

SGEL6000 Independent Project

DOUBLE MARKING SHEET AND COMBINED STUDENT FEEDBACK

Assessment 3 of 4

Assignment 2: Project Design, implementation and evaluation

2020-2021

Agreed mark

65

Student Name: **Sean Jones**

Student Number **1602826**

Generic Assessment Criteria	Marks available	1st Marker (RD)	2 nd Marker (MH)	Agreed Mark
1. Engagement with Literature Skills.				
Section 3: Judicial use and critical evaluation of technical literature in the design of the project: Good evidence of use of literature in the design process, all design decisions appear to be well informed. Technical data came from many sources (Trabesinger, Staubli, Omar, RS, Schneider, Jones, IFM etc), but it wasn't clear how you evaluated the credibility of these sources.	5	4	3	4
Section 4: Extent of reading, range of credible sources and use of Harvard method: A wide range of sources have been consulted and cited. A good range of sources were listed in the reference list, but not always using the Harvard convention. In text citations were excessive at times and were used to quote a single value, when a screenshot of a datasheet would have been more informative. (see p7 of your report)	5	3	3	3
Total	10	7	6	7
2. Knowledge and Understanding Skills				
Section 3: Advanced knowledge and critical understanding demonstrated in the design of the project: There is good evidence of advanced knowledge in the design of the system and the safety requirements in order to ensure compliance with regulations and standards. You have demonstrated good technical knowledge throughout the project, however you have also underestimated the amount of time much of the work would take, resulting in an unfinished project.	10	7	6	7
Total	10	7	6	7
3. Cognitive and Intellectual Skills				
Section 5: Testing and analysis of result: There is good evidence of testing and analysis of results. Testing of the parts of the project that you did complete was carried out, however your test schedule was devised more like a checklist of tasks left to complete rather than an evaluation of correct functionality. You were also vague on outcomes with statements such as 'The camera gave the correct output every time' and 'The robots function effectively didn't work'	10	7	6	7
Section 5: Critical evaluation of the project outcomes: The project has been critically evaluated in part and an honest report given of where it went wrong or how the original plan was weak. You have clearly learned a lot from this process.	10	6	5	6

Not all of the requirements of the FDS were evaluated, in fact some were even changed. Wider issues such as H&S and ethical engineering only received cursory mentions.				
Section 6: Conclusions and recommendations: A good section with many conclusions and recommendations for the project and your method of planning and design. You have concluded more about your own performance, rather than that of the project and admitted that planning was poor and no contingency was planned for. Recommendations for future development were suggested such as a <i>'tracking picking method'</i>	10	6	6	6
Total	30	19	17	19
4. Practical Application Skills				
Section 3: Formulation of innovative and creative design solution to the project problem: The project shows a high level of thinking and creativity in the design of the hardware system and software programming. The chosen solution appears to be valid, although without a working project this is difficult to state definitively.	10	7	6	7
Section 4: Deployment method, use of material, tools, equipment and techniques in the construction of the project: Excellent methods deployed. Professional approach adopted to electrical design and software programming is evident. The report lacked photographs showing the work carried out and this aspect wasn't described in detail either.	5	4	3	4
Section 4: Quality of the final product or system: Good quality panel build and system layout. The programme is well written and the visual look of the system is good. Final product was not completed, however the work that was completed is of a good standard	10	6	6	6
Section 5: Use of test equipment and presentation of results of the project: Satisfactory use of testing methods, results shown in the appendix but the final system is incomplete. The test schedule had vague success metrics and a simple tick or cross to show success or failure respectively.	5	3	3	3
Sections 3 and 5: Management of the design process: The design process was not well managed but reviewed using flow charts, timing chart and costing sheets. This was generally poor with Gantt charts, flow charts and WBS that lacked clarity and contingency	5	2	2	3
Total	35	22	20	22
5. Transferable Skills for Life and Professional Practice				
Sections 1 and 2: Executive summary, acknowledgements and introduction: Summary should contain an overview of all that was done not just an evaluation of the end product. Good introduction but no acknowledgement section. The Executive Summary and Introduction were both brief and vague. No acknowledgements were included.	5	2	2	2

All Sections: Quality of the report: Well structured, good diagrams and images. Style is mixed and there are numerous spelling, punctuation and grammatical errors. Much of what has been said belongs in a log book and should have been summarised. Reads too much like a long story with things that went wrong inappropriately included. The report was difficult to read at times, with a lot of information hidden away in external sources (referenced) and in the appendices.	5	3	3	3
Word count: Not exceeded.	5	5	5	5
Total	15	10	10	10
Grand Total	100	65	59	65

Assignment 2 1602826

by Sean Jones

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Good Structure

*where are
the
acknowled
gements?*

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1. Executive Summary

This is supposed to be a lesson of

The project is incomplete so this is an evaluation of the current state of the project and what's left to complete it. The electrical and software design have been completed with relevant documentation. The project has been wired, powered and commissioning has started. Issues with the robot delayed the commissioning so it is still not completed. An IFM vision sensor was used to detect the parts which showed to be an effective solution when tested. Because the robot's software couldn't be tested effectively the software had to be tested using simulation software from the Staubli suite.

The project currently has 59 % of its tasks completed and has used £7674.66 of the budget. The project has run on 1 month after the deadline as it was intended to be completed by 31st of march. This was due to a poor timing plan at the start and the risks of the project not being evaluated enough when the timing plan was created.

The project has met most points from the original FDS. The points that haven't been met are due to the tasks being incomplete or the FDS point changing as information on the project was developed further.

This shows the importance of developing a more accurate FDS. You have learned that projects should be front loaded to avoid failure at the end.

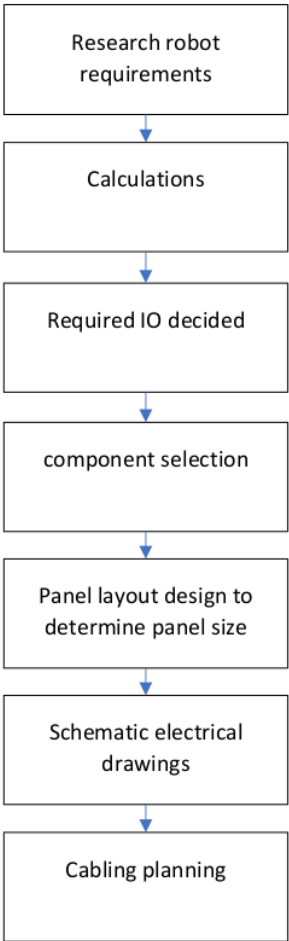
2. Introduction

The project is to make a customer demonstration system that can be used to attract new customers when they visit the factory as well as be taken to automation shows. The previous assignment saw the plan of the project to be completed by the 31st of March with a budget of £12,500. The system was decided to have a vision system to detect parts mixed with a robot. The safety of the system was decided to be controlled from the robot. The design of the machine has to meet the FDS that was created in assignment 1.

3. Design and Implementation

The electrical design was based around the existing system so everything would be *compatible* with the robot and conveyor. The flow diagram showed in Figure 1 gives the sequence that was followed to design the electrical circuit. It was done this way so all the information required to do a task was already gathered in the previous tasks. This method of design was suggested by Tamayoa (2018)

Correctly cited



This is a planning chart not a design, it belongs as part of a work break down structure (RD)

Figure 1 Electrical design flow diagram

Correctly cited

The robot was looked at in 3 ways; power, safety and inputs/outputs. According to Staubli (2017) the controller requires a single phase 230VAC 10A supply so this was integrated into the circuit ensuring the cabling, breaker and isolator was capable of supplying the current, Figure 6 shows this. The cable sizes were taken from BATT (2021) which gives the correct cable size in tri rated cable for the current. The robot's safety requirements were taken from the Staubli (2009) electrical manual. This

gave the connection requirements that have been illustrated in Figure 8. The controller had the capability of having more than 1 e-stop and door on separate connections. The unused connections had to be linked out so the controller thinks it's healthy. According to Jones (2021) the control on push button will go to the IO not the robot safety circuit. The safety circuit has been designed to meet the requirements for the machine building Crown copyright (2008). Jones states "All safety components must be at least C safety level " (2021) the dual channel e-stop is safety level C and the selected door guard switch used is suitable for category 3 machines which is suitable for a level c safety according to the data sheet from Rockwell Automation (2015) . It was decided that there was no need for auxiliary contacts on the safety stops as the robot can access internal IO to establish if an e-stop or guard door is unhealthy to flag an error on the pendant. BS EN 13849 – Safety Related Control Systems regulations were followed whilst designing the safety circuit. Trabesinger (2020) suggests the Staubli robot's reaction to faults should be fast enough to meet category 3 safety ratings. The IO connections were suggested from Staubli (2009) Figure 9 shows the input configuration and Figure 10 shows the outputs. According to Staubli (2009) the IO would take less than 1A when all the IO is in use.

The motor on the system is 3 phase 0.25KW. According to Omar (2020) a suitable way to make this motor run is a DOL setup. It was considered to use an inverter to run the motor to give variable speed control and a gentler start up but it was decided to go for the simpler option to save the cost of components, time for design and to reduce panel size. A suitable overload and contactor were designed from the datasheet provided by RS (2021). According to Schneider (2021) The coil of the chosen contactor takes 0.25A to switch on and hold in. This is less than the maximum current of the transistor outputs of the robot so it can be run directly off the output.

The vision system used was decided to be a 02D222. This is a basic vision system that can perform edge detection only. A more expensive version could have been bought which would have included the ability to apply filters onto an image and other tools such as a blob tool. The edge detection tool learns a profile of a part and its exact shape. A blob tool learns the parts size so it recognises the number of pixels that makes up the part and not necessarily its shape. Figure 2 shows the squares surface area against the circle. If the squares width was less than the circles diameter the is a chance that the camera would think they are the same weight when using the blob tool. Edge detection can have a scaling factor so if the same shape was used but at a smaller scale it would still detect it.

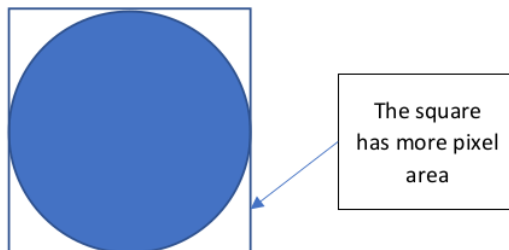


Figure 2 Blob tool shape weight comparison

Although the original plan from Jones (2021) was the vision system to cost less than £1000 it's been decided to reduce the cost of the vision system as much as possible to give more room in the budget for hours to spend on design. The cameras wiring configuration was sourced from IFM (2021). The camera IO can be configured in the software. The datasheet suggested using 1 input with rising edge detection to the camera for the trigger, 1 output to give a high signal when the camera has given the

results of the image and is ready for another trigger. The other outputs can be used for part identification. Table 1 shows the output configuration. According to IFM (2021) the current drawn to run this sensor is less than 1A.

Output	Result
Out0	Circle part
Out 1	Square part
Out 2	Fail part

Table 1 Camera output configuration

The 24VDC requirement of the system is 2.25A. because this is the continuous currents not the peak currents of the devices a 5A output power supply was chosen. Siemens (2021) state in their datasheet that their 24VDC 5A power supply should pull 1.15A. Table 3 shows the power requirements for each component.

Once the components were selected and the schematic drawings were completed the panel layout was drawn shown in Figure 5. This drawing allowed the panel size to be determined to check it can be suitable to fit on the machine. The panel decided is a 210x 400 mm which fits underneath the base of the machine. An isolator was designed into the panel in order to shut the power off before entering the panel. The isolator handles as well as the electrical panel had to meet ip61 ratings. Rittal (2021) state that their compact enclosure has a "Protection category IP to IEC 60 529 : IP 66"

The drawings were produced on EPLAN software. This required the reference manual to be used to understand how to use the software from EPLAN (2021). This drawing method is standard to be used in all electrical drawings in the company to allow the drawings to be on a .dwg file as required by Jones (2021).

Software design was implemented in a strategic approach. It was split up into different sub programs which work in different methods. Figure 3 shows the layout of the software programs. The application will start in the start program. This program will run straight through with no loops or delays. The sole purpose of this program is it initialize any values and to launch any continuous running tasks. Figure 14 shows the code for the start program. In this case the start program is launching the user display, cell manager and IO Mapping.

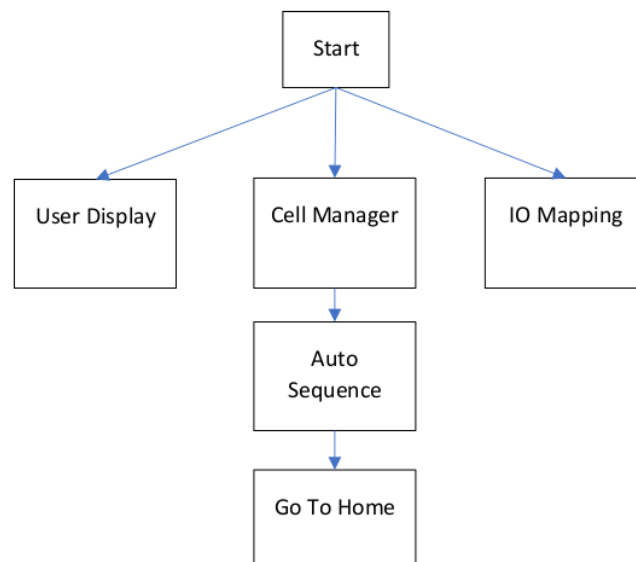


Figure 3 software program layout

The User Display program controls what is displayed on the pendant. This system doesn't have a friendly interface as what may be found on an HMI or an IP interface. There aren't any pre-set pages that can be designed. Any information written on the screen is displayed via x, y co-ordinates. For information to be removed of the screen either the `cls()` function which clears the entire screen has to be used or if text is written on top of the existing text it will overwrite it. Gookin (2004) suggests a strong method for having multiple display interface pages with this style of programming is to use a switch statement. The return of the "F" keys gives numbers between 271 (F1) and 278 (F8). The switch statement is set up so that the default setting of the page is case 0. When this case is entered it displays the choice of pages that can be selected. The program then waits for a return of the key between 271 and 278. Figure 15 shows the code for the main menu of the program. As the code was written the program was simulated using a pendant emulator to ensure each screen worked correctly and no writing was over lapping. This emulator only simulated what the pendant displays as the program runs through not the robot's actions. Figure 16 shows the simulated view of the main menu. This is better to be simulated before the machine is online at it saves commissioning time. The main pages that display information work similar to the main menu but they have a do until loop in them. They firstly display the headers for the information that is to be displayed. The do until loop is then entered. The loop moves the current value for the message or display value into a variable and displays that onto the screen. When it loops around again it will check if the message has changed and only then it will clear the old message with a string of blank spaces and display the new

Use of 11pt Arial, full justification with 1.5 line spacing allows easier reading and marking

message. If the message was updated every cycle, it would cause the writing to flicker. This method was suggested from Staubli (2018). Figure 17 shows this method. The purpose of having this interactive teach pendant was suggested by Galen (2017)

The cell manager program controls the safety recovery of the cell as well as the starting and stopping of movement programs. This program also utilizes the switch statement function. Each of the cases is a check of certain parameters of the robot. Below in Figure 4 is the flow diagram of the checks that the cell manager makes. The program cannot have any delays or loops within it other than the main loop around the outside of the switch statement. If this occurs the response time of the program is reduced as it will be scanning through the switch continually checking each recovery step. If this program didn't exist the robot would recover from an e-stop poorly as it would start where it left off. This is the only place in the robot code that the function power() is used that turns the robot arm on allowing movement. Figure 18, Figure 19, Figure 20 and Figure 21 show the cell manager program including detailed comments.

There is too much detail here on each part of the design (RD)

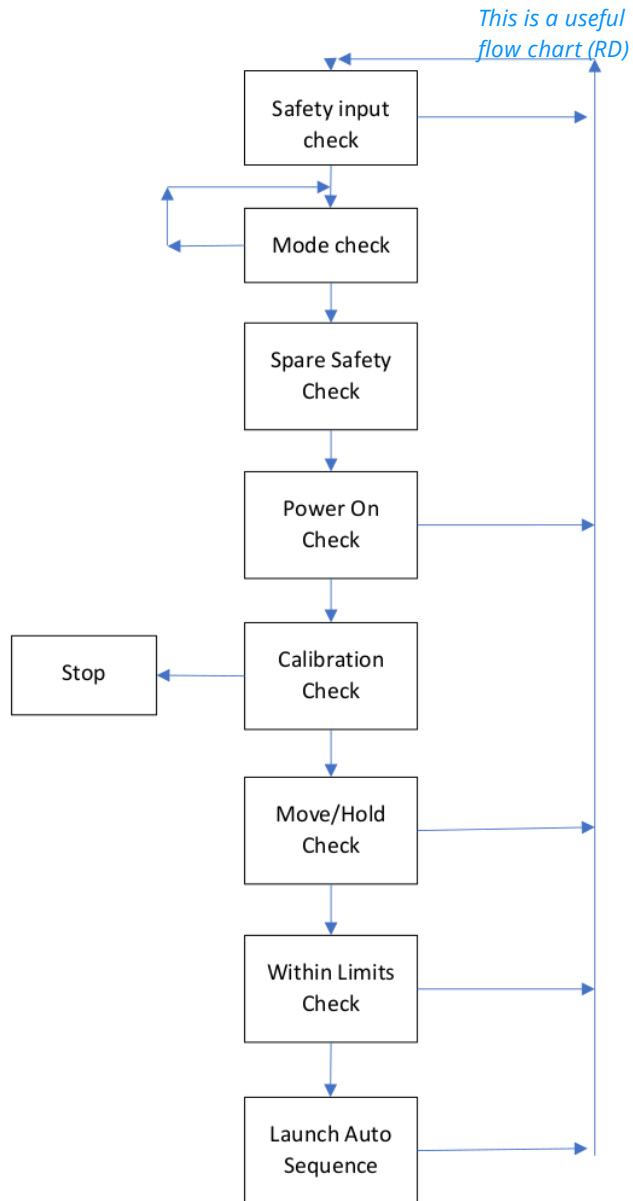


Figure 4 Cell Manager flow diagram

The Auto Sequence program launched from cell manager controls the robot's movements and decision making. It starts by launching a separate homing program to ensure the robot is in a safe starting position. There is a specific program for this function so it can be used multiple times without cluttering the program. The flow diagram shown in Figure 22 from Jones (2021) shows the original spec of the intended function for the robot. It was decided to change this slightly to give the robot more control over the part and a higher quality image from the camera. Instead of the camera

being mounted above the conveyor and continually being pulsed until it saw a part. The FDS has been changed so that there is a sensor that the robot waits for a high signal of then picks up the part and takes it to the camera and triggers it once. The overall function remains the same but the method to achieve this is changed. This method of checking parts was suggested from Semeniuta (2016). Figure 23 shows the auto sequence program that controls this. The auto sequence will continually loop until the stop program is called or the cell manager kills the task. there can be loops and delays within the auto sequence.

The IO mapping program in Figure 24 links the variables used in the programs to the physical IO of the controller which is stored in the library “io”. This program runs through once.

The components that were listed in Figure 12 from the electrical design were ordered in order to start the implementation process. The work breakdown structure wasn't detailed enough from Jones (2021) so the work was broken down further as shown in Figure 27. The plan to implement the stages of the project shown in Figure 28 is less specific as the new work breakdown document was used to determine specific tasks. The project was falling behind the deadline at an early stage due to the poor judgement of the resources that would be available for the project. The original agreement with management was that the mechanical design and implementation would be handled by an internal employee. When it came to the deadlines of the project it was made apparent that there were no mechanical engineers available to perform the design or implementation stages. To work around this there haven't been documented mechanical drawings which is poor practice of designing a machine as it would be difficult to repeat the same design to a set standard. All the mechanical implementation was done by the electrical engineer which prevented them to complete all the commissioning tasks.

The first part of the implementation was to build the electrical panel. The layout was followed from the Panel layout design in Figure 5. All the trunking and din rail was mounted using pop rivets. Din rail was used for the components to make them easily maintainable as they can be removed quickly. Figure 25 shows the electrical panel before it was wired. the earth terminals are mechanically and electrically connected to the din rail to meet the safety standard BS EN 60404 – Electrical safety of machinery which was a requirement set out by Jones (2021). Relevant PPE was worn during implementation such as safety goggles whilst drilling holes. This was to comply with the health and safety at work act 1997.

The field wiring was the next stage where safety standard BS EN 60404 – Electrical safety of machinery was used frequently ensuring that the cable routing and glanding was safe. An SY cable was used on all AC cables that weren't contained in trunking or conduit to reduce the risk of shearing cable. All cables going between the robot the electrical panel were labelled to make them easily traceable to the electrical drawings. The mechanical implementation had to start alongside the field wiring as items such as the camera and guard switch couldn't be wired until they were mounted.

Brackets were made to mount the camera to the bed of the table shown in Figure 31. The bracket was made using a milling machine. The robot gripper head was also made and mounted to align where the camera should be mounted. The cylindrical parts were made on the lathe. The size of the parts were increased for an easier grip and camera detection. The material was also changed from nylon to aluminium as material was readily available and didn't have to wait for delivery. Only trained personnel used equipment that was required to make some mechanical components such as a milling machine and lathe. Figure 39 shows the robot cell in its current state.

*There is too much implementation detail here,
reads like a long story*

When there was power on the machine the camera was set up to recognize the different parts. This was done by picking a part and hovering it over the camera. The first part to set up was the exposure rate of the camera. A well-tuned exposure setting gave a much clearer part to detect. Because the camera is using edge detection a complete part with a sharp edge must be on display. Figure 32 shows an example of the exposure being set. The square parts didn't have the neat uniform light reflection that was found on the circle part. This was likely due to the way the parts were machined forming scratches on the surface which reflect in different manners. The edge detection tool was set up giving a clear definition between the circle and the square. Because it is nearly impossible to have the same image twice the parts are decided if it matches the taught part via a match tolerance. This tolerance had to be slack enough that it allowed all the correct parts through but tight enough it wouldn't mistake it for the wrong part. The circle was set to 60% tolerance and the square was set to 70%. The outputs from the camera were configured according to the electrical drawings.

