MANUFACTURING SYSTEMS AUTOMATION NMM3512-2122

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AUTOMATION DESIGN

A report submitted to the School of Computing and Engineering, University of Huddersfield, in part fulfilment of the Degree of Master of Science in

MSc Engineering Control Systems and Instrumentation

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19th November 2021

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1. INTRODUCTION

A major advantage of an ever-improving knowledge and technology is the ability to transfer certain tasks and manufacturing processes to machines. Such tasks include ones that are inherently hard and repetitive, thereby improving peoples' quality of life while at the same time, improving the yield of the process. In an industrial setting, mechanical relays which were used for switching circuits could not meet up with the speed and durability of most industries, hence a programmable logic controller (PLC) which greatly enabled automation of tasks came to be.

1.1. Aim

To design part of a safe and functional automated manufacturing process with the use of a PLC.

1.2. Objectives

- Define a manufacturing process which includes transporting components and stopping them at a point on a conveyor to perform inspection.
- Include timing and counting capabilities in the process.
- Make use of switches, sensors, pushbuttons, and a conveyor belt.

2. DESCRIPTION OF AUTOMATION TASK

This design automates part of a popcorn manufacturing process that includes the filling of a desired number of sachets in a box, sorting of the boxes such that the number of sachets within the box and the weight of every shipped box remains consistent, thereby improving quality assurance. Table 1 details the hardware employed for this task and the reason they were chosen.

Table 1: Hardware chosen and justification

<table>
<tr><th>SN</th><th colspan="3">Device</th><th>Justification</th></tr>
<tr><td rowspan="7">1</td><td rowspan="7">Modular PLC</td><td colspan="2">Q03UD CPU [1]</td><td rowspan="7">To allow for a possible expansion of the process when the need for more production of the popcorn arises.
The photoelectric sensor gives output in voltage, so Q64AD module was used for it whereas the load cell gives output in resistance and so Q61LD module was used for it.
The QX80 module was used for the digital inputs, QY10 module was used for the digital outputs and QJ1E71-100 module was used to communicate with the HMI via ethernet protocol.</td></tr>
<tr><td colspan="2">QX80 Input module [2]</td></tr>
<tr><td colspan="2">QY10 Output module</td></tr>
<tr><td colspan="2">QJ1E71-100 Intelligent module [3]</td></tr>
<tr><td colspan="2">Q64AD converter module [4]</td></tr>
<tr><td colspan="2">Mitsubishi Q61LD Analogue to Digital converter [5]</td></tr>
<tr><td colspan="2">Q38B/Q63P Power supply</td></tr>
<tr><td>2</td><td colspan="2">Emergency switch</td><td rowspan="5">Input</td><td>Serves as an immediate safety measure</td></tr>
<tr><td>3</td><td colspan="2">On/Off switch</td><td>A switch was preferred over double push buttons for its simplicity and the less space taken up on the HMI display.</td></tr>
<tr><td>4</td><td colspan="2">Photo-optic sensor [6]</td><td>Detects the location of a sachet/box on the conveyor.</td></tr>
<tr><td>5</td><td colspan="2">Photo-electric proximity sensor [7]</td><td>Detects the presence of a box.</td></tr>
<tr><td>6</td><td colspan="2">Load cell [8]</td><td>Measures the weight of the box.</td></tr>
<tr><td>7</td><td colspan="2">Solenoid</td><td></td><td>Drives the pneumatic valve that controls the push arm and box stopper</td></tr>
</table>

8	Stepper motor	Output	Its unit step or combination of unit steps will equate to the exact length a sachet or box will occupy on the conveyor thereby ensuring fairly accurate metering of the sachets and boxes on the conveyor. No need for the extreme precision that a servo motor provides, also cheaper than a servo motor.	Controlled with a stepper driver
9	AC induction motor		Will be used to drive a conveyor that will be in continuous motion at a constant speed, hence no need for precise displacement.	Controlled with a variable frequency drive (inverter).

