

SGEL6000 Independent Project

2020-2021

DOUBLE MARKING SHEET AND COMBINED STUDENT FEEDBACK

Assessment 1 of 4

Assignment 1: Project Definition, Research and Quality Planning

Agreed mark

47

Student Name: Sean Jones

Student Number 1602826

Generic Assessment Criteria	Marks available	1st Marker (RD)	2nd Marker (MH)	Agreed Mark
1. Engagement with Literature Skills.				
Section 5: Engagement in research, judicial use and critical evaluation sources, depth of literature review of solutions (5/10) There is some evidence of research with respect to the robot and machine safety with regulations considered. (RD) An average range of sources are listed in the reference list.(MH)	10	5	5	5
Sections 3, 5 and 8: Extent of reading, use of credible sources, use of Harvard method for listing and citing (3/5) There is evidence of a good range of sources correctly cited and listed in most cases. (RD) Limited sources used, several entries in the reference list do not appear to be cited, citations restricted to a limited number of sources such as Staubli. (MH)	5	3	2	3
Total	15	8	7	8
2. Knowledge and Understanding Skills				
Section 3: Project background and context, commercial, economic and social context (4/10) Briefly stated with commercial and other factors considered. (RD) Executive summary and introduction lacked specific detail as to what the problem was, what the "parts" referred to actually entailed and how the problem would be solved (MH)	10	5	4	4
Section 3: Project constraints, professional and ethical conduct, codes of practice, standards, security, intellectual property, legal requirements etc. (5/10) Good consideration given to most aspects (RD) Some mention of generic standards in the FDS (MH)	10	5	4	5
Section 3: Environmental and sustainability limitations and promotion of sustainable development (3/5) Some consideration given (RD) Little consideration of these in the report, just a generic statement of the company's standards and codes of practice (MH)	5	3	2	3
Section 3: Project risks, health and safety etc. (3/5) Good consideration given with use of PL rating (RD) Main risks to the project were from company management pulling the project from him and COVID 19 shut down (MH)	5	3	3	3

Total	30	16	13	15
3. Cognitive and Intellectual Skills				
Section 3: Problem Definition (3/5) Some parts give a good explanation yet little it said of the vision system (RD) Broadly defined with specifics only becoming apparent later in the report (MH)	5	3	2	3
Section 4: Functional Design Specification (6/10) Some sections are detailed but nothing much said about the requirements of the vision system and what the different the components to be distinguish and picked up would look like (RD) FDS was explained with good detail (MH)	10	6	6	6
Section 4: Test planning (2/5) A good list of tests but columns should be added showing expected and actual results rather than a simple column for pass-fail. This system could not be tested by a third party using this table. (RD) A comprehensive test plan is included, however this lacked clarity of metrics on some tests, e.g. "correctly aligned", "easily loaded". It also included project success criteria such as being on budget. (MH)	5	2	2	2
Section 7: Conclusions and Recommendations (3/5) Good comments made, project is on track for completion in the new year.(RD) This section was more descriptive than evaluative.(MH)	5	3	2	3
Total	25	14	12	14
4. Practical Application Skills				
Section 5: Critical choice and justification of final solution (2/5) Solution choice is valid but only relates to the safety aspects of the project. (RD) 3 solutions given and comprehensive grading of each was explained, justification for final choice was mentioned. Budget of £12,500 was mentioned in the proposal and introduction, yet solution chosen only cost £91.56. From the assessment given, Solution 2 seems the best option yet Solution 1 was chosen. (MH)	5	2	3	2
Section 6: Project Planning, working breakdown structure and management techniques. (4/10) Good evidence of planning but Gantt chart could contain more detailed tasks. Management techniques are relevant. (RD) Gantt chart and WBS used as planning tools, both of these lacked detail and were very basic in nature. (MH)	10	4	3	4
Total	15	6	6	6
5. Transferable Skills for Life and Professional Practice				
Section 1: Executive summary (2/5) Brief (RD) Lacked a lot of detail and didn't give a reader unfamiliar with the project much insight into the why, what and how aspects of the project. (MH)	5	2	2	2
All Sections: Quality of the report – (2/5) Well structured and generally well presented. However, it contains many grammatical, spelling and punctuation errors. You must learn to proof read your work before submission. (RD) Grammatically poor at times, some smaller diagrams didn't need to be in the annex (MH)	5	2	2	2

Word count – (0/5) Exceeded. (RD) Word count exceeded (MH)	5	0	0	0
Total	15	5	4	4
Grand Total	100	49	43	47

Assignment 1 1602826

by Sean Jones

FILE	10202_SEAN_JONES_ASSIGNMENT_1_1602826_178708_1162541701.DOCX (1.48M)		
TIME SUBMITTED	11-DEC-2020 03:40PM (UTC+0000)	WORD COUNT	6905
SUBMISSION ID	139276179	CHARACTER COUNT	35750

Course: BSc (Hons) Electrical and Electronic Engineering
Module: SGEL6000 Independent Project
Assignment: 1. Project Definition, Research and Quality Planning
Name: Sean Jones
University number: 1602826
Date submitted: 11/12/2020
Word count: 4657

Contents

Executive Summary.....	5
Introduction	6
3. Project Background and Problem Definition and Constraints	7
3.1.1 Problem.....	7
3.1.2 Proposal	7
3.2. Environmental impact And Sustainability.....	8
3.3.1. Ethical.....	8
3.3.2. Health and safety	8
3.3.3. Security	8
3.3.4. Risks	8
3.4. Intellectual property	9
3.5. Codes of practice and standards.....	9
4. Functional Design Specification (FDS) and Test Plan	10
4.1 Overview	10
4.1.1 Conveyor:	10
4.1.2 Camera:	10
4.1.3 Robot:.....	10
4.1.4 Guarding:.....	11
4.2 Requirement	11
4.3 Electrical requirements	11
4.4 Basic machine sequence	13
4.5 ROBOT software requirement overview.....	14
4.6. Devices	14
4.6.1 push buttons, lamps & e-stops	14
4.6.2 Actuators.....	14
4.6.3 Proximity switches	14
4.6.4 Guard Switches	14
4.7 Safety performance	14
4.8 Performance	15
4.9 User community.....	15
4.9.1 Operator.....	15
4.9.2 Maintenance Engineer	15
4.10 Error & fault handling	15
4.10.1 Machine Error	15

4.10.2 Product Fault	15
4.11. Budget	15
4.12. Time scale	15
5. Testing Plan	16
6. Literature Review	17
6.1 Solution 1 – Robots internal system	17
6.1.1 justifications	17
6.1.2 Limitations.....	17
6.1.3 Function explanation	17
6.1.4 Parts required	18
6.1.5 Solution cost.....	18
6.1.6 Safety levels	18
6.2 Solution 2 – Safety PLC.....	19
6.2.1 justifications	19
6.2.2 Limitations.....	19
6.2.3 Function explanation	19
6.2.4 Parts required	19
6.2.5 Solution cost.....	20
6.2.6 Safety levels	21
6.3 Solution 3 – Safety Relays	22
6.3.1 justifications	22
6.3.2 Limitations.....	22
6.3.3 Function explanation	22
6.3.4 Parts required	23
6.3.5 Solution cost.....	23
6.3.6 Safety levels	24
6.4 Comparison	24
6.5 Chosen solution.....	25
7. Project Planning, Work breakdown and Management Techniques	26
7.1 Work breakdown.....	26
7.1.1 Electrical Design	26
7.1.2 Electrical Implementation	26
7.1.3 Electrical commissioning.....	26
7.1.4 mechanical design.....	27
7.1.5 Mechanical Implementation	27
7.1.6 Mechanical Commissioning	27

7.1.7 Software design	27
7.1.8 Software commissioning	27
7.1.9 Machine trails	27
7.1.10 FAT Test.....	27
7.1.11 Machine Manual	27
7.1.12 Documentation	27
7.2 Project Plan	28
7.3 Costing Plan.....	28
7.4 Management techniques	28
Conclusions and Recommendations	29
Citation List	30
Appendix	33
PROJECT PROPOSAL DOCUMENT	42
Figure 1 Block diagram.....	7
Figure 2 Basic sequence	13
Figure 3 Solution 1 block diagram.....	17
Figure 4 solution 2 block diagram for safety PLC.....	20
Figure 5 solution 3 block diagram	23
Figure 6 Work breakdown structure.....	26
Figure 7 Existing system	33
Figure 8 PL performance	33
Figure 9 Machine Risk Assessment	34
Figure 10 Controller safety circuit.....	38
Figure 11 Safety component selection	39
Figure 12 Pilz safety relay guide.....	39
Figure 14 Cost break down	41

Executive Summary

should be numbered as section 1

The project is based in an automation company that specialises in one off production machines. A project has been initialised to attract more customers to the company. A demonstration system has been decided to be implemented where customers can view on a company visit and when the company takes it to Automation shows. The system will include a robot and a vision system to sort parts off a conveyor. The specifics of the system includes a robot linked to a camera which identifies parts coming down a conveyor and sorts the accordingly.

spelling (RD)

There was a decision to be made on how the safety of the robot cell should work. it was researched and 3 possible solutions were compared. They were scored against each other and the method of using the robot's internal safety system was chosen even though it was equal on score to the safety PLC it was a cheaper solution a better suited to the budget.

*New sentences
should start with a capital letter (RD)*

spelling (RD)

The planning of the project was done through a work breakdown structure where all tasks became a week long and these were used on a timing plan gaunt chart. These stages have budgets which can be monitored alongside of the timing plan to ensure budget and time scale is maintained throughout the project.

spelling (RD)

The project has to be completed in a budget of £12,500. The implementation will start in January 2021 and will be completed by march 2021.

Introduction *this is section 2*

attrac

The aim of the project is to develop a demonstration system to ^{attract} source new customers. The clients tend to have large production lines needing automated systems. Robots are more commonly being integrated into these machines to reduce the number of people required to operate them which speeds up production lines and reduces overhead costs. The company is looking for ways to expand its customer base into this market also improving their employee's knowledge and understanding in programming. This will be a system that can be transported to automation events. The final product must demonstrate a typical system that the company produces. This will involve a robot and a camera to show the new direction the company is taking in automation within the food and health care industry

3. Project Background and Problem Definition and Constraints

3.1.1 Problem

Robots are more commonly being integrated into these machines to reduce the number of people required to operate them which speeds up production lines and reduces overhead costs. The clients tend to have large production lines needing automated systems. The company is looking for ways to expand its customer base into this market also improving their employee's knowledge and understanding in programming. *This is repeated from a previous section (RD)*

3.1.2 Proposal

A robotic demonstration rig suits this criterion as customers can see it running in shows and through company visits. Engineers and technicians can be trained using this system to improve quality on live jobs. The concept of the system involves a robot integrated with a vision system which can sort parts.

Figure 1 Block diagram shows the concept of this system where the 4 main parts are the Robot, Vision, Conveyor and safety. The parts used can be a 20mm cube made from nylon in the colour black and 20mm diameter cylinder by 20mm high from nylon in the colour black.

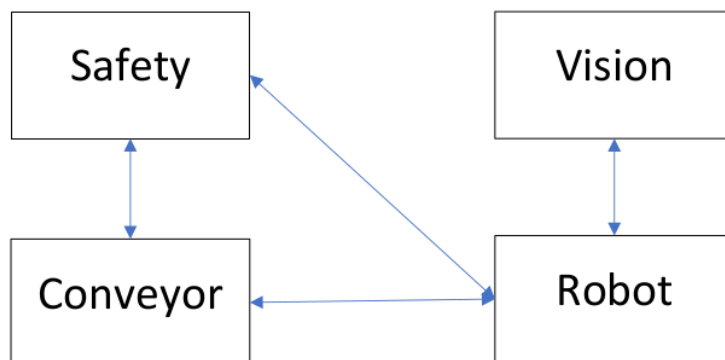


Figure 1 Block diagram

3.2. Environmental impact And Sustainability

For environmental reasons, the system will be made using recycled materials. The equipment shown in Figure 7 in the appendix, shows the current system which includes a Staubli TX40 6 axis robot, a 20mm aluminium base plate, item guarding frame work on wheels and a 300 x 1000mm belt conveyor positioned perpendicular to the robot. Currently no electrical design has been carried out on this system and this will be part of the project.

3.3.1. Ethical

what standards? (RD)

In order for the project to be ethical it must obey to all appropriate standards and safety regulations. The most appropriate safety systems must be used to make the machine as safe as possible so operators have low chance of injury. If required at any point in the project work can be subcontracted to spread work to external companies.

3.3.2. Health and safety

A risk assessment was undertaken to identify all the hazards and reduce the risks of injury. The conclusion of this risk assessment is shown in the appendix as Figure 9. HSE (2020) suggests that the risk assessment should consider the frequency of the hazard, danger level of the hazard and the possibility of avoiding the hazard. Every hazard gains a value and is added up at the end of the assessment as probability of someone getting injured. These values can be used to give a performance level. *spelling (RD)* Keyence states “required performance level (PLr) must be determined” (2020). The PLr graph completed is shown in Figure 8 in the appendix and shows the performance level of the machine is C. *spelling (RD)* Figure 11 shows the guide to part categorized selection from Omron (2020). This machine is category *thrashed? (RD)* 2/3.

3.3.3. Security

The machine will have all its programs password protected so that it can't be tampered with without an approved engineer. There will be no internet *punctuation (RD)* connection the machine will eliminate the risk of a cyber-attack. The user profile on the robot controller will be password protected to prevent to operator affecting the program.

3.3.4. Risks

The main technical risk of the project is the vision as the decision in which camera to use will affect the function of the system. The budget can be easily jeopardized if the incorrect vision system is chosen and doesn't work. Project planning risk will be the risk of Covid19 spreading in the workplace causing the factory being shut down for 2 weeks could adversely affect the project timing plan.

3.4. Intellectual property

There will be no patenting of this machine but drawings and programs may be copyrighted at the discretion of management at the end of the job. Budgeting of the job will be kept confidential to the company.

3.5. Codes of practice and standards

A technical file is going to be produced to satisfy Crown copyright (2008) as it states “ensure that the technical file is compiled and made available”. Company standards for project procedures will be complied to in order to make the project successful

*Direct
copyright
need a
page
number
(RD)*

*What other standards do you need to follow? More
citations needed here (RD)*

4. Functional Design Specification (FDS) and Test Plan

4.1 Overview

The company must allow the following processes on the customer demonstration rig

4.1.1 Conveyor:

Allow parts that *are (RD)* are placed on the conveyor to travel to the robot work area. As these parts move along the conveyor, they must funnel down into a single line and stop against a constant position. The part in the position must not get effected by the parts bunched up behind it and the 2nd part in the queue must not be affected when the 1st part gets picked up. The constant position will be referred to as the picking position.

4.1.2 Camera:

Take an image of the part in the picking position and determine the type of part that is ready for picking. This information is to be passed onto the robot for correctly placing procedure. The trigger for the camera must be pulsed to detect a part in the picking area to spare the use of a part present sensor.

4.1.3 Robot: *What do the parts look like, how many different types are there? (RD)*

Must home above the conveyor and wait for a signal to go pick a part. When it has picked a part it must then place the part in an appropriate position depending on what part its picked. After the part is placed it must wait for the next part to pick.

Figure 10 in the appendix shows the controller safety diagram from Staubli (2011) shows the safety module on the CS8 controller. The configuration of safety is limited to this circuit. According to Staubli (2011) it split into 2 sections with external E-stop and door inputs and internal e-stop status. According to this drawing the mode that is selected depends on the validation and e-stop of the robot. If it's in manual it will need a validation from the pendant to turn arm power on. If in auto it will also need this same validation. When in remote auto the CS8 controller can automatically validate its safety if the internal and external e-stops are healthy and arm power can be achieved. According to Staubli (2011) the doors can be overridden if the controller is in manual mode and the dead man switch is healthy on the pendant.

4.1.4 Guarding:

There must be guarding that stops the access to the robot when its running. This must have an ITEM aluminium extrusion frame and 4mm polycarbonate windows. This guard must have an access door which is integrated into the safety to still allow the robot to run in manual when its open. According to Knackstedt (2020) Due to the PL_r level Being C, any guards that are designed onto the machine must have interlocks integrated into the safety circuit. To allow the robot to run in manual with the door open there must be a hold to run button. BSI Group states "Hold-to-run controls shall require continuous actuation of the control device" (2010). According to Rockwell Automation (2014) non locking interlock switches will be safe enough on this machine but the robot will have to perform a very fast braking stop.

4.2 Requirement

1. Electrical enclosure for distribution and control
2. A list of the spare parts for this system will be placed in the machine manual.
3. Any related documentation for the project will be in English.
4. All drawings produced will be in DWG, DXF or PDF format.
5. The equipment and components will comply with UK and European standards and regulations. This will include:

BS EN 60404 – Electrical safety of machinery

BS EN 13849 – Safety Related Control Systems

BS EN 12100 – Machinery Risk Assessment

Machinery Directive 2006/42/EC

4.3 Electrical requirements

1. Incoming supply will be 240VAC 50Hz less than 16A so a conventional PCE socket can be used
2. Controls systems 24VDC
3. Inputs will be wired PNP
4. Outputs will be wired PNP
5. 240vac cables outside of the electrical enclosure must be SY cable
6. Only Tri-rated cable to be used
7. Cable ferals will be used where ever possible

8. Enclosure must be at least ip61
9. 20% spare IO must be given in case of future requirement
10. Incoming supply to the panel will be separated into terminals before entering the isolator.
11. An isolator must be fitted to isolate mains supply before entering the panel
12. Cable colouring will be as Table 1

Voltage	Colour
240vac live	Black
240vac neutral	Light blue
24vdc positive	Dark blue
0v	Dark blue

Table 1 cable colouring

4.4 Basic machine sequence

This is the sequence in which the machine must run when in automatic mode. A more detailed version must be put in the machine manual. Figure 2 shows this sequence.