The physical guarding of the machine hasn't been refined in the designs yet but the concept has been designed. Aida Haghighi states "a lack of visibility, failures and a lack of reliability of the safeguards" (2019). This suggested if clear guards are used it would give more visibility into the machine reducing the risk of the guard being removed. A well sized door that will give good access into the machine will also reduce the likelihood of a guard being removed as the machine can be easily maintained.

Issues with getting the robot running postponed the commissioning of the software. The 3 main problems that caused delays were the robots internal CPU board needed reseating due to being out of use for a long period. A fuse had blown for the safety circuit which required a strip down of the robot in order to change it. The IO mapping was giving errors when trying to run the program. The robot should have been powered up at the start of the project to prevent this delay. A more detailed evaluation of the risks would have kept the project on track with more research into what common risks of an engineering project are.

Throughout the project hours spent on each sector were documented to keep a detailed track of the cost. This cost was monitored weekly to ensure there wasn't a risk of going over budget. Figure 29 shows the broken-down costing for electrical. The current cost of electrical hours is £5658 which is still under the budget for this area of labour which was £6166. There is a risk that when the issue with the IO mapping is solved the cost for this area could go over budget. The program sequence still hasn't been tested so it is likely this area will go over budget.

4. Testing and Results

The system was tested at intervals at critical stages of the project. This wasn't the original intention but after the design stage it was decided it would be the most appropriate way to ensure the FDS in being met.

*This layout is
much easier to
read (RD)*

There was testing performed during the commissioning stage to ensure the machine was safe to work on. The first evidence of this was before the machine was powered on after the field wiring. All the breakers were turned on with the machine disconnected from the mains supply. A multi-meter was used to check the resistance across the phases and relevant connections in the panel in case there was a short anywhere that could be fixed before a greater issue occurs on power on. This test highlighted an issue that the 0v wasn't tied to earth. This was forgotten about in the design stage so a link was then added. When it was proven safe to power the machine on, all the breakers and isolator were turned off and the machine was connected to the supply. The voltage before the isolator was checked to ensure the correct voltage was coming to the machine. The isolator was then turned on as well as the breakers where the 24VDC could be checked also. Figure 33 shows the results from these tests.

Too much detail, fixed faults do not need to be mentioned (RD)

To ensure the machine meets the safety requirements the safety circuit had to be checked to ensure they work as intended. Consideration was paid to not only the stopping of the robot but to the restarting of safety on the machine. According to Staubli (2017) this can be done by checking the internal IO status. The inputs from the safety are included here as well as the power status of the arm. The e-stop inputs are called UESB1 and UESB2, the door inputs are called UEN1_DOOR1 and UEN2_DOOR2. The robot arm power is called PWR. It has to be checked that when the safety input is back healthy the robots arm power doesn't come on until the control on button is pressed. If the safety auto reset the machine would not be safe as a person could climb into the machine, close the door behind them and the robot could start up. The robots own e-stop was checked as well as the externally wired one. Figure 34 and Figure 35 show that the safety circuit performed as intended.

The main part of the testing was to ensure that the final outcome met the intended outcome that was set out by Jones (2021) in the FDS. Because the machine wasn't complete by the project deadline and is still currently being worked on, this testing will be from the current state of the machine.

The camera was tested using the IFM software. Although the machine wasn't running this could be tested. Figure 36 shows the camera simulating the test. This also enabled the outputs with the test to

test the functionality. This was run through multiple times using the 2 parts and no parts. The camera gave the correct output every time.

The robots function effectively didn't work. The robot couldn't run in auto or manual mode as it was in error as soon as the application was started due to the IO mapping issue. The positions were taught as per the FDS. Only non-application functions of the robot worked such as manual jog movements on the pendant which showed the safety was connected appropriately. This is point 4.1.3. The sequence for the robot was changed in point 4.4 due to the picking issue but the plans to meet the new requirement but cannot yet be tested until the robot commissioning is completed. parts of the robot software were tested from point 4.5. This test was only using the simulation software provided from Staubli using their SRS software manual (2019). Simulating an offline device to check its function before connecting to in online was suggested by Vergnano (2017). This simulation allowed a 3d view of the robot where the program was stepped through with virtual IO attached to the programs io. It doesn't give a definite answer than the robot would work as crash zones weren't taken into account as that would require cad models to be imported into the simulation software but the machine hasn't been drawn on cad yet. It did prove the software was very close to what's intended. Run time errors were found from this simulation such as wrong variables used in places but these were simply fixed and will save time testing when the robot is running. The machines running rate could not be proven. Simulating the robots cycle time on the software would not be accurate as it doesn't account for the time it takes to pick and place a part accurately. The robots error displays were tested briefly through the program but for an accurate test it needs to be running properly and the errors occur. Figure 36

Camera Testing

*Much of this detail belongs in a log book
(RD)*

Point 4.1.1 required guarding to be fitted to the machine. At the moment there is no guarding or door on the machine which means the machine has to be taped off with warning tape and signs have to be in place to power on the machine to make workers aware of the risks of the unguarded system. an operator cannot run the machine until this task is complete.

5. Evaluation and the Wider Issues

The project has been relevant to original goals set out in assignment 1 FDS. The overall goal was to make a system that incorporates a robot with a vision system that could be used to demonstrate company capabilities to customers and also be used to train staff.

Table 2 shows the testing results. some parts of the FDS were changed mid project as circumstance changed. These are shown in Table 4. The testing table is in relation to the original FDS.

When it came to testing the robot's internal valves it was found it didn't have any which was unusual for this style of robot. It is likely that the robots spec has changed over the years meaning only the newer robots come with internal valves. The solution to this problem is to use an external 3 port 2 position spring return valve as suggested by Tameson (2021) this will be powered from a robot external output. Figure 38 shows Tameson's (2021) concept using vacuum to close the rubber cup and pressure to blow the part off instead of relying on gravity. This change doesn't affect the functionality of the machine it just changes the method of obtaining the overall outcome.

Punctuation Error

The Robots supply being changed to 3 phase 415VAC from 240vac hasn't changed the functionality of the machine so this wasn't a major change in the FDS. This change was done just to avoid having to put an inverter in for the conveyor motor to save cost of bought outs and time. The 5 pole plug that the 3 phase uses is just as common as the 3 pole single phase one so it will still be convenient to connect the machine up to a supply around the factory and in shows.

The robot's sequence had to change to allow the robot to pick the part up without crashing into the camera. An alternative solution would have been to mount the camera high up above the picking area and have the robot waiting outside the picking area so that the camera can see the part. The down side this solution would have been the cameras capability as its field of view isn't designed to be a meter away from the detection area. This meant a more expensive camera with interchangeable lenses to get the correct field of view at that distance would have had to be used. This change of the FDS to rearrange the sequence to pick before detecting the part didn't add any additional cost as this fault in concept design was captured before the software was written meaning it was implemented from the start. This change has saved cost in a mechanical sense also as a more elaborate bracket would have needed to be manufactured in order to mount the camera above the conveyor.

4.1.1 could have had more detail on the FDS. This point was for the conveyor functionality. Although it meets the spec there was more ways it should be tested for example speed. The speed was measured at 8M/m which is suitable for this application.

Throughout the project the wider issues were considered as well as the FDS. According to Jones (2021) the machine had to impact the environment as little as possible. The components that were planned to be reused into this project including the Frame, robot and conveyor were used. Some components were purchased as refurbished and 2nd hand. According to Ardente (2018) this gives a smaller carbon footprint of the component selection of the machine. These included the electrical enclosure and the vision system.

It was planned for some mechanical work to be sub contracted out if there weren't enough resources to support local businesses but this wasn't done. Other methods of being ethical were illustrated through implementing safety standards whilst implementing the project as well as the design that went into the machine.

The risk assessment that was implemented in assignment 1 by Jones (2021) was taken on board throughout the design stages to ensure that the suggested methods of reducing the risks we implemented. Before the implementation stage there should have ideally been a risk assessment for working on the machine. This would have improved the planning of the project and complied closer with health and safety regulations. This risk assessment would have looked closer at what tasks are required during implementation and what tools are required, from this it could be determined what safety equipment and training is required.

The programs for the robot haven't been password protected but the user passwords have been implemented and the ability to upload has been taken away from personnel that isn't logged in meaning the code can't be backed up from an untrusted user.

The risks of the project looked at by Jones (2021) were not detailed enough and focused in the wrong areas. The risk highlighted by Jones of the selection of the vision system was fine after testing and posed no risk when implemented. Covid also didn't cause any issues with timing. The risks that should have been investigated was the resources not being available throughout the project. This caused the biggest delays at the start of the project. The next risk was the functionality of the robot. The robot should have been powered up at the very start of the project and a basic program placed into it to check it functioned correctly. This might have saved time in the implementation stage which was 5 weeks behind to start with without hurdles stopping the project.

The technical file that was intended to produced alongside of the project is incomplete due to critical stages of the project not being complete. The technical file was intended to include all drawings mechanical and electrical, risk assessment, FDS, factory acceptance test and a machine manual. The

mechanical drawings, FAT and a machine manual haven't been completed which reduce the compliance with internal company standards as well as Crown copyright's (2008) machine building standards.

6. Conclusions and Recommendations

Throughout the project the planning was very poor. It was underestimated in the first assignment how long tasks would actually take as opposed to what was planned. The original timing plan wasn't detailed enough in what tasks had to be done. The time scales on the timing plan were set in order for the project to meet the march 31st deadline instead of the amount of time it actually takes to complete each task. This optimistic approach made the plan unusable. If every task was analysed closer so that a more accurate time estimation was produced then it would have been clear that the resources weren't possible to complete all the tasks. There were no contingency plans put in place which prevented avoiding delays when problems occurred. The 2 weeks of the project was on stop due to other jobs within the company which disallowed any work on this job as it was low priority to the company. The project is late by 1 month and only 59% of the work is completed which is down to these compounded issues.

The cost tracking of the project worked very effectively. The current cost of the project is £7,674.66 out of the £12,500 budget. This cost will go up as the guards and mechanical parts are made as well as the final commissioning but it seems very likely that the project will come in under budget. The cost tracking document that was used gave clear spending in each part of the project including labour and bought outs and helped the control. In every part of the project cost was reduced as much as possible to ensure that if there were difficulties and more time needed on a sector then the budget as a whole could compensate for that. The electrical design went well as using the EPLAN software allowed quality standardised drawings to be produced. Mistakes could have been reduced by having the drawings checked before the implementation stage. The revision system on the drawings allowed a newer version to be added easily. The software structure was very suitable when it was tested on the simulation it allowed the system to access tasks without confliction.

To complete the project, it is recommended that a new detailed timing plan is created using the new break down structure that has more specific tasks that need completed on it. If the old plan is used the issues that are currently in place from it would be dragged out to the end of the project. The remaining £4825.34 of the budget could then be wisely put back into the cost tracking to utilize it as efficiently as possible to ensure it doesn't go over budget. It should be possible to keep the project under budget and within the FDS but it will not be possible to keep it within the original timing scales to take it to automation shows.

The overall of the machine is fit for purpose and as a training facility as well as a customer demonstration gives a lot of potential to expand on areas. A specific area I would recommend to

expand on would be introducing a tracking picking method. This would allow the robot to pick a part that is traveling down the conveyor. this would be done using a more intelligent camera that can either display information into a spreadsheet that can be accessed via the robot comms or send a string to the robot after a trigger. The conveyor would need an encoder. The robot would have to have the Staubli Val Track software installed. The camera would trigger as the part travels underneath it and at the same time the robot would store the encoders position. The robot would then be able to keep track of the part as its moving down the conveyor as it would also obtain x,y co-ordinates from a reference point of the camera. When the part comes into reach of the robot it could pick the part of the conveyor without the need of the part being organised first. This style of part picking would allow parts the oriented as well with rotation. Customers would find this more impressive in shows. This also coincides closer to robot jobs the company produces in the food industry which have similar setups.

You have clearly learnt much from doing this project from better planning and costing to better time management and up front designs. (RD)

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Your design process has been well informed by research and consultation with manufacturer's literature RD)

8. Appendix

Test	Tick to confirm	Comments
4.1.1 conveyor operation	✓	The conveyor has a capability to be started and stopped from the robot IO
4.1.2 camera operation	✓	Camera can define parts and give relevant outputs according to what it sees
4.1.3 robot operation	X	This part was untestable as the IO mapping prevented testing
4.1.4 Guarding requirements	X	The guarding design or implementation has not been completed
4.2.1 includes electrical enclosure	✓	Can IP67 enclosure houses the electrical components
4.2.2 list of spare parts placed in the manual	X	The machine manual has not been completed
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	X	The Spec was changed so that the incoming supply was 3 phase 415VAC 50Hz
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 ferals used where possible	✓	There are no cables without ferals
4.3.8 Enclosure is at least ip61	✓	Enclosure is IP67
4.3.9 20% spare IO	✓	The is at least 50% spare IO. This isn't shown on the drawings as it's on an additional IO card
4.3.10 Incoming supply to the panel will be separated into terminals before entering the isolator	✓	X0 is the terminal block used
4.3.11 isolator is fitted	✓	4 pole fused isolator with a neutral bar is used
4.3.12 cable colouring is correct	✓	Followed from FDS
4.4. Machine follows correct sequence	X	This wasn't tested

4.5 robot software requirements are correct	X	The design was created from the FDS but the functionality can only be checked after commissioning
4.6.1 Push buttons perform correct tasks	✓	The only push button was the control on button which brings on robot power
4.6.2 Valves in robot's arm is used for Vacuum switching	X	These valves weren't present as expected for this style robot. An alternative need to be designed
4.6.3 a proximity switch is used to check the part is in position	✓	M18 Sensor is wired in but hasn't been mounted.
4.6.4 guard switch is mounted onto the guard door and prong is correctly aligned.	X	A guard switch is mounted but the door isn't in place yet.
4.7 at least C safety rating components were used in safety circuits.	✓	The machine meets the requirements set out from the risk assessment
4.8 20 parts per minute	X	Wasn't tested
4.9.1.1 parts can be loaded easily by the operator	X	
4.9.1.2 parts can be removed easily by the operator	X	
4.9.2.1 the machine is easy to clean down for maintenance engineer	✓	From design this is true as cables are brought up through the bed stopping ingress of dirt

4.9.2.2 Robot points can be easily taught	✓	The pendant allows the positions to be taught
4.9.2.3 Robot tooling can be easily checked	✓	The park position is by the intended door entrance
4.10.1 errors are displayed on the pendant	X	Untested
4.10.2 faulty parts are placed in the reject bin	X	Untested
4.11 project is completed under 12,500	✓	Project is currently at £7,674.66 but requires more work.
4.12 project is completed before march 2021	X	The project is a month late and still unfinished

Table 2 Testing Results

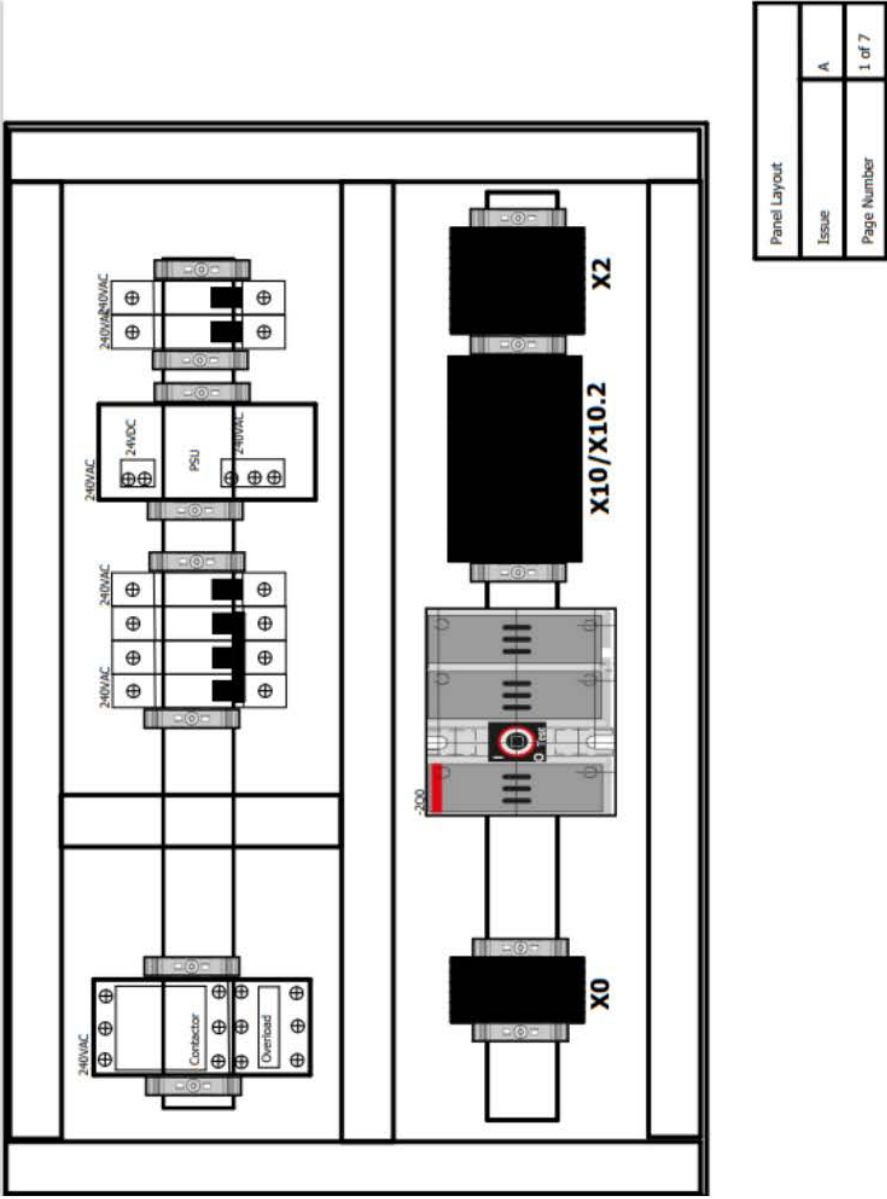


Figure 5 Electrical drawings Page 1 panel layout



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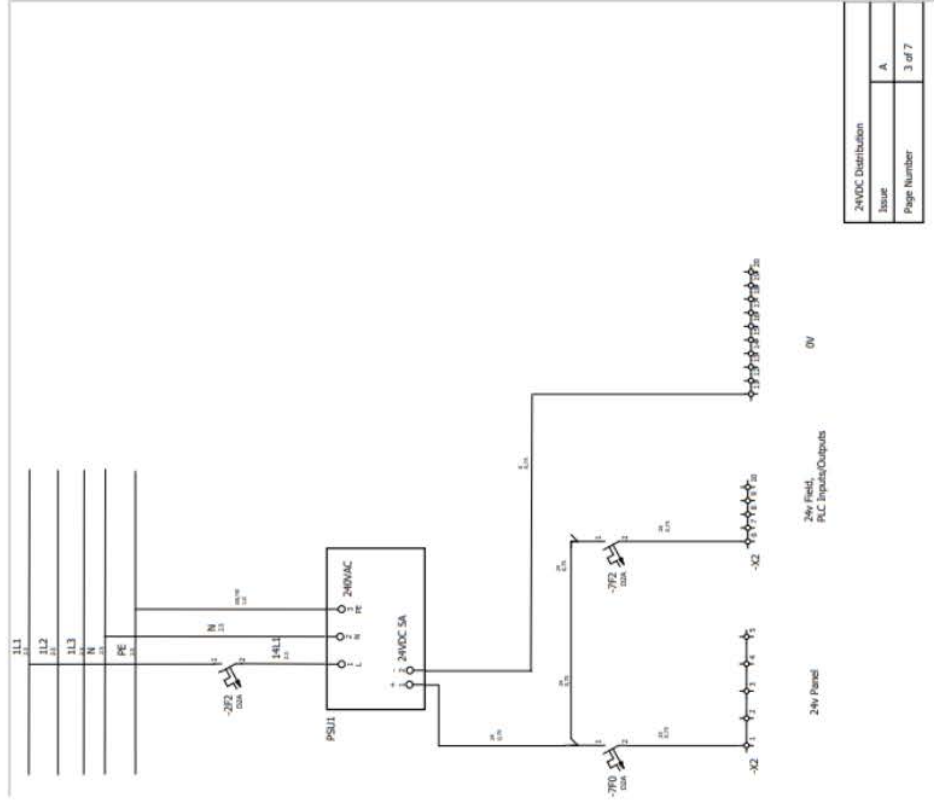