2.1. Hardware connection to the PLC

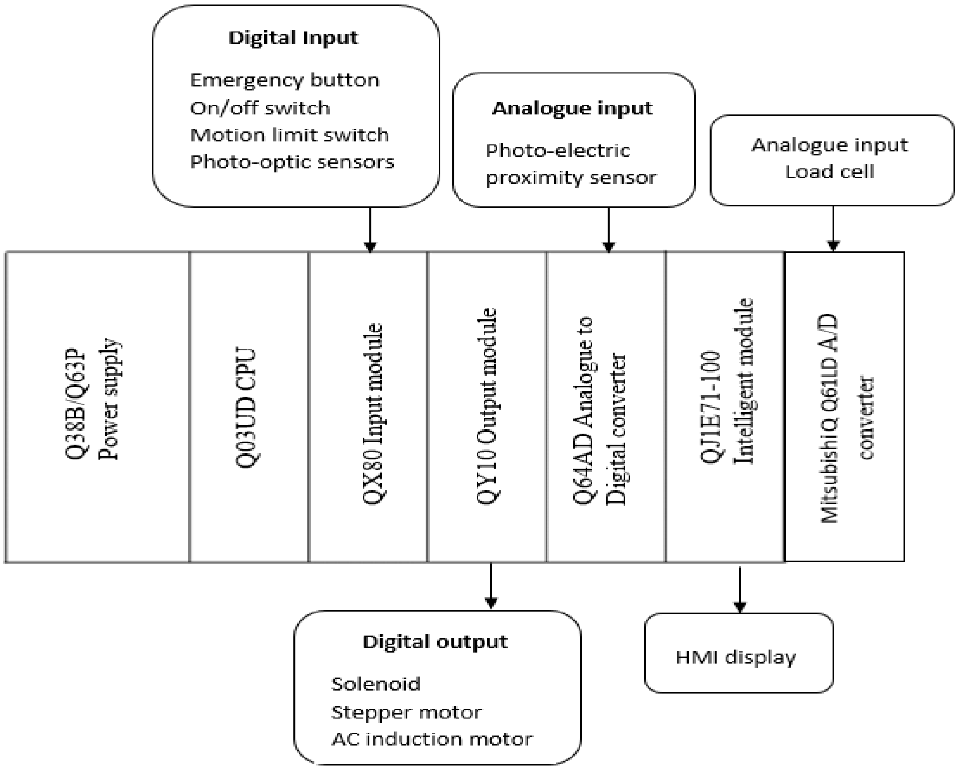


Figure 1: Hardware connection to PLC

2.2. Analogue input

Table 2: Analogue Sensors

SN	Analogue Sensor	Range
1	Applied Measurements OBUG platform load cell [8]	0-5000 grams
2	XUB1BPANL2 Photo-electric sensor [7]	0-5500 mm

2.2.1. Scaling of the input values:

Q64AD Converter module digital output range (x axis): 0-4000. See appendix A
Q61LD Analogue to Digital converter output range: 0-10,000. See appendix B
Photoelectric sensor range: 0-5500mm. See appendix C
Load cell range: 0-5000g. See appendix D
Y value for photoelectric sensor = 10mm
Y value for load cell =1700g

$$Y = (ymax - ymin) * (norm.x) + ymin \qquad \text{.....1}$$

But $norm.x = \frac{x}{xmax}$ 2

$$Y = (ymax - ymin) * \left(\frac{x}{xmax}\right) + ymin \qquad \text{.....3}$$

$$x = \frac{(Y - ymin) * xmax}{(ymax - ymin)} \qquad \text{.....4}$$

$\therefore \frac{(10-0)*4000}{(5500-0)} = 7.28$ (X value for photo-electric proximity sensor) …..5

$\therefore \frac{(1700-0)*10000}{(5000-0)} = 3400$ (X value for load cell) …..6

3. SYSTEM INPUTS AND OUTPUTS

Table 3: System inputs and outputs

Input				
S/N	Name	Device	Type	Device tag
1	Emergency Stop	Push Button	Normally closed	X1
2	Start/Stop switch	Switch	Normally open	X2
3	Batch reset	Push Button	Normally open	X7
4	Sensor 1	Motion limit switch	Normally open	X3
5	Sensor 2	Photo-optic sensor	Normally open	X4
6	Sensor 3	Photo-optic sensor	Normally open	X5
7	Sensor 4	Photo-optic sensor	Normally open	X6
8	Sensor 5	Load cell	Normally open	D2
Output				
9	Box stopper actuator	Solenoid	Coil	Y10
10	Push Arm actuator	Solenoid	Coil	Y15
11	Conveyor A	Stepper motor		Y11
12	Conveyor B	Stepper motor		Y12
13	Conveyor C	AC induction motor		Y13
14	Conveyor D	Stepper motor		Y14

4. ORGANISATION AND STRUCTURE OF LOGIC

Main POU: Starts up the program, engages the first two conveyors and holds most commands that controls the movement of the conveyors as shown in Figure 3.