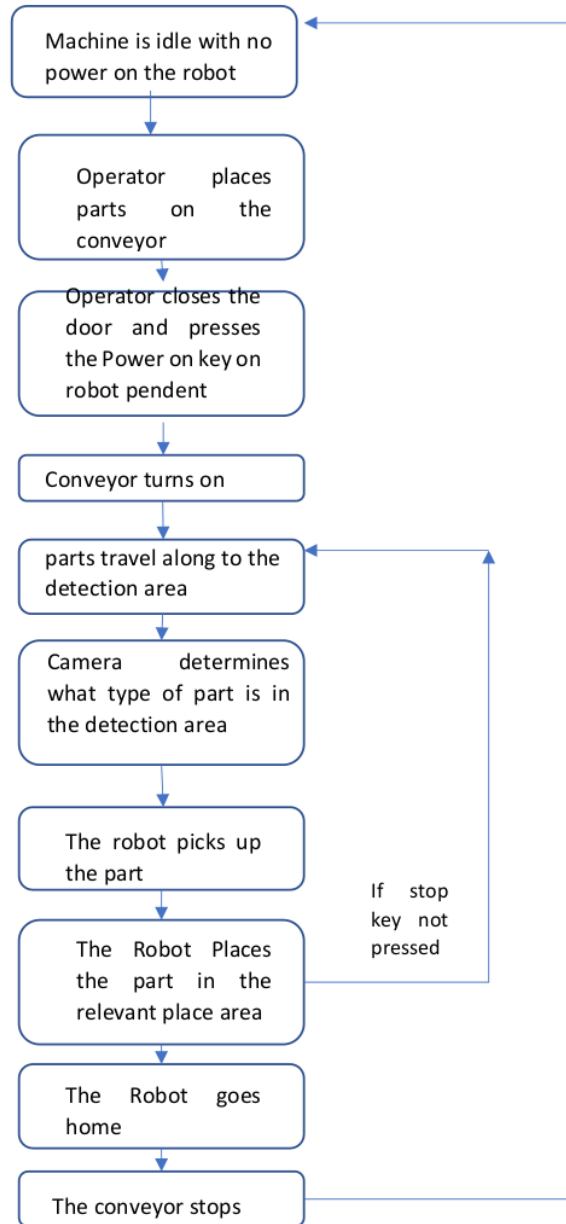


Figure 2 Basic sequence

4.5 ROBOT software requirement overview

The robot will have to have 2 running modes, Auto and manual. In Auto the robot will run at full speed when the user presses the control on button. In manual it will run at a reduced speed with the user having to hold the dead man switch on the robot pendant. The pendant will have to also display alarms and messages to help the user run the system.

4.6. Devices

4.6.1 push buttons, lamps & e-stops

The cell will have a control on button and an e-stop button. The control on button will allow the robot to have arm power if the estop circuit is healthy. The E-stop will have to prevent any robot movement as BSI Group ^{spelling (RD)} Sates "Once active operation of an emergency stop or emergency switching off actuator has ceased following a command" (2010). The E-stop status will need to be feedback to the robot so a message can be displayed if its pressed.

4.6.2 Actuators

The robot has 2 valves within its arm that can be used for switching the vacuum on and off. So no extra valves will be required.

4.6.3 Proximity switches

There is 1 proximity switch required to check there is a part in the detection area

4.6.4 Guard Switches

There will be 1 guard switch mounted on the cell entry door. there will need to be a feedback to the robot to display a message if this door is open.

4.7 Safety performance

All safety components must be at least C safety level. Because of the safety category required on the machine, Pilz states "a single fault in any of these parts does not lead to the loss of the safety function" (2011). According to Štohl (2017) Dual channel safety circuit on the E-stop and the guard door circuit would prevent this.

According to BSI Group (2010) if an e-stop is pressed it should remain in an e-stop state even if the e-stop is released. The machine should only go back to a healthy state when a reset or power on button is pressed. There shall be no automatic reset on the E-stop or guard door circuit. Omron (2020). A rising edge pulse shall reset (validate) the safety circuit to prevent a false restart if a button was stuck open or close.

4.8 Performance

The machine is targeted for 20 parts per minute at 100 % efficiency.

4.9 User community

4.9.1 Operator

1. Load Parts on the conveyor
2. Remove parts from the place areas

4.9.2 Maintenance Engineer

1. Clean down work stations.
2. Teach points of pick and place if necessary
3. Check the condition of the suction cup on robot

4.10 Error & fault handling

4.10.1 Machine Error

Operator will be notified by way of message on the robot pendant screen if a machine error has occurred.

4.10.2 Product Fault

If a part is present in the detection area and isn't the Circle or square then is put in a reject bin.

4.11. Budget

The project has to completed under £12,500 which includes hours of working on the project and bought outs. ^{?(RD)}

4.12. Time scale

The project has to have its concepts completed by the end of December ready to be designed in the new year. The final completion is March 2021 where the system has to be tested with the machine manual completed.

5. Testing Plan

To ensure that the projects final outcome meets the original functional design specification a test plan is created. Table 6 is a testing document which ensures the final outcome. The numbers reference the FDS sections.

*This table should contain columns for expected
and actual results, pass or fail is not enough (RD)*

6. Literature Review

A solution for the safety circuit and control has to be established to ensure full safety on the system is met and covers the risk assessment. The requirements of safety have to be established before finding a solution.

6.1 Solution 1 – Robots internal system *punctuation (RD)*

6.1.1 justifications

This method allows a simple safety system which meets the minimum requirements of the FDS

6.1.2 Limitations

There is very little room for expandability on this solution. If extra E-stops and guard doors were added then diagnosis for faults would be difficult. Turning the power onto the robot's arm using software only does have the possibility of going wrong without any double safety precaution that the other solutions have but according to Staubli (2009) it is within regulations. This method wouldn't be as attractive to customers as it doesn't show the full use of modern technologies. Hornbeck suggests (2008) doing the minimum for safety regulations isn't a long-term method of designing a safety circuit which this method effectively will be.

6.1.3 Function explanation

staubli, (2011) suggests using the external E-stop and guard door circuit directly onto the robot controller. The E-stop and guard door will wire straight into the cs8 controller without any safety relays. The robot will effectively be the safety relay. As shown in Figure 11 in the appendix the robot's safety can be by passed in "Remote Auto" mode. This will allow the arm power on using the Applications program using the "EnablePower" function as stated by Staubli "In remote mode, this instruction switches the arm power on." (2018). The control on button can then be wired to the robots IO board. This is shown in Figure 3

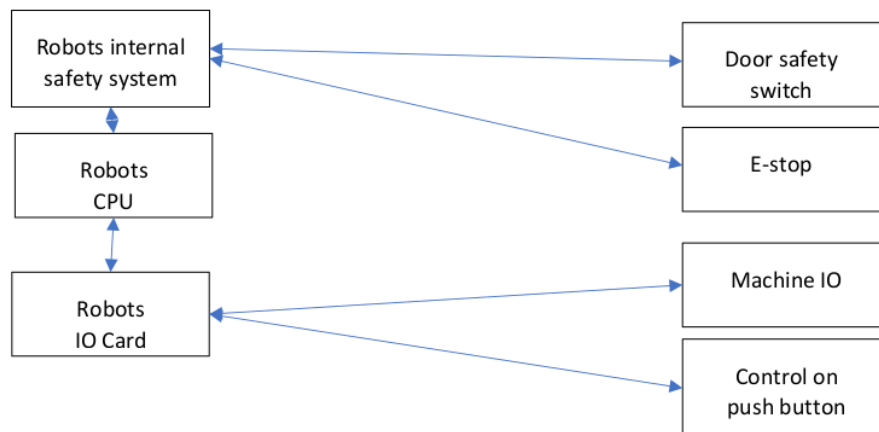


Figure 3 Solution 1 block diagram

6.1.4 Parts required

The only parts required for this solution would be a dual channel E-stop and a dual channel door guard switch.

6.1.5 Solution cost

This solution can be done with buying only the E-stop and guards which is required in all solutions. Price is shown in Table 2.

<i>Part</i>	<i>Cost from RS (2020)</i>
<i>2 pole N/C Estop Pushbutton</i>	£37.20
<i>Force guided relays 4 off</i>	£54.36
<i>Total</i>	£91.56

Table 2 Solution 1 cost

6.1.6 Safety levels

Staubli States (2009) "The robot and its controller are designed to meet a "Category III" safety level" which meets the requirements of the machine.

6.2 Solution 2 – Safety PLC

6.2.1 justifications

Darvas (2016) suggests a safety PLC can be used in critical safety applications. Rastocny states that a safety PLC is “designed to be used in industrial safety relevant applications” (2012) which would suit the machine as is aimed at industrial customers. The Safety PLC is one of the highest safety solutions when it comes to machine building. This is because of the way it monitors all its I/O continually and gives a very detailed diagnostic when a fault occurs. This is explained by Muehlfellner as he states “no individual error could happen twice and go unnoticed.” (2009). According to Macdonald (2004) a safety PLC is very easily expandable device on a machine as any extra devices can be added onto an extra safety IO card. This may be useful for the machine because there may be the future requirement to add external E-stops in if it gets adapted to work with another system.

6.2.2 Limitations

There aren't many limitations to a safety PLC other than cost of the devices. the software writing and commissioning can be time consuming. This may disrupt the timing plan.

6.2.3 Function explanation

Figure 4 shows the fundamentals of the safety PLC being integrated to the Robot. The E-stop and Door guard switch will come into the safety PLC's inputs which will be continually monitored by the Safety PLC looking for faults such as cross circuit or open circuit. The inputs of the machine will go back to the main part of the PLC as a standard input. The control on button will go back to a safe input. The advantage of this is it can be configured so that the safe input won't supply the push button with voltage until the safety circuit is in a safe state to be validated. The internal safety state of the robots will also feed back to the safety PLC and impact the safety state. If the robot's internal safety is healthy as well as the machine e-stop and guard door, then the control on is pressed the safety plc will turn on its outputs for the force guided relays. There are 4 in total 2 for the dual channel of the robot's external e-stop circuit and 2 for the robot's external door circuit. There are 2 relays for each in case one relay failed it would only hold on one safety channel. The outputs are fed back to the safety PLC so it can monitor that the relays came on. The machines IO would be fed back to the safety PLC and communicated to the robot using a Modbus protocol where the PLC would be the server as suggested by Sridevi (2019).

6.2.4 Parts required

According to Omron (2020) the Safety PLC would have to be bought in at least 5 sections in order to complete the required task. A main CPU for the PLC is required. The part NXECC203. This includes ethernet RJ45 port to communicate with the robot. To incorporate the machines inputs an input module will need to be used. An nx-id400 will be able to do this as the machine will only need an

letter (RD)

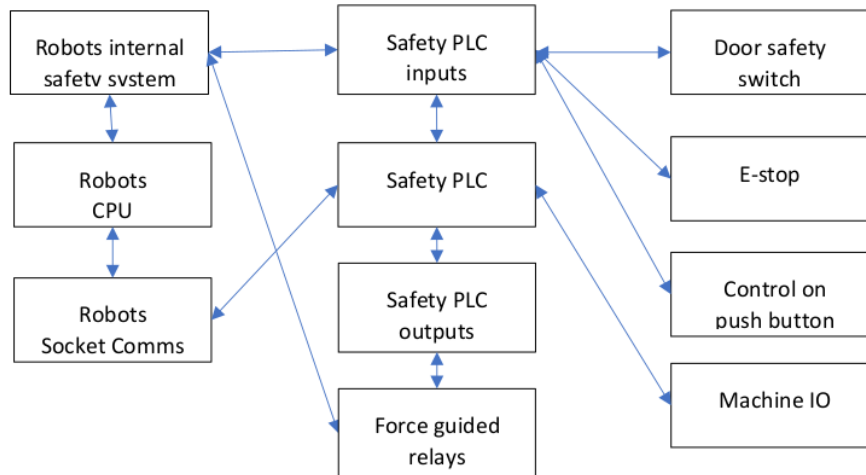


Figure 4 solution 2 block diagram for safety PLC

6.2.5 Solution cost

The cost of this solution shown in Table 3 is quite high and would take over 10% of the budget. It can be made cheaper by using a different brand but Omron PLC's are the company's standard if a different manufacture of PLC is not specified by a customer.

Part	Costing from RS (2020)
PLC Main CPU (NXECC203)	£222.84
Basic input card (NX-ID400)	£50.52
Safety PLC CPU (NX-SL3300)	£328.92
Safety IO card (NX-SID800)	£440.16
Safety additional output card (NX-SOD400)	£362.88

<i>Force guided relays 4 off</i>	£54.36
<i>2 pole N/C Estop Pushbutton</i>	£37.20
<i>Force guided relays 4 off</i>	£54.36
Total	£1551.24

Table 3 Solution 2 Cost

6.2.6 Safety levels

Omron States “The safety controller meets Category 4” (2020) which is more than what is required by law which would future proof the machine if minimum safety standards are increased. As Hornbeck states “The machine safety world continues to evolve” (2008)

6.3 Solution 3 – Safety Relays

6.3.1 justifications

Safety relays allow the combination of more advanced safety monitoring with a smaller cost than a safety PLC. A safety relay is fairly simple as opposed to a safety PLC and requires no programming just typically a mode selection. Pilz states “maximum functionality in minimum width” (2020). a more compact safety solution allows a smaller electrical enclosure to be used which will save costs. Pilz (2020) suggest that diagnostics on their safety relays are simple with led lights on the front. A PLC without an HMI would require to be connected to fault diagnose.

6.3.2 Limitations

Expansion of a circuit isn't as simple than a safety PLC. If an additional e-stop is needed to be added in the future then the circuit would have to be modified to put the e-stop in series. This could be solved by building the circuit to have removable links where additional safety sensors can be added. The outputs aren't monitored like the safety PLC it is just a contact which reduces diagnostic levels.

6.3.3 Function explanation

The system will function similar to the Safety PLC concept but would have 2 safety relays instead. 1 safety relay is for the door circuit and the other is for the e-stop channel. These safety relays will drive force guided relays which would control the robot's safety circuit. Pilz suggests (2020) that the control on push button that will reset the safety circuit is by placed after the Door guard or e-stops 24V safety channel so that there is only a chance of resetting the circuit when at least one of the safety channels is healthy. Figure 5 solution 3 block diagram this concept.

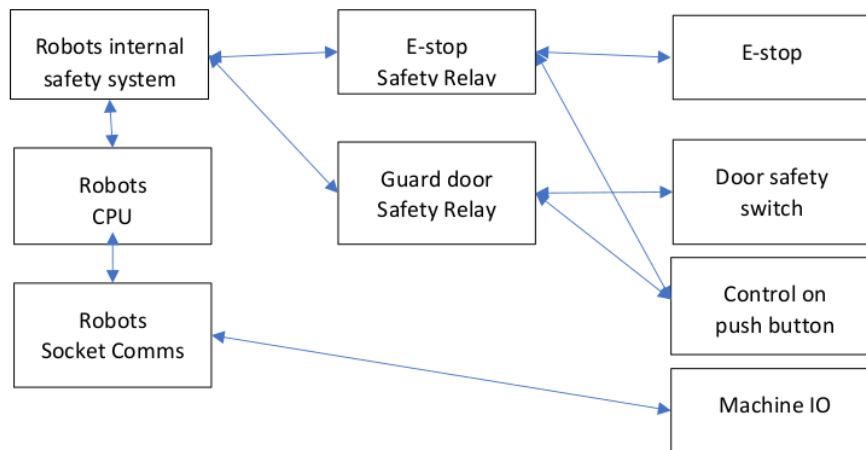


Figure 5 solution 3 block diagram

6.3.4 Parts required

One safety relay will be required for the e-stop circuit with at least 2 output channels. According to Pilz (2011) a PNOZ S2 will be a suitable safety relay for this solution. Another safety relay of the same part will be used for the guard door circuit. Four force guided relays that would link the safety relays would be required.

6.3.5 Solution cost

Table 4 shows the additional costing for this safety system. Compared to the safety PLC its approximately 10% of the cost making this a more plausible solution with the budget but the extra design time may cause the budget to be broken.

Part	Cost from RS (2020)
Pilz Pnoz s2 Safety Relay	£148.48

Force guided relays 4 off	£54.36
2 pole N/C Estop Pushbutton	£37.20
Force guided relays 4 off	£54.36
Total	£294.40

Table 4 Solution 3 cost

6.3.6 Safety levels

Figure 12 in the appendix shows the guide to selecting a Pilz safety relay from Pilz (2020). It shows a Pnoz2 safety relay has a PLr rating of c and the component category of 3 which would meet design requirements.