Figure 7 Electrical drawings Page 3 24V

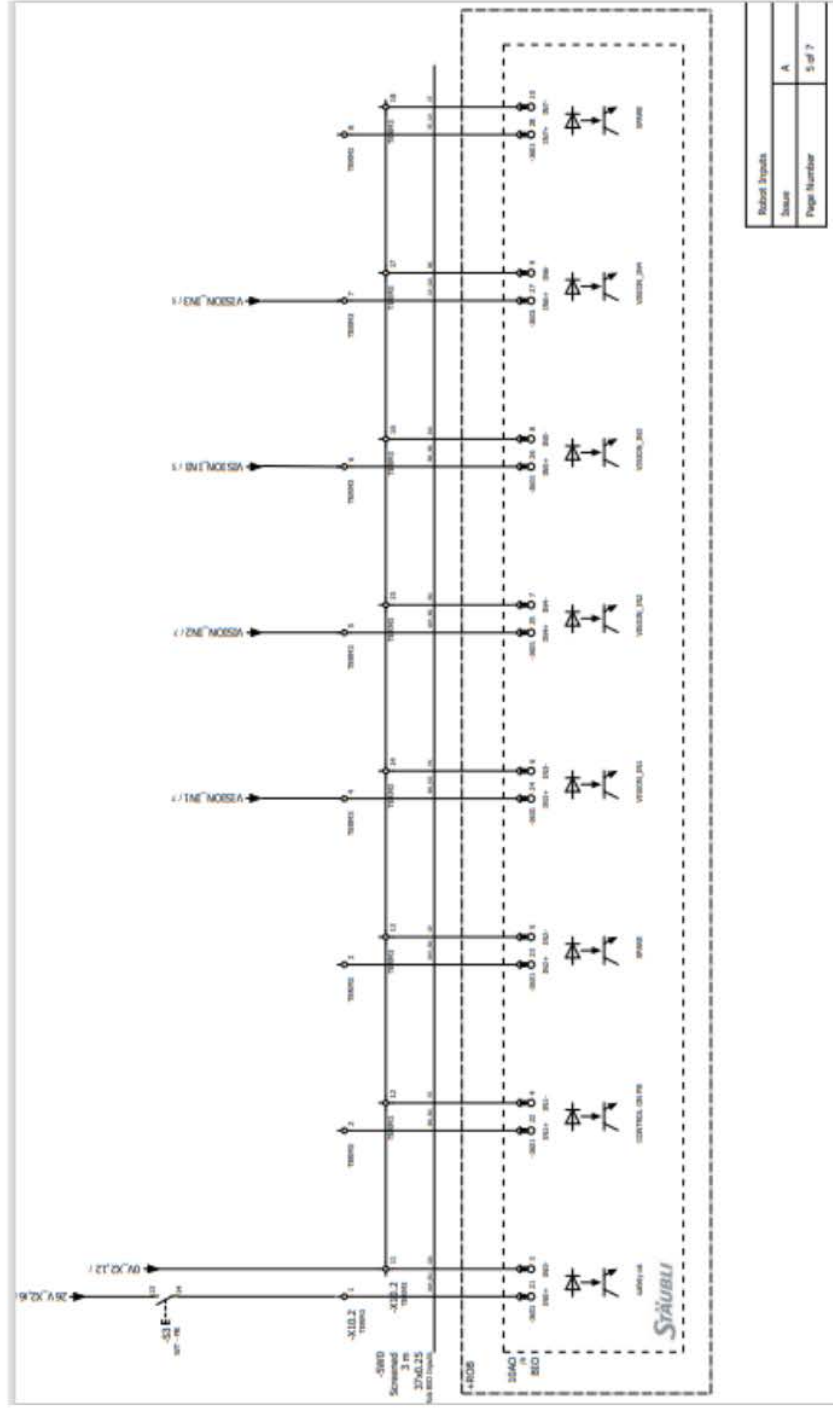
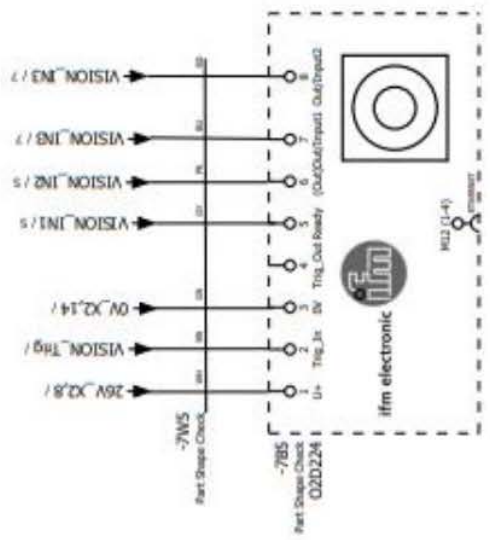
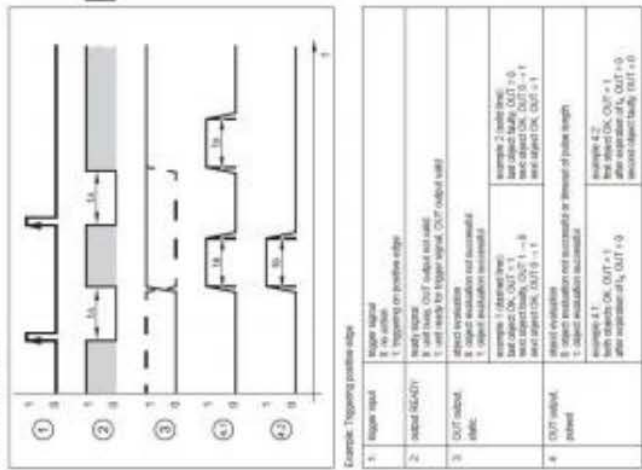


Figure 9 Electrical drawings Page 5 robot inputs

6.5 Timing diagrams
6.5.1 Inputs/outputs



Vision	
Issue	A
Page Number	7 of 7

Figure 11 Electrical drawings Page 7 Vision

Component	Voltage	Current
Motor	415VAC	2A
Staubli CS8 controller	240VAC	10A
Power supply	240VAC	1.15A
Staubli I/O	24VDC	1A
Contacto coil	24VDC	0.25A
IFM Vision sensor	24VDC	1A

Table 3 Power requirements

			Original Estimate	
Part No.	Material Description	Unit Cost	Qty	Cost
1 XB4BS8442	Panel Mount Mushroom Head Emergency Button	£ 24.58	1	£ 24.58
2 440K-T11090	Safety Interlock Switch	£ 32.60	1	£ 32.60
3	vision system must be less than £1000	£ 1,000.00	1	£ 1,000.00
4	cabling	£ 200.00	1	£ 200.00
5 AE1034500	Rittal AE, Steel Wall Box, IP66, 210mm x 400 mm x	£ 66.03	1	£ 66.03
6	miscellaneous	£ 500.00	1	£ 500.00
7				£ -
			Total	£ 1,823.21

Figure 13 proposed cost for electrical parts

Part No.	Material Description	Unit Cost	Qty	Cost
1 XB4BS8442	Panel Mount Mushroom Head Emergency Button	£ 24.58	1	£ 24.58
2 440K-T11090	Safety Interlock Switch	£ 32.60	1	£ 32.60
3			1	£ -
4	cabling	£ 200.00	1	£ 200.00
5 AE1034500	Rittal AE, Steel Wall Box, IP66, 210mm x 400 mm	£ 66.03	1	£ 66.03
6 o2d222	IFM vision sensor	£ 562.00	1	£ 562.00
7 3210567	PTTB 2.5, 500 V Double Level Terminal Block	£ 1.81	100	£ 181.00
8 3211634	D-PTTB 2.5 Cover for Terminal Block	£ 0.38	10	£ 3.80
9 LRD10	Schneider Electric Overload Relay	£ 39.00	1	£ 39.00
10 LC1D09BD	Schneider Electric TeSys D LC1D 3 Pole Contact	£ 60.53	1	£ 60.53
11 3022276	CLIPFIX ATEX Terminal Bracket for Terminal Bloc	£ 0.38	20	£ 7.64
12 3030213	FBS 10-5 Jumper Bar for Terminal Block	£ 10.45	5	£ 52.25
13 A9F54310	Schneider Electric Acti 9 10A MCB Mini Circuit Bre	£ 75.00	1	£ 75.00
14 5SY4102-7	Siemens Sentron 2A MCB Mini Circuit Breaker	£ 17.30	4	£ 69.20
15 467-416	RS PRO, Slotted Din Rail, 1000mm x 35mm x 7.5r	£ 4.34	1	£ 4.34
16 HTWD-PN-25X80-PVC-GY	HTWD-PN Grey Slotted Panel Trunking	£ 10.15	1	£ 10.15
17 544-3840	RS PRO 37 Way Panel Mount D-sub Connector Pl	£ 1.68	3	£ 5.04
18 6EP1333-1LB00	Switch Mode DIN Rail Power Supply	£ 71.00	1	£ 71.00
			Total	£ 1,464.16

Figure 12 Cost of electrical components

```

begin
  // This program is the Start, it manages:
  // - launching of the initial tasks
  // this program must not loop
  // Loaction launched in : application run
  //
  // Author : Sean Jones
  //-----
  //
  taskCreate "Control",100,Control()
  taskCreate "CellManager",100,CellManager()
  taskCreate "UserScreen",100,UserScreen()
  taskCreate "IOMapping",15,IOMapping()
end
  
```

Figure 14 Start Program

```

begin
  // This program is the User Screen Data Control, it manages:
  // - Current page on the users pendant
  // - The Changing between differnt pages
  // - Displays Data
  // Loaction launched in : Start()
  //
  // Author : Sean Jones
  //-----
  //
  userPage()
  nSwitchIndex=0
  bPageSelected=false
  getKey()
  nkey=0
  do
    switch nSwitchIndex
    case 0
      ////////////////////////////////// Main Menu //////////////////////////////////

      cls()
      title("MAIN MENU")
      gotoxy(0,0)
      put("EBS Automation")
      gotoxy(0,1)
      put("Customer Demonstration System")
      gotoxy(0,4)
      put("F1 : Running Information")
      gotoxy(0,6)
      put("F2 : Maintenance")
      gotoxy(0,8)
      put("F3 : Safety Status")
      delay(0)

      do
        nkey=getKey()
        if nkey>=271
          if nkey<278
            bPageSelected = true
          else
            bPageSelected=false
          endIf
        else
          bPageSelected=false
        endIf
        delay(0)
      until bPageSelected==true
      nSwitchIndex=nkey-270
    break
  end
end

```

Figure 15 User display main menu

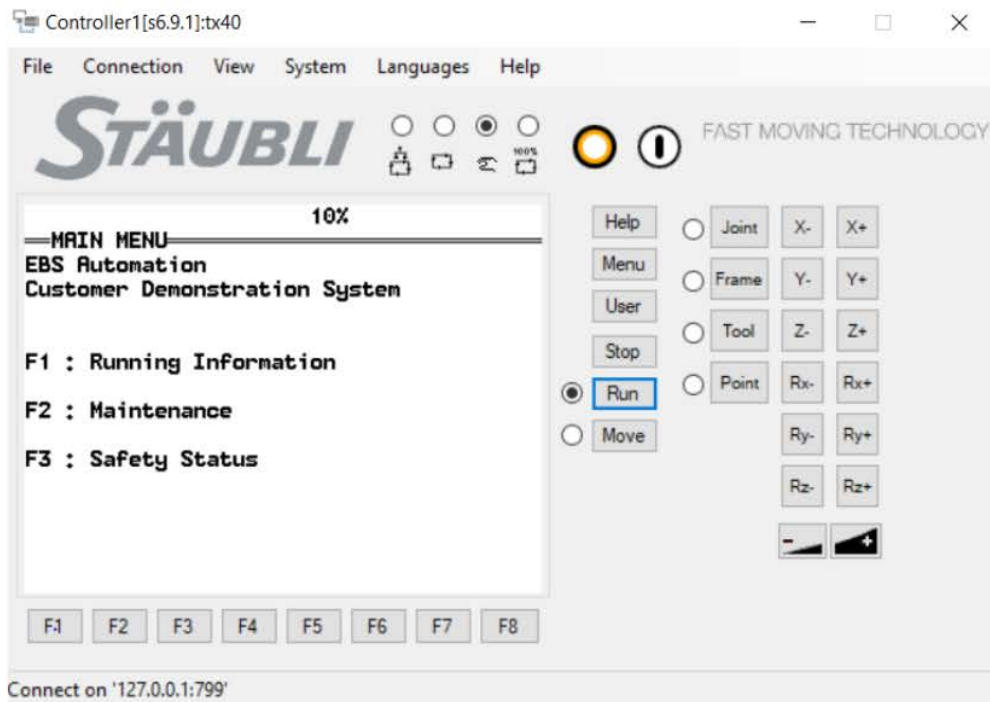


Figure 16 Software simulation main menu

```

case 1
    ////////////////////////////////// Running Info //////////////////////////////////

    cls()
    title("RUNNING INFO")
    gotoxy(36,13)
    put("BACK")
    // Init Running info screen
    gotoxy(0,1)
    put("Operation Message:")
    gotoxy(0,5)
    put("Robot Status Message:")
    do
        //if sOpMsgDisplay != sOpMsg
        sOpMsgDisplay=sOpMsg
        gotoxy(0,2)
        put("
        gotoxy(0,2)
        put(sOpMsgDisplay)
        //endIf
        // if sStatMsgDisplay != sStatMsg
        sStatMsgDisplay=sStatMsg
        gotoxy(0,6)
        put("
        gotoxy(0,6)
        put(sStatMsgDisplay)
        // endIf
        delay(0)
        nkey=getKey()
        until nkey==278
        nSwitchIndex=0
    break
    case 2

```

Figure 17 User display running info screen

```

begin
// This program is the cell manager, it manages:
// - Variable initializing
// - Launch Tracking
// - Arm Power
// - Robot home position
// - Launch user's tasks, kills and re-launch user's task in
//   case of tracking error
// - Displays cycle times and counters.
//
// Location launched in : Start()
//
// Author : Sean Jones
//-----
//

// This program works like an escape room but with a Switch Statement.
// For the program which runs the auto sequence to be launched the program must get to the last case.
// Each case is a check that the robot is in a healthy state to run.
// There is a while true loop around this case so it will run forever unless this task is killed in the stop program.
// There are 2 results of a case. 1 being it didnt meet the healthy criterior and the case switch number Remains the same.
// Or the case is healthy and the index number is incremented by 1.

while true
    LCM_nIndex=1
    do
        switch LCM_nIndex

        case 1
            //Kills main task on estop and wait until estop reset

            // Retains E-stop Status
            nEstopReturn=esStatus()
            if nEstopReturn > 1

                // Update cell status for user fault diagnosis
                nCellStatus=1
                // give a relivent status message on the user screen
                sStatMsg="Safety Not OK"
                // Give operator instructions on how to resolve the issue
                sOpMsg="Close Door, Release All Estops"

                // Kill all the tasks that control robot movement
                if taskStatus("AutoSeq")==1
                    taskKill("AutoSeq")
                endif

                // ResetMotion cancels all the movements in the robots motion stack.
                resetMotion()
            else
                // Switch increments by 1
                LCM_nIndex=2
            endif
        break
    end
end

```

Figure 18 Cell Manger Snippet 1

```

case 2
    //Make sure controller in Auto mode
    if workingMode()!=3
        nCellStatus=3
        sStatMsg="Invalid Working Mode"
        bRunning=false

        if taskStatus("AutoSeq")==1
            taskSuspend("AutoSeq")
        endIf

        switch workingMode()
            case 1
                //set message variable - select MANUAL mode
                sOpMsg="In Manual Mode - Select Auto"
                break
            case 2
                //set message variable - select TEST mode
                sOpMsg="In Test Mode - Select Auto"
                break
            case 3
                //set message variable - select AUTO mode
                sOpMsg="In Auto Mode"
                break
            case 4
                //set message variable - select REMOTE AUTO mode
                sOpMsg="In Remote Mode - Select Auto"
                break
        endSwitch
    else

        lCM_nIndex=3
    endIf
    break
case 3
    // This case has been left spare for future capability

    lCM_nIndex=4

    break

case 4
    //Enable armpower
    // Checks if the arm power is on
    if !(isPowered())
        // If arm power is not on the task is killed
        if taskStatus("AutoSeq")==1
            taskKill("AutoSeq")
            resetMotion()
        endIf
        // A message will be displayed to press control on
        nCellStatus=2
        sOpMsg = "Press Control On"

        lCM_nIndex=1
    else
        lCM_nIndex=5
    endIf
    break
// End of case 2 - 4

```

Figure 19 Cell Manger Snippet 2

```

case 5
    // If the robot is not calibrated to its original factory marks it is not safe to operate.
    // Calibration can be lost if the arm is moved physically on power up
    if !isCalibrated()

        nCellStatus=6
        sStatMsg="Robot NOT Calibrated"
        if taskStatus("AutoSeq")==1
            taskKill("AutoSeq")
        endIf
        // The stop program is called to end the application
        call stop()
    else
        LCM_nIndex=6
    endIf
break
//make sure program is not in hold from pendant
case 6
    // Check move/hold on MCP
    workingMode(nRobWMStatus)
    // Pause programs if in hold
    if(nRobWMStatus!=0) and isPowered()
        if taskStatus("AutoSeq")==1
            taskSuspend("AutoSeq")
        endIf
        // The operator needs to press the hold button to continue
        if nRobWMStatus==2
            bRunning=false
            sStatMsg="Robot in HOLD..."
            sOpMsg="Press HOLD"
            nCellStatus=4
        endIf
        delay(0)
        LCM_nIndex=1
    else
        LCM_nIndex=7
    endIf
break
case 7
    //Check axis are within limits. if they are not it
    //must be done manually before homing
    if isInRange(herej())==false

        bRunning=false
        sStatMsg="Robot Outside Of Cell Limits"
        sOpMsg="Move Robot Manually Back Within The Limits"
        if taskStatus("AutoSeq")==1
            taskSuspend("AutoSeq")
        endIf

        nCellStatus=5
        LCM_nIndex=1
    else
        LCM_nIndex=8
    endIf
break
default
break

```

Figure 20 Cell Manger Snippet 3

```

        endSwitch
        delay(0)
    until(LCM_nIndex==8)

    //Programs can now be launched
    // Task for Auto Sequence
    if taskStatus("AutoSeq")==-1
        taskCreate "AutoSeq",100,AutoSeq()
    endIf
    bRunning=true
    sStatMsg="Running"
    sOpMsg=""
    nCellStatus=16
endWhile

end

```

Figure 21 Cell Manger Snippet 4

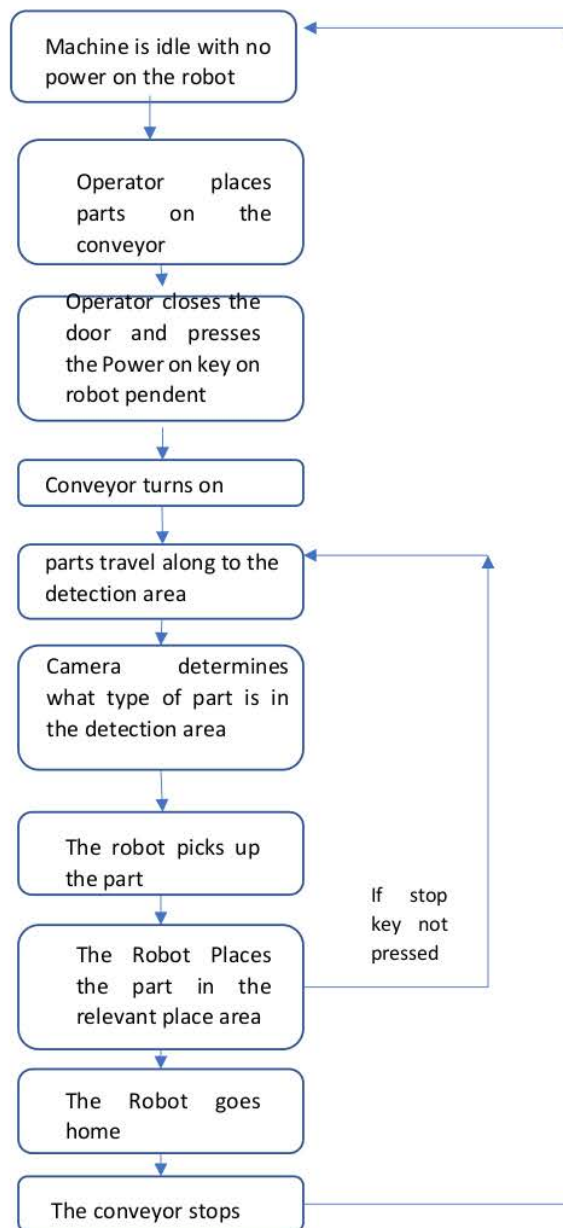


Figure 22 Software flow diagram from original FDS (Jones, 2021)

```

begin
// This program is the Auto Sequence, it manages:
// - Robot Movements
// - Camera Control
// Location launched in : CellManager()
//
// Author : Sean Jones
//-----
//
// The sequence will continually run until it is killed in the cell manager
do
//the program first decides if the robot is home and if not, it moves home.
if pCurrentPos != pHome
// a separate program is called for moving home as this may need to be an elaborate sequence and will save code if it needs to be called more than once
call GoToHome()
endif
// the robot waits for a part present before moving to the pick position
wait(bPartPresent)
movej(pPickApproach,tVac,mNomSpeed)
waitEndMove()
// the wait end move function ensures the robot reaches the position before moving on to the next move in the motion descriptor stack.
movej(pPick,tVac,mNomSpeed)
waitEndMove()
// turn on vacuum gripper to grip part
bVac=true
// delay to ensure part is picked
delay(0.2)
// the move function will ensure the robot moves up straight
movej(pPickApproach,tVac,mNomSpeed)
waitEndMove()
// the part needs to be verified which part it is so the robot moves to the camera
movej(pCamera,tVac,mNomSpeed)
waitEndMove()
// the camera is triggered for a 200ms pulse
dCamTrig = true
delay(0.2)
dCamTrig = false
//when result is true the robot places the part in the correct bin
wait(bResult)
if bReject
movej(pRejectApproach,tVac,mNomSpeed)
waitEndMove()
movej(pReject,tVac,mNomSpeed)
waitEndMove()

elseif bCylinder
movej(pCylinderApp,tVac,mNomSpeed)
waitEndMove()
movej(pCylinder,tVac,mNomSpeed)
waitEndMove()

elseif bCube
movej(pCubeApproach,tVac,mNomSpeed)
waitEndMove()
movej(pCube,tVac,mNomSpeed)
waitEndMove()
endif
until false
end

```

Figure 23 Auto Sequence program

```

begin
    // This program is the I/O mapping, it manages:
    // - mapping of software i/o to physical i/o
    // Location launched in : Start()
    //
    // Author : Sean Jones
    //-----
    //
    do

        // input mapping
        dioLink(dControlOn,io:b2In0)
        dioLink(dCamReady,io:b2In3)
        dioLink(dCircle,io:b2In4)
        dioLink(dSquare,io:b2In5)
        dioLink(dFailPart,io:b2In6)
        // output mapping
        dioLink(dCamTrig,io:b2Out8)
        dioLink(dVac,io:b2Out9)
        dioLink(dConveyorEn,io:b2Out10)
    until true
end