Timing POU: Determines how long conveyor D remains stopped.

Weighing POU: Measures and compares a box’s weight with a set weight.

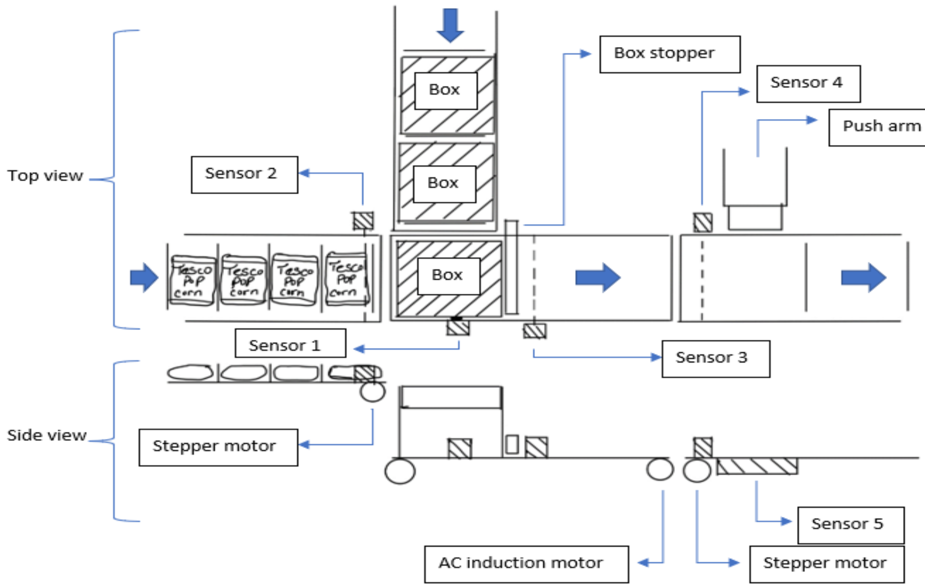


Figure 2: Top and side view of the Process diagram

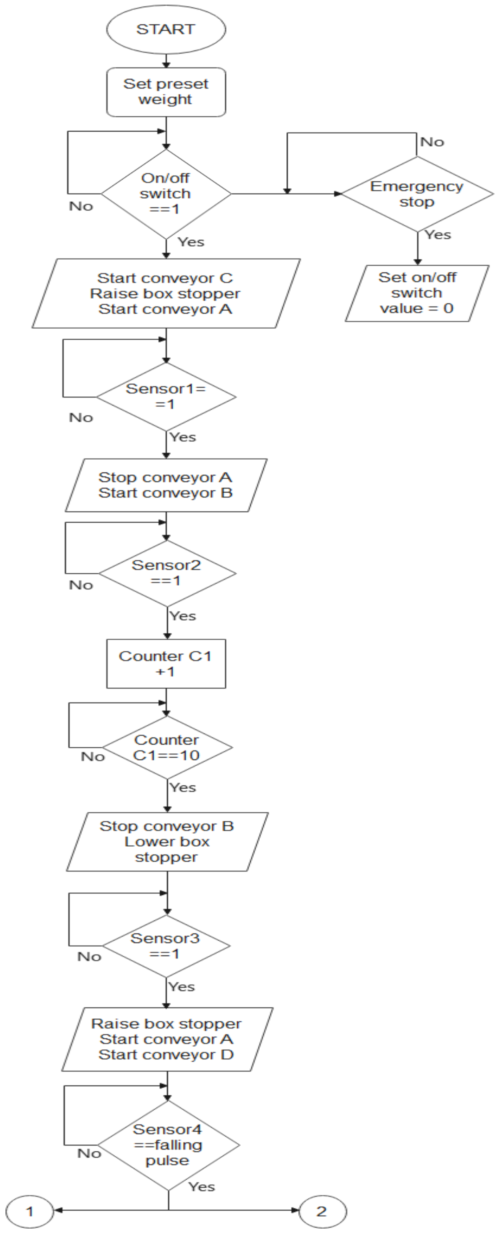


Figure 3: Main POU

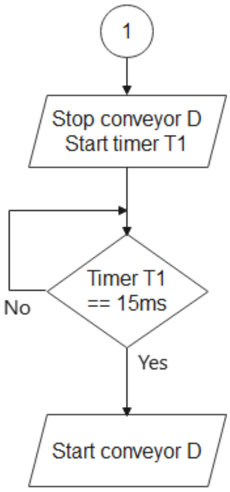


Figure 4: Timing POU

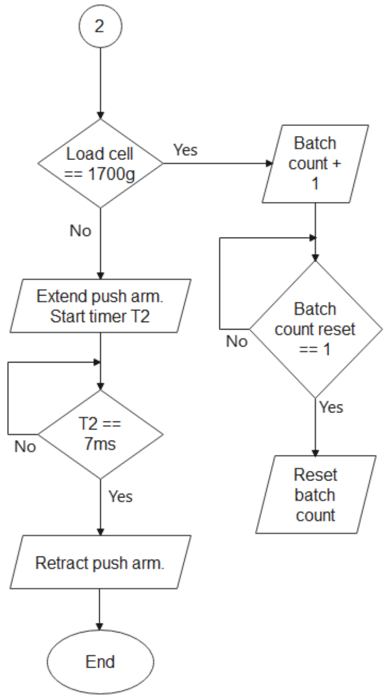


