


Fig. 33 robot unloading station 3, step 46

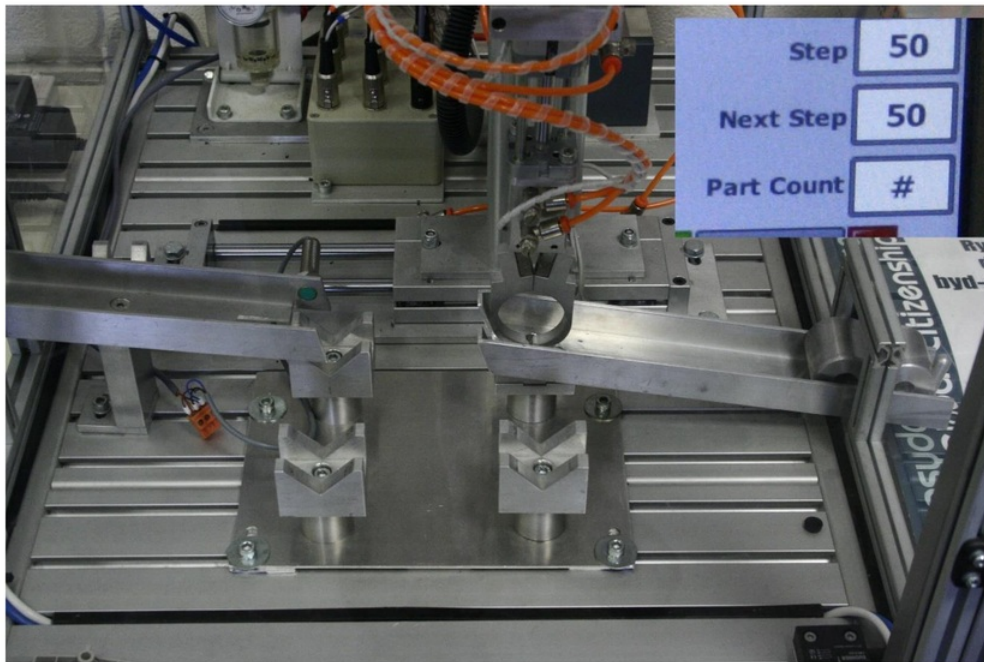


Fig. 34 robot finishing unloading sequence, step 50

5. Conclusions and recommendations

The aims and objectives have been completed as the robot have been programmed and tested according to the specifications given. The concepts and theory used for this and previous assignments have been well understood and employed, as an example: sequence programming, comparison and logic functions, ability of using all three programming languages.

It is recommended, for safety and more control reasons, to implement another three object sensors, one in station 2, one in station 3 and one in the exit chute. The sensors in the station would prevent any possible collisions of a closed gripper with any possible part already on the station as well as it would give more information about what is happening inside the robot. The sensor in the exit chute will allow a better functionality of the up/down counter of the parts inside as well, if placed close to the station 4, would detect when the chute is full and will stop the robot from colliding with part actually there. With those sensors implemented there wouldn't be a need for a counter as every station would be monitored. It is recommended to implement a dispensing rotatory solenoid as if two parts are put in the entrance chute the robot will collide with them, that would need another sensor on station 1. To implement all the additional sensors (a total of 4), the pushbuttons and/or toggle switches could be removed to free the 2 needed inputs apart from the 2 that are already free, having an HMI screen make those pushbuttons and toggle switches unnecessary and that would save costs on the additional modules for the PLC. There would be no problems implementing the rotatory solenoid as there is two spare digital outputs.

Software wise it is recommended to implement a full auto sequence mode in which, when enabled, the robot would perform one run in unload mode to clear the stations and then run constantly in load mode. If the hardware recommendations will be implemented, when in full auto, the unload sequence would be activated only when unexpected objects are on any of the stations and the load mode would run constantly as long as there is part in the loading chute.

PSDE4005 Assignment 2 Adam Bedner

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

79/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

Text Comment. Very useful explanations

PAGE 5

PAGE 6

PAGE 7

Text Comment. An accurate diagram

PAGE 8

Text Comment. button?

PAGE 9

PAGE 10

PAGE 11

Text Comment. You should force the robot to move up when not over a station

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GRADING FORM: CSG-RUBIC

ADAM BEDNER

71

RESEARCH-INFORMED LITERATURE



n/a

KNOWLEDGE AND UNDERSTANDING

 Section 1: Hardware Investigation - Excellent, contains very useful information about the system. (10/10) Section 1: System Design and I/O list - A very detailed I/O list and a well design program and SFC chart. (9/10) Section 2: Program Explanation – A good explanation is provided for the sequence but the ladder networks could also have been explained. (6/10)

25

ANALYSIS

 Section 3: System Testing – A very detailed testing table has been provided with some supporting evidence in the form of photos. (9/10) Section 3: Maintenance and Reliability - Both issues have been considered and this is evidenced in the program and screen designs, testing and in the conclusions and recommendation sections. However, you could have included a separate subsection devoted to explaining how these issues have been addressed. (6/10) Section 4: Conclusions and Recommendations - Good with some useful recommendations. (7/10)

22

PRACTICAL APPLICATION AND DEP.

 Section 2: Program Network Comments - Each ladder network contains a brief title and comments. The SCL code for the automatic sequence contains some comments also. (6/10) Section 2: HMI Screen Designs – Excellent screen designs. You could have password protected the engineer's screen. (9/10) Section 3: Presentation of Test Results - Excellent presentation of results. (9/10)

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SKILLS FOR PROFESSIONAL PRAC.