```

Figure 24 IO Mapping program



Figure 25 Electrical Panel Before wiring



Figure 26 Electrical panel complete

Area	Task	Percentage complete	Area completion
Electrical	1. Panel build	100%	100%
	2. Mount Panel on machine	100%	
	3. Wire power from robot to panel using 5Y cable	100%	
	4. Solder 32 way d sub for Inputs, Outputs and safety connections of robot	100%	
	5. Wire Guard Switch	100%	
	6. Wire E-stop and push buttons on door	100%	
	7. Wire conveyor motor	100%	
	8. Wire camera	100%	
Mechanical	1. Make item front access door	0%	50%
	2. Make vacuum gripper fit robot head pipe back through arm to attach to vac genera	100%	
	3. Connect air pressure to arm valve for blow to ungrip parts	0%	
	4. Make a stop and guide for parts to go down conveyor	0%	
	5. Make Parts to run on the machine	100%	
	6. Mount camera in a place where robot can present part to the camera	100%	
Commissioning	1. Configure vision system	100%	71%
	2. Connect to the robot	100%	
	3. Download software	100%	
	4. Test IO	25%	
	5. Test safety	100%	
	6. Test sequence	0%	
	7. Test Recovery	0%	
Documentation and quality checkir	1. Run trials to test repeatability	0%	12.5
	2. Machine manual	0%	
	3. FAT Test	0%	
	4. File machine documentation including electrical drawing and risk assesment	50%	
		overall completion	59%

Figure 27 Work completed

Project Plan

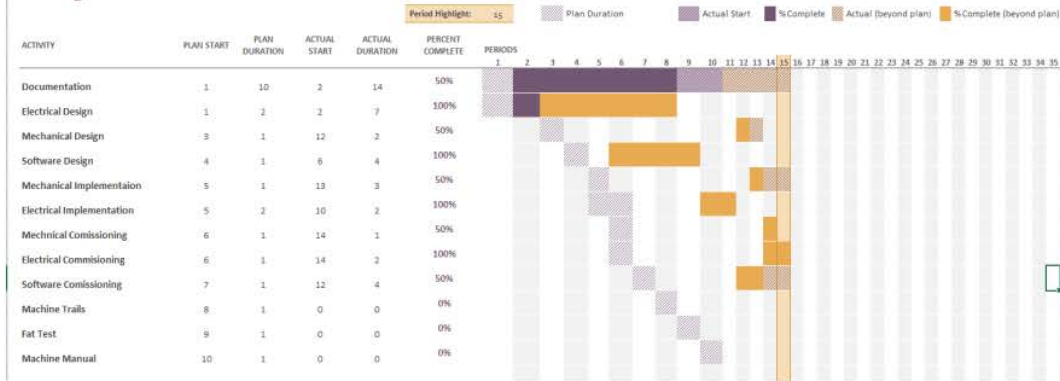


Figure 28 Project timing plan

9	Electrical	General Estimate Electrical Time	
Rate	£ 45.00		
		Hrs	Cost
ELEC 01	Project Meeting		£ -
ELEC 02	Site Visit		£ -
ELEC 03	Electrical Design	32	£ 1,440.00
ELEC 04	Software		£ -
ELEC 09	Electrical Documentation		£ -
ELEC 10	Electrical Concept Design	0	£ -
ELEC 12	Software Commissioning		£ -
ELEC 20	New Quote Work		£ -
ELEC 31	Customer Training		£ -
9	Electrical		
Rate	£ 37.00		
ELEC 05	Panel Build	10	£ 370.00
ELEC 06	Machine Wiring	15	£ 555.00
ELEC 07	Machine Integration/Trials		£ -
ELEC 08	Electrical Commissioning	32	£ 1,184.00
ELEC 11	Robot Programming	57	£ 2,109.00
ELEC 15	Rework		£ -
Total		146.00	£ 5,658.00

Figure 29 Electrical hours costing

9	Electrical	General Estimate Electrical Time	
Rate	£ 45.00		
		Hrs	Cost
ELEC 01	Project Meeting		£ -
ELEC 02	Site Visit		£ -
ELEC 03	Electrical Design	24	£ 1,080.00
ELEC 04	Software		£ -
ELEC 09	Electrical Documentation		£ -
ELEC 10	Electrical Concept Design	16	£ 720.00
ELEC 12	Software Commissioning		£ -
ELEC 20	New Quote Work		£ -
ELEC 31	Customer Training		£ -
9	Electrical		
Rate	£ 37.00		
ELEC 05	Panel Build	16	£ 592.00
ELEC 06	Machine Wiring	16	£ 592.00
ELEC 07	Machine Integration/Trials		£ -
ELEC 08	Electrical Commissioning	8	£ 296.00
ELEC 11	Robot Programming	78	£ 2,886.00
ELEC 15	Rework		£ -
Total		158.00	£ 6,166.00

Figure 30 Electrical labour budget cost



Figure 31 Camera location with robot holding part

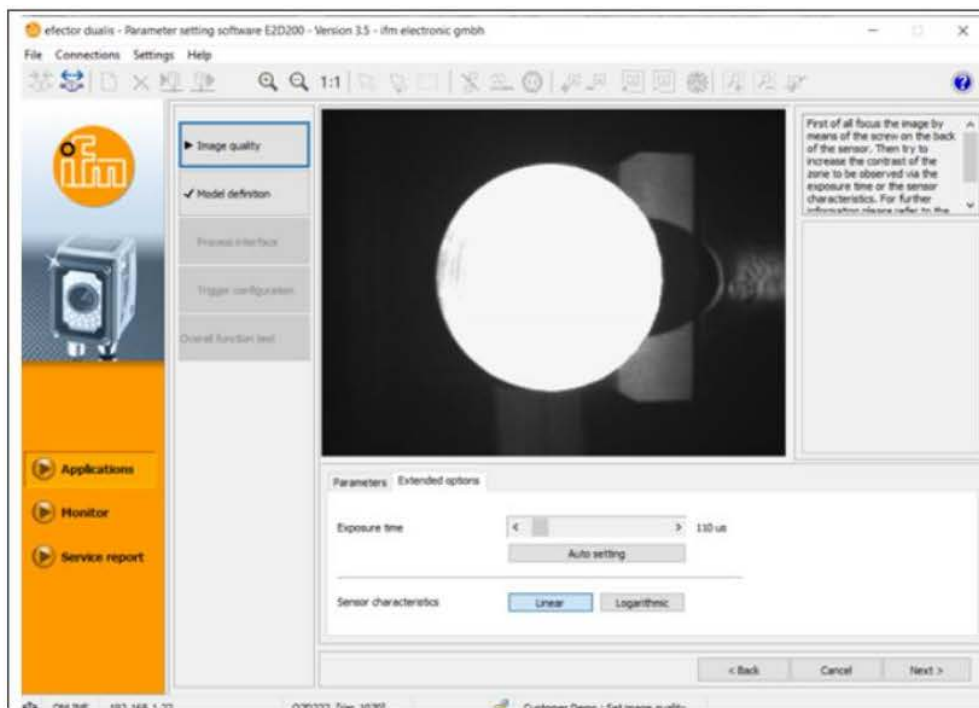


Figure 32 Exposure setting

Testing points	Measured Resistance (Ω)
L1 - L2	>100M
L1 - L3	>100M
L1 - PE	>100M
L1 - N	>100M
L2 - L3	>100M
L2 - PE	>100M
L2 - N	>100M
L3 - PE	>100M
L3 - N	>100M
N - PE	>100M
24 - 0V	0.5M
0V - PE	0.1
Testing points	Measured Voltage (V)
L1 - PE	243VAC
L2 - PE	245VAC
L3 - PE	240VAC
L1 - L3	415VAC
L1 - L2	415VAC
L2 - L3	415VAC
24 - 0V	24VDC

Figure 33 Resistance and power checks

State 1 – Ensure that the all-safety systems are healthy and reset

Check	Panel	Robot
	Tick to Confirm	Tick to Confirm
UESB1 on pendant internal IO is on	/	/
UESB2 on pendant internal IO is on	/	/
PWR on pendant internal IO is on	/	/

State 2 – Hit E-Stop

Check	Panel	Robot
	Tick to Confirm	Tick to Confirm
UESB1 on pendant internal IO is off	/	/
UESB2 on pendant internal IO is off	/	/
PWR on pendant internal IO is off	/	/

State 3 – Reset E-Stop Button

Check	Panel	Robot
	Tick to Confirm	Tick to Confirm
UESB1 on pendant internal IO is on	/	/
UESB2 on pendant internal IO is on	/	/
PWR on pendant internal IO is off	/	/

State 4 – Press Control On

Check	Panel	Robot
	Tick to Confirm	Tick to Confirm
UESB1 on pendant internal IO is on	/	/
UESB2 on pendant internal IO is on	/	/
PWR on pendant internal IO is on	/	/

Figure 34 E-stop safety testing

State 1 – Ensure that the all-safety systems are healthy and reset

Check	Front Door
	Tick to Confirm
UEN2 DOOR2 on pendant internal IO is on	/
UEN1 DOOR1 on pendant internal IO is on	/
PWR on pendant internal IO is on	/

State 2 – Open Door

Check	Front Door
	Tick to Confirm
UEN2 DOOR2 on pendant internal IO is off	/
UEN1 DOOR1 on pendant internal IO is off	/
PWR on pendant internal IO is off	/

State 3 – Close Door

Check	Front Door
	Tick to Confirm
UEN2 DOOR2 on pendant internal IO is on	/
UEN1 DOOR1 on pendant internal IO is on	/
PWR on pendant internal IO is off	/

State 4 – Press Control On

Check	Front Door
	Tick to Confirm
UEN2 DOOR2 on pendant internal IO is on	/
UEN1 DOOR1 on pendant internal IO is on	/
PWR on pendant internal IO is on	/

Figure 35 Door safety testing

FDS point	Original FDS	Revised
4.3.1	Jones states “Incoming supply will be 240VAC 50Hz less than 16A so a conventional PCE socket can be used” (2021)	Incoming supply: 415VAC 50Hz 16A with a 5 pole PCE Plug
4.4	Sequence where camera detects part before picking	Robot will pick part then move to the camera to detect the part shape

4.6.2	Jones states “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.” (2021)	The vacuum valves are to be mounted externally of the robot and run off the robot’s external outputs.
-------	--	---

Table 4 Revised FDS points

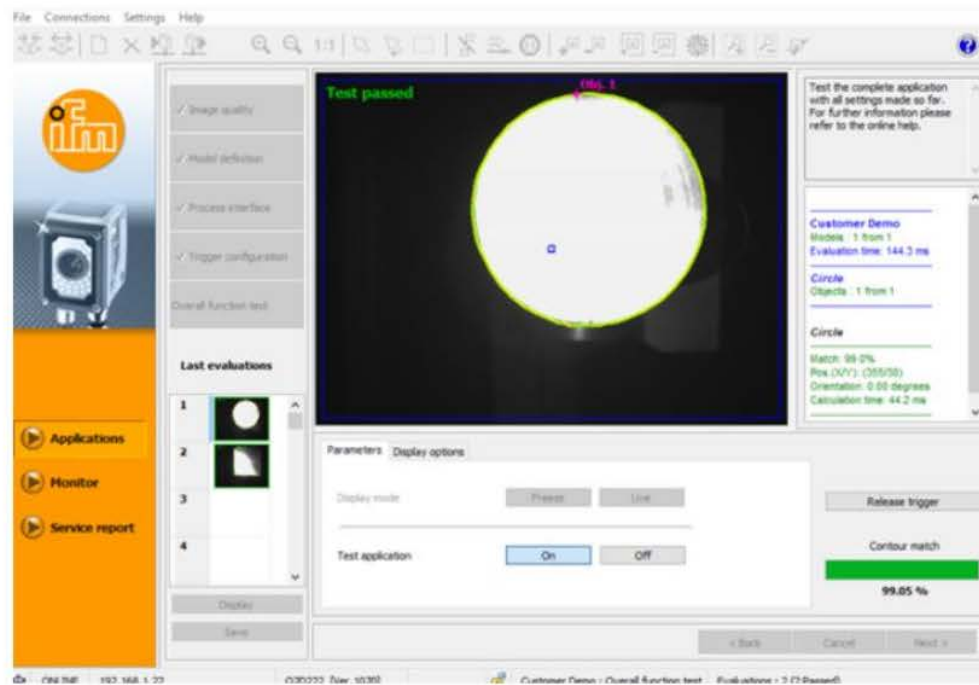


Figure 36 Camera Testing

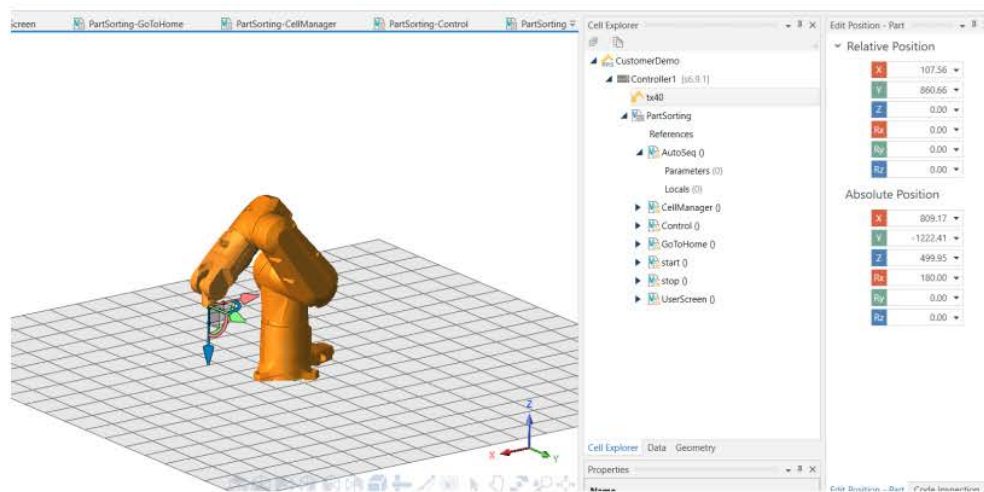


Figure 37 Robot simulation

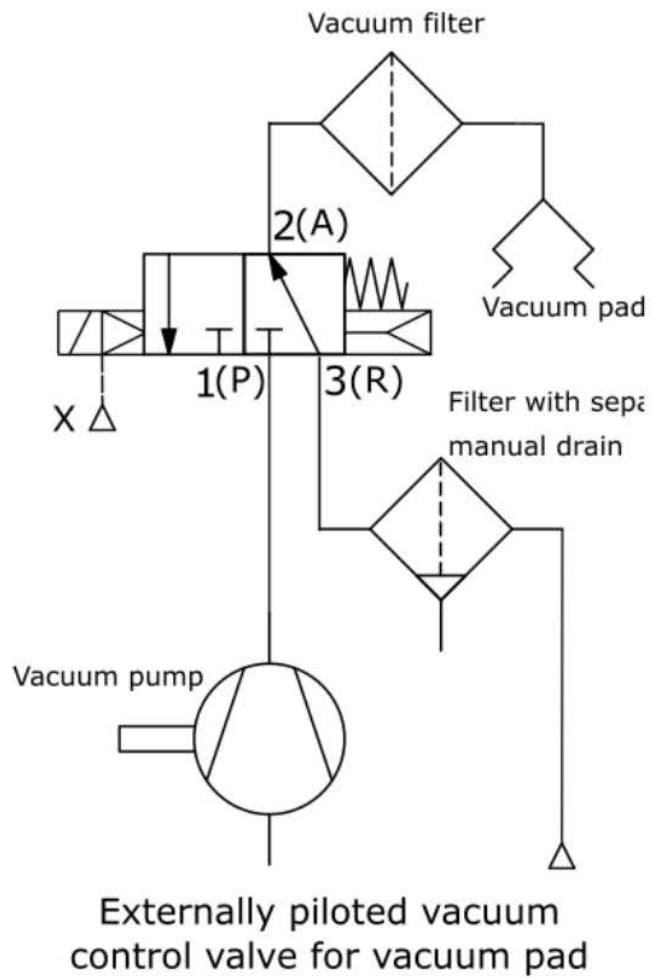


Figure 38 Vacuum valve concept (tameson, 2021)



Figure 39 Robot Cell Current

Assignment 2 1602826

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

65/100

PAGE 1

PAGE 2

QM

Good Structure

Report is structured exactly as stated in the assignment brief.

Text Comment. where are the acknowledgements?

PAGE 3

PAGE 4

Text Comment. This is supposed to be a summary

Text Comment. This shows the importance of developing a more accurate FDS. You have learned that projects should be front loaded to avoid failure at the end.

PAGE 5

PAGE 6

Text Comment. compatible

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

Text Comment. This is a planning chart not a design, it belongs as part of a work break down structure (RD)

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

PAGE 7

QM

Use of 11pt Arial, full justification with 1.5 line spacing allows easier reading and marking

Your presentation could be improved making the text easier to read and mark. Your tutor will then be able to add comments between lines

QM

Correctly cited

Citation method conforms to Harvard standard, well done.

QM

Punctuation Error

Punctuation error

PAGE 8

PAGE 9

QM

Use of 11pt Arial, full justification with 1.5 line spacing allows easier reading and marking

Your presentation could be improved making the text easier to read and mark. Your tutor will then be able to add comments between lines

PAGE 10

Text Comment. There is too much detail here on each part of the design (RD)

PAGE 11

Text Comment. This is a useful flow chart (RD)

PAGE 12

PAGE 13

Text Comment. There is too much implementation detail here, reads like a long story

PAGE 14

Text Comment. This layout is much easier to read (RD)

Text Comment. Too much detail, fixed faults do not need to be mentioned (RD)

Text Comment. Much of this detail belongs in a log book (RD)



Punctuation Error

Punctuation error

Text Comment. You have clearly learnt much from doing this project from better planning and costing to better time management and up front designs. (RD)



Good range of sources

You have demonstrated reading from a good range of sources shown by your list below

Text Comment. Your design process has been well informed by research and consultation with manufacturer's literature RD)

PAGE 32

PAGE 33

PAGE 34

PAGE 35

PAGE 36

PAGE 37

PAGE 38

PAGE 39

PAGE 40

PAGE 41

PAGE 42

PAGE 43

PAGE 44

PAGE 45

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PAGE 53

PAGE 54

PAGE 55

1. ENGAGEMENT WITH LITERATURE

-  Section 3: Judicial use and critical evaluation of technical literature in the design of the project: Good evidence of use of literature in the design process, all design decisions appear to be well informed. Section 4: Extent of reading, range of credible sources and use of Harvard method: A wide range of sources have been consulted and cited. (7/10) **7**

2. KNOWLEDGE AND UNDERSTANDING

-  Section 3: Advanced knowledge and critical understanding demonstrated in the design of the project: There is good evidence of advanced knowledge in the design of the system and the safety requirements in order to ensure compliance with regulations and standards. (7/10) **7**

3. COGNITIVE AND INTELLECTUAL

-  Section 5: Testing and analysis of result: There is good evidence of testing and analysis of results. Section 5: Critical evaluation of the project outcomes: The project has been critically evaluated in part and an honest report given of where it went **19**

wrong or how the original plan was weak. You have clearly learned a lot from this process.
Section 6: Conclusions and recommendations: A good section with many conclusions and recommendations for the project and your method of planning and design. (19/30)

4. PRACTICAL APPLICATION



Section 3: Formulation of innovative and creative design solution to the project problem: The project shows a high level of thinking and creativity in the design of the hardware system and software programming. Section 4: Deployment method, use of material, tools, equipment and techniques in the construction of the project: Excellent methods deployed. Professional approach adopted to electrical design and software programming is evident. Section 4: Quality of the final product or system: Good quality panel build and system layout. The programme is well written and the visual look of the system is good. Section 5: Use of test equipment and presentation of results of the project: Satisfactory use of testing methods, results shown in the appendix but the final system is incomplete. Sections 3 and 5: Management of the design process: The design process was not well managed but reviewed using flow charts, timing chart and costing sheets. (22/30)

22

5. TRANSFERABLE SKILLS



Sections 1 and 2: Executive summary, acknowledgements and introduction: Summary

10

should contain an overview of all that was done not just an evaluation of the end product. Good introduction but no acknowledgement section. The Executive Summary and Introduction were both brief and vague. No acknowledgements were included. All Sections: Quality of the report: Well structured, good diagrams and images. Style is mixed and there are numerous spelling, punctuation and grammatical errors. Much of what has been said belongs in a log book and should have been summarised. Reads too much like a long story with things that went wrong inappropriately included. The report was difficult to read at times, with a lot of information hidden away in external sources (referenced) and in the appendices. (10/15)

SECOND MARKER - MH



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

Course: BSc (Hons) Electrical and Electronic Engineering

Module: SGEL6000 Independent Project

Assignment: Project Design, Implementation and Evaluation

Name: Sean Jones

University number: 1602826

Date submitted: 01/05/2021

Word count: 5957

① AN EXTENSIVE RANGE OF SOURCES, BUT NOT ALWAYS IN HARVARD. YOU ALSO SEEMED TO CITE SOURCES FOR THE SAME IT, RATHER THAN BECAUSE THEY WERE NEEDED. (A7)

② TECHNICAL KNOWLEDGE HAS BEEN DEMONSTRATED, ALTHOUGH TIMING PREDICTIONS WERE INACCURATE AND RESULTED IN A POOR PLAN AND UNFINISHED PROJECT.

③ TESTING WAS DIFFICULT AS THE PROJECT IS ULTIMATELY INCOMPLETE. THE EVALUATION OF WHAT YOU HAVE COMPLETED AND WHY THE PROJECT IS INCOMPLETE WAS HOWEVER WELL EXPLAINED.