Figure 5: Weighing POU

4.1. Description of selected parts of program

The function block: Contains the logic for the scaling of the analogue input. It was used for the two instances of analogue inputs in this program and Figure 6 shows its implementation in the weighing POU.

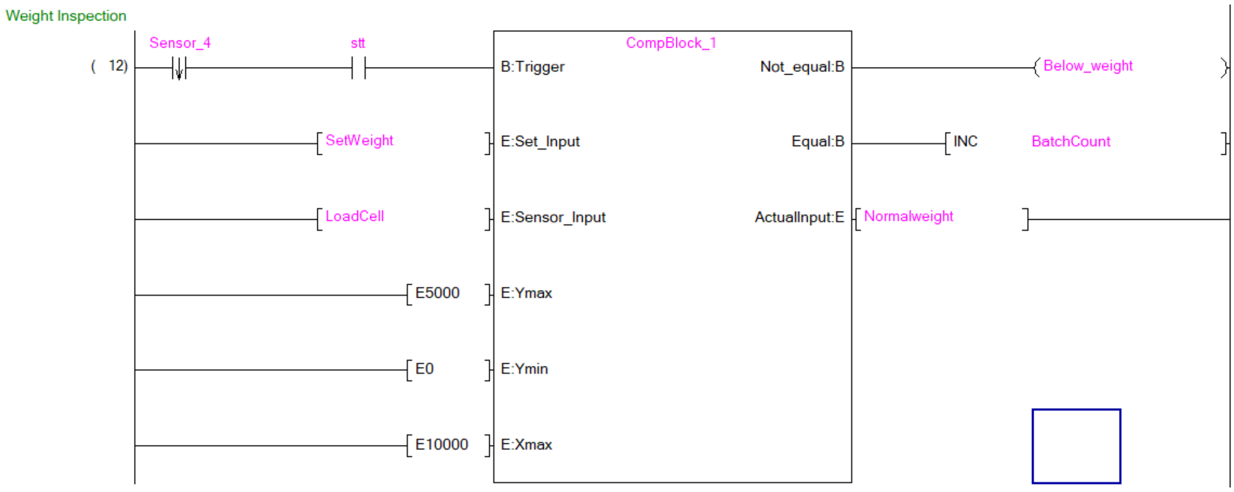
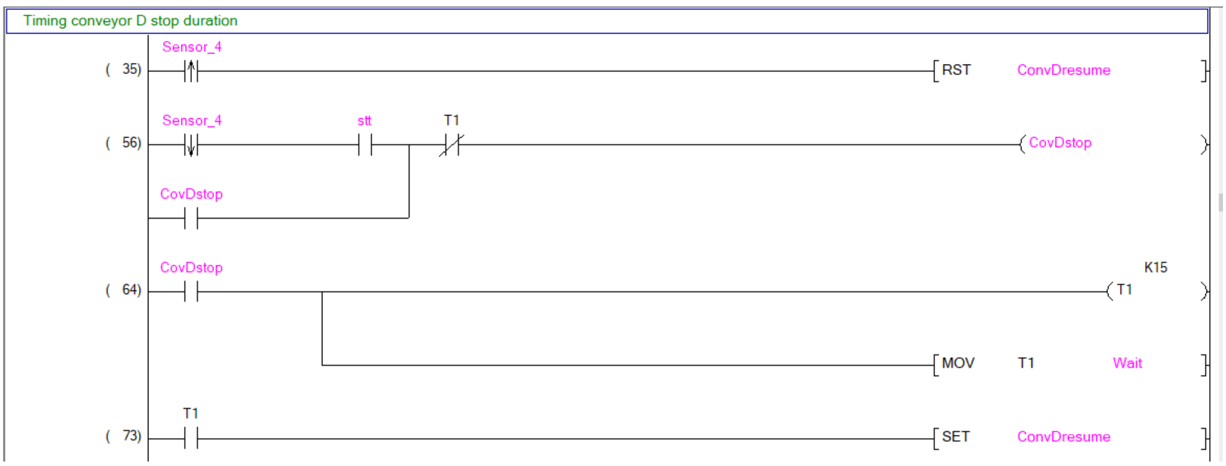