6.4 Comparison

Table 5 shows the comparison of the solutions. Areas covered in this comparison were safety rating, Diagnosis, Cost, Time to design, time to install and commission and future expansion. A scoring system was used on the solutions ranking them from best to worst in each area. If it was the best solution for that area is scored a 3 if it was 2nd it scored a 2 and the worst had a 1. The scores were added up at the end to find the best solution. Solution 1 and 2 drew equally first and solution 3 scored the worst.

COMPARISON POINT	SOLUTION 1		SOLUTION 2		SOLUTION 3	
SAFETY RATING	Category 3	2	Category 4	3	Category 3	2
DIAGNOSIS	Basic robot diagnosis	1	If connected to PLC full diagnosis	3	Led lights flash to indicate fault	2
COST	£91.56	3	£1551.24	1	£294.40	2
TIME TO DESIGN	Basic circuit required	3	Circuit design is more involved than the robot but more time consuming	2	Longest time	1

TIME TO INSTALL AND COMMISSION	Basic wiring and settings in robot	3	Wiring more involved than solution 1 put programming time is a lot more	1	Wiring is the most time-consuming part. Setting up just contains setting a dial	2
FUTURE EXPANSION	Little ability for expansion	1	Easy expansion with just programming and adding IO cards	3	Expansion is possible but will require rewiring	2
SCORE		13		13		11

Table 5 Solution comparison

6.5 Chosen solution

Solution 1 is the chosen solution. It was chosen as although it doesn't offer the advancements in technology as safety PLC it is a lot cheaper solution which is more likely to be completed on the budget given. Time in design and implementation was also a big factor in choosing this solution. There would have been a risk in choosing solution 2 or 3 as the extra design time and programming time may cause the project to go over budget in labour and be late.

Your solutions are limited to the safety aspect of the project but there was much more scope for looking at the robot interface and programming methods and the vision system interface and programming methods (RD)

7. Project Planning, Work breakdown and Management Techniques

7. 1 Work breakdown

This sentence states the obvious and is a waste of words (RE)

Figure 6 Work breakdown structure shows the work breakdown structure of the project. The breakdown splits into 5 main areas of implementation which including electrical, mechanical, software, testing and professional standards. These are all in turn split down further to create approximately week-long tasks which makes this an effective method in project planning.

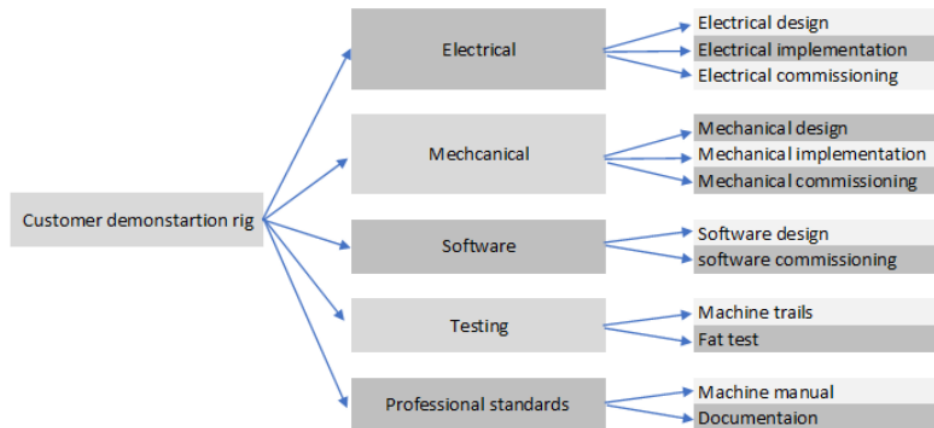


Figure 6 Work breakdown structure

7..1.1 Electrical Design

Design of the electrical drawings for the system as well as a detailed parts list that needs to be ordered to wire the system. Electrical safety standards for automation systems must be complied with in this design from cable rating to safety interlock circuits. The electrical concept design will be the what major components will be needed to link the safety and vision system to the robot. A detailed electrical parts list is created at the end of this stage

7. 1.2 Electrical Implementation

There will have to be an electrical panel on this job to include a power supply for the vision system and terminals for the safety circuit. Machine wiring is for the cabling going between the components and the electrical panel which is included in this section. This can only be done after the mechanical implementation is completed

7. 1.3 Electrical commissioning

Setting up of any sensory and safety circuits. This will also involve making the machine in the correct state ready for software commissioning.

7.1.4 mechanical design

Design of the guarding for the cell. Design of conveyor guide and for parts as well as mounts for the camera is to be done in this section. A detailed mechanical parts list is created at the end of this stage

7.1.5 Mechanical Implementation

Manufacturing of any parts required to complete the mechanical work as well as the assembly of the mechanical sections of the system including guarding

7.1.6 Mechanical Commissioning

Aligning all the guard doors and any conveyor guides that may be used to align the parts down the conveyor. A bolt tightness check will be done at this stage.

7.1.7 Software design

In this stage the robot's software will be designed implementing Staubli SRS 2019 programming and simulation software which will allow a visual representation of the robot's movements without the risk of physically crashing the robot.

7.1.8 Software commissioning

The program is downloaded to the robot controller and all IP addresses will be set up. All robot positions will be taught and the robot will be trailed through its movements to ensure no crashes occur.

7.1.9 Machine trials

The machine is continually run under all conditions to prove its workings.

7.1.10 FAT Test

Every part of the machine will be tested against the spec to ensure it meets requirements. Safety tests are also taken in this section.

7.1.11 Machine Manual

Produce a document that explains how to run and maintain the machine. This must include any safety notes and guidance.

7.1.12 Documentation

This stage runs alongside the project ensuring all stages are documented with all information easily accessed.

7.2 Project Plan

Figure 13 in the appendix shows the plan for the implementation stage of the project. It spans from the 4th January 2021 which is indicated as week 1, up to week 10 which is March 15th 2021 when the project will have to be completed. When the project gets to week 3 after the design stages all the parts required will be ordered to ensure they arrive by the implementation stage. The implementation of mechanical and electrical must be done before commissioning either of them as it will have to be done twice as settings may get affected. The software commissioning is done next as all the positions will be final. When the machine is completed the testing will commence this will include the machine trails and Fat test. The machine manual will be completed at the end of the project when all functions are final.

7.3 Costing Plan

Figure 13 shows the original budget from the project. It's a company document that had to be filled in to produce to budget. It considers labour and bought out parts for the project. When the project is implemented every hour that is spent on it will be documented in a duplicate of the excel spreadsheet to compare with to keep track of the budget. At the end of the project a comparison between the budget breakdown and the actual spending can be done to see where budgeting can be improved on in the future.

7.4 Management techniques

The main management technique on this project has been a bottom-up approach where the robot controller used has been a factor in almost every decision. the planning techniques have been the *spelling (RD)* gaunt chart which has broken down the deadlines. The work break down structure helps put the tasks into manageable sections which can be progress monitored easier to ensure the project is on track.

Conclusions and Recommendations

The project is now at the stage where it can begin its implementation stage. The most optimum solution chosen for the safety which should keep it within the budget and timing plan. Doing this at this stage has reduced the risk of having to stick with the wrong solution. A lot of unknowns have been made clear from the FDS where the machines outcomes and specifics have been laid out in an easy to see format that can be reviewed through the implementation stages to ensure it looks on track to be met. The project plan has given a clear idea of the work tasks that have to be done with deadlines that can be tracked every week. The work breakdown structure has spread all the work out which is an effective project management technique. The wider engineering issues have been covered to ensure the modern engineering standards are going to be met throughout the project.

The recommendations are to keep careful track of the project timing plan from the very start as a small delay can accumulate to the project being late very quickly with the tight schedule. When it noticeable that a task isn't going to be completed on time it is going to be wise to organise work load sharing and allow some implementation tasks to be done by another personal to allow myself more time for design and commissioning. Safety must be kept as the main priority throughout the project and ensure it is put before the timing plan and budget

Citation List

- BSI Group. (2010, 2). BS EN 60204-Safety of machinery. London, London, Britan: BSI Group.
- Crown copyright. (2008, June). The Supply of Machinery (Safety) Regulations 2008. London, United Kingdom: Crown copyright.
- Darvas, D. (2016). Formal Verification of Safety PLC Based Control Software. *International Conference on Integrated Formal Methods* (pp. 508-522). Ábrahám E: Springer, Cham.
- Hornbeck, D. (2008). A Holistic Approach to Safety Automation. *XVIII World Congress on Safety and Health at Work* (pp. 1-11). Rockwell Automation.
- HSE. (2020, 11 27). <https://www.hse.gov.uk/simple-health-safety/risk/index.htm>. Retrieved from <https://www.hse.gov.uk/simple-health-safety/risk/index.htm>: <https://www.hse.gov.uk/simple-health-safety/risk/index.htm>
- Keyence. (2020, 11 27). <https://www.keyence.co.uk/ss/products/safetyknowledge/performance/level/>. Retrieved from <https://www.keyence.co.uk/ss/products/safetyknowledge/performance/level/>: <https://www.keyence.co.uk/ss/products/safetyknowledge/performance/level/>
- Knackstedt, H. (2020, 11 28). <https://www.robotics.org/robotic-standards>. Retrieved from www.robotics.org: <https://www.robotics.org>
- Macdonald, D. M. (2004). *Practical Machinery Safety*. south africa : Elsevier Ltd.
- Muehlfellner, R. (2009). Its all about error detection . *What Controls Safety*.
- Omron. (2020, 11 30). *nx safety stand-alone datasheet*. Retrieved from [assets.omron.eu](https://assets.omron.eu/downloads/datasheet/en/v3/i185e_nx-s_nx_safety_stand-alone_datasheet_en.pdf): https://assets.omron.eu/downloads/datasheet/en/v3/i185e_nx-s_nx_safety_stand-alone_datasheet_en.pdf
- Omron. (2020, 11 29). *nx-safety-stand-alone*. Retrieved from [industrial.omron.co.uk](https://industrial.omron.co.uk/en/products/nx-safety-stand-alone): <https://industrial.omron.co.uk/en/products/nx-safety-stand-alone>
- Omron. (2020, 12 1). *Safety Control Unit*. Retrieved from [www.omron.eu](https://assets.omron.eu/downloads/datasheet/en/v6/f109_nx-sl_si_so_datasheet_en.pdf): https://assets.omron.eu/downloads/datasheet/en/v6/f109_nx-sl_si_so_datasheet_en.pdf

- Omron. (2020, 11 28). *www.omron.com*. Retrieved from *www.omron.com*:
https://www.omron.com.au/service_support/technical_guide/safety_component/safety_functions.asp
- Pilz. (2011). *Safety relays PNOZsigma*. Retrieved from *www.pilz.com*:
https://www.pilz.com/download/open/PNOZsigma_Appl_Manual_1002430-EN-05.pdf
- Pilz. (2020, 11 29). <https://www.pilz.com/en-GB/eshop/0010000200700380G9/Monitoring-of-E-STOP-safety-gates-light-barriers>. Retrieved from *www.pilz.com*: <https://www.pilz.com/en-GB/eshop/0010000200700380G9/Monitoring-of-E-STOP-safety-gates-light-barriers>
- pilz. (2020, 12 2). *PNOZ sigma safety relays*. Retrieved from *www.pilz.com*: <https://www.pilz.com/en-GB/eshop/00100002007003/PNOZsigma-safety-relays>
- Rastocny, K. (2012). Specificities of safety PLC based implementation of the safety functions. *International Conference on Applied Electronics* (pp. 229 - 232). Slovak: 2012.
- Rockwell Automation. (2014, 2). *Safety Switches*. Retrieved from *www.rockwellautomation.com*:
https://literature.rockwellautomation.com/idc/groups/literature/documents/br/glsafe-br002_-en-p.pdf
- RS. (2020, 12 11). *emergency stop push buttons*. Retrieved from *uk.rs-online.com*: <https://uk.rs-online.com/web/p/emergency-stop-push-buttons/4258449/>
- RS. (2020, 12 1). *non latching relays*. Retrieved from *uk.rs-online.com*: <https://uk.rs-online.com/web/p/non-latching-relays/4882575/>
- RS. (2020, 11 27). *safety relays*. Retrieved from */uk.rs-online.com*: <https://uk.rs-online.com/web/p/safety-relays/4896350/>
- RS. (2020, 11 29). *safety-io-modules*. Retrieved from *uk.rs-online.com*: <https://uk.rs-online.com/web/p/safety-io-modules/8625767/?relevancy-data=7365617263685F636173636164655F6F726465723D31267365617263685F696E746572666163655F6E616D653D4931384E53656172636847656E65726963267365617263685F6C616E67756167655F757365643D656E2673656172>
- Sridevi, G. (2019). Effective Protocols for Industrial Communication. *Emerging Research in Electronics, Computer Science and Technology* (pp. 1093-1105). Singapore: Springer.

Staubli. (2009, 03 26). *Staubli-Cs8c manual*. Retrieved from www.manualslib.com:
<https://www.manualslib.com/manual/812489/Staubli-Cs8c.html#manual>

staubli. (2011, 10 6). <https://www.staubli.com/en-us/>. Retrieved from <https://www.staubli.com/en-us/>: <https://www.staubli.com/en-us/>

Staubli. (2018, 11 22). VAL 3 REFERENCE MANUAL Version 8. France: Staubli.

Štohl, R. (2017). The CIP safety protocol in connecting single machines to create production lines. (pp. 512-516). Sinaia: 18th International Carpathian Control Conference (ICCC).

Appendix

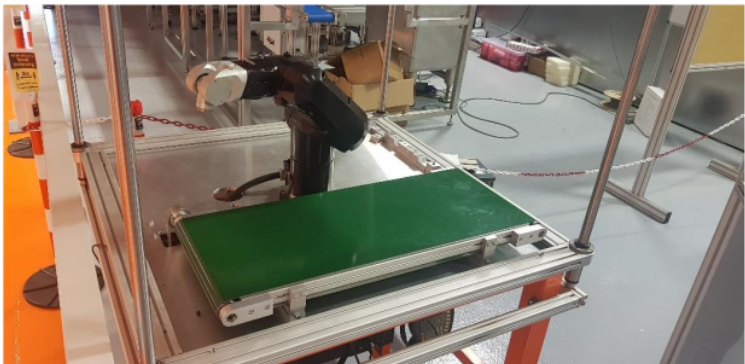


Figure 7 Existing system

What does the vision system look like? (RD)

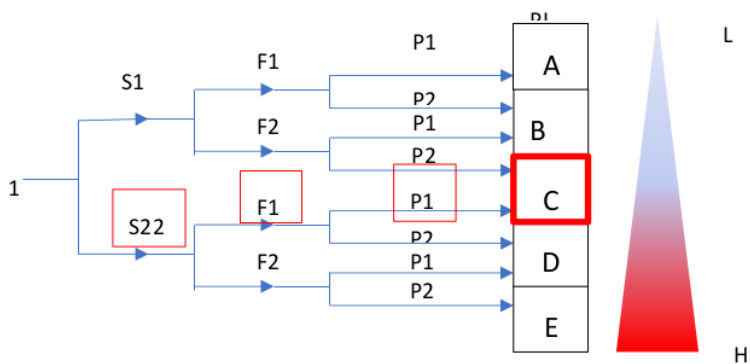


Figure 8 PL performance

MACHINE RISK ASSESSMENT

1.6 Conclusions

Hazard number	Remarks
1	The Customer Demonstration rig needs wheels to move it around shows so the wheels cant be taken out of the design. The risk instead reduced by having locking wheels to park the machine. Correct safety procedures will be put into the machine manual and the machine manual will have to be read before moving the machine.
2, 3, 4, 5, 6	The robot being able to move in the cell is very important and cannot be removed from the design. The risk can be reduced by placing guarding around the robot and the robot will only run in manual mode with the guard opened. The manual mode allows the robot to move only if the deadman switch is pressed which is low risk.
10	The turning pulleys of the conveyor is very important and cannot be removed from the design. The risk can be reduced by placing guarding around the robot and the robot will only run in manual mode with the guard opened. The manual mode allows the robot to move only if the deadman switch is pressed which is low risk.
14, 15, 16, 17, 18, 19, 20, 21, 22	The 240VAC is required to power the robot controller but 24VAC can be used for control to reduce risk and all 240 components in the panel can be approved to make it very difficult to touch the live areas directly. The panel will be locked with a key and a sticker will be placed on the front warning that there is 240VAC and to isolate power before entering.
26	If noise levels exceed 85db's, then a warning sticker will be placed on the machine telling the
28	industry standard of reducing pneumatic noise radiation is used
36	By providing access to the machine at ground level through an appropriate sized space, the
37, 38, 39, 40, 41	Any controls to the machine will be placed at a comfortable height to ease the use to reduce the
47, 48, 50, 70, 71, 73	Due to the size and weight of the machine it must only be moved by way of forklift truck and only by qualified personnel. Lifting aids will need to be fitted to aid the process. Instructions on machine movement to be included in the machine manual along with the approximate size and weight of the machine
49, 72	Due to the size and weight of the machine it is vital that it has been securely fastened to any transportation vehicle before departure.
52, 53, 54	Although a low level risk, potentially it could be fatal, machine must not be connected/unconnected by unauthorised, unqualified personnel, this must be stated in the accompanying machine manual along with the documented energy supplies required. Further more warning labels are to be used on the outside and also inside of the electrical enclosure.
51	It is necessary to set the machine up for commissioning and trials. Only authorised personnel who have read the machine manual should carry out this task.
56, 64	Handling of Ethanol & Methoxy Propanol should only be carried out by qualified personnel who have read the appropriate regulations and are authorised to perform such duties.
58, 65, 66, 67	No dismantling/removal of parts, components, devices of the machine are to be carried out without the written consent of the manufacturer. This to be stated in the machine manual.
59, 60, 61, 63	All power to the machine must be isolated before attempting any cleaning, maintenance work, fault finding or repairs. This must be stated in the Machine Manual.
62	Considered as negligible risk as cylinder centre positions are open. Hazard removed.
68, 69, 70, 71, 72, 73	When decommissioning and dismantling the machine, the machine should be disconnected. Only authorised personnel who have read the machine manual should carry out this task, only with the written consent of the manufacturer. Any loading & unloading of the machine should be carried out with a forklift truck, lifting socket will be positioned on the machine to assist this and documented in the machine manual.