THE EVALUATION SECTION AND THE CONCLUSION SECTION WERE DIFFICULT TO DIFFERENTIATE. SOME PARAGRAPHS IN ONE WOULD HAVE BEEN BETTER IN THE OTHER

④ THERE WERE VERY FEW PHOTOGRAPHS OF THE WORK CARRIED OUT. POOR PROJECT MANAGEMENT TECHNIQUES RESULTED IN AN UNFINISHED PROJECT.

⑤ EXECUTIVE SUMMARY AND INTRODUCTION WERE BRIEF AND VAQUE.

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1. Executive Summary

The project is incomplete so this is an evaluation of the current state of the project and what's left to complete it. The electrical and software design have been completed with relevant documentation. The project has been wired, powered and commissioning has started. Issues with the robot delayed the commissioning so it is still not completed. An IFM vision sensor was used to detect the parts which showed to be an effective solution when tested. Because the robot's software couldn't be tested effectively the software had to be tested using simulation software from the Staubli suite.

The project currently has 59 % of its tasks completed and has used £7674.66 of the budget. The project has run on 1 month after the deadline as it was intended to be completed by 31st of march. This was due to a poor timing plan at the start and the risks of the project not being evaluated enough when the timing plan was created.

The project has met most points from the original FDS. The points that haven't been met are due to the tasks being incomplete or the FDS point changing as information on the project was developed further.

THE EXECUTIVE SUMMARY SHOULD COVER THE WHOLE REPORT. THIS IS MORE OF A PROGRESS REPORT.

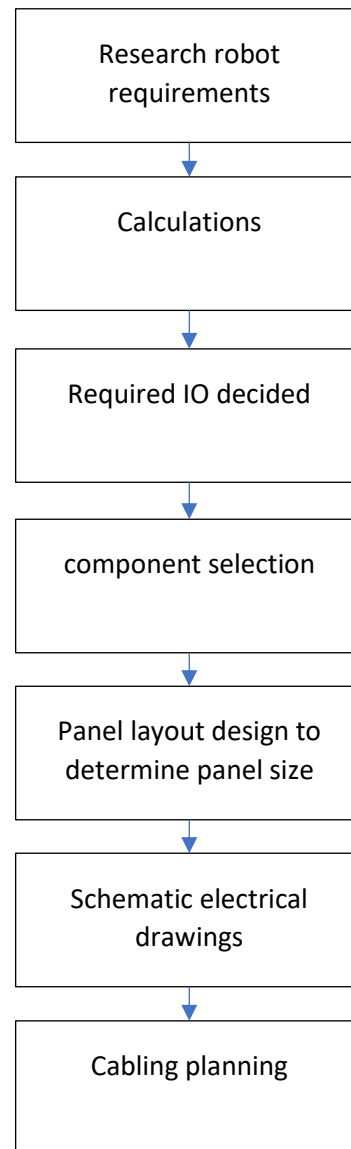
2. Introduction

DEMONSTRATING WHAT?

The project is to make a customer demonstration system that can be used to attract new customers when they visit the factory as well as be taken to automation shows. The previous assignment saw the plan of the project to be completed by the 31st of March with a budget of £12,500. The system was decided to have a vision system to detect parts mixed with a robot. The safety of the system was decided to be controlled from the robot. The design of the machine has to meet the FDS that was created in assignment 1.

3. Design and Implementation

The electrical design was based around the existing system so everything would be compliant with the robot and conveyor. The flow diagram showed in Figure 1 gives the sequence that was followed to design the electrical circuit. It was done this way so all the information required to do a task was already gathered in the previous tasks. This method of design was suggested by Tamayoa (2018) ?



IS A FLOW CHART
REALLY NEEDED FOR
A SIMPLE SEQUENTIAL
PROCESS.

Figure 1 Electrical design flow diagram

The robot was looked at in 3 ways; power, safety and inputs/outputs. According to Staubli (2017) the controller requires a single phase 230VAC 10A supply so this was integrated into the circuit ensuring the cabling, breaker and isolator was capable of supplying the current, Figure 6 shows this. The cable sizes were taken from BATT (2021) which gives the correct cable size in tri rated cable for the current. The robot's safety requirements were taken from the Staubli (2009) electrical manual. This

gave the connection requirements that have been illustrated in Figure 8. The controller had the capability of having more than 1 e-stop and door on separate connections. The unused connections had to be linked out so the controller thinks it's healthy. According to Jones (2021) the control on push button will go to the IO not the robot safety circuit. The safety circuit has been designed to meet the requirements for the machine building Crown copyright (2008). Jones states "All safety components must be at least C safety level " (2021) the dual channel e-stop is safety level C and the selected door guard switch used is suitable for category 3 machines which is suitable for a level c safety according to the data sheet from Rockwell Automation (2015) . It was decided that there was no need for auxiliary contacts on the safety stops as the robot can access internal IO to establish if an e-stop or guard door is unhealthy to flag an error on the pendant. BS EN 13849 – Safety-Related Control Systems regulations were followed whilst designing the safety circuit. Trabesinger (2020) suggests the Staubli robot's reaction to faults should be fast enough to meet category 3 safety ratings. The IO connections were suggested from Staubli (2009) Figure 9 shows the input configuration and Figure 10 shows the outputs. According to Staubli (2009) the IO would take less than 1A when all the IO is in use.

The motor on the system is 3 phase 0.25KW. According to Omar (2020) a suitable way to make this motor run is a DOL setup. It was considered to use an inverter to run the motor to give variable speed control and a gentler start up but it was decided to go for the simpler option to save the cost of components, time for design and to reduce panel size. A suitable overload and contactor were designed from the datasheet provided by RS (2021). According to Schneider (2021) The coil of the chosen contactor takes 0.25A to switch on and hold in. This is less than the maximum current of the transistor outputs of the robot so it can be run directly off the output.

The vision system used was decided to be a 02D222. This is a basic vision system that can perform edge detection only. A more expensive version could have been bought which would have included the ability to apply filters onto an image and other tools such as a blob tool. The edge detection tool learns a profile of a part and its exact shape. A blob tool learns the parts size so it recognises the number of pixels that makes up the part and not necessarily its shape. Figure 2 shows the squares surface area against the circle. If the squares width was less than the circles diameter there is a chance that the camera would think they are the same weight when using the blob tool. Edge detection can have a scaling factor so if the same shape was used but at a smaller scale it would still detect it.

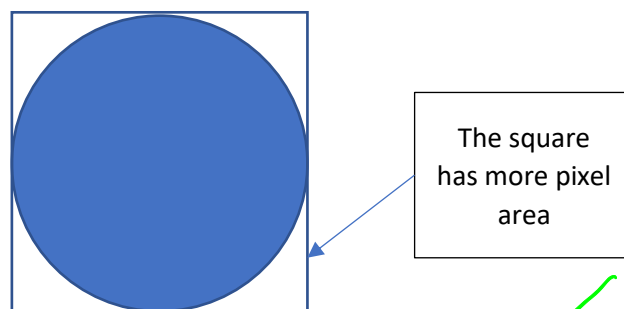


Figure 2 Blob tool shape weight comparison

Although the original plan from Jones (2021) was the vision system to cost less than £1000 it's been decided to reduce the cost of the vision system as much as possible to give more room in the budget for hours to spend on design. The cameras wiring configuration was sourced from IFM (2021). The camera IO can be configured in the software. The datasheet suggested using 1 input with rising edge detection to the camera for the trigger, 1 output to give a high signal when the camera has given the

DO YOU REALLY NEED TO CITE A SOURCE FOR SOME OF THESE VALUES. A LOCALLY CHOSEN VALUE OR A SPECIFIC DATASHEET MAY BE MORE APPROPRIATE

results of the image and is ready for another trigger. The other outputs can be used for part identification. Table 1 shows the output configuration. According to IFM (2021) the current drawn to run this sensor is less than 1A.

Output	Result
Out0	Circle part
Out 1	Square part
Out 2	Fail part

Table 1 Camera output configuration

The 24VDC requirement of the system is 2.25A. because this is the continuous currents not the peak currents of the devices a 5A output power supply was chosen. Siemens (2021) state in their datasheet that their 24VDC 5A power supply should pull 1.15A. Table 3 shows the power requirements for each component.

Once the components were selected and the schematic drawings were completed the panel layout was drawn shown in Figure 5. This drawing allowed the panel size to be determined to check it can be suitable to fit on the machine. The panel decided is a 210x 400 mm which fits underneath the base of the machine. An isolator was designed into the panel in order to shut the power off before entering the panel. The isolator handles as well as the electrical panel had to meet ip61 ratings. Rittal (2021) state that their compact enclosure has a "Protection category IP to IEC 60 529 : IP 66"

The drawings were produced on EPLAN software. This required the reference manual to be used to understand how to use the software from EPLAN (2021). This drawing method is standard to be used in all electrical drawings in the company to allow the drawings to be on a .dwg file as required by Jones (2021).

Software design was implemented in a strategic approach. It was split up into different sub programs which work in different methods. Figure 3 shows the layout of the software programs. The application will start in the start program. This program will run straight through with no loops or delays. The sole purpose of this program is to initialize any values and to launch any continuous running tasks. Figure 14 shows the code for the start program. In this case the start program is launching the user display, cell manager and IO Mapping.

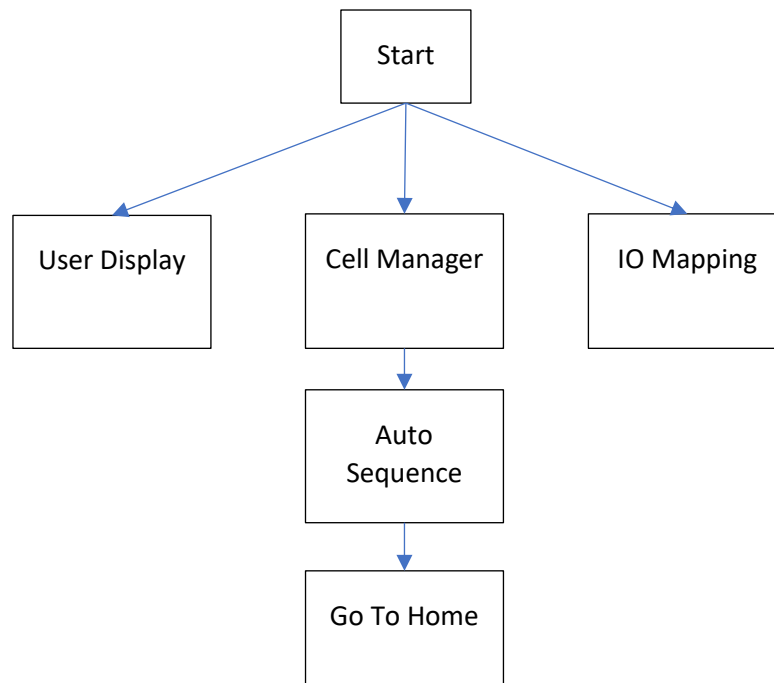


Figure 3 software program layout

The User Display program controls what is displayed on the pendant. This system doesn't have a friendly interface as what may be found on an HMI or an IP interface. There aren't any pre-set pages that can be designed. Any information written on the screen is displayed via x, y co-ordinates. For information to be removed of the screen either the `cls()` function which clears the entire screen has to be used or if text is written on top of the existing text it will overwrite it. Gookin (2004) suggests a strong method for having multiple display interface pages with this style of programming is to use a switch statement. The return of the "F" keys gives numbers between 271 (F1) and 278 (F8). The switch statement is set up so that the default setting of the page is case 0. When this case is entered it displays the choice of pages that can be selected. The program then waits for a return of the key between 271 and 278. Figure 15 shows the code for the main menu of the program. As the code was written the program was simulated using a pendant emulator to ensure each screen worked correctly and no writing was over lapping. This emulator only simulated what the pendant displays as the program runs through not the robot's actions. Figure 16 shows the simulated view of the main menu. This is better to be simulated before the machine is online as it saves commissioning time. The main pages that display information work similar to the main menu but they have a do until loop in them. They firstly display the headers for the information that is to be displayed. The do until loop is then entered. The loop moves the current value for the message or display value into a variable and displays that onto the screen. When it loops around again it will check if the message has changed and only then it will clear the old message with a string of blank spaces and display the new

message. If the message was updated every cycle, it would cause the writing to flicker. This method was suggested from Staubli (2018). Figure 17 shows this method. The purpose of having this interactive teach pendant was suggested by Galen (2017)

The cell manager program controls the safety recovery of the cell as well as the starting and stopping of movement programs. This program also utilizes the switch statement function. Each of the cases is a check of certain parameters of the robot. Below in Figure 4 is the flow diagram of the checks that the cell manager makes. The program cannot have any delays or loops within it other than the main loop around the outside of the switch statement. If this occurs the response time of the program is reduced as it will be scanning through the switch continually checking each recovery step. If this program didn't exist the robot would recover from an e-stop poorly as it would start where it left off. This is the only place in the robot code that the function `power()` is used that turns the robot arm on allowing movement. Figure 18, Figure 19, Figure 20 and Figure 21 show the cell manager program including detailed comments.

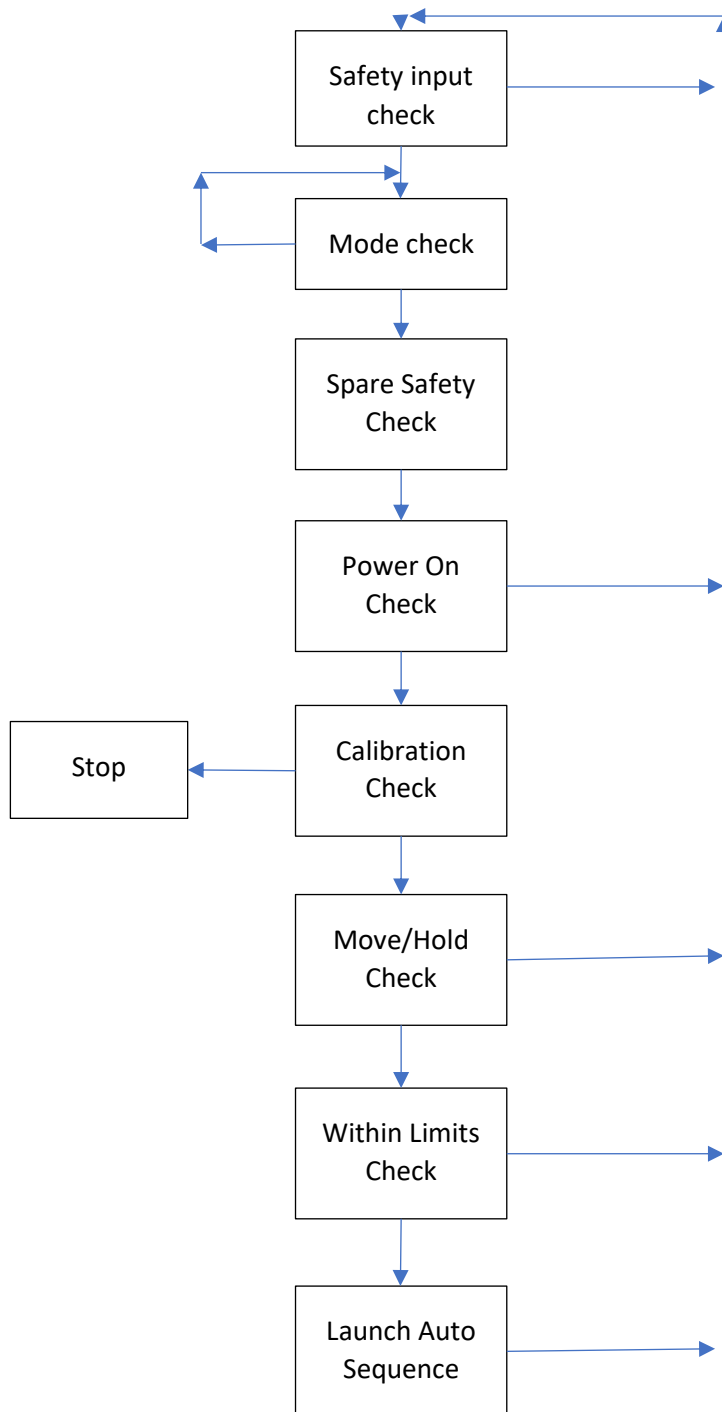


Figure 4 Cell Manager flow diagram

The Auto Sequence program launched from cell manager controls the robot's movements and decision making. It starts by launching a separate homing program to ensure the robot is in a safe starting position. There is a specific program for this function so it can be used multiple times without cluttering the program. The flow diagram shown in Figure 22 from Jones (2021) shows the original spec of the intended function for the robot. It was decided to change this slightly to give the robot more control over the part and a higher quality image from the camera. Instead of the camera

being mounted above the conveyor and continually being pulsed until it saw a part. The FDS has been changed so that there is a sensor that the robot waits for a high signal of then picks up the part and takes it to the camera and triggers it once. The overall function remains the same but the method to achieve this is changed. This method of checking parts was suggested from Semeniuta (2016). Figure 23 shows the auto sequence program that controls this. The auto sequence will continually loop until the stop program is called or the cell manager kills the task. there can be loops and delays within the auto sequence.

The IO mapping program in Figure 24 links the variables used in the programs to the physical IO of the controller which is stored in the library “io”. This program runs through once.

The components that were listed in Figure 12 from the electrical design were ordered in order to start the implementation process. The work breakdown structure wasn't detailed enough from Jones (2021) so the work was broken down further as shown in Figure 27. The plan to implement the stages of the project shown in Figure 28 is less specific as the new work breakdown document was used to determine specific tasks. The project was falling behind the deadline at an early stage due to the poor judgement of the resources that would be available for the project. The original agreement with management was that the mechanical design and implementation would be handled by an internal employee. When it came to the deadlines of the project it was made apparent that there were no mechanical engineers available to perform the design or implementation stages. To work around this there haven't been documented mechanical drawings which is poor practice of designing a machine as it would be difficult to repeat the same design to a set standard. All the mechanical implementation was done by the electrical engineer which prevented them to complete all the commissioning tasks.

The first part of the implementation was to build the electrical panel. The layout was followed from the Panel layout design in Figure 5. All the trunking and din rail was mounted using pop rivets. Din rail was used for the components to make them easily maintainable as they can be removed quickly. Figure 25 shows the electrical panel before it was wired. the earth terminals are mechanically and electrically connected to the din rail to meet the safety standard BS EN 60404 – Electrical safety of machinery which was a requirement set out by Jones (2021). Relevant PPE was worn during implementation such as safety goggles whilst drilling holes. This was to comply with the health and safety at work act 1997.

The field wiring was the next stage where safety standard BS EN 60404 – Electrical safety of machinery was used frequently ensuring that the cable routing and glanding was safe. An SY cable was used on all AC cables that weren't contained in trunking or conduit to reduce the risk of shearing cable. All cables going between the robot the electrical panel were labelled to make them easily traceable to the electrical drawings. The mechanical implementation had to start alongside the field wiring as items such as the camera and guard switch couldn't be wired until they were mounted.

Brackets were made to mount the camera to the bed of the table shown in Figure 31. The bracket was made using a milling machine. The robot gripper head was also made and mounted to align where the camera should be mounted. The cylindrical parts were made on the lathe. The size of the parts were increased for an easier grip and camera detection. The material was also changed from nylon to aluminium as material was readily available and didn't have to wait for delivery. Only trained personnel used equipment that was required to make some mechanical components such as a milling machine and lathe. Figure 39 shows the robot cell in its current state.

When there was power on the machine the camera was set up to recognize the different parts. This was done by picking a part and hovering it over the camera. The first part to set up was the exposure rate of the camera. A well-tuned exposure setting gave a much clearer part to detect. Because the camera is using edge detection a complete part with a sharp edge must be on display. Figure 32 shows an example of the exposure being set. The square parts didn't have the neat uniform light reflection that was found on the circle part. This was likely due to the way the parts were machined forming scratches on the surface which reflect in different manners. The edge detection tool was set up giving a clear definition between the circle and the square. Because it is nearly impossible to have the same image twice the parts are decided if it matches the taught part via a match tolerance. This tolerance had to be slack enough that it allowed all the correct parts through but tight enough it wouldn't mistake it for the wrong part. The circle was set to 60% tolerance and the square was set to 70%. The outputs from the camera were configured according to the electrical drawings.

The physical guarding of the machine hasn't been refined in the designs yet but the concept has been designed. Aida Haghighi states "a lack of visibility, failures and a lack of reliability of the safeguards" (2019). This suggested if clear guards are used it would give more visibility into the machine reducing the risk of the guard being removed. A well sized door that will give good access into the machine will also reduce the likelihood of a guard being removed as the machine can be easily maintained.

Issues with getting the robot running postponed the commissioning of the software. The 3 main problems that caused delays were the robots internal CPU board needed reseating due to being out of use for a long period. A fuse had blown for the safety circuit which required a strip down of the robot in order to change it. The IO mapping was giving errors when trying to run the program. The robot should have been powered up at the start of the project to prevent this delay. A more detailed evaluation of the risks would have kept the project on track with more research into what common risks of an engineering project are.

Throughout the project hours spent on each sector were documented to keep a detailed track of the cost. This cost was monitored weekly to ensure there wasn't a risk of going over budget. Figure 29 shows the broken-down costing for electrical. The current cost of electrical hours is £5658 which is still under the budget for this area of labour which was £6166. There is a risk that when the issue with the IO mapping is solved the cost for this area could go over budget. The program sequence still hasn't been tested so it is likely this area will go over budget.

SOME PHOTOGRAPHS OF THE WORK CARRIED
OUT WOULD HAVE REALLY HELPED YOU EXPLAIN
THIS BETTER.

4. Testing and Results

The system was tested at intervals at critical stages of the project. This wasn't the original intention but after the design stage it was decided it would be the most appropriate way to ensure the FDS is being met.

There was testing performed during the commissioning stage to ensure the machine was safe to work on. The first evidence of this was before the machine was powered on after the field wiring. All the breakers were turned on with the machine disconnected from the mains supply. A multi-meter was used to check the resistance across the phases and relevant connections in the panel in case there was a short anywhere that could be fixed before a greater issue occurs on power on. This test highlighted an issue that the 0v wasn't tied to earth. This was forgotten about in the design stage so a link was then added. When it was proven safe to power the machine on, all the breakers and isolator were turned off and the machine was connected to the supply. The voltage before the isolator was checked to ensure the correct voltage was coming to the machine. The isolator was then turned on as well as the breakers where the 24VDC could be checked also. Figure 33 shows the results from these tests.