Figure 6: Function block

Timers and Latching: Figure 7 illustrates the use of timers to implement a delay when Conveyor D stops. Latching convDstop ensures that conveyor D remains stopped until the timing is complete.



Counters: Counter C1 was used to indicate the number of sachets detected by the sensor and when the count gets to 10, it triggers the stop of conveyor B as shown in Figure 8.

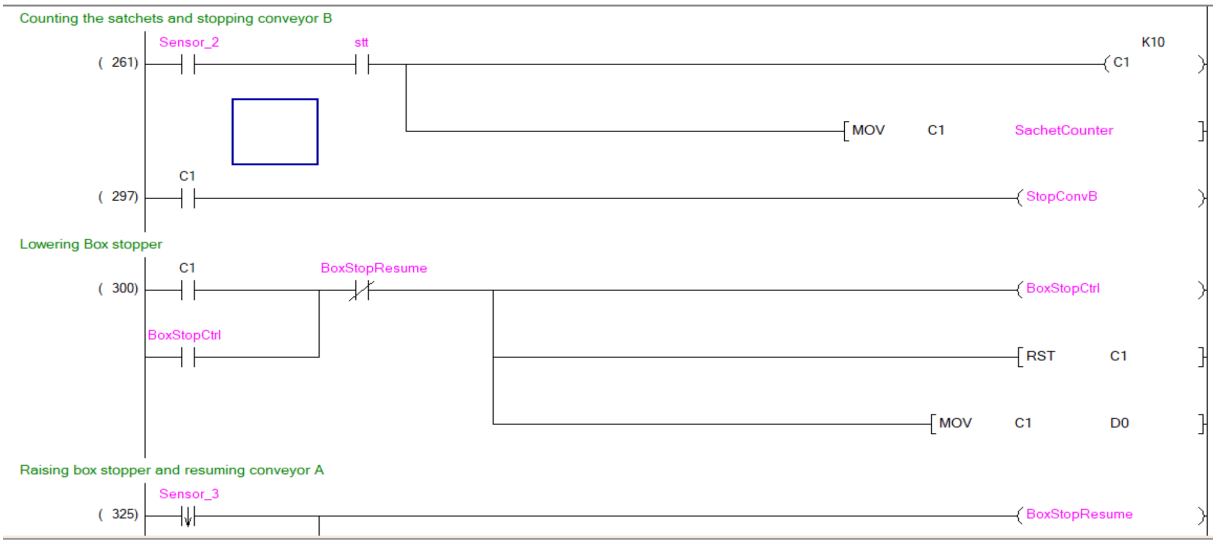


Figure 8: Counters

5. HUMAN MACHINE INTERFACE

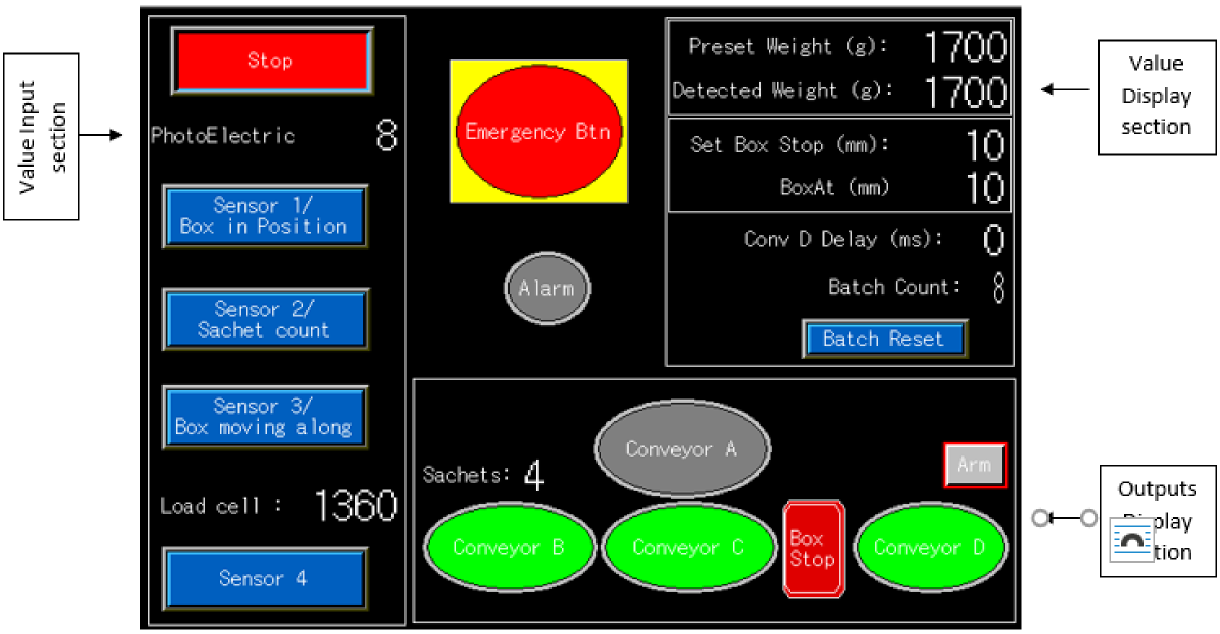


Figure 9: HMI

The HMI consists of three segments. The inputs, values and outputs display. The emergency push button and alarm are positioned at the centre of the HMI. The stop switch turns red when on and stays green when off. The conveyors turn green when active and grey when off. The box stopper turns red when raised and grey when lowered. The push arm turns yellow when extended and grey when retracted. Batch reset is a virtual push button.

6. OPERATING MANUAL

1. Press the **on/off switch** to turn on **conveyors C and A**. The **Box stopper raises** as well.
2. Set the box stop distance to 10mm by inputting 7.28 in the photoelectric input terminal.
3. Press the **sensor 1 push button** to simulate that the photoelectric sensor has determined the box is in position. This stops **conveyor A** and starts **conveyor B**.
4. Press the **sensor 2 push button** to simulate each time a popcorn sachet enters the box from **conveyor B**. Once the **sachet count** is up to 10, **box stopper** lowers letting the box move along with **conveyor C**.
5. Press the **sensor 3 push button** to simulate that the presence of the box has been detected after the **box stopper**. This raises the **box stopper** and re-engages **conveyor A**.
6. Setting the **load cell value** to 3400 digital value, simulates that the load cell will have measured 1700g from a box and will display that on the values display section. Variating this value will also variate the detected weight of the box.
7. Pressing the **sensor 4 push button** pauses **Conveyor D** for some time, allowing the box to be weighed. If the value of the detected weight is not equal to 1700g, a **push arm** removes the box from the conveyor, but if weight is 1700g, the **batch count** will increase by one and the box will continue moving towards the other end of **conveyor D**.
8. The **batch reset button** resets the batch count when pressed.
9. Pressing the on/off switch at any point during operation will stop all active processes.
10. Pressing the **emergency button** at any point during operation also stops all active processes and engages the **alarm**.