Figure 9 Machine Risk Assessment

This table should have columns for expected result and actual result so your reader knows what the outcome should be. (RD)

Test	Tick to confirm	Comments
4.1.1 conveyor operation		<i>too vague, how and when should it operate? (RD)</i>
4.1.2 camera operation		<i>what does this mean? (RD)</i>
4.1.3 robot operation		
4.1.4 Guarding requirements		
4.2.1 includes electrical enclosure		
4.2.2 list of spare parts placed in the manual		
4.2.3 all documentation is in English		
4.2.4 all drawings are in DWG, DXF or PDF		
4.2.5 relevant regulations are met		
4.3.1 Incoming supply is 240VAC 50Hz less than 16A		
4.3.2 controls system is 24VDC		
4.3.3 Inputs are wired PNP		
4.3.4 Outputs are wired PNP		
4.3.5 240VAC cables outside enclosure are SY		
4.3.6 Only Tri-rated cable used		
4.3.7 cables ferrets used where possible		

4.3.8 Enclosure is at least ip61		
4.3.9 20% spare IO		
4.3.10 Incoming supply to the panel will be separated into terminals before entering the isolator		
4.3.11 isolator is fitted		
4.3.12 cable colouring is correct		
4.4. Machine follows correct sequence		
4.5 robot software requirements are correct		
4.6.1 Push buttons perform correct tasks		
4.6.2 Valves in robot's arm is used for Vacuum switching		
4.6.3 a proximity switch is used to check the part is in position		
4.6.4 guard switch is mounted onto the guard door and prong is correctly aligned.		
4.7 at least C safety rating components were used in safety circuits.		
4.8 20 parts per minute		
4.9.1.1 parts can be loaded easily by the operator		

4.9.1.2 parts can be removed easily by the operator		
4.9.2.1 the machine is easy to clean down for maintenance engineer		
4.9.2.2 Robot points can be easily taught		
4.9.2.3 Robot tooling can be easily checked		
4.10.1 errors are displayed on the pendant		
4.10.2 faulty parts are placed in the reject bin		
4.11 project is completed under 12,500		
4.12 project is completed before march 2021		

2.14. CELL WITH RSI2

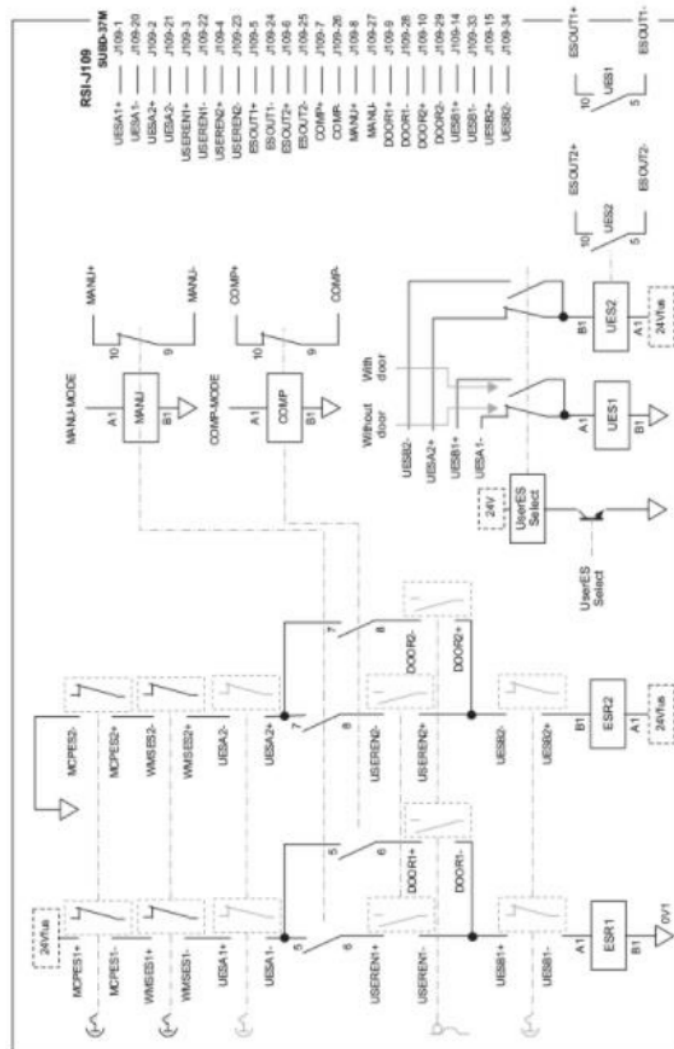


Figure 10 Controller safety circuit

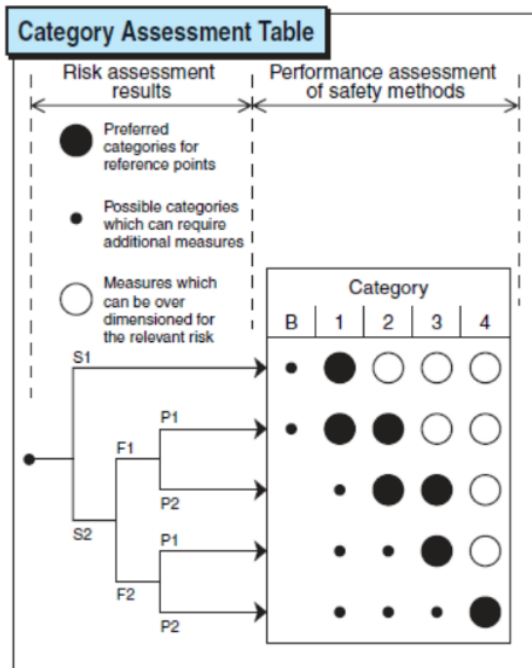


Figure 11 Safety component selection

Type	PNOZ s1	PNOZ s2	PNOZ s3	PNOZ s4	PNOZ s4.1
Emergency stop	✓	✓	✓	✓	✓
Safety gate	✓	✓	✓	✓	✓
Light grids			✓	✓	✓
Performance Level (PL)	c	e	e	e	e
Safety Integrity Level (SIL) CL	2	3	3	3	3
Output contacts (safe)	2	3	2	3	3
Width in mm	12.5	17.5	17.5	22.5	22.5
Special approvals	-	-	-	-	Burner control/ Burner management EN 50156-1

Figure 12 Pilz safety relay guide

Project Plan

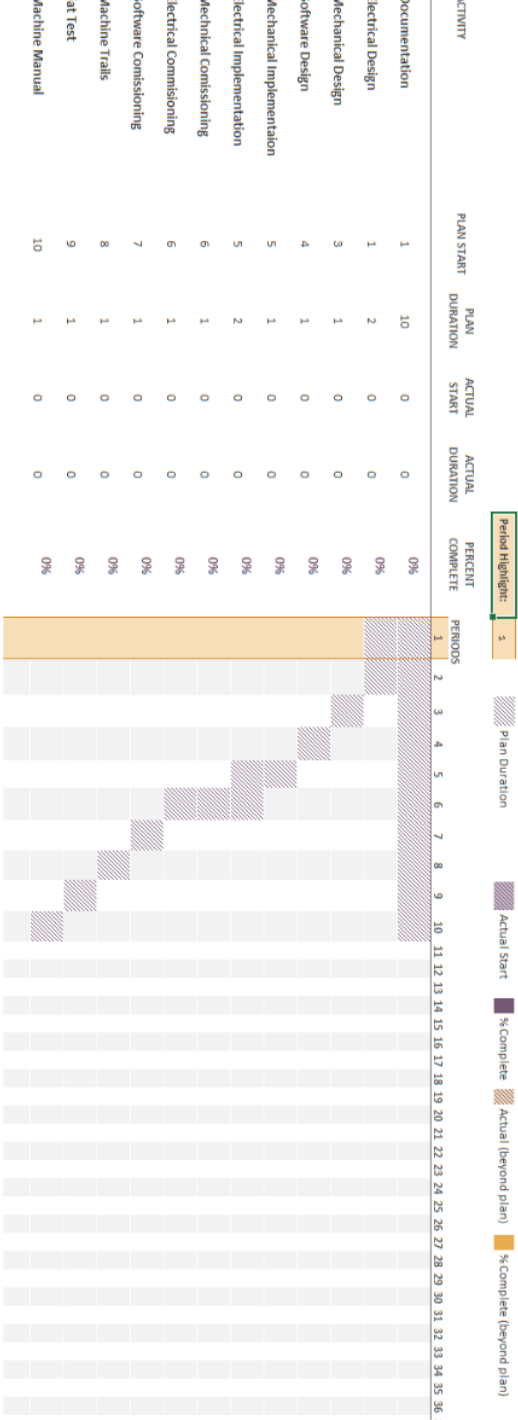


Figure 13 Project plan gaunt chart

					Estimate Hrs	Estimate Cost	Estimated Wks
7	4.44%	LABOUR	ENG	ENGINEERING	12.00	£ 540.00	0.30
8	17.03%	LABOUR	MAN	MANUFACTURE	56.00	£ 2,072.00	1.40
9	50.67%	LABOUR	ELEC	ELECTRICAL	158.00	£ 6,166.00	3.95
10	5.92%	LABOUR	DOC	COMPLIANCE	16.00	£ 720.00	0.40
TOTAL LABOUR					242.00	£ 9,498.00	
11	4.11%	MATERIAL	MAT 1	RAW MANUFACTURING MATERIAL		£ 500.00	
11	0.00%	BO MATERIAL	MAT 2	MATERIAL - MECHANICAL		£ -	
						£ 500.00	
12	2.18%	BO MATERIAL	ITEM 1	ITEM		£ 265.32	
13	0.67%	BO MATERIAL	PNEU 1	PNEUMATICS		£ 81.69	
14	14.98%	BO MATERIAL	ELECT 1	ELECTRICS		£ 1,823.21	
15	0.00%	MISCELLANEOUS	MISC 1	MISCELLANEOUS		£ -	
16	0.00%	BO MATERIAL	HYDR 1	HYDRAULICS		£ -	
TOTAL MATERIAL						£ 2,670.22	
17	0.00%	SUBCONTRACT	SUB 1	SUBCONTRACT MECHANICAL		£ -	
17	0.00%	SUBCONTRACT	SUB 2	SUBCONTRACT ELECTRICS		£ -	
TOTAL SUBCONTRACT						£ -	
GRAND TOTAL						£ 12,168.22	

Figure 13 Cost break down

SGEL6000 INDEPENDENT PROJECT 2020-2021

PROJECT PROPOSAL DOCUMENT

Student Name: Sean Jones
Project Title: Customer Demonstration System
Date: 09/10/2020
Budget: £12,500

Description of Project

The purpose of the project is to develop a visual demonstration rig to show to customers when they visit the factory. It will also be transported to an automation event where new customers may visit the company stand. The system will have the availability to be used for robot and vision training. The final product must demonstrate a typical system that the company produces. This will involve a robot and a camera to show the new direction the company is taking in automation within the food and health care industry, where it is best to minimise human interaction with the product. Parts are fed onto a conveyor and move along until they stop against a constant position. A vision system will be required above this area in order to examine the markings on the parts. The robot must then pick up the part and place it in a designated area depending on the part marking. On food packaging lines, parts are often picked and packaged into containers and this system could provide evidence to a potential customer of the need to change their packaging methods to become fully automated for speed and quality improvements.

The lead in the project will be Sean Jones, who will also be responsible for the design, drawings, construction, programming and implementation of the system. The electrical safety design drawings will be approved by the company's electrical engineer Ceri Davies to ensure the system conforms to legal requirements and company standards. At the end of project testing, documentation will be produced and checked by an engineer to ensure they meet the company's quality standard. The entire project will be overseen by my manager Keith Harland to ensure the demonstration system represents the company's capability as intended.

The project is planned to be completed and tested by the end of March 2021 which should still be early enough in the year to take the system to automation demonstration shows throughout the year with the main one being the PPMA show in October 2021.

Agreement for project proposal

Student Signature: _____ **SEAN JONES** _____ **Date:** 09 10 2020
Industrial Supervisor Signature: _____ **KEITH HARLAND** _____ **Date:** 05 11 2020
Academic Tutor Signature: _____ **ROBERT DAVIES** _____ **Date :** 06/11/2020

Assignment 1 1602826

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

47/100

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5

Text Comment. should be numbered as section 1

Text Comment. spelling (RD)

Text Comment. New sentences should start with a capital letter (RD)

Text Comment. spelling (RD)

Text Comment. spelling (RD)

PAGE 6

Text Comment. this is section 2

Text Comment. attract? (RD)

PAGE 7

Text Comment. This is repeated from a previous section (RD)

Text Comment. spelling

Text Comment. what standards? (RD)

Text Comment. spelling (RD)

Text Comment. spelling (RD)

Text Comment. thrashed? (RD)

Text Comment. punctuation (RD)

Text Comment. Direct quotes need a page number (RD)

Text Comment. What other standards do you need to follow? More citations needed here (RD)

Text Comment. are (RD)

Text Comment. What do the parts look like, how many different types are there? (RD)

Text Comment. spelling (RD)

Text Comment. ? (RD)

Text Comment. This table should contain columns for expected and actual results, pass or fail is not enough (RD)

Text Comment. punctuation (RD)

Text Comment. ? (RD)

Text Comment. All sentences should begin with a capital letter (RD)

Text Comment. Previously, you stated there would be two of these? (RD)

Text Comment. Your solutions are limited to the safety aspect of the project but there was much more scope for looking at the robot interface and programming methods and the vision system interface and programming methods (RD)

Text Comment. This sentence states the obvious and is a waste of words (RD)

Text Comment. spelling (RD)

Text Comment. What does the vision system look like? (RD)

Text Comment. This table should have columns for expected result and actual result so your reader knowledge what the outcome should be. (RD)

Text Comment. too vague, how and when should it operate? (RD)

Text Comment. what does this mean? (RD)

GRADING FORM: NEW CSG-RUBRIC

SEAN JONES

47

1. ENGAGEMENT WITH LITERATURE



Section 5: Engagement in research, judicial use and critical evaluation sources, depth of literature

8

review of solutions (5/10) There is some evidence of research with respect to the robot and machine safety with regulations considered. (RD) An average range of sources are listed in the reference list.(MH) Sections 3, 5 and 8: Extent of reading, use of credible sources, use of Harvard method for listing and citing (3/5) There is evidence of a good range of sources correctly cited and listed in most cases. (RD) Limited sources used, several entries in the reference list do not appear to be cited, citations restricted to a limited number of sources such as Staubli. (MH)

2. KNOWLEDGE AND UNDERSTANDING



Section 3: Project background and context, commercial, economic and social context (4/10) Briefly stated with commercial and other factors considered. (RD) Executive summary and introduction lacked specific detail as to what the problem was, what the “parts” referred to actually entailed and how the problem would be solved (MH) Section 3: Project constraints, professional and ethical conduct, codes of practice, standards, security, intellectual property, legal requirements etc. (5/10) Good consideration given to most aspects (RD) Some mention of generic standards in the FDS (MH) Section 3: Environmental and sustainability limitations and promotion of sustainable development (3/5) Some consideration given (RD) Little consideration of these in the report, just a generic statement of the company’s standards and codes of practice (MH) Section 3: Project risks, health and safety etc. (3/5) Good

15

consideration given with use of PL rating (RD) Main risks to the project were from company manag

3. COGNITIVE AND INTELLECTUAL



Section 3: Problem Definition (3/5) Some parts give a good explanation yet little it said of the vision system (RD) Broadly defined with specifics only becoming apparent later in the report (MH) Section 4: Functional Design Specification (6/10) Some sections are detailed but nothing much said about the requirements of the vision system and what the different the components to be distinguish and picked up would look like (RD) FDS was explained with good detail (MH) Section 4: Test planning (2/5) A good list of tests but columns should be added showing expected and actual results rather than a simple column for pass-fail. This system could not be tested by a third party using this table. (RD) A comprehensive test plan is included, however this lacked clarity of metrics on some tests, e.g. "correctly aligned", "easily loaded". It also included project success criteria such as being on budget. (MH) Section 7: Conclusions and Recommendations (3/5) Good comments made, project is on track fo