To ensure the machine meets the safety requirements the safety circuit had to be checked to ensure they work as intended. Consideration was paid to not only the stopping of the robot but to the restarting of safety on the machine. According to Staubli (2017) this can be done by checking the internal IO status. The inputs from the safety are included here as well as the power status of the arm. The e-stop inputs are called UESB1 and UESB2, the door inputs are called UEN1_DOOR1 and UEN2_DOOR2. The robot arm power is called PWR. It has to be checked that when the safety input is back healthy the robots arm power doesn't come on until the control on button is pressed. If the safety auto reset the machine would not be safe as a person could climb into the machine, close the door behind them and the robot could start up. The robots own e-stop was checked as well as the externally wired one. Figure 34 and Figure 35 show that the safety circuit performed as intended.

The main part of the testing was to ensure that the final outcome met the intended outcome that was set out by Jones (2021) in the FDS. Because the machine wasn't complete by the project deadline and is still currently being worked on, this testing will be from the current state of the machine.

The camera was tested using the IFM software. Although the machine wasn't running this could be tested. Figure 36 shows the camera simulating the test. This also enabled the outputs with the test to

test the functionality. This was run through multiple times using the 2 parts and no parts. The camera gave the correct output every time.

The robots function effectively didn't work. The robot couldn't run in auto or manual mode as it was in error as soon as the application was started due to the IO mapping issue. The positions were taught as per the FDS. Only non-application functions of the robot worked such as manual jog movements on the pendant which showed the safety was connected appropriately. This is point 4.1.3. The sequence for the robot was changed in point 4.4 due to the picking issue but the plans to meet the new requirement but cannot yet be tested until the robot commissioning is completed. parts of the robot software were tested from point 4.5. This test was only using the simulation software provided from Staubli using their SRS software manual (2019). Simulating an offline device to check its function before connecting to in online was suggested by Vergnano (2017). This simulation allowed a 3d view of the robot where the program was stepped through with virtual IO attached to the programs io. It doesn't give a definite answer than the robot would work as crash zones weren't taken into account as that would require cad models to be imported into the simulation software but the machine hasn't been drawn on cad yet. It did prove the software was very close to what's intended. Run time errors were found from this simulation such as wrong variables used in places but these were simply fixed and will save time testing when the robot is running. The machines running rate could not be proven. Simulating the robots cycle time on the software would not be accurate as it doesn't account for the time it takes to pick and place a part accurately. The robots error displays were tested briefly through the program but for an accurate test it needs to be running properly and the errors occur. Figure 36

Camera Testing

Point 4.1.1 required guarding to be fitted to the machine. At the moment there is no guarding or door on the machine which means the machine has to be taped off with warning tape and signs have to be in place to power on the machine to make workers aware of the risks of the unguarded system. an operator cannot run the machine until this task is complete.

EVEN THOUGH THE PROJECT IS INCOMPLETE, YOU COULD HAVE WRITTEN TEST SCHEDULE FOR INITIAL DEPLOYMENT AND ON-GOING PREVENTATIVE ROUTINE MAINTENANCE. THE TEST SCHEDULE ON P24 + IS MORE OF A CHECKLIST FOR OUTSTANDING WORK.

5. Evaluation and the Wider Issues

The project has been relevant to original goals set out in assignment 1 FDS. The overall goal was to make a system that incorporates a robot with a vision system that could be used to demonstrate company capabilities to customers and also be used to train staff.

Table 2 shows the testing results. some parts of the FDS were changed mid project as circumstance changed. These are shown in Table 4. The testing table is in relation to the original FDS.

When it came to testing the robot's internal valves it was found it didn't have any which was unusual for this style of robot. It is likely that the robots spec has changed over the years meaning only the newer robots come with internal valves. The solution to this problem is to use an external 3 port 2 position spring return valve as suggested by Tameson (2021) this will be powered from a robot external output. Figure 38 shows Tameson's (2021) concept using vacuum to close the rubber cup and pressure to blow the part off instead of relying on gravity. This change doesn't affect the functionality of the machine it just changes the method of obtaining the overall outcome.

The Robots supply being changed to 3 phase 415VAC from 240vac hasn't changed the functionality of the machine so this wasn't a major change in the FDS. This change was done just to avoid having to put an inverter in for the conveyor motor to save cost of bought outs and time. The 5 pole plug that the 3 phase uses is just as common as the 3 pole single phase one so it will still be convenient to connect the machine up to a supply around the factory and in shows.

The robot's sequence had to change to allow the robot to pick the part up without crashing into the camera. An alternative solution would have been to mount the camera high up above the picking area and have the robot waiting outside the picking area so that the camera can see the part. The down side this solution would have been the cameras capability as its field of view isn't designed to be a meter away from the detection area. This meant a more expensive camera with interchangeable lenses to get the correct field of view at that distance would have had to be used. This change of the FDS to rearrange the sequence to pick before detecting the part didn't add any additional cost as this fault in concept design was captured before the software was written meaning it was implemented from the start. This change has saved cost in a mechanical sense also as a more elaborate bracket would have needed to be manufactured in order to mount the camera above the conveyor.

4.1.1 could have had more detail on the FDS. This point was for the conveyor functionality. Although it meets the spec there was more ways it should be tested for example speed. The speed was measured at 8M/m which is suitable for this application.

Throughout the project the wider issues were considered as well as the FDS. According to Jones (2021) the machine had to impact the environment as little as possible. The components that were planned to be reused into this project including the Frame, robot and conveyor were used. Some components were purchased as refurbished and 2nd hand. According to Ardente (2018) this gives a smaller carbon footprint of the component selection of the machine. These included the electrical enclosure and the vision system.

It was planned for some mechanical work to be sub contracted out if there weren't enough resources to support local businesses but this wasn't done. Other methods of being ethical were illustrated through implementing safety standards whilst implementing the project as well as the design that went into the machine.

The risk assessment that was implemented in assignment 1 by Jones (2021) was taken on board throughout the design stages to ensure that the suggested methods of reducing the risks we implemented. Before the implementation stage there should have ideally been a risk assessment for working on the machine. This would have improved the planning of the project and complied closer with health and safety regulations. This risk assessment would have looked closer at what tasks are required during implementation and what tools are required, from this it could be determined what safety equipment and training is required.

The programs for the robot haven't been password protected but the user passwords have been implemented and the ability to upload has been taken away from personnel that isn't logged in meaning the code can't be backed up from an untrusted user.

The risks of the project looked at by Jones (2021) were not detailed enough and focused in the wrong areas. The risk highlighted by Jones of the selection of the vision system was fine after testing and posed no risk when implemented. Covid also didn't cause any issues with timing. The risks that should have been investigated was the resources not being available throughout the project. This caused the biggest delays at the start of the project. The next risk was the functionality of the robot. The robot should have been powered up at the very start of the project and a basic program placed into it to check it functioned correctly. This might have saved time in the implementation stage which was 5 weeks behind to start with without hurdles stopping the project.

The technical file that was intended to produced alongside of the project is incomplete due to critical stages of the project not being complete. The technical file was intended to include all drawings mechanical and electrical, risk assessment, FDS, factory acceptance test and a machine manual. The

mechanical drawings, FAT and a machine manual haven't been completed which reduce the compliance with internal company standards as well as Crown copyright's (2008) machine building standards.

A GOOD EVALUATION , BUT YOU HAVE NOT-
GIVEN THE WIDER ISSUES A LOT OF CONSIDERATION.
'EVALUATION' AND 'WIDER ISSUES' SHOULD
HAVE BEEN SPLIT INTO THEIR OWN SECTIONS.

6. Conclusions and Recommendations

Throughout the project the planning was very poor. It was underestimated in the first assignment how long tasks would actually take as opposed to what was planned. The original timing plan wasn't detailed enough in what tasks had to be done. The time scales on the timing plan were set in order for the project to meet the March 31st deadline instead of the amount of time it actually takes to complete each task. This optimistic approach made the plan unusable. If every task was analysed closer so that a more accurate time estimation was produced then it would have been clear that the resources weren't possible to complete all the tasks. There were no contingency plans put in place which prevented avoiding delays when problems occurred. The 2 weeks of the project was on stop due to other jobs within the company which disallowed any work on this job as it was low priority to the company. The project is late by 1 month and only 59% of the work is completed which is down to these compounded issues.

The cost tracking of the project worked very effectively. The current cost of the project is £7,674.66 out of the £12,500 budget. This cost will go up as the guards and mechanical parts are made as well as the final commissioning but it seems very likely that the project will come in under budget. The cost tracking document that was used gave clear spending in each part of the project including labour and bought outs and helped the control. In every part of the project cost was reduced as much as possible to ensure that if there were difficulties and more time needed on a sector then the budget as a whole could compensate for that. The electrical design went well as using the EPLAN software allowed quality standardised drawings to be produced. Mistakes could have been reduced by having the drawings checked before the implementation stage. The revision system on the drawings allowed a newer version to be added easily. The software structure was very suitable when it was tested on the simulation it allowed the system to access tasks without confliction.

To complete the project, it is recommended that a new detailed timing plan is created using the new break down structure that has more specific tasks that need completed on it. If the old plan is used the issues that are currently in place from it would be dragged out to the end of the project. The remaining £4825.34 of the budget could then be wisely put back into the cost tracking to utilize it as efficiently as possible to ensure it doesn't go over budget. It should be possible to keep the project under budget and within the FDS but it will not be possible to keep it within the original timing scales to take it to automation shows.

The overall of the machine is fit for purpose and as a training facility as well as a customer demonstration gives a lot of potential to expand on areas. A specific area I would recommend to

expand on would be introducing a tracking picking method. This would allow the robot to pick a part that is traveling down the conveyor. this would be done using a more intelligent camera that can either display information into a spreadsheet that can be accessed via the robot comms or send a string to the robot after a trigger. The conveyor would need an encoder. The robot would have to have the Staubli Val Track software installed. The camera would trigger as the part travels underneath it and at the same time the robot would store the encoders position. The robot would then be able to keep track of the part as its moving down the conveyor as it would also obtain x,y co-ordinates from a reference point of the camera. When the part comes into reach of the robot it could pick the part of the conveyor without the need of the part being organised first. This style of part picking would allow parts the oriented as well with rotation. Customers would find this more impressive in shows. This also coincides closer to robot jobs the company produces in the food industry which have similar setups.

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AN EXTENSIVE REFERENCE LIST, BUT
YOU HAVE NOT USED HARVARD CONSISTENTLY.

8. Appendix

Test	Tick to confirm	Comments
4.1.1 conveyor operation	✓	The conveyor has a capability to be started and stopped from the robot IO
4.1.2 camera operation	✓	Camera can define parts and give relevant outputs according to what it sees
4.1.3 robot operation	X	This part was untestable as the IO mapping prevented testing
4.1.4 Guarding requirements	X	The guarding design or implementation has not been completed
4.2.1 includes electrical enclosure	✓	Can IP67 enclosure houses the electrical components
4.2.2 list of spare parts placed in the manual	X	The machine manual has not been completed
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	✓	

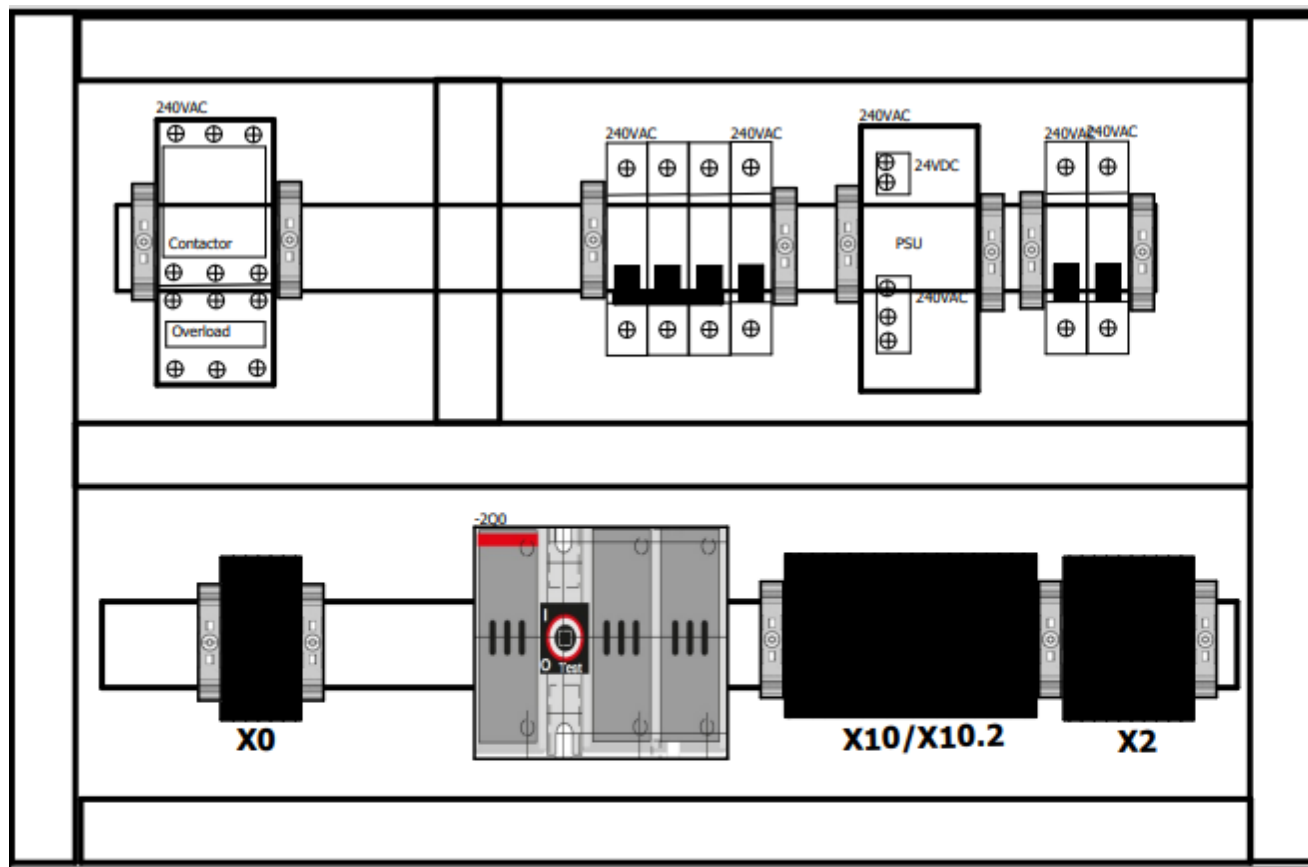
4.3.1 Incoming supply is 240VAC 50Hz less than 16A	X	The Spec was changed so that the incoming supply was 3 phase 415VAC 50Hz
4.3.2 controls system is 24VDC	✓	
4.3.3 Inputs are wired PNP	✓	
4.3.4 Outputs are wired PNP	✓	
4.3.5 240VAC cables outside enclosure are SY	✓	
4.3.6 Only Tri-rated cable used	✓	
4.3.7 cables ferals used where possible	✓	There are no cables without ferals
4.3.8 Enclosure is at least ip61	✓	Enclosure is IP67
4.3.9 20% spare IO	✓	The is at least 50% spare IO. This isn't shown on the drawings as it's on an additional IO card
4.3.10 Incoming supply to the panel will be separated into terminals before entering the isolator	✓	X0 is the terminal block used
4.3.11 isolator is fitted	✓	4 pole fused isolator with a neutral bar is used
4.3.12 cable colouring is correct	✓	Followed from FDS
4.4. Machine follows correct sequence	X	This wasn't tested

4.5 robot software requirements are correct	X	The design was created from the FDS but the functionality can only be checked after commissioning
4.6.1 Push buttons perform correct tasks	✓	The only push button was the control on button which brings on robot power
4.6.2 Valves in robot's arm is used for Vacuum switching	X	These valves weren't present as expected for this style robot. An alternative need to be designed
4.6.3 a proximity switch is used to check the part is in position	✓	M18 Sensor is wired in but hasn't been mounted.
4.6.4 guard switch is mounted onto the guard door and prong is correctly aligned.	X	A guard switch is mounted but the door isn't in place yet.
4.7 at least C safety rating components were used in safety circuits.	✓	The machine meets the requirements set out from the risk assessment
4.8 20 parts per minute	X	Wasn't tested
4.9.1.1 parts can be loaded easily by the operator	X	
4.9.1.2 parts can be removed easily by the operator	X	
4.9.2.1 the machine is easy to clean down for maintenance engineer	✓	From design this is true as cables are brought up through the bed stopping ingress of dirt

4.9.2.2 Robot points can be easily taught	✓	The pendant allows the positions to be taught
4.9.2.3 Robot tooling can be easily checked	✓	The park position is by the intended door entrance
4.10.1 errors are displayed on the pendant	X	Untested
4.10.2 faulty parts are placed in the reject bin	X	Untested
4.11 project is completed under 12,500	✓	Project is currently at £7,674.66 but requires more work.
4.12 project is completed before march 2021	X	The project is a month late and still unfinished

Table 2 Testing Results

MORE OF A TASK CHECKLIST THAN
A RIGOROUS TEST SCHEDULE.



Panel Layout	
Issue	A
Page Number	1 of 7

Figure 5 Electrical drawings Page 1 panel layout

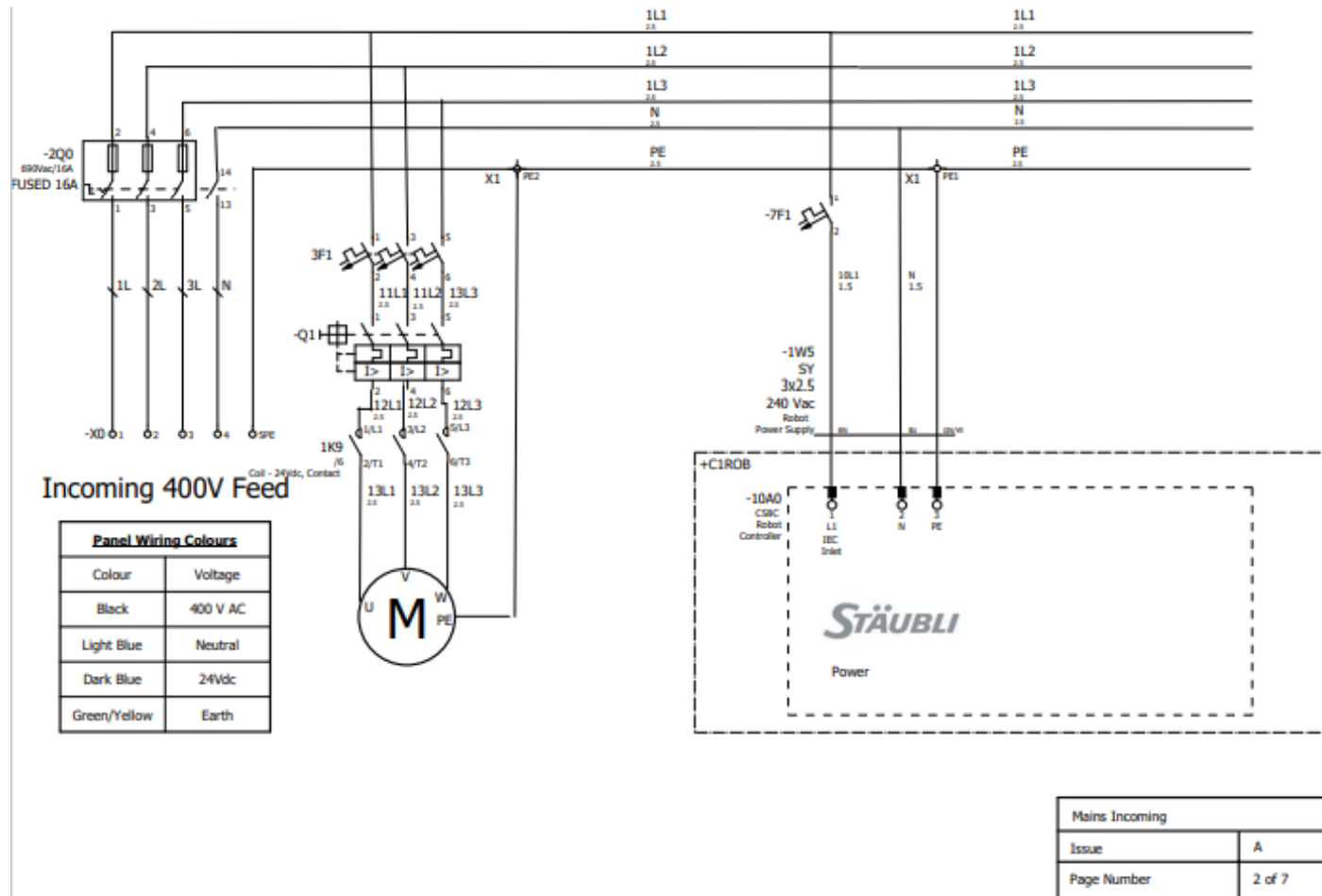


Figure 6 Electrical drawings Page 2 power

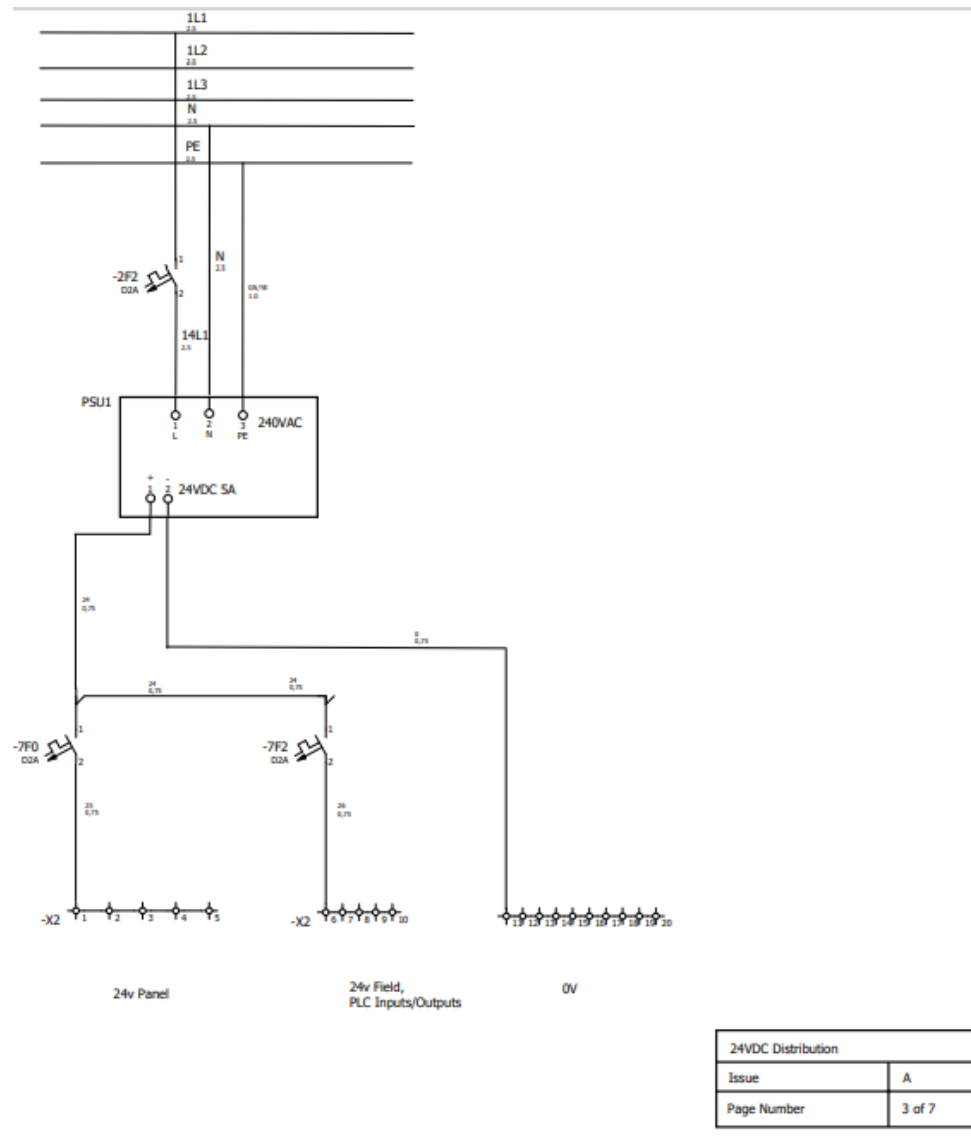
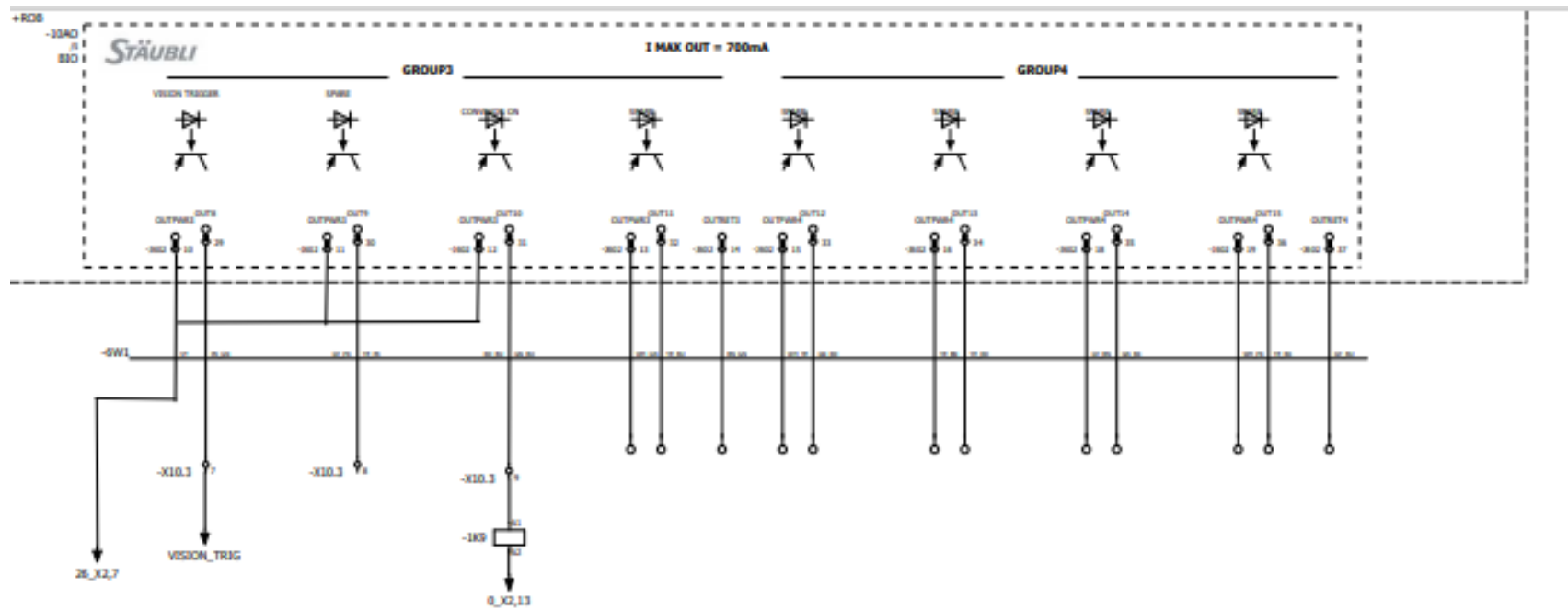


Figure 7 Electrical drawings Page 3 24V

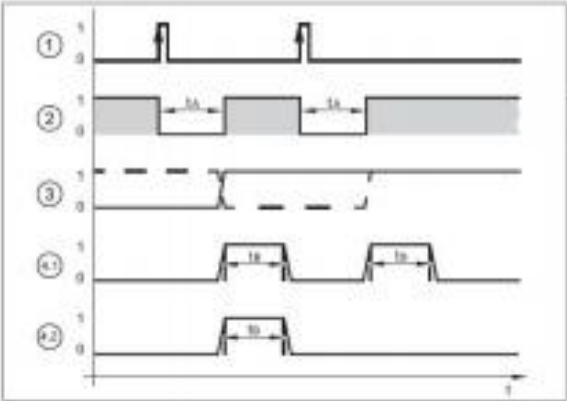


Robot Outputs	
Issue	A
Page Number	6 of 7

Figure 10 Electrical drawings Page 6 robot outputs

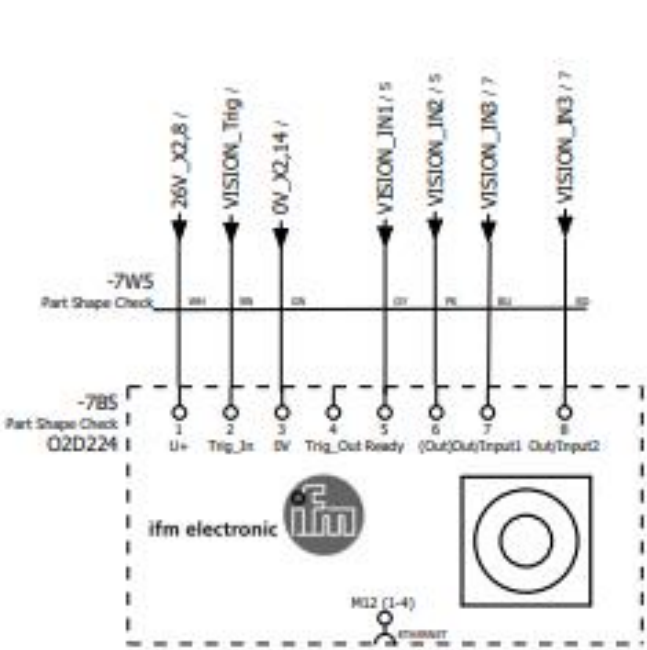
6.5 Timing diagrams

6.5.1 Inputs/outputs



Example: Triggering positive edge

1. trigger input	trigger signal 0: no action 1: triggering on positive edge
2. output READY	ready signal 0: unit busy, OUT output not valid 1: unit ready for trigger signal, OUT output valid
3. DUT output, static	object evolution 0: object evaluation not successful 1: object evaluation successful example 1 (object line): first object OK, OUT = 1 next object faulty, OUT 1 → 0 next object OK, OUT 0 → 1 example 2 (solid line): first object faulty, OUT = 0 next object OK, OUT 0 → 1 next object OK, OUT = 1
4. DUT output, pulsed	object evolution 0: object evaluation not successful or timeout of pulse length 1: object evaluation successful example 4.1: both objects OK, OUT = 1 after expiration of t_{th} , OUT = 0 example 4.2: first object OK, OUT = 1 after expiration of t_{th} , OUT = 0 second object faulty, OUT = 0



Wiring
Core colours:
BR brown
BU blue
GN green
GY grey
PK pink
RD red
WH white
YE yellow



Vision	
Issue	A
Page Number	7 of 7

Figure 11 Electrical drawings Page 7 Vision

Component	Voltage	Current
Motor	415VAC	2A
Staubli CS8 controller	240VAC	10A
Power supply	240VAC	1.15A
Staubli I/O	24VDC	1A
Contactor coil	24VDC	0.25A
IFM Vision sensor	24VDC	1A

Table 3 Power requirements

				Original Estimate	
	Part No.	Material Description	Unit Cost	Qty	Cost
1	XB4BS8442	Panel Mount Mushroom Head Emergency Button	£ 24.58	1	£ 24.58
2	440K-T11090	Safety Interlock Switch	£ 32.60	1	£ 32.60
3		vision system must be less than £1000	£ 1,000.00	1	£ 1,000.00
4		cabling	£ 200.00	1	£ 200.00
5	AE1034500	Rittal AE, Steel Wall Box, IP66, 210mm x 400 mm x	£ 66.03	1	£ 66.03
6		miscellaneous	£ 500.00	1	£ 500.00
7					£ -
				Total	£ 1,823.21

Figure 13 proposed cost for electrical parts

	Part No.	Material Description	Unit Cost	Qty	Cost
1	XB4BS8442	Panel Mount Mushroom Head Emergency Button	£ 24.58	1	£ 24.58
2	440K-T11090	Safety Interlock Switch	£ 32.60	1	£ 32.60
3				1	£ -
4		cabling	£ 200.00	1	£ 200.00
5	AE1034500	Rittal AE, Steel Wall Box, IP66, 210mm x 400 mm	£ 66.03	1	£ 66.03
6	o2d222	IFM vision sensor	£ 562.00	1	£ 562.00
7	3210567	PTTB 2.5, 500 V Double Level Terminal Block	£ 1.81	100	£ 181.00
8	3211634	D-PTTB 2.5 Cover for Terminal Block	£ 0.38	10	£ 3.80
9	LRD10	Schneider Electric Overload Relay	£ 39.00	1	£ 39.00
10	LC1D09BD	Schneider Electric TeSys D LC1D 3 Pole Contacto	£ 60.53	1	£ 60.53
11	3022276	CLIPFIX ATEX Terminal Bracket for Terminal Bloc	£ 0.38	20	£ 7.64
12	3030213	FBS 10-5 Jumper Bar for Terminal Block	£ 10.45	5	£ 52.25
13	A9F54310	Schneider Electric Acti 9 10A MCB Mini Circuit Bre	£ 75.00	1	£ 75.00
14	5SY4102-7	Siemens Sentron 2A MCB Mini Circuit Breaker	£ 17.30	4	£ 69.20
15	467-416	RS PRO, Slotted Din Rail, 1000mm x 35mm x 7.5r	£ 4.34	1	£ 4.34
16	HTWD-PN-25X80-PVC-GY	HTWD-PN Grey Slotted Panel Trunking	£ 10.15	1	£ 10.15
17	544-3840	RS PRO 37 Way Panel Mount D-sub Connector Pl	£ 1.68	3	£ 5.04
18	6EP1333-1LB00	Switch Mode DIN Rail Power Supply	£ 71.00	1	£ 71.00
				Total	£ 1,464.16

Figure 12 Cost of electrical components

```

begin
  // This program is the Start, it manages:
  // - launching of the initial tasks
  // this program must not loop
  // Loaction launched in : application run
  //
  // Author : Sean Jones
  //-----
  //
  taskCreate "Control",100,Control()
  taskCreate "CellManager",100,CellManager()
  taskCreate "UserScreen",100,UserScreen()
  taskCreate "IOMapping",15,IOMapping()
end
  |

```

Figure 14 Start Program

```

begin
  // This program is the User Screen Data Control, it manages:
  // - Current page on the users pendant
  // - The Changing between differnt pages
  // - Displays Data
  // Loaction launched in : Start()
  //
  // Author : Sean Jones
  //-----
  //
  userPage()
  nSwitchIndex=0
  bPageSelected=false
  getKey()
  nkey=0
  do
    switch nSwitchIndex
    case 0
      ////////////////////////////////// Main Menu //////////////////////////////////

      cls()
      title("MAIN MENU")
      gotoxy(0,0)
      put("EBS Automation")
      gotoxy(0,1)
      put("Customer Demonstration System")
      gotoxy(0,4)
      put("F1 : Running Information")
      gotoxy(0,6)
      put("F2 : Maintenance")
      gotoxy(0,8)
      put("F3 : Safety Status")
      delay(0)

      do
        nkey=getKey()
        if nkey>=271
          if nkey<278
            bPageSelected = true
          else
            bPageSelected=false
          endIf
        else
          bPageSelected=false
        endIf
        delay(0)
      until bPageSelected==true
      nSwitchIndex=nkey-270
    break
  end
end

```

Figure 15 User display main menu

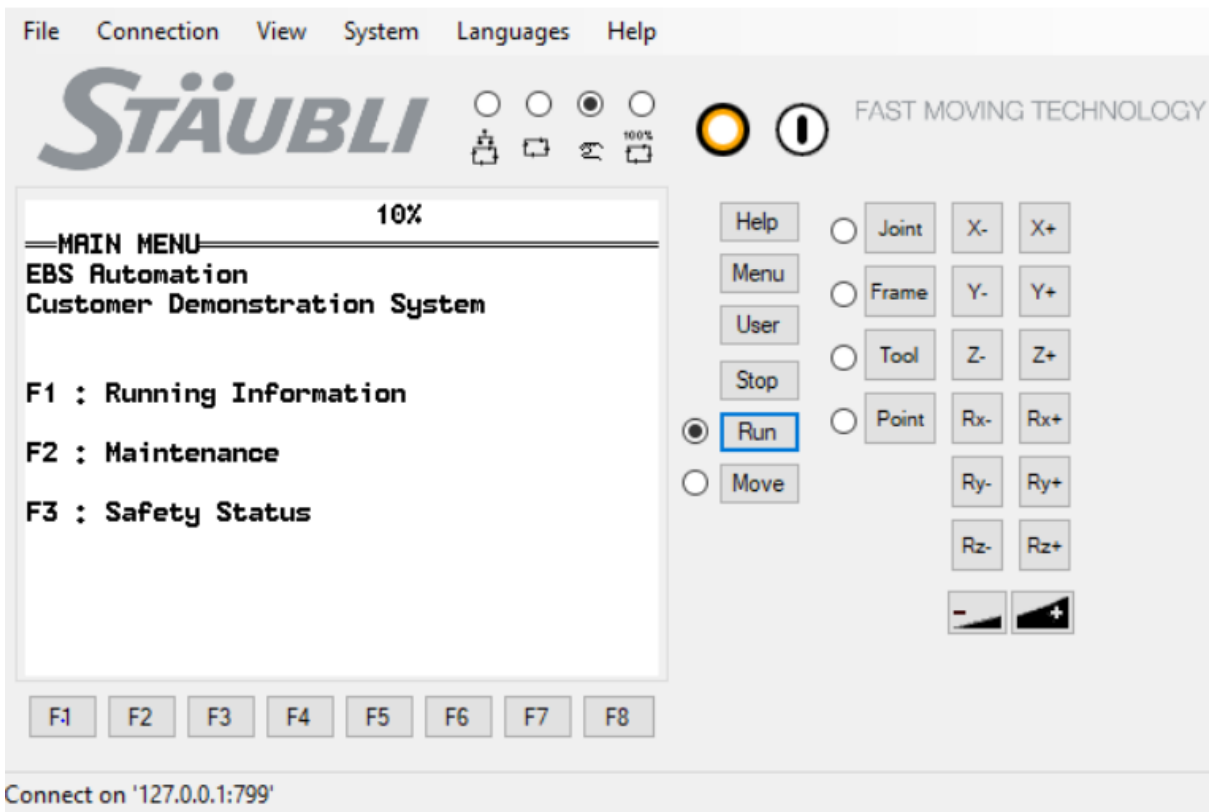


Figure 16 Software simulation main menu

```

case 1
    /////////////// Running Info ///////////////////

    cls()
    title("RUNNING INFO")
    gotoxy(36,13)
    put("BACK")
    // Init Running info screen
    gotoxy(0,1)
    put("Operation Message:")
    gotoxy(0,5)
    put("Robot Status Message:")
    do
        //if sOpMsgDisplay != sOpMsg
        sOpMsgDisplay=sOpMsg
        gotoxy(0,2)
        put("                                ")
        gotoxy(0,2)
        put(sOpMsgDisplay)
        //endIf
        // if sStatMsgDisplay != sStatMsg
        sStatMsgDisplay=sStatMsg
        gotoxy(0,6)
        put("                                ")
        gotoxy(0,6)
        put(sStatMsgDisplay)
        // endIf
        delay(0)
        nkey=getKey()
        until nkey==278
        nSwitchIndex=0
    break
    case 2

```

Figure 17 User display running info screen

```

begin
// This program is the cell manager, it manages:
// - Variable initializing
// - Launch Tracking
// - Arm Power
// - Robot home position
// - Launch user's tasks, kills and re-launch user's task in
//   case of tracking error
// - Displays cycle times and counters.
//
// Loaction launched in : Start()
//
// Author : Sean Jones
//-----
//

// This program works like an escape room but with a Switch Statement.
// For the program which runs the auto sequence to be launched the program must get to the last case.
// Each case is a check that the robot is in a healthy state to run.
// There is a while true loop around this case so it will run forever unless this task is killed in the stop program.
// There are 2 results of a case. 1 being it didnt meet the healthy criterior and the case switch number Remains the same.
// Or the case is healthy and the index number is incremented by 1.

while true
    LCM_nIndex=1
    do
        switch LCM_nIndex

        case 1
            //Kills main task on estop and wait until estop reset

            // Retains E-stop Status
            nEstopReturn=esStatus()
            if nEstopReturn > 1

                // Update cell status for user fault diagnosis
                nCellStatus=1
                // give a relivent status message on the user screen
                sStatMsg="Safety Not OK"
                // Give operator instructions on how to resolve the issue
                sOpMsg="Close Door, Release All Estops"

                // Kill all the tasks that control robot movement
                if taskStatus("AutoSeq")==1
                    taskKill("AutoSeq")
                endIf

                // ResetMotion cancels all the movements in the robots motion stack.
                resetMotion()
            else
                // Switch increments by 1
                LCM_nIndex=2
            endIf
        break
    end
end

```

Figure 18 Cell Manger Snippet 1

```

case 2
    //Make sure controller in Auto mode
    if workingMode()!=3
        nCellStatus=3
        sStatMsg="Invalid Working Mode"
        bRunning=false

        if taskStatus("AutoSeq")==1
            taskSuspend("AutoSeq")
        endif

        switch workingMode()
            case 1
                //set message variable - select MANUAL mode
                sOpMsg="In Manual Mode - Select Auto"
                break
            case 2
                //set message variable - select TEST mode
                sOpMsg="In Test Mode - Select Auto"
                break
            case 3
                //set message variable - select AUTO mode
                sOpMsg="In Auto Mode"
                break
            case 4
                //set message variable - select REMOTE AUTO mode
                sOpMsg="In Remote Mode - Select Auto"
                break
        endSwitch
    else
        LCM_nIndex=3
    endif
break
case 3
    // This case has been left spare for future capability

    LCM_nIndex=4

break

case 4
    //Enable armpower
    // Checks if the arm power is on
    if !(isPowered())
        // If arm power is not on the task is killed
        if taskStatus("AutoSeq")==1
            taskKill("AutoSeq")
            resetMotion()
        endif
        // A message will be displayed to press control on
        nCellStatus=2
        sOpMsg = "Press Control On"

        LCM_nIndex=1
    else
        LCM_nIndex=5
    endif
break
//Check arm for re-enabled

```

Figure 19 Cell Manger Snippet 2

```

case 5
// If the robot is not calibrated to its original factory marks it is not safe to operate.
// Calibration can be lost if the arm is moved physically on power up
if !isCalibrated()

    nCellStatus=6
    sStatMsg="Robot NOT Calibrated"
    if taskStatus("AutoSeq")==1
        taskKill("AutoSeq")
    endIf
    // The stop program is called to end the application
    call stop()
else
    lCM_nIndex=6

endIf
break
//make sure program is not in hold from pendant
case 6
// Check move/hold on MCP
workingMode(nRobWMStatus)
// Pause programs if in hold
if(nRobWMStatus!=0) and isPowered()
    if taskStatus("AutoSeq")==1
        taskSuspend("AutoSeq")
    endIf
    // The operator needs to press the hold button to continue
    if nRobWMStatus==2
        bRunning=false
        sStatMsg="Robot in HOLD..."
        sOpMsg="Press HOLD"
        nCellStatus=4
    endIf
    delay(0)
    lCM_nIndex=1
else
    lCM_nIndex=7
endIf
break
case 7
//Check axis are within limits. if they are not it
//must be done manually before homing
if isInRange(herej())==false

    bRunning=false
    sStatMsg="Robot Outside Of Cell Limits"
    sOpMsg="Move Robot Manually Back Within The Limits"
    if taskStatus("AutoSeq")==1
        taskSuspend("AutoSeq")
    endIf

    nCellStatus=5
    lCM_nIndex=1
else
    lCM_nIndex=8
endIf
break
default
break

```

Figure 20 Cell Manger Snippet 3

```

        endSwitch
        delay(0)
    until(LCM_nIndex==8)

    //Programs can now be launched
    // Task for Auto Sequence
    if taskStatus("AutoSeq")==-1
        taskCreate "AutoSeq",100,AutoSeq()
    endif
    bRunning=true
    sStatMsg="Running"
    sOpMsg=""
    nCellStatus=16
endWhile

end

```

Figure 21 Cell Manger Snippet 4

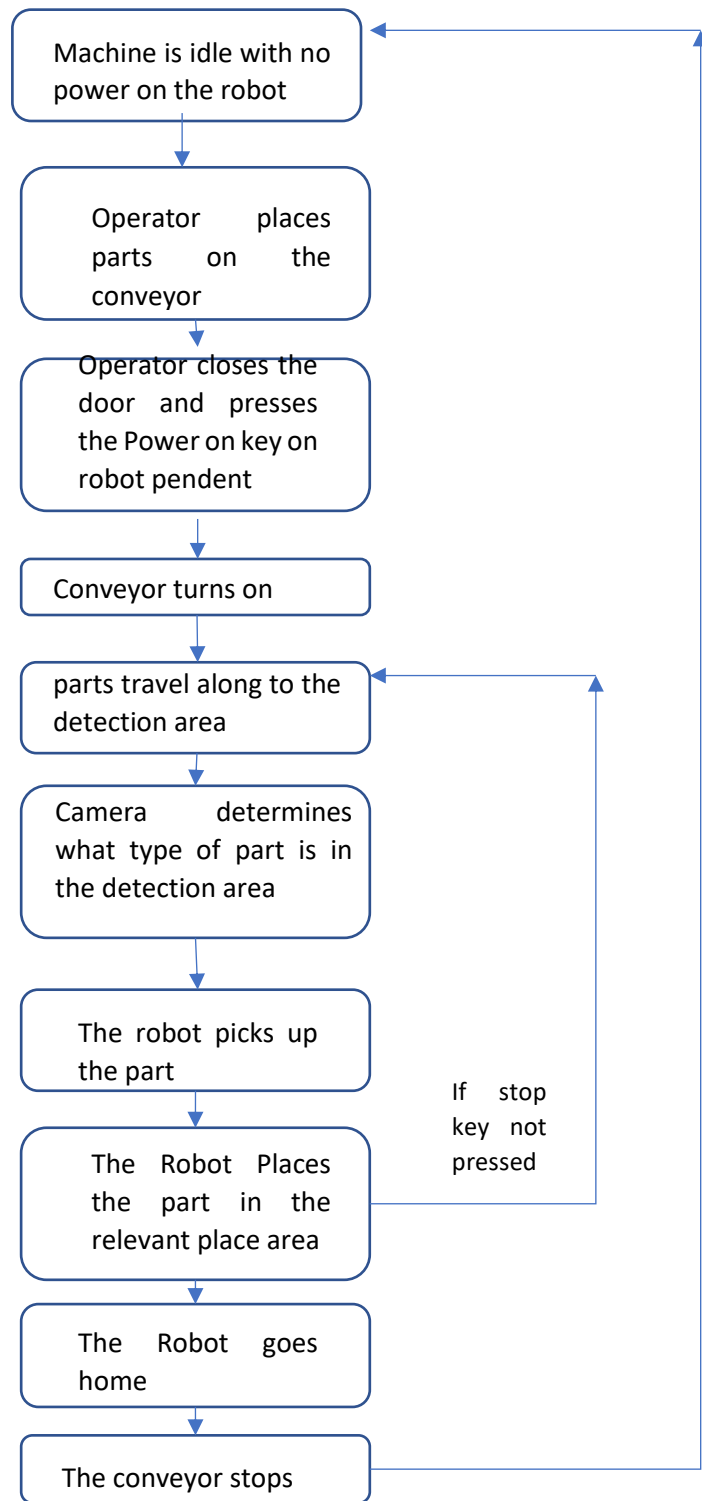


Figure 22 Software flow diagram from original FDS (Jones, 2021)

```

begin
// This program is the Auto Sequence, it manages:
// - Robot Movements
// - Camera Control
// Location launched in : CellManager()
//
// Author : Sean Jones
//-----
//
// The sequence will continually run until it is killed in the cell manager
do
//the program first decides if the robot is home and if not, it moves home.
if pCurrentPos != pHome
// a separate program is called for moving home as this may need to be an elaborate sequence and will save code if it needs to be called more than once
call GoToHome()
endif
// the robot waits for a part present before moving to the pick position
wait(bPartPresent)
movej(pPickApproach,tVac,mNomSpeed)
waitEndMove()
// the wait end move function ensures the robot reaches the position before moving on to the next move in the motion descriptor stack.
movej(pPick,tVac,mNomSpeed)
waitEndMove()
// turn on vacuum gripper to grip part
bVac=true
// delay to ensure part is picked
delay(0.2)
// the move function will ensure the robot moves up straight
move1(pPickApproach,tVac,mNomSpeed)
waitEndMove()
// the part needs to be verified which part it is so the robot moves to the camera
movej(pCamera,tVac,mNomSpeed)
waitEndMove()
// the camera is triggered for a 200ms pulse
dCamTrig = true
delay(0.2)
dCamTrig = false
//when result is true the robot places the part in the correct bin
wait(bResult)
if bReject
movej(pRejectApproach,tVac,mNomSpeed)
waitEndMove()
movej(pReject,tVac,mNomSpeed)
waitEndMove()

elseif bCylinder
movej(pCylinderApp,tVac,mNomSpeed)
waitEndMove()
movej(pCylinder,tVac,mNomSpeed)
waitEndMove()

elseif bCube
movej(pCubeApproach,tVac,mNomSpeed)
waitEndMove()
movej(pCube,tVac,mNomSpeed)
waitEndMove()
endif
until false
end

```

Figure 23 Auto Sequence program

```

begin
    // This program is the I/O mapping, it manages:
    // - mapping of software i/o to physical i/o
    // Location launched in : Start()
    //
    // Author : Sean Jones
    //-----
    //
    do

        // input mapping
        dioLink(dControlOn,io:b2In0)
        dioLink(dCamReady,io:b2In3)
        dioLink(dCircle,io:b2In4)
        dioLink(dSquare,io:b2In5)
        dioLink(dFailPart,io:b2In6)
        // output mapping
        dioLink(dCamTrig,io:b2Out8)
        dioLink(dVac,io:b2Out9)
        dioLink(dConveyorEn,io:b2Out10)
    until true
end

```

Figure 24 IO Mapping program



Figure 25 Electrical Panel Before wiring



Figure 26 Electrical panel complete

Area	Task	Percentage complete	Area completion
Electrical	1. Panel build	100%	100%
	2. Mount Panel on machine	100%	
	3. Wire power from robot to panel using SY cable	100%	
	4. Solder 32 way d sub for Inputs, Outputs and safety connections of robot	100%	
	5. Wire Guard Switch	100%	
	6. Wire E-stop and push buttons on door	100%	
	7. Wire conveyor motor	100%	
	8. Wire camera	100%	
Mechanical	1. Make item front access door	0%	50%
	2. Make vacuum gripper fit robot head pipe back through arm to attach to vac genera	100%	
	3. Connect air pressure to arm valve for blow to ungrip parts	0%	
	4. Make a stop and guide for parts to go down conveyor	0%	
	5. Make Parts to run on the machine	100%	
	6. Mount camera in a place where robot can present part to the camera	100%	
Commissioning	1. Configure vision system	100%	71%
	2. Connect to the robot	100%	
	3. Download software	100%	
	4. Test IO	25%	
	5. Test safety	100%	
	6. Test sequence	0%	
	7. Test Recovery	0%	
Documentation and quality checkin	1. Run trials to test repeatability	0%	12.5
	2. Machine manual	0%	
	3. FAT Test	0%	
	4. File machine documentation including electrical drawing and risk assesment	50%	
		overall completion	59%

Figure 27 Work completed

Project Plan

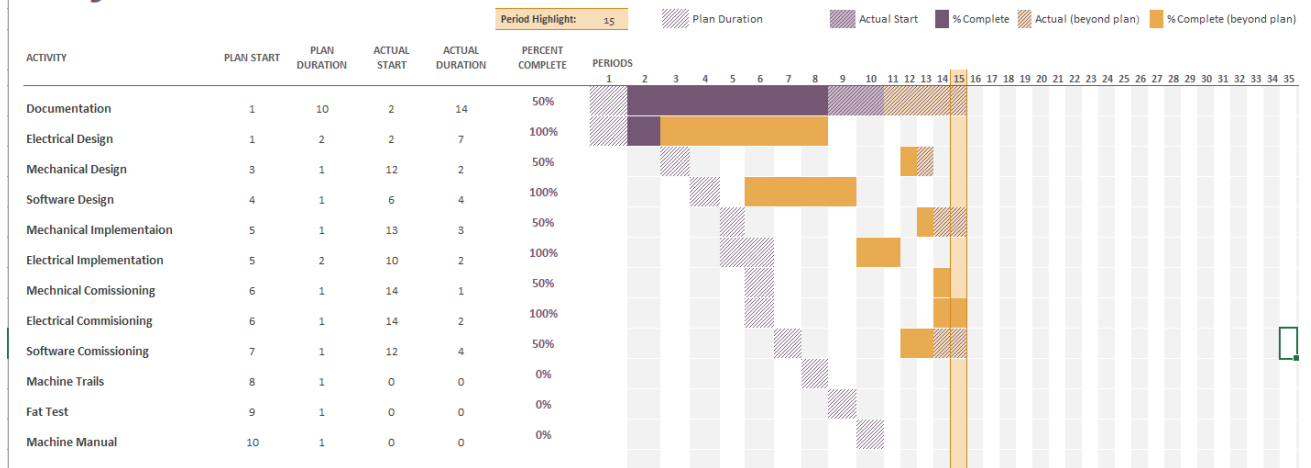


Figure 28 Project timing plan

9 Electrical		General Estimate Electrical Time	
Rate	£ 45.00		
		Hrs	Cost
ELEC 01	Project Meeting		£ -
ELEC 02	Site Visit		£ -
ELEC 03	Electrical Design	32	£ 1,440.00
ELEC 04	Software		£ -
ELEC 09	Electrical Documentation		£ -
ELEC 10	Electrical Concept Design	0	£ -
ELEC 12	Software Commissioning		£ -
ELEC 20	New Quote Work		£ -
ELEC 31	Customer Training		£ -
9 Electrical			
Rate	£ 37.00		
ELEC 05	Panel Build	10	£ 370.00
ELEC 06	Machine Wiring	15	£ 555.00
ELEC 07	Machine Integration/Trials		£ -
ELEC 08	Electrical Commissioning	32	£ 1,184.00
ELEC 11	Robot Programming	57	£ 2,109.00
ELEC 15	Rework		£ -
Total		146.00	£ 5,658.00

Figure 29 Electrical hours costing

9	Electrical	General Estimate Electrical Time	
Rate	£ 45.00		
		Hrs	Cost
ELEC 01	Project Meeting		£ -
ELEC 02	Site Visit		£ -
ELEC 03	Electrical Design	24	£ 1,080.00
ELEC 04	Software		£ -
ELEC 09	Electrical Documentation		£ -
ELEC 10	Electrical Concept Design	16	£ 720.00
ELEC 12	Software Commissioning		£ -
ELEC 20	New Quote Work		£ -
ELEC 31	Customer Training		£ -
9	Electrical		
Rate	£ 37.00		
ELEC 05	Panel Build	16	£ 592.00
ELEC 06	Machine Wiring	16	£ 592.00
ELEC 07	Machine Integration/Trials		£ -
ELEC 08	Electrical Commissioning	8	£ 296.00
ELEC 11	Robot Programming	78	£ 2,886.00
ELEC 15	Rework		£ -
Total		158.00	£ 6,166.00

Figure 30 Electrical labour budget cost



Figure 31 Camera location with robot holding part

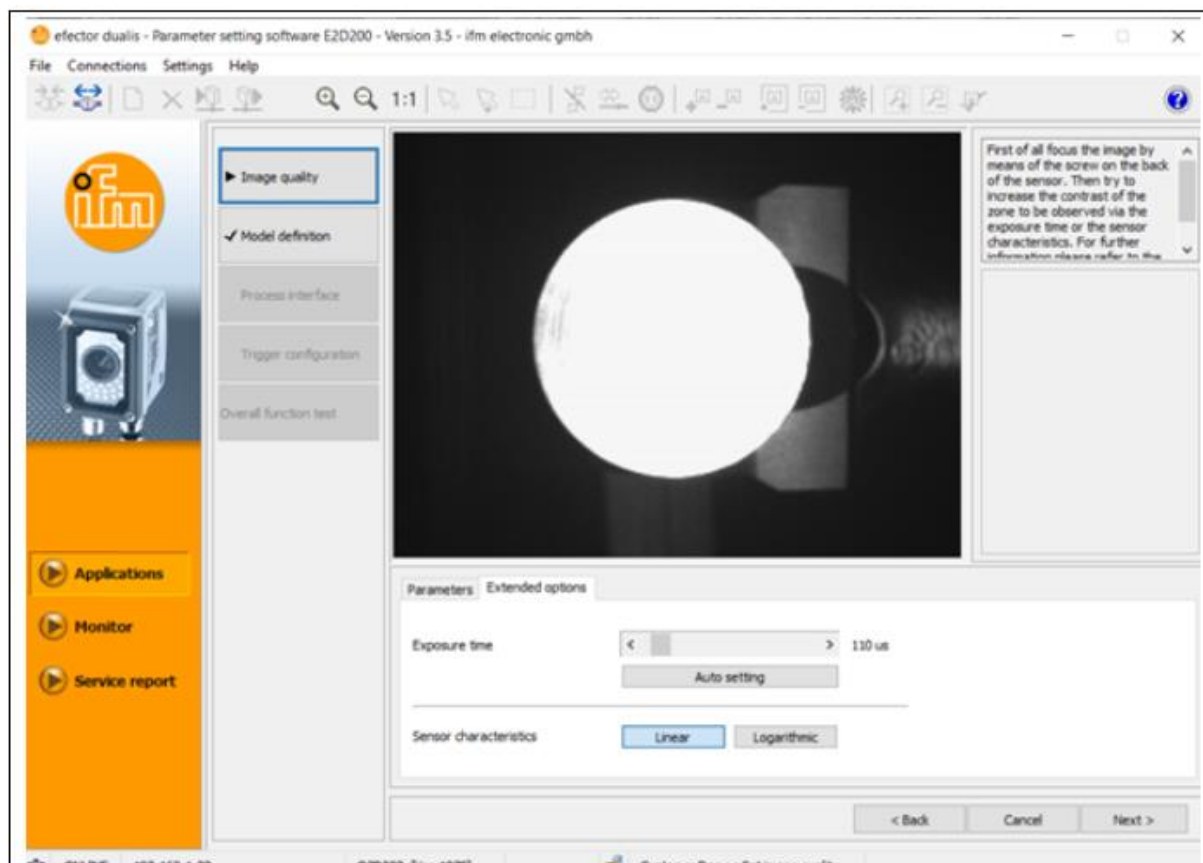


Figure 32 Exposure setting

Testing points	Measured Resistance (Ω)
L1 - L2	>100M
L1 - L3	>100M
L1 - PE	>100M
L1 - N	>100M
L2 - L3	>100M
L2 - PE	>100M
L2 - N	>100M
L3 - PE	>100M
L3 - N	>100M
N - PE	>100M
24 - 0V	0.5M
0V - PE	0.1
Testing points	Measured Voltage (V)
L1 - PE	243VAC
L2 - PE	245VAC
L3 - PE	240VAC
L1 - L3	415VAC
L1 - L2	415VAC
L2 - L3	415VAC
24 - 0V	24VDC

Figure 33 Resistance and power checks

State 1 – Ensure that the all-safety systems are healthy and reset

Check	Panel	Robot
	Tick to Confirm	Tick to Confirm
UESB1 on pendant internal IO is on	/	/
UESB2 on pendant internal IO is on	/	/
PWR on pendant internal IO is on	/	/

State 2 – Hit E-Stop

Check	Panel	Robot
	Tick to Confirm	Tick to Confirm
UESB1 on pendant internal IO is off	/	/
UESB2 on pendant internal IO is off	/	/
PWR on pendant internal IO is off	/	/

State 3 – Reset E-Stop Button

Check	Panel	Robot
	Tick to Confirm	Tick to Confirm
UESB1 on pendant internal IO is on	/	/
UESB2 on pendant internal IO is on	/	/
PWR on pendant internal IO is off	/	/

State 4 – Press Control On

Check	Panel	Robot
	Tick to Confirm	Tick to Confirm
UESB1 on pendant internal IO is on	/	/
UESB2 on pendant internal IO is on	/	/
PWR on pendant internal IO is on	/	/

Figure 34 E-stop safety testing

State 1 – Ensure that the all-safety systems are healthy and reset

Check	Front Door
	Tick to Confirm
UEN2_DOOR2 on pendant internal IO is on	/
UEN1_DOOR1 on pendant internal IO is on	/
PWR on pendant internal IO is on	/

State 2 – Open Door

Check	Front Door
	Tick to Confirm
UEN2_DOOR2 on pendant internal IO is off	/
UEN1_DOOR1 on pendant internal IO is off	/
PWR on pendant internal IO is off	/

State 3 – Close Door

Check	Front Door
	Tick to Confirm
UEN2_DOOR2 on pendant internal IO is on	/
UEN1_DOOR1 on pendant internal IO is on	/
PWR on pendant internal IO is off	/

State 4 – Press Control On

Check	Front Door
	Tick to Confirm
UEN2_DOOR2 on pendant internal IO is on	/
UEN1_DOOR1 on pendant internal IO is on	/
PWR on pendant internal IO is on	/

Figure 35 Door safety testing

FDS point	Original FDS	Revised
4.3.1	Jones states “Incoming supply will be 240VAC 50Hz less than 16A so a conventional PCE socket can be used” (2021)	Incoming supply: 415VAC 50Hz 16A with a 5 pole PCE Plug
4.4	Sequence where camera detects part before picking	Robot will pick part then move to the camera to detect the part shape

4.6.2	Jones states “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.” (2021)	The vacuum valves are to be mounted externally of the robot and run off the robot’s external outputs.
-------	--	---

Table 4 Revised FDS points

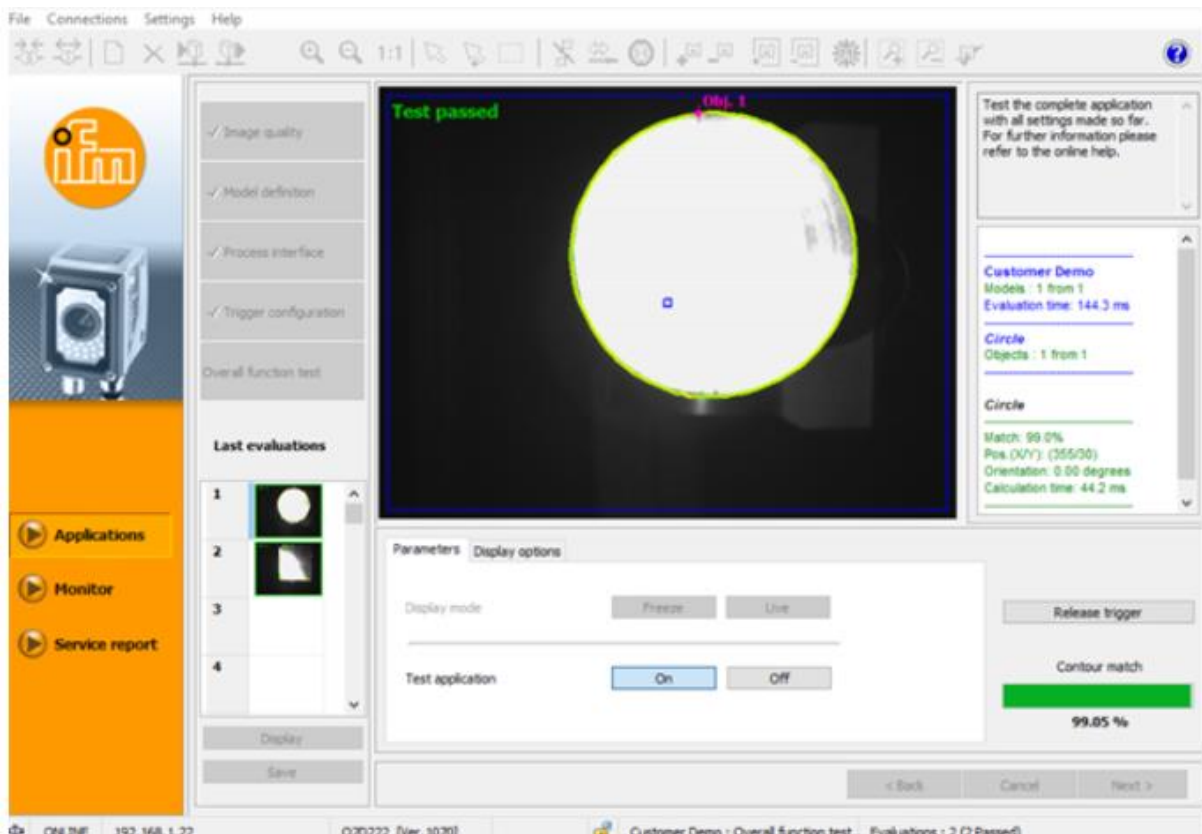


Figure 36 Camera Testing