7. CONCLUSION

The successful execution of this assignment demonstrates a clear understanding of the design and implementation of an automation task for a manufacturing process using a PLC, which includes the proper use of safety devices. Popcorn being a solid and edible product, also influenced the choice of sensors and actuators used amongst other considerations. The HMI was designed to be intuitive, easy to understand and navigate for an operator with little or no technical skills.

8. REFERENCES

[1] Mitsubishi Electric, "Programmable Controllers MELSEC-Q series [QnU] Reaching higher, to the summit of the Q Series | CPU," .

[2] Mitsubishi Electric, "MELSEC System Q Programmable Logic Controllers User's Manual MITSUBISHI ELECTRIC | QX80," 2003.

[3] Mitsubishi Electric, "Q Corresponding Ethernet Interface Module User's Manual (Basic) -QJ71E71-100 -QJ71E71-B5 -QJ71E71-B2," Available: https://ru3a.mitsubishielectric.com/fa/ru/dl/12468/QJ71E71_-_Users_Manual_(Basic)_SH(NA)-080009-U_(02.19).pdf.

[4] Mitsubishi Electric, "Analog-Digital Converter Module User's Manual -Q64AD -Q68ADV -Q68ADI -GX Configurator-AD (SW2D5C-QADU-E)," .

[5] Mitsubishi Electric, "Load Cell Input Module User's Manual -Q61LD," .

[6] Omron, "Omron Retroreflective Photoelectric Sensor Block Sensor data sheet," *Omron*, Available: https://docs.rs-online.com/788a/0900766b8142886b.pdf.

[7] Schneider Electric, "Product datasheet Characteristics XUB1BPANL2 photo-electric sensor -XUB -reflex -Sn 4m - 12..24VDC -cable 2m," .

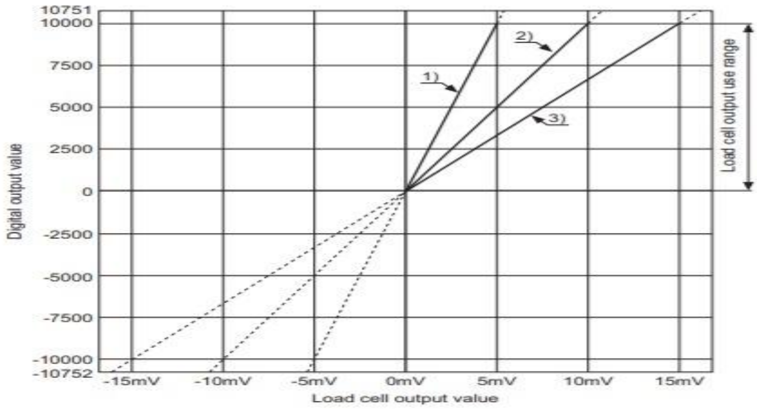
[8] Applied Measurements Ltd, "Platform Load Cell | Single Point Load Cell," *Applied Measurements Ltd*, Available: https://appmeas.co.uk/products/load-cells-force-sensors/platform-load-cell-obug/.