14

4. PRACTICAL APPLICATION



Section 5: Critical choice and justification of final solution (2/5) Solution choice is valid but only relates to the safety aspects of the project. (RD) 3 solutions given and comprehensive grading of each was explained, justification for final choice

6

was mentioned. Budget of £12,500 was mentioned in the proposal and introduction, yet solution chosen only cost £91.56. From the assessment given, Solution 2 seems the best option yet Solution 1 was chosen. (MH) Section 6: Project Planning, working breakdown structure and management techniques. (4/10) Good evidence of planning but Gantt chart could contain more detailed tasks. Management techniques are relevant. (RD) Gantt chart and WBS used as planning tools, both of these lacked detail and were very basic in nature. (MH)

5. TRANSFERABLE SKILLS



Section 1: Executive summary (2/5) Brief (RD) Lacked a lot of detail and didn't give a reader unfamiliar with the project much insight into the why, what and how aspects of the project. (MH) All Sections: Quality of the report – (2/5) Well structured and generally well presented. However, it contains many grammatical, spelling and punctuation errors. You must learn to proof read your work before submission. (RD) Grammatically poor at times, some smaller diagrams didn't need to be in the annex (MH) Word count – (0/5) Exceeded. (RD) Word count exceeded (MH)

4

SECOND MARKER - MH

Course: BSc (Hons) Electrical and Electronic Engineering
Module: SGEL6000 Independent Project
Assignment: 1. Project Definition, Research and Quality Planning
Name: Sean Jones
University number: 1602826
Date submitted: 11/12/2020
Word count: 4657

3600 + 10%

Contents

Executive Summary	5
Introduction	6
3. Project Background and Problem Definition and Constraints	7
3.1.1 Problem.....	7
3.1.2 Proposal	7
3.2. Environmental impact And Sustainability.....	8
3.3.1. Ethical.....	8
3.3.2. Health and safety	8
3.3.3. Security	8
3.3.4. Risks	8
3.4. Intellectual property	9
3.5. Codes of practice and standards.....	9
4. Functional Design Specification (FDS) and Test Plan	10
4.1 Overview	10
4.1.1 Conveyor:	10
4.1.2 Camera:	10
4.1.3 Robot:.....	10
4.1.4 Guarding:.....	11
4.2 Requirement	11
4.3 Electrical requirements	11
4.4 Basic machine sequence	13
4.5 ROBOT software requirement overview.....	14
4.6. Devices	14
4.6.1 push buttons, lamps & e-stops	14
4.6.2 Actuators.....	14
4.6.3 Proximity switches	14
4.6.4 Guard Switches	14
4.7 Safety performance	14
4.8 Performance	15
4.9 User community.....	15
4.9.1 Operator.....	15
4.9.2 Maintenance Engineer	15
4.10 Error & fault handling	15
4.10.1 Machine Error	15

4.10.2 Product Fault.....	15
4.11. Budget.....	15
4.12. Time scale	15
5. Testing Plan.....	16
6. Literature Review	17
6.1 Solution 1 – Robots internal system	17
6.1.1 justifications.....	17
6.1.2 Limitations.....	17
6.1.3 Function explanation	17
6.1.4 Parts required	18
6.1.5 Solution cost.....	18
6.1.6 Safety levels	18
6.2 Solution 2 – Safety PLC.....	19
6.2.1 justifications.....	19
6.2.2 Limitations.....	19
6.2.3 Function explanation	19
6.2.4 Parts required	19
6.2.5 Solution cost.....	20
6.2.6 Safety levels	21
6.3 Solution 3 – Safety Relays	22
6.3.1 justifications.....	22
6.3.2 Limitations.....	22
6.3.3 Function explanation	22
6.3.4 Parts required	23
6.3.5 Solution cost.....	23
6.3.6 Safety levels	24
6.4 Comparison.....	24
6.5 Chosen solution.....	25
7. Project Planning, Work breakdown and Management Techniques	26
7. 1 Work breakdown.....	26
7..1.1 Electrical Design	26
7. 1.2 Electrical Implementation.....	26
7. 1.3 Electrical commissioning.....	26
7.1.4 mechanical design.....	27
7.1.5 Mechanical Implementation.....	27
7.1.6 Mechanical Commissioning	27

7.1.7 Software design	27
7.1.8 Software commissioning.....	27
7.1.9 Machine trails	27
7.1.10 FAT Test.....	27
7.1.11 Machine Manual	27
7.1.12 Documentation	27
7.2 Project Plan	28
7.3 Costing Plan.....	28
7.4 Management techniques	28
Conclusions and Recommendations	29
Citation List	30
Appendix	33
PROJECT PROPOSAL DOCUMENT	42
Figure 1 Block diagram.....	7
Figure 2 Basic sequence	13
Figure 3 Solution 1 block diagram.....	17
Figure 4 solution 2 block diagram for safety PLC.....	20
Figure 5 solution 3 block diagram	23
Figure 6 Work breakdown structure.....	26
Figure 7 Existing system.....	33
Figure 8 PL performance	33
Figure 9 Machine Risk Assessment	34
Figure 10 Controller safety circuit.....	38
Figure 11 Safety component selection	39
Figure 12 Pilz safety relay guide.....	39
Figure 14 Cost break down	41

Executive Summary

The project is based in an automation company that specialises in one off production machines. A project has been initialised to attract more customers to the company. A demonstration system has been decided to be implemented where customers can view on a company visit and when the company takes it to Automation shows. The system will include a robot and a vision system to sort parts off a conveyor. The specifics of the system includes a robot linked to a camera which identifies parts coming down a conveyor and sorts the accordingly.

QUITE VAGUE
WHAT PARTS AND WHY SORT THEM

There was a decision to be made on how the safety of the robot cell should work. it was researched and 3 possible solutions were compared. They were scored against each other and the method of using the robot's internal safety system was chosen even though it was equal on score to the safety PLC it was a cheaper solution a better suited to the budget.

The planning of the project was done through a work breakdown structure where all tasks became a week long and these were used on a timing plan ^{GAUNT} chart. These stages have budgets which can be monitored alongside of the timing plan to ensure budget and time scale is maintained throughout the project.

The project has to be completed in a budget of £12,500. The implementation will start in January 2021 and will be completed by march 2021.

The executive summary should give the reader a good idea of what the project is about. This was more of a brief introduction.

Introduction

The aim of the project is to develop a demonstration system to source new customers. The clients tend to have large production lines needing automated systems. Robots are more commonly being integrated into these machines to reduce the number of people required to operate them which speeds up production lines and reduces overhead costs. The company is looking for ways to expand its customer base into this market also improving their employee's knowledge and understanding in programming. This will be a system that can be transported to automation events. The final product must demonstrate a typical system that the company produces. This will involve a robot and a camera to show the new direction the company is taking in automation within the food and health care industry

*I am still not the wiser on
what your project is actually
about.*

3. Project Background and Problem Definition and Constraints

3.1.1 Problem

Robots are more commonly being integrated into these machines to reduce the number of people required to operate them which speeds up production lines and reduces overhead costs. The clients tend to have large production lines needing automated systems. The company is looking for ways to expand its customer base into this market also improving their employee's knowledge and understanding in programming.

3.1.2 Proposal

A robotic demonstration rig suits this criterion as customers can see it running in shows and through company visits. Engineers and technicians can be trained using this system to improve quality on live jobs. The concept of the system involves a robot integrated with a vision system which can sort parts.

Figure 1 Block diagram shows the concept of this system where the 4 main parts are the Robot, Vision, Conveyor and safety. The parts used can be a 20mm cube made from nylon in the colour black and 20mm diameter cylinder by 20mm high from nylon in the colour black.

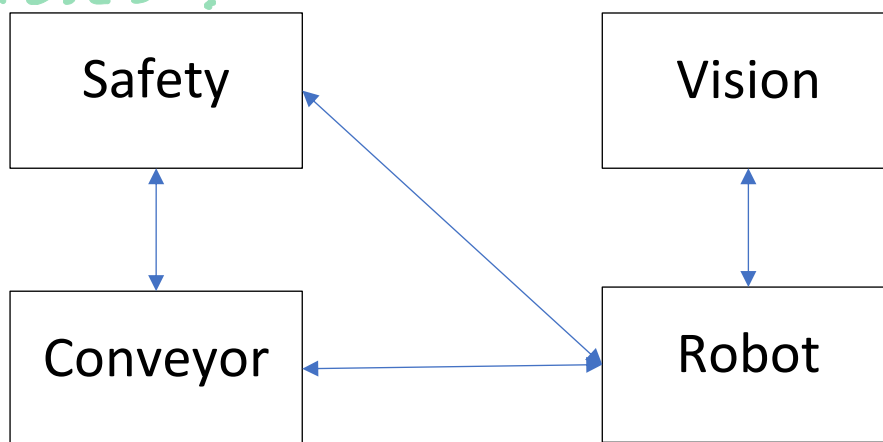


Figure 1 Block diagram

3.2. Environmental impact And Sustainability

For environmental reasons, the system will be made using recycled materials. The equipment shown in Figure 7 in the appendix, shows the current system which includes a Staubli TX40 6 axis robot, a 20mm aluminium base plate, item guarding frame work on wheels and a 300 x 1000mm belt conveyor positioned perpendicular to the robot. Currently no electrical design has been carried out on this system and this will be part of the project.

3.3.1. Ethical

In order for the project to be ethical it must obey to all appropriate standards and safety regulations. The most appropriate safety systems must be used to make the machine as safe as possible so operators have low chance of injury. If required at any point in the project work can be subcontracted to spread work to external companies.

COMPLY WITH

YOU SHOULD PROBABLY

KNOW BY NOW IF THIS
IS REQUIRED.

3.3.2. Health and safety

A risk assessment was undertaken to identify all the hazards and reduce the risks of injury. The conclusion of this risk assessment is shown in the appendix as Figure 9. HSE (2020) suggests that the risk assessment should consider the frequency of the hazard, danger level of the hazard and the possibility of avoiding the hazard. Every hazard gains a value and is added up at the end of the assessment as probability of someone getting injured. These values can be used to give a performance level. Keyence states "required performance level (PLr) must be determined" (2020). The PLr graph completed is shown in Figure 8 in the appendix and shows the performance level of the machine is C. Figure 11 shows the guide to part categorized selection from Omron (2020). This machine is category 2/3.

3.3.3. Security

The machine will have all its programs password protected so that it can't be tampered with without an approved engineer. There will be no internet connection the machine will eliminate the risk of a cyber-attack. The user profile on the robot controller will be password protected to prevent to operator affecting the program.

3.3.4. Risks

The main technical risk of the project is the vision as the decision in which camera to use will affect the function of the system. The budget can be easily jeopardized if the incorrect vision system is chosen and doesn't work. Project planning risk will be the risk of Covid19 spreading in the workplace causing the factory being shut down for 2 weeks could adversely affect the project timing plan.

3.4. Intellectual property

There will be no patenting of this machine but drawings and programs may be copyrighted at the discretion of management at the end of the job. Budgeting of the job will be kept confidential to the company.

3.5. Codes of practice and standards

A technical file is going to be produced to satisfy Crown copyright (2008) as it states “ensure that the technical file is compiled and made available”. Company standards for project procedures will be complied to in order to make the project successful

4. Functional Design Specification (FDS) and Test Plan

4.1 Overview

The company must allow the following processes on the customer demonstration rig

4.1.1 Conveyor:

Allow parts that is placed on the conveyor to travel to the robot work area. As these parts move along the conveyor, they must funnel down into a single line and stop against a constant position. The part in the position must not get effected by the parts bunched up behind it and the 2nd part in the queue must not be affected when the 1st part gets picked up. The constant position will be referred to as the picking position.

4.1.2 Camera:

Take an image of the part in the picking position and determine the type of part that is ready for picking. This information is to be passed onto the robot for correctly placing procedure. The trigger for the camera must be pulsed to detect a part in the picking area to spare the use of a part present sensor.

4.1.3 Robot:

Must home above the conveyor and wait for a signal to go pick a part. When it has picked a part it must then place the part in an appropriate position depending on what part its picked. After the part is placed it must wait for the next part to pick.

Figure 10 in the appendix shows the controller safety diagram from staubli (2011) shows the safety module on the CS8 controller. The configuration of safety is limited to this circuit. According to staubli (2011) it split into 2 sections with external E-stop and door inputs and internal e-stop status. According to this drawing the mode that is selected depends on the validation and e-stop of the robot. If it's in manual it will need a validation from the pendant to turn arm power on. If in auto it will also need this same validation. When in remote auto the CS8 controller can automatically validate its safety if the internal and external e-stops are healthy and arm power can be achieved. According to staubli (2011) the doors can be overridden if the controller is in manual mode and the dead man switch is healthy on the pendant.

4.1.4 Guarding:

There must be guarding that stops the access to the robot when its running. This must have an ITEM aluminium extrusion frame and 4mm polycarbonate windows. This guard must have an access door which is integrated into the safety to still allow the robot to run in manual when its open. According to Knackstedt (2020) Due to the PL_r level Being C, any guards that are designed onto the machine must have interlocks integrated into the safety circuit. To allow the robot to run in manual with the door open there must be a hold to run button. BSI Group states “Hold-to-run controls shall require continuous actuation of the control device” (2010). According to Rockwell Automation (2014) non locking interlock switches will be safe enough on this machine but the robot will have to perform a very fast braking stop.

4.2 Requirement

1. Electrical enclosure for distribution and control
2. A list of the spare parts for this system will be placed in the machine manual.
3. Any related documentation for the project will be in English.
4. All drawings produced will be in DWG, DXF or PDF format.
5. The equipment and components will comply with UK and European standards and regulations. This will include:

BS EN 60404 – Electrical safety of machinery

BS EN 13849 – Safety Related Control Systems

BS EN 12100 – Machinery Risk Assessment

Machinery Directive 2006/42/EC

4.3 Electrical requirements

1. Incoming supply will be 240VAC 50Hz less than 16A so a conventional PCE socket can be used
2. Controls systems 24VDC
3. Inputs will be wired PNP
4. Outputs will be wired PNP
5. 240vac cables outside of the electrical enclosure must be SY cable
6. Only Tri-rated cable to be used
7. Cable ferals will be used where ever possible

8. Enclosure must be at least ip61
9. 20% spare IO must be given in case of future requirement
10. Incoming supply to the panel will be separated into terminals before entering the isolator.
11. An isolator must be fitted to isolate mains supply before entering the panel
12. Cable colouring will be as Table 1

Voltage	Colour
240vac live	Black
240vac neutral	Light blue
24vdc positive	Dark blue
0v	Dark blue

Table 1 cable colouring

4.4 Basic machine sequence

This is the sequence in which the machine must run when in automatic mode. A more detailed version must be put in the machine manual. Figure 2 shows this sequence.

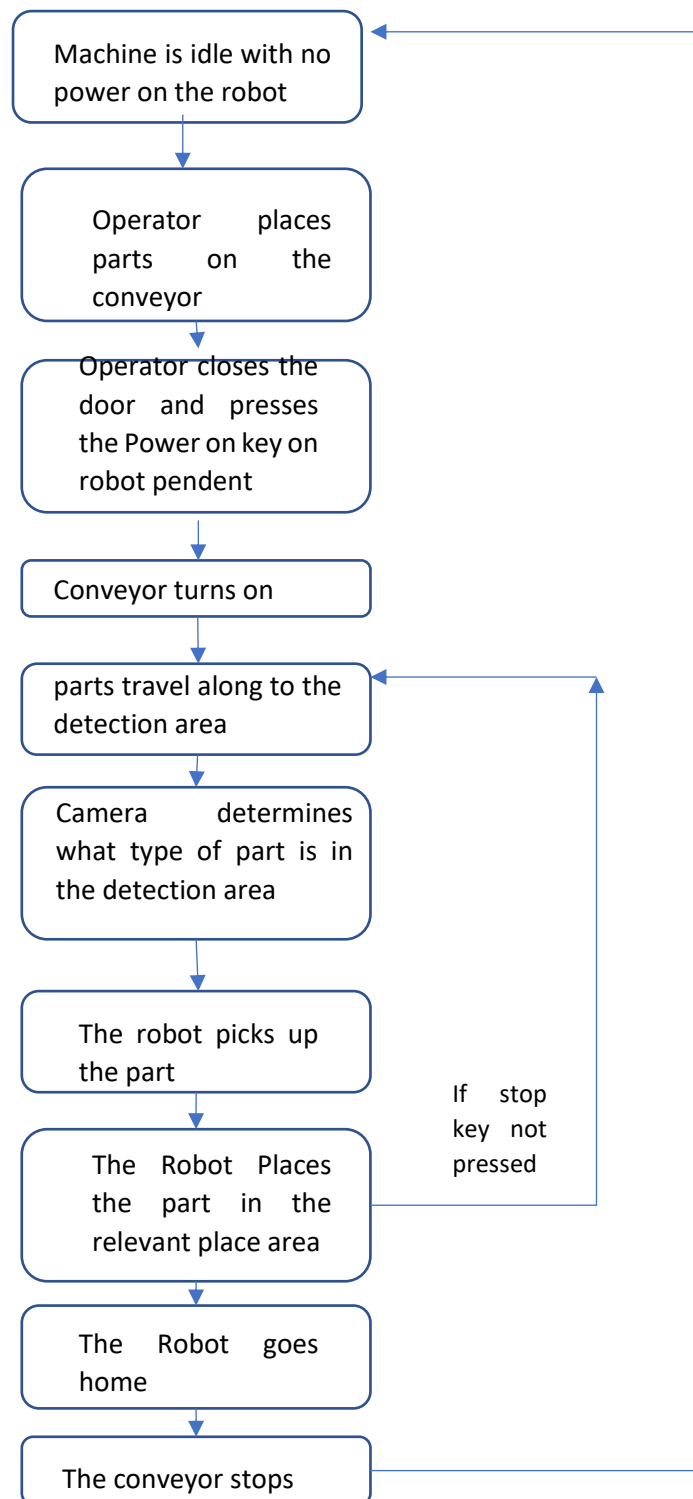


Figure 2 Basic sequence

4.5 ROBOT software requirement overview

The robot will have to have 2 running modes, Auto and manual. In Auto the robot will run at full speed when the user presses the control on button. In manual it will run at a reduced speed with the user having to hold the dead man switch on the robot pendant. The pendant will have to also display alarms and messages to help the user run the system.

4.6. Devices

4.6.1 push buttons, lamps & e-stops

The cell will have a control on button and an e-stop button. The control on button will allow the robot to have arm power if the estop circuit is healthy. The E-stop will have to prevent any robot movement as BSI Group Sates “Once active operation of an emergency stop or emergency switching off actuator has ceased following a command” (2010). The E-stop status will need to be feedback to the robot so a message can be displayed if its pressed.

4.6.2 Actuators

The robot has 2 valves within its arm that can be used for switching the vacuum on and off. So no extra valves will be required.

4.6.3 Proximity switches

There is 1 proximity switch required to check there is a part in the detection area

4.6.4 Guard Switches

There will be 1 guard switch mounted on the cell entry door. there will need to be a feedback to the robot to display a message if this door is open.

4.7 Safety performance

All safety components must be at least C safety level. Because of the safety category required on the machine, Pilz states “a single fault in any of these parts does not lead to the loss of the safety function” (2011). According to Štohl (2017) Dual channel safety circuit on the E-stop and the guard door circuit would prevent this.

According to BSI Group (2010) if an e-stop is pressed it should remain in an e-stop state even if the e-stop is released. The machine should only go back to a healthy state when a reset or power on button is pressed. There shall be no automatic reset on the E-stop or guard door circuit. Omron (2020). A rising edge pulse shall reset (validate) the safety circuit to prevent a false restart if a button was stuck open or close.

4.8 Performance

The machine is targeted for 20 parts per minute at 100 % efficiency.

4.9 User community

4.9.1 Operator

1. Load Parts on the conveyor
2. Remove parts from the place areas

4.9.2 Maintenance Engineer

1. Clean down work stations.
2. Teach points of pick and place if necessary
3. Check the condition of the suction cup on robot

4.10 Error & fault handling

4.10.1 Machine Error

Operator will be notified by way of message on the robot pendant screen if a machine error has occurred.

4.10.2 Product Fault

If a part is present in the detection area and isn't the Circle or square then is put in a reject bin.

4.11. Budget

The project has to be completed under £12,500 which includes hours of working on the project and bought outs.

4.12. Time scale

The project has to have its concepts completed by the end of December ready to be designed in the new year. The final completion is March 2021 where the system has to be tested with the machine manual completed.

5. Testing Plan

To ensure that the projects final outcome meets the original functional design specification a test plan is created. Table 6 is a testing document which ensures the final outcome. The numbers reference the FDS sections.

6. Literature Review

A solution for the safety circuit and control has to be established to ensure full safety on the system is met and covers the risk assessment. The requirements of safety have to be established before finding a solution.

6.1 Solution 1 – Robots internal system

6.1.1 justifications

This method allows a simple safety system which meets the minimum requirements of the FDS

6.1.2 Limitations

There is very little room for expandability on this solution. If extra E-stops and guard doors were added then diagnosis for faults would be difficult. Turning the power onto the robot's arm using software only does have the possibility of going wrong without any double safety precaution that the other solutions have but according to Staubli (2009) it is within regulations. This method wouldn't be as attractive to customers as it doesn't show the full use of modern technologies. Hornbeck suggests (2008) doing the minimum for safety regulations isn't a long-term method of designing a safety circuit which this method effectively will be.

6.1.3 Function explanation

staubli, (2011) suggests using the external E-stop and guard door circuit directly onto the robot controller. The E-stop and guard door will wire straight into the cs8 controller without any safety relays. The robot will effectively be the safety relay. As shown in Figure 11 in the appendix the robot's safety can be by passed in "Remote Auto" mode. This will allow the arm power on using the Applications program using the "EnablePower" function as stated by Staubli "In remote mode, this instruction switches the arm power on." (2018). The control on button can then be wired to the robots IO board. This is shown in Figure 3

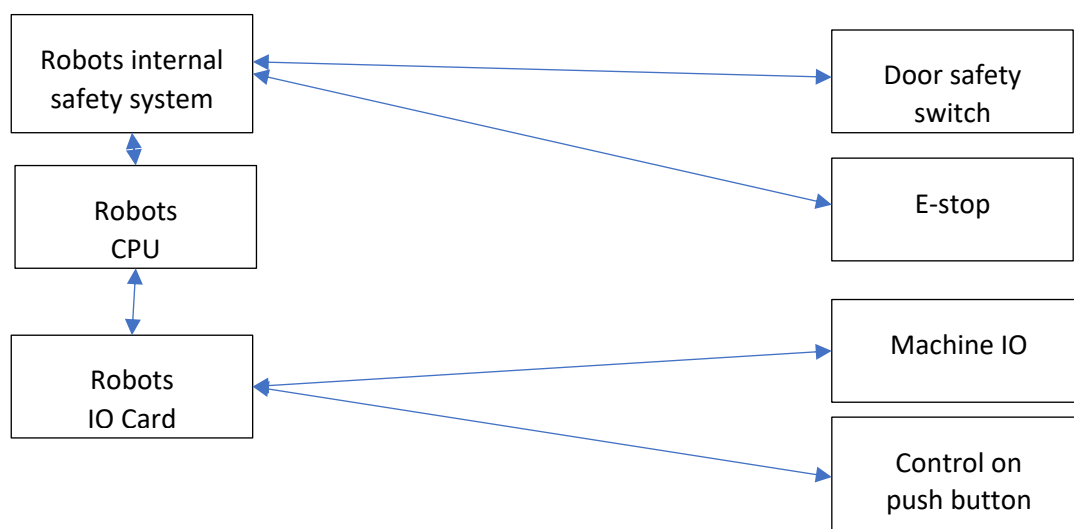


Figure 3 Solution 1 block diagram

6.1.4 Parts required

The only parts required for this solution would be a dual channel E-stop and a dual channel door guard switch.

6.1.5 Solution cost

This solution can be done with buying only the E-stop and guards which is required in all solutions. Price is shown in Table 2.

<i>Part</i>	<i>Cost from RS (2020)</i>
<i>2 pole N/C Estop Pushbutton</i>	£37.20
<i>Force guided relays 4 off</i>	£54.36
<i>Total</i>	£91.56

Table 2 Solution 1 cost

6.1.6 Safety levels

Staubli States (2009) "The robot and its controller are designed to meet a "Category III" safety level" which meets the requirements of the machine.

6.2 Solution 2 – Safety PLC

6.2.1 justifications

Darvas (2016) suggests a safety PLC can be used in critical safety applications. Rastocny states that a safety PLC is “designed to be used in industrial safety relevant applications” (2012) which would suit the machine as is aimed at industrial customers. The Safety PLC is one of the highest safety solutions when it comes to machine building. This is because of the way it monitors all its I/O continually and gives a very detailed diagnostic when a fault occurs. This is explained by Muehlfellner as he states “no individual error could happen twice and go unnoticed.” (2009). According to Macdonald (2004) a safety PLC is a very easily expandable device on a machine as any extra devices can be added onto an extra safety I/O card. This may be useful for the machine because there may be the future requirement to add external E-stops in if it gets adapted to work with another system.

6.2.2 Limitations

There aren't many limitations to a safety PLC other than cost of the devices. the software writing and commissioning can be time consuming. This may disrupt the timing plan.

6.2.3 Function explanation

Figure 4 shows the fundamentals of the safety PLC being integrated to the Robot. The E-stop and Door guard switch will come into the safety PLC's inputs which will be continually monitored by the Safety PLC looking for faults such as cross circuit or open circuit. The inputs of the machine will go back to the main part of the PLC as a standard input. The control on button will go back to a safe input. The advantage of this is it can be configured so that the safe input won't supply the push button with voltage until the safety circuit is in a safe state to be validated. The internal safety state of the robots will also feed back to the safety PLC and impact the safety state. If the robot's internal safety is healthy as well as the machine e-stop and guard door, then the control on is pressed the safety PLC will turn on its outputs for the force guided relays. There are 4 in total 2 for the dual channel of the robot's external e-stop circuit and 2 for the robot's external door circuit. There are 2 relays for each in case one relay failed it would only hold on one safety channel. The outputs are fed back to the safety PLC so it can monitor that the relays came on. The machine's I/O would be fed back to the safety PLC and communicated to the robot using a Modbus protocol where the PLC would be the server as suggested by Sridevi (2019).

6.2.4 Parts required

According to Omron (2020) the Safety PLC would have to be bought in at least 5 sections in order to complete the required task. A main CPU for the PLC is required. The part NXECC203. This includes ethernet RJ45 port to communicate with the robot. To incorporate the machine's inputs an input module will need to be used. An nx-id400 will be able to do this as the machine will only need an

input for the part present. according to Omron (2020) The safety CPU can be the Part number NX-SL3300 which will control the safety IO modules and have to be programmed. The safe IO card NX-SID800 alongside the safe output card NX-SOD400 will have Enough safe I/O to complete the task.

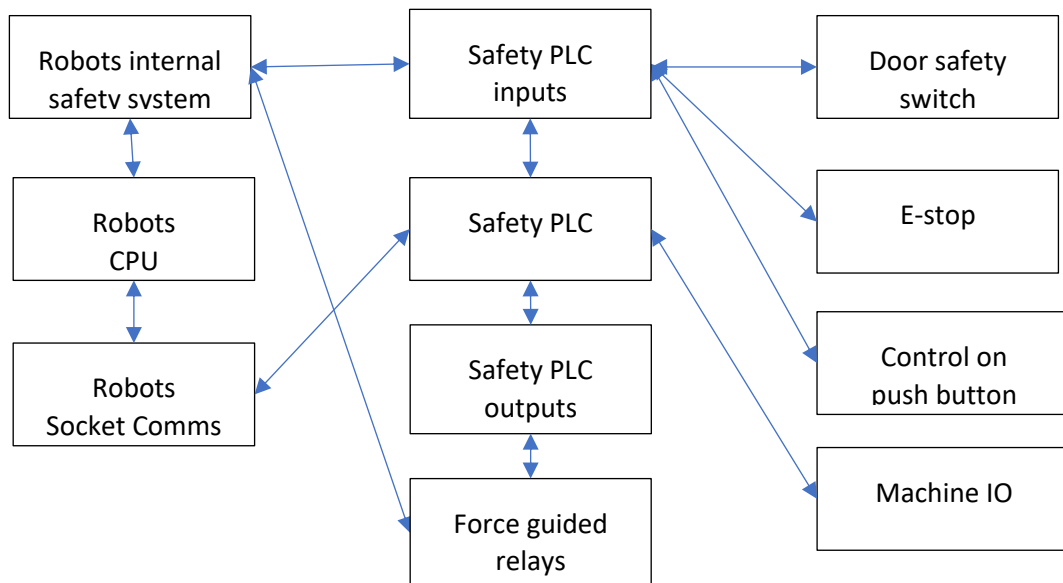


Figure 4 solution 2 block diagram for safety PLC

6.2.5 Solution cost

The cost of this solution shown in Table 3 is quite high and would take over 10% of the budget. It can be made cheaper by using a different brand but Omron PLC's are the company's standard if a different manufacture of PLC is not specified by a customer.

Part	Costing from RS (2020)
PLC Main CPU (NXECC203)	£222.84
Basic input card (NX-ID400)	£50.52
Safety PLC CPU (NX-SL3300)	£328.92
Safety IO card (NX-SID800)	£440.16
Safety additional output card (NX-SOD400)	£362.88

<i>Force guided relays 4 off</i>	£54.36
<i>2 pole N/C Estop Pushbutton</i>	£37.20
<i>Force guided relays 4 off</i>	£54.36
<i>Total</i>	£1551.24

Table 3 Solution 2 Cost

6.2.6 Safety levels

Omron States “The safety controller meets Category 4” (2020) which is more than what is required by law which would future proof the machine if minimum safety standards are increased. As Hornbeck states “The machine safety world continues to evolve” (2008)

6.3 Solution 3 – Safety Relays

6.3.1 justifications

Safety relays allow the combination of more advanced safety monitoring with a smaller cost than a safety PLC. A safety relay is fairly simple as opposed to a safety PLC and requires no programming just typically a mode selection. Pilz states “maximum functionality in minimum width” (2020). a more compact safety solution allows a smaller electrical enclosure to be used which will save costs. Pilz (2020) suggest that diagnostics on their safety relays are simple with led lights on the front. A PLC without an HMI would require to be connected to fault diagnose.

6.3.2 Limitations

Expansion of a circuit isn't as simple than a safety PLC. If an additional e-stop is needed to be added in the future then the circuit would have to be modified to put the e-stop in series. This could be solved by building the circuit to have removable links where additional safety sensors can be added. The outputs aren't monitored like the safety PLC it is just a contact which reduces diagnostic levels.

6.3.3 Function explanation

The system will function similar to the Safety PLC concept but would have 2 safety relays instead. 1 safety relay is for the door circuit and the other is for the e-stop channel. These safety relays will drive force guided relays which would control the robot's safety circuit. Pilz suggests (2020) that the control on push button that will reset the safety circuit is by placed after the Door guard or e-stops 24V safety channel so that there is only a chance of resetting the circuit when at least one of the safety channels is healthy. Figure 5 solution 3 block diagram this concept.

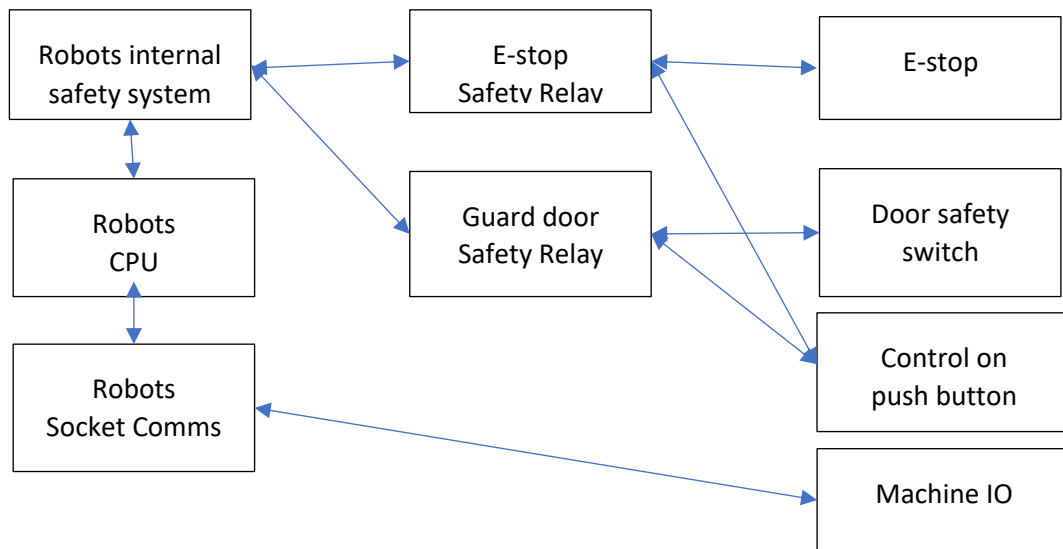


Figure 5 solution 3 block diagram

6.3.4 Parts required

One safety relay will be required for the e-stop circuit with at least 2 output channels. According to Pilz (2011) a PNOZ S2 will be a suitable safety relay for this solution. Another safety relay of the same part will be used for the guard door circuit. Four force guided relays that would link the safety relays would be required.

6.3.5 Solution cost

Table 4 shows the additional costing for this safety system. Compared to the safety PLC its approximately 10% of the cost making this a more plausible solution with the budget but the extra design time may cause the budget to be broken.

Part	Cost from RS (2020)
Pilz Pnoz s2 Safety Relay	£148.48

Force guided relays 4 off	£54.36
2 pole N/C Estop Pushbutton	£37.20
Force guided relays 4 off	£54.36
Total	£294.40

Table 4 Solution 3 cost

6.3.6 Safety levels

Figure 12 in the appendix shows the guide to selecting a Pilz safety relay from Pilz (2020). It shows a Pnoz2 safety relay has a PLr rating of c and the component category of 3 which would meet design requirements.

6.4 Comparison

Table 5 shows the comparison of the solutions. Areas covered in this comparison were safety rating, Diagnosis, Cost, Time to design, time to install and commission and future expansion. A scoring system was used on the solutions ranking them from best to worst in each area. If it was the best solution for that area is scored a 3 if it was 2nd it scored a 2 and the worst had a 1. The scores were added up at the end to find the best solution. Solution 1 and 2 drew equally first and solution 3 scored the worst.

COMPARISON POINT	SOLUTION 1		SOLUTION 2		SOLUTION 3	
SAFETY RATING	Category 3	2	Category 4	3	Category 3	2
DIAGNOSIS	Basic robot diagnosis	1	If connected to PLC full diagnosis	3	Led lights flash to indicate fault	2
COST	£91.56	3	£1551.24	1	£294.40	2
TIME TO DESIGN	Basic circuit required	3	Circuit design is more involved than the robot but more time consuming	2	Longest time	1

You STAKED THE BUDGET
WAS £12,500.?

TIME TO INSTALL AND COMMISSION	Basic wiring and settings in robot	3	Wiring more involved than solution 1 put programming time is a lot more	1	Wiring is the most time-consuming part. Setting up just contains setting a dial	2
FUTURE EXPANSION	Little ability for expansion	1	Easy expansion with just programming and adding IO cards	3	Expansion is possible but will require rewiring	2
SCORE		13		13		11

Table 5 Solution comparison

6.5 Chosen solution

Solution 1 is the chosen solution. It was chosen as although it doesn't offer the advancements in technology as safety PLC it is a lot cheaper solution which is more likely to be completed on the budget given. Time in design and implementation was also a big factor in choosing this solution. There would have been a risk in choosing solution 2 or 3 as the extra design time and programming time may cause the project to go over budget in labour and be late.

SOLUTION 2 SEEMS THE BEST OPTION.

7. Project Planning, Work breakdown and Management Techniques

7.1 Work breakdown

Figure 6 Work breakdown structure shows the work breakdown structure of the project. The breakdown splits into 5 main areas of implementation which including electrical, mechanical, software, testing and professional standards. These are all in turn split down further to create approximately week-long tasks which makes this an effective method in project planning.

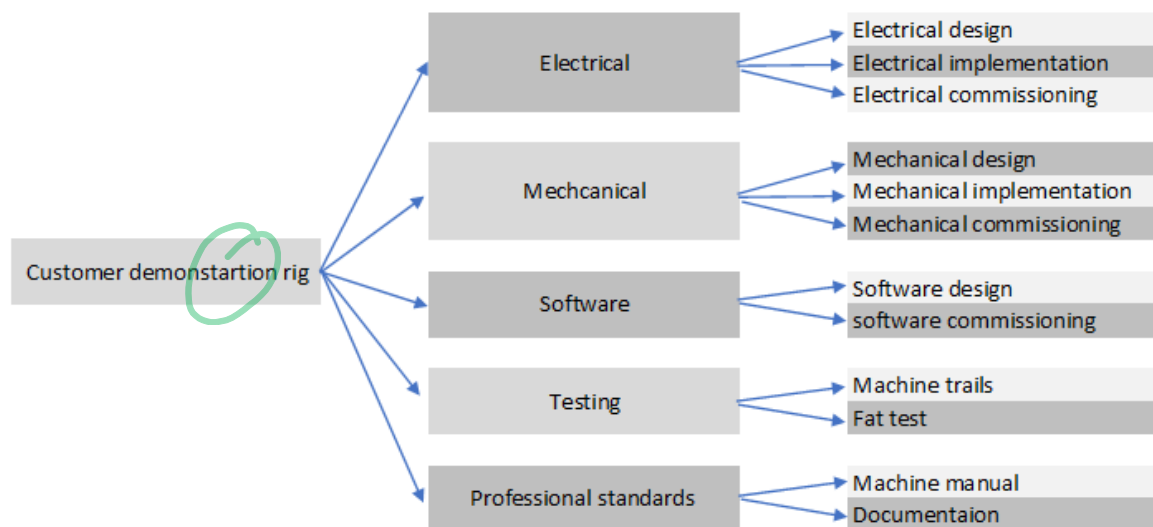


Figure 6 Work breakdown structure

SOME OF THESE ARE
AMBITIOUS FOR 1 WEEK

7.1.1 Electrical Design

Design of the electrical drawings for the system as well as a detailed parts list that needs to be ordered to wire the system. Electrical safety standards for automation systems must be complied with in this design from cable rating to safety interlock circuits. The electrical concept design will be the what major components will be needed to link the safety and vision system to the robot. A detailed electrical parts list is created at the end of this stage

7.1.2 Electrical Implementation

There will have to be an electrical panel on this job to include a power supply for the vision system and terminals for the safety circuit. Machine wiring is for the cabling going between the components and the electrical panel which is included in this section. This can only be done after the mechanical implementation is completed

7.1.3 Electrical commissioning

Setting up of any sensory and safety circuits. This will also involve making the machine in the correct state ready for software commissioning.

7.1.4 mechanical design

Design of the guarding for the cell. Design of conveyor guide and for parts as well as mounts for the camera is to be done in this section. A detailed mechanical parts list is created at the end of this stage

7.1.5 Mechanical Implementation

Manufacturing of any parts required to complete the mechanical work as well as the assembly of the mechanical sections of the system including guarding

7.1.6 Mechanical Commissioning

Aligning all the guard doors and any conveyor guides that may be used to align the parts down the conveyor. A bolt tightness check will be done at this stage.

7.1.7 Software design

In this stage the robot's software will be designed implementing Staubli SRS 2019 programming and simulation software which will allow a visual representation of the robot's movements without the risk of physically crashing the robot.

7.1.8 Software commissioning

The program is downloaded to the robot controller and all IP addresses will be set up. All robot positions will be taught and the robot will be trailed through its movements to ensure no crashes occur.

7.1.9 Machine trials

The machine is continually run under all conditions to prove its workings.

7.1.10 FAT Test

Every part of the machine will be tested against the spec to ensure it meets requirements. Safety tests are also taken in this section.

7.1.11 Machine Manual

Produce a document that explains how to run and maintain the machine. This must include any safety notes and guidance.

7.1.12 Documentation

This stage runs alongside the project ensuring all stages are documented with all information easily accessed.

7.2 Project Plan

Figure 13 in the appendix shows the plan for the implementation stage of the project. It spans from the 4th January 2021 which is indicated as week 1, up to week 10 which is March 15th 2021 when the project will have to be completed. When the project gets to week 3 after the design stages all the parts required will be ordered to ensure they arrive by the implementation stage. The implementation of mechanical and electrical must be done before commissioning either of them as it will have to be done twice as settings may get affected. The software commissioning is done next as all the positions will be final. When the machine is completed the testing will commence this will include the machine trails and Fat test. The machine manual will be completed at the end of the project when all functions are final.

7.3 Costing Plan

Figure 13 shows the original budget from the project. It's a company document that had to be filled in to produce to budget. It considers labour and bought out parts for the project. When the project is implemented every hour that is spent on it will be documented in a duplicate of the excel spreadsheet to compare with to keep track of the budget. At the end of the project a comparison between the budget breakdown and the actual spending can be done to see where budgeting can be improved on in the future.

7.4 Management techniques

The main management technique on this project has been a bottom-up approach where the robot controller used has been a factor in almost every decision. the planning techniques have been the gaunt chart which has broken down the deadlines. The work break down structure helps put the tasks into manageable sections which can be progress monitored easier to ensure the project is on track.

Conclusions and Recommendations

WAS SAFETY THE
PRIME REASON?

The project is now at the stage where it can begin its implementation stage. The most optimum solution chosen for the safety which should keep it within the budget and timing plan. Doing this at this stage has reduced the risk of having to stick with the wrong solution. A lot of unknowns have been made clear from the FDS where the machines outcomes and specifics have been laid out in an easy to see format that can be reviewed through the implementation stages to ensure it looks on track to be met. The project plan has given a clear idea of the work tasks that have to be done with deadlines that can be tracked every week. The work breakdown structure has spread all the work out which is an effective project management technique. The wider engineering issues have been covered to ensure the modern engineering standards are going to be met throughout the project.

The recommendations are to keep careful track of the project timing plan from the very start as a small delay can accumulate to the project being late very quickly with the tight schedule. When it noticeable that a task isn't going to be completed on time it is going to be wise to organise work load sharing and allow some implementation tasks to be done by another personal to allow myself more time for design and commissioning. Safety must be kept as the main priority throughout the project and ensure it is put before the timing plan and budget

Citation List

- BSI Group. (2010, 2). BS EN 60204-Safety of machinery. London, London, Britan: BSI Group.
- Crown copyright. (2008, June). The Supply of Machinery (Safety) Regulations 2008. London, United Kingdom: Crown copyright.
- Darvas, D. (2016). Formal Verification of Safety PLC Based Control Software. *International Conference on Integrated Formal Methods* (pp. 508-522). Ábrahám E: Springer, Cham.
- Hornbeck, D. (2008). A Holistic Approach to Safety Automation. *XVIII World Congress on Safety and Health at Work* (pp. 1-11). Rockwell Automation.
- HSE. (2020, 11 27). <https://www.hse.gov.uk/simple-health-safety/risk/index.htm>. Retrieved from <https://www.hse.gov.uk/simple-health-safety/risk/index.htm>: <https://www.hse.gov.uk/simple-health-safety/risk/index.htm>
- Keyence. (2020, 11 27). <https://www.keyence.co.uk/ss/products/safetyknowledge/performance/level/>. Retrieved from <https://www.keyence.co.uk/ss/products/safetyknowledge/performance/level/>: <https://www.keyence.co.uk/ss/products/safetyknowledge/performance/level/>
- Knackstedt, H. (2020, 11 28). <https://www.robotics.org/robotic-standards>. Retrieved from www.robotics.org: <https://www.robotics.org/robotic-standards>
- Macdonald, D. M. (2004). *Practical Machinery Safety*. south africa : Elsevier Ltd.
- Muehlfellner, R. (2009). Its all about error detection . *What Controls Safety*.
- Omron. (2020, 11 30). *nx safety stand-alone datasheet*. Retrieved from [assets.omron.eu: https://assets.omron.eu/downloads/datasheet/en/v3/i185e_nx-s_nx_safety_stand-alone_datasheet_en.pdf](https://assets.omron.eu/downloads/datasheet/en/v3/i185e_nx-s_nx_safety_stand-alone_datasheet_en.pdf)
- Omron. (2020, 11 29). *nx-safety-stand-alone*. Retrieved from [industrial.omron.co.uk: https://industrial.omron.co.uk/en/products/nx-safety-stand-alone](https://industrial.omron.co.uk/en/products/nx-safety-stand-alone)
- Omron. (2020, 12 1). *Safety Control Unit*. Retrieved from [www.omron.eu: https://assets.omron.eu/downloads/datasheet/en/v6/f109_nx-sl_si_so_datasheet_en.pdf](https://assets.omron.eu/downloads/datasheet/en/v6/f109_nx-sl_si_so_datasheet_en.pdf)

- Omron. (2020, 11 28). *www.omron.com*. Retrieved from *www.omron.com*: https://www.omron.com.au/service_support/technical_guide/safety_component/safety_functions.asp
- Pilz. (2011). *Safety relays PNOZsigma*. Retrieved from *www.pilz.com*: https://www.pilz.com/download/open/PNOZsigma_Appl_Manual_1002430-EN-05.pdf
- Pilz. (2020, 11 29). <https://www.pilz.com/en-GB/eshop/0010000200700380G9/Monitoring-of-E-STOP-safety-gates-light-barriers>. Retrieved from *www.pilz.com*: <https://www.pilz.com/en-GB/eshop/0010000200700380G9/Monitoring-of-E-STOP-safety-gates-light-barriers>
- pilz. (2020, 12 2). *PNOZ sigma safety relays*. Retrieved from *www.pilz.com*: <https://www.pilz.com/en-GB/eshop/00100002007003/PNOZsigma-safety-relays>
- Rastocny, K. (2012). Specificities of safety PLC based implementation of the safety functions. *International Conference on Applied Electronics* (pp. 229 - 232). Slovak: 2012.
- Rockwell Automation. (2014, 2). *Safety Switches*. Retrieved from *www.rockwellautomation.com*: https://literature.rockwellautomation.com/idc/groups/literature/documents/br/glsafe-br002_-en-p.pdf
- RS. (2020, 12 11). *emergency stop push buttons*. Retrieved from *uk.rs-online.com*: <https://uk.rs-online.com/web/p/emergency-stop-push-buttons/4258449/>
- RS. (2020, 12 1). *non latching relays*. Retrieved from *uk.rs-online.com*: <https://uk.rs-online.com/web/p/non-latching-relays/4882575/>
- RS. (2020, 11 27). *safety relays*. Retrieved from */uk.rs-online.com*: <https://uk.rs-online.com/web/p/safety-relays/4896350/>
- RS. (2020, 11 29). *safety-io-modules*. Retrieved from *uk.rs-online.com*: <https://uk.rs-online.com/web/p/safety-io-modules/8625767/?relevancy-data=7365617263685F636173636164655F6F726465723D31267365617263685F696E746572666163655F6E616D653D4931384E53656172636847656E65726963267365617263685F6C616E67756167655F757365643D656E2673656172>
- Sridevi, G. (2019). Effective Protocols for Industrial Communication. *Emerging Research in Electronics, Computer Science and Technology* (pp. 1093-1105). Singapore: Springer.

Staubli. (2009, 03 26). *Staubli-Cs8c manual*. Retrieved from [www.manualslib.com: https://www.manualslib.com/manual/812489/Staubli-Cs8c.html#manual](http://www.manualslib.com/manual/812489/Staubli-Cs8c.html#manual)

staubli. (2011, 10 6). <https://www.staubli.com/en-us/>. Retrieved from <https://www.staubli.com/en-us/>: <https://www.staubli.com/en-us/>

Staubli. (2018, 11 22). VAL 3 REFERENCE MANUAL Version 8. France: Staubli.

Štohl, R. (2017). The CIP safety protocol in connecting single machines to create production lines. (pp. 512-516). Sinaia: 18th International Carpathian Control Conference (ICCC).

Appendix

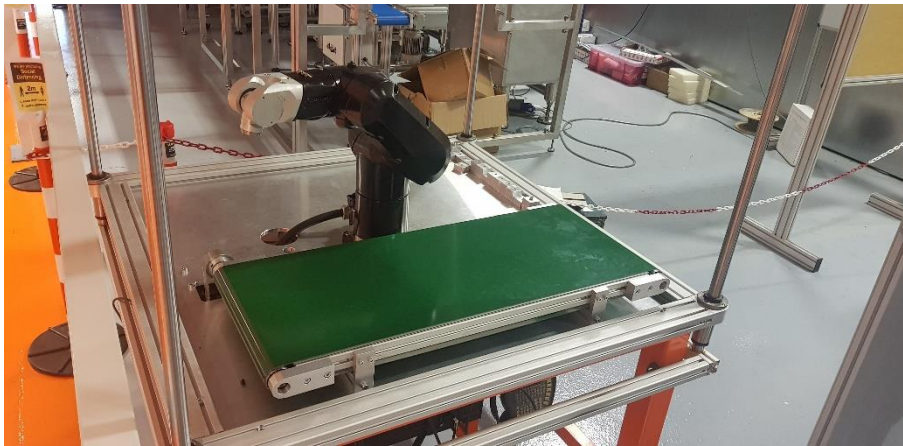


Figure 7 Existing system

BOTH OF THEM WOULD
BE IN THE REPORT TEST.

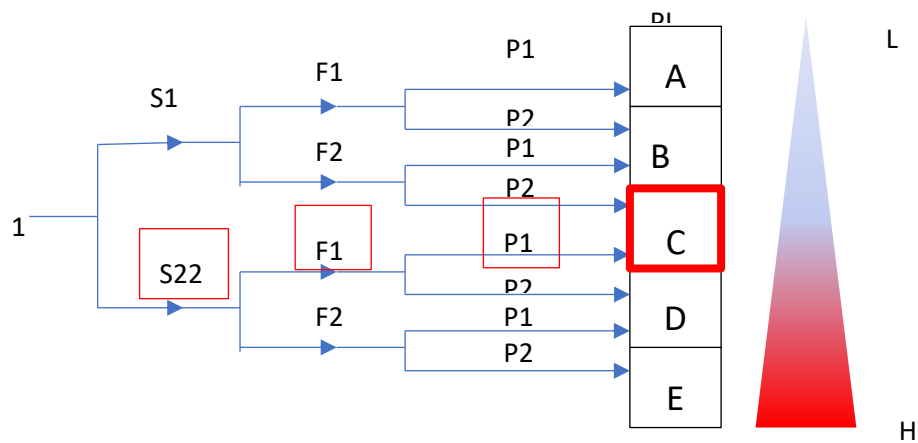


Figure 8 PL performance

MACHINE RISK ASSESSMENT

1.6 Conclusions

<u>Hazard number</u>	<u>Remarks</u>
1	The Customer Demonstration rig needs wheels to move it around shows so the wheels cant be taken out of the design. The risk instead reduced by having locking wheels to park the machine. Correct safety procedures will be put into the machine manual and the machine manual will have to be read before moving the machine.
2, 3, 4, 5, 6	The robot being able to move in the cell is very important and cannot be revmoved from the design. The risk can be reduced by placing guarding around the robot and the robot will only run in manual mode with the guard opened. The manual mode allows the robot to move only if the deadman switch is pressed which is low risk.
10	The turning pulleys of the conveyor is very important and cannot be revmoved from the design. The risk can be reduced by placing guarding around the robot and the robot will only run in manual mode with the guard opened. The manual mode allows the robot to move only if the deadman switch is pressed which is low risk.
14, 15, 16, 17, 18, 19, 20, 21, 22	The 240VAC is required to power the robot contorller but 24VAC can be used for control to reduce risk and all 240 components in the panel can be approved to make it very difficult to touch the live areas directly. The panel will be locked with a key and a sticker will be placed on the front warning that there is 240VAC and to isolate power before entering.
26	If noise levels exceed 85db's, then a warning sticker will be placed on the machine telling the
28	industry standard of reducing pneumatic noise radiation is used
36	By providing access to the machine at ground level through an appropriate sized space, the
37, 38, 39, 40, 41	Any controls to the machine will be placed at a comfortable hieght to ease the use to reduce the
47, 48, 50, 70, 71, 73	Due to the size and weight of the machine it must only be moved by way of forklift truck and only by qualified personnel. Lifting aids will need to be fitted to aid the process. Instructions on machine movement to be included in the machine manual along with the approximate size and weight of the machine
49, 72	Due to the size and weight of the machine it is vital that it has been securely fastened to any transportation vehicle before departure.
52, 53, 54	Although a low level risk, potentially it could be fatal, machine must not be connected/unconnected by unauthorised, unqualified personnel, this must be stated in the accompanying machine manual along with the documented energy supplies required. Further more warning labels are to be used on the outside and also inside of the electrical enclosure.
51	It is necessary to set the machine up for commissioning and trials. Only authorised personnel who have read the machine manual should carry out this task.
56, 64	Handling of Ethanol & Methoxy Propanol should only be carried out by qualified personnel who have read the appropriate regulations and are authorised to perform such duties.
58, 65, 66, 67	No dismantling/removal of parts, components, devices of the machine are to be carried out without the written consent of the manufacturer. This to be stated in the machine manual.
59, 60, 61, 63	All power to the machine must be isolated before attempting any cleaning, maintenance work, fault finding or repairs. This must be stated in the Machine Manual.
62	Considered as negligible risk as cylinder centre positions are open.Hazard removed.
68, 69, 70, 71, 72,73	When decommissioning and dismantling the machine, the machine should be disconnected. Only authorised personnel who have read the machine manual should carry out this task, only with the written consent of the manufacturer. Any loading & unloading of the machine should be carried out with a forklift truck, lifting socket will be positioned on the machine to assist this and documented in the machine manual.

Figure 9 Machine Risk Assessment

Test	Tick to confirm	Comments
4.1.1 conveyor operation		
4.1.2 camera operation		
4.1.3 robot operation		
4.1.4 Guarding requirements		
4.2.1 includes electrical enclosure		
4.2.2 list of spare parts placed in the manual		
4.2.3 all documentation is in English		
4.2.4 all drawings are in DWG, DXF or PDF		
4.2.5 relevant regulations are met		
4.3.1 Incoming supply is 240VAC 50Hz less than 16A		
4.3.2 controls system is 24VDC		
4.3.3 Inputs are wired PNP		
4.3.4 Outputs are wired PNP		
4.3.5 240VAC cables outside enclosure are SY		
4.3.6 Only Tri-rated cable used		
4.3.7 cables ferrets used where possible		

4.3.8 Enclosure is at least ip61		
4.3.9 20% spare IO		
4.3.10 Incoming supply to the panel will be separated into terminals before entering the isolator		
4.3.11 isolator is fitted		
4.3.12 cable colouring is correct		
4.4. Machine follows correct sequence		
4.5 robot software requirements are correct		
4.6.1 Push buttons perform correct tasks		
4.6.2 Valves in robot's arm is used for Vacuum switching		
4.6.3 a proximity switch is used to check the part is in position		
4.6.4 guard switch is mounted onto the guard door and prong is correctly aligned.		
4.7 at least C safety rating components were used in safety circuits.		
4.8 20 parts per minute		
4.9.1.1 parts can be loaded easily by the operator		

4.9.1.2 parts can be removed easily by the operator		
4.9.2.1 the machine is easy to clean down for maintenance engineer		
4.9.2.2 Robot points can be easily taught		
4.9.2.3 Robot tooling can be easily checked		
4.10.1 errors are displayed on the pendant		
4.10.2 faulty parts are placed in the reject bin		
4.11 project is completed under 12,500		
4.12 project is completed before march 2021		

2.14. CELL WITH RS12

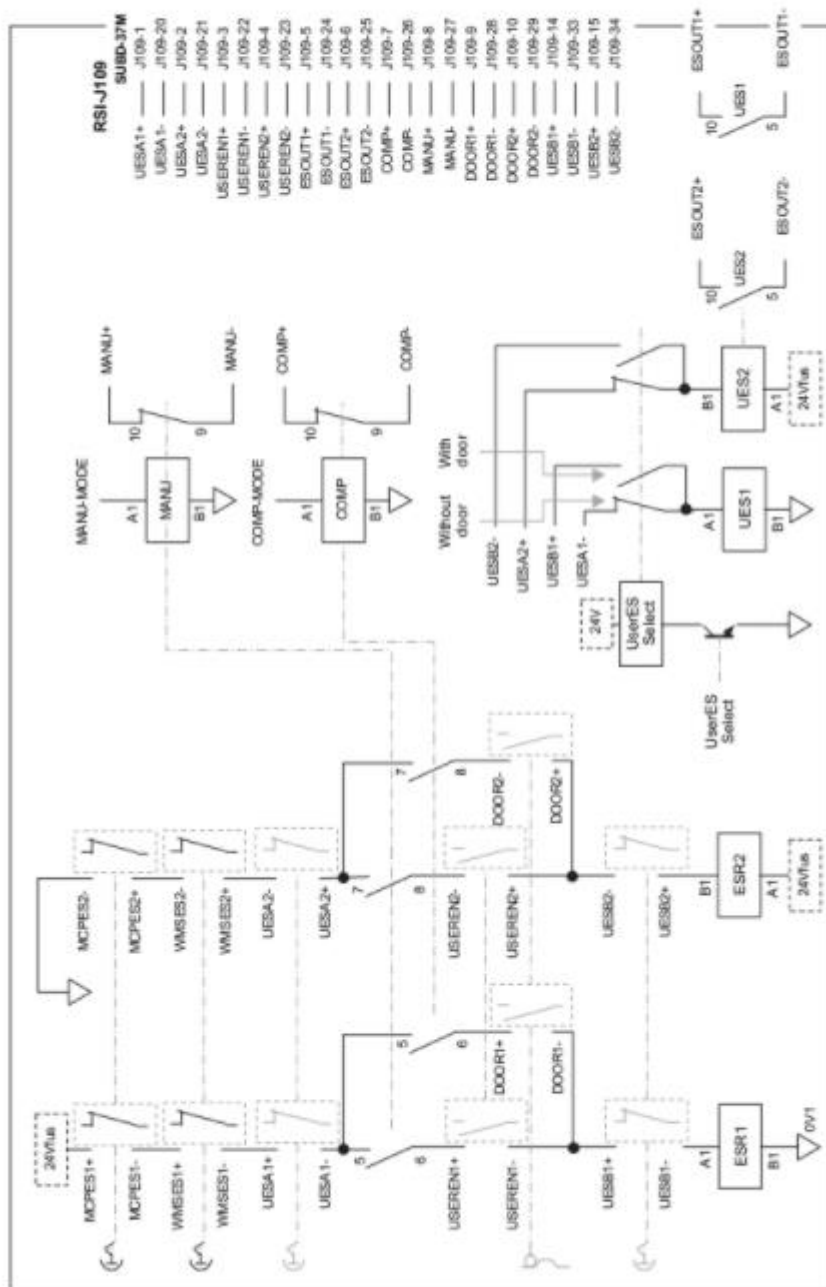


Figure 10 Controller safety circuit

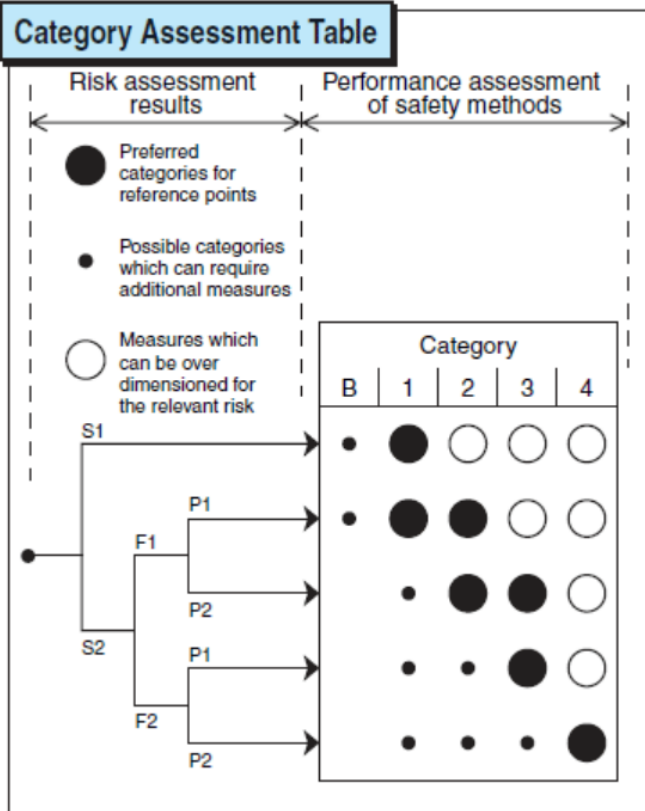


Figure 11 Safety component selection

Type	PNOZ s1	PNOZ s2	PNOZ s3	PNOZ s4	PNOZ s4.1
Emergency stop	✓	✓	✓	✓	✓
Safety gate	✓	✓	✓	✓	✓
Light grids			✓	✓	✓
Performance Level (PL)	c	e	e	e	e
Safety Integrity Level (SIL) CL	2	3	3	3	3
Output contacts (safe)	2	3	2	3	3
Width in mm	12.5	17.5	17.5	22.5	22.5
Special approvals	-	-	-	-	Burner control/ Burner management EN 50156-1

Figure 12 Pilz safety relay guide

Project Plan

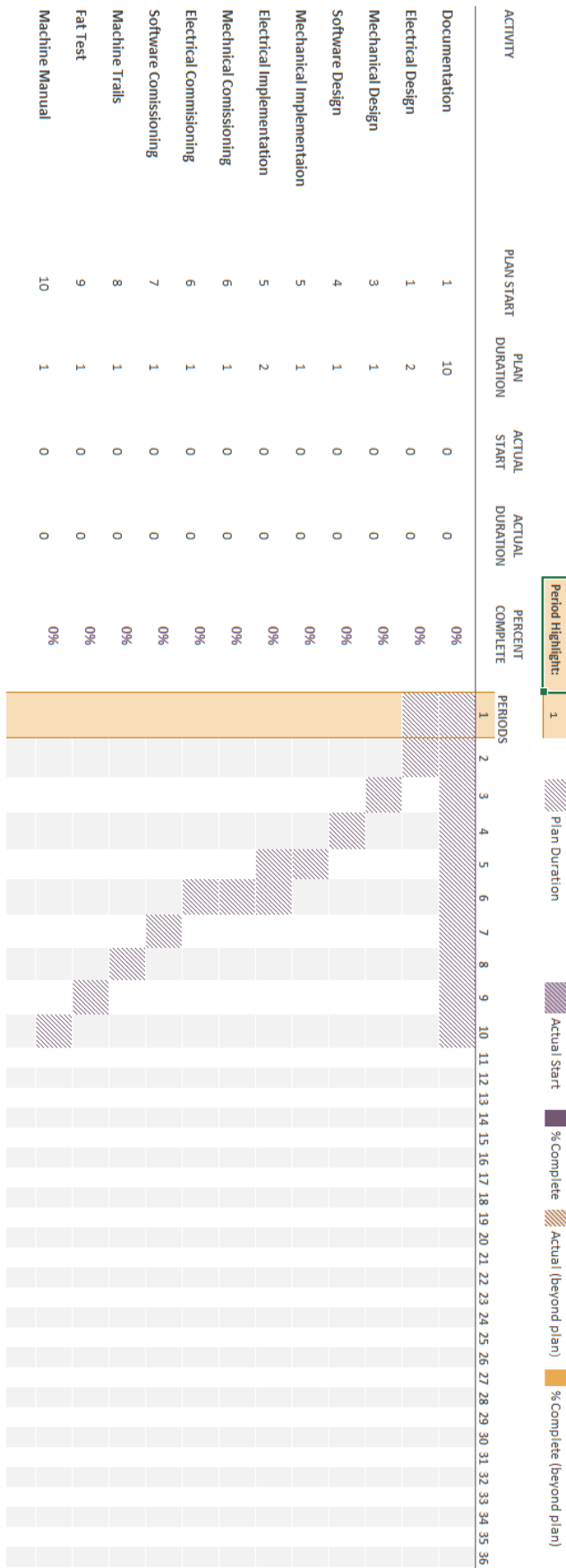


Figure 13 Project plan gaunt chart

VERY BASIC AND INCOMPLETE. SHOULD SHOW INTERDEPENDANCE AND CONCURRENT EVENTS.

MECHANICAL DOESN'T NEED TO WAIT FOR ELECTRICAL TO FINISH.

					Estimate Hrs	Estimate Cost	Estimated Wks
7	4.44%	LABOUR	ENG	ENGINEERING	12.00	£ 540.00	0.30
8	17.03%	LABOUR	MAN	MANUFACTURE	56.00	£ 2,072.00	1.40
9	50.67%	LABOUR	ELEC	ELECTRICAL	158.00	£ 6,166.00	3.95
10	5.92%	LABOUR	DOC	COMPLIANCE	16.00	£ 720.00	0.40
TOTAL LABOUR					242.00	£ 9,498.00	
11	4.11%	MATERIAL	MAT 1	RAW MANUFACTURING MATERIAL		£ 500.00	
11	0.00%	BO MATERIAL	MAT 2	MATERIAL- MECHANICAL		£ -	
						£ 500.00	
12	2.18%	BO MATERIAL	ITEM 1	ITEM		£ 265.32	
13	0.67%	BO MATERIAL	PNEU 1	PNEUMATICS		£ 81.69	
14	14.98%	BO MATERIAL	ELECT 1	ELECTRICS		£ 1,823.21	
15	0.00%	MISCELLANEOUS	MISC 1	MISCELLANEOUS		£ -	
16	0.00%	BO MATERIAL	HYDR 1	HYDRAULICS		£ -	
TOTAL MATERIAL						£ 2,670.22	
17	0.00%	SUBCONTRACT	SUB 1	SUBCONTRACT MECHANICAL		£ -	
17	0.00%	SUBCONTRACT	SUB 2	SUBCONTRACT ELECTRICS		£ -	
TOTAL SUBCONTRACT						£ -	
GRAND TOTAL						£ 12,168.22	

Figure 13 Cost break down

SGEL6000 INDEPENDENT PROJECT 2020-2021

PROJECT PROPOSAL DOCUMENT

Student Name: Sean Jones
Project Title: Customer Demonstration System
Date: 09/10/2020
Budget: £12,500

Description of Project

The purpose of the project is to develop a visual demonstration rig to show to customers when they visit the factory. It will also be transported to an automation event where new customers may visit the company stand. The system will have the availability to be used for robot and vision training. The final product must demonstrate a typical system that the company produces. This will involve a robot and a camera to show the new direction the company is taking in automation within the food and health care industry, where it is best to minimise human interaction with the product. Parts are fed onto a conveyor and move along until they stop against a constant position. A vision system will be required above this area in order to examine the markings on the parts. The robot must then pick up the part and place it in a designated area depending on the part marking. On food packaging lines, parts are often picked and packaged into containers and this system could provide evidence to a potential customer of the need to change their packaging methods to become fully automated for speed and quality improvements.

The lead in the project will be Sean Jones, who will also be responsible for the design, drawings, construction, programming and implementation of the system. The electrical safety design drawings will be approved by the company's electrical engineer Ceri Davies to ensure the system conforms to legal requirements and company standards. At the end of project testing, documentation will be produced and checked by an engineer to ensure they meet the company's quality standard. The entire project will be overseen by my manager Keith Harland to ensure the demonstration system represents the company's capability as intended.

The project is planned to be completed and tested by the end of March 2021 which should still be early enough in the year to take the system to automation demonstration shows throughout the year with the main one being the PPMA show in October 2021.

Agreement for project proposal

Student Signature: SEAN JONES **Date:** 09 10 2020

Industrial Supervisor Signature: KEITH HARLAND **Date:** 05 11 2020

Academic Tutor Signature: ROBERT DAVIES **Date :** 06/11/2020

SHOULD HAVE
PUT SOME OF
THE IMPORTANT
DETAILS IN THE
EXECUTIVE
SUMMARY