9. APPENDICES

9.1. Appendix A

(1) Analog to digital conversion characteristics

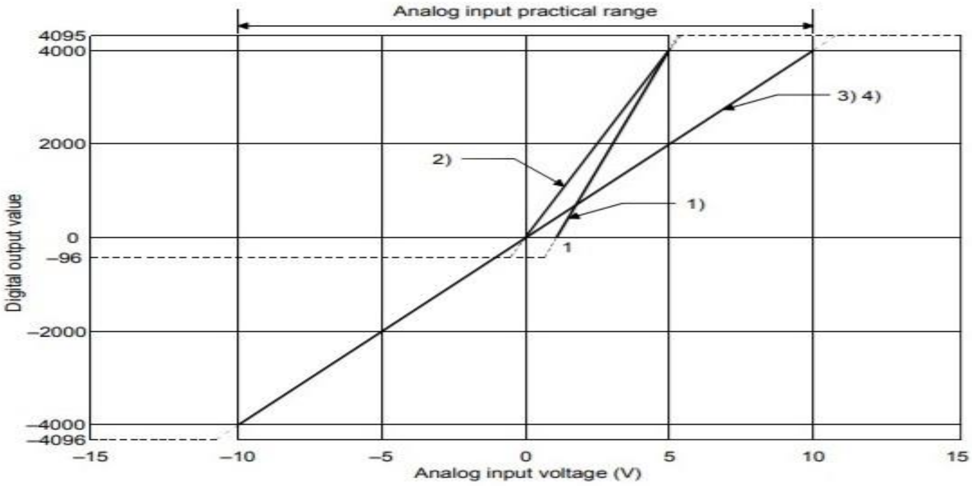
The following figure shows the analog to digital conversion characteristics of the Q61LD.



No.	Analog input range setting (load cell rated output)	Zero value	Span value	Digital output value*1	Maximum resolution
1)	1mV/V	0mV	5mV	0 to 10000	0.5μV
2)	2mV/V	0mV	10mV		1.0μV
3)	3mV/V	0mV	15mV		1.5μV

Figure 10: Mitsubishi Q Q61LD Analogue to Digital converter performance specifications [5]

9.2. Appendix B



Number	Analog input range setting	Offset value	Gain value	Digital output value *2	Maximum resolution
1)	1 to 5 V	1 V	5 V	0 to 4000	1.0 mV
2)	0 to 5 V	0 V	5 V		1.25 mV
3)	−10 to 10 V	0 V	10 V	−4000 to 4000	2.5 mV
4)	0 to 10 V	0 V	10 V	0 to 4000	2.5 mV
—	User range setting	*1	*1	−4000 to 4000	0.375 mV

Figure 11: Q64AD Analogue to Digital converter performance specifications [4]

9.3. Appendix C

Main	
Range of product	Telemecanique Photoelectric sensors XU
Series name	General purpose single mode
Electronic sensor type	Photo-electric sensor
Sensor name	XUB
Sensor design	Cylindrical M18
Detection system	Reflex
Material	Metal
Line of sight type	Axial
Type of output signal	Discrete
Supply circuit type	DC
Wiring technique	3-wire
Discrete output type	PNP
Discrete output function	1 NO
Electrical connection	Cable
Cable length	2 m
Product specific application	-
Emission	Infrared reflex
[Sn] nominal sensing distance	4 m reflex need reflector XUZC50

Complementary	
Enclosure material	Nickel plated brass
Lens material	PMMA
Maximum sensing distance	5.5 m reflex
Output type	Solid state
Add on output	Without
Wire insulation material	PvR

Figure 12: Photo-electric sensor specifications [7]

9.4. Appendix D

Technical Specifications

CHARACTERISTICS	OBUG	OBUG	OBUC	UNITS
Rated Capacity (RC)	0-0.25, 0-0.5, 0-1, 0-2	0-3, 0-5, 0-10, 0-15, 0-20, 0-30, 0-40	0-10, 0-15, 0-20, 0-30, 0-50, 0-100, 0-200	kgf
Operating Modes	Compression only			
Sensitivity (RO)	1.5 nominal	2±10%	2±10%	mV/V
Maximum Platform Dimensions	200 x 200	350 x 350	400 x 400	mm
Zero Balance/Offset	<1	<1	<10	±%/Rated Output
Creep (30 mins)	<0.08	<0.03		±%/Rated Capacity
Non-Linearity	<0.03			±%/Rated Capacity
Hysteresis	<0.02			%/Rated Capacity
Repeatability	<0.02			±%/Rated Capacity
Temperature Effect on Zero	<0.005	<0.002	<0.006	±%/Rated Capacity/°C
Temperature Effect on Sensitivity	<0.015	<0.002	<0.015	±%/Applied Load/°C
Effect of Eccentricity	<0.015	<0.006		±%/Rated Capacity/cm
Input Resistance	400 nominal			Ohms

Figure 13: Load cell specifications [8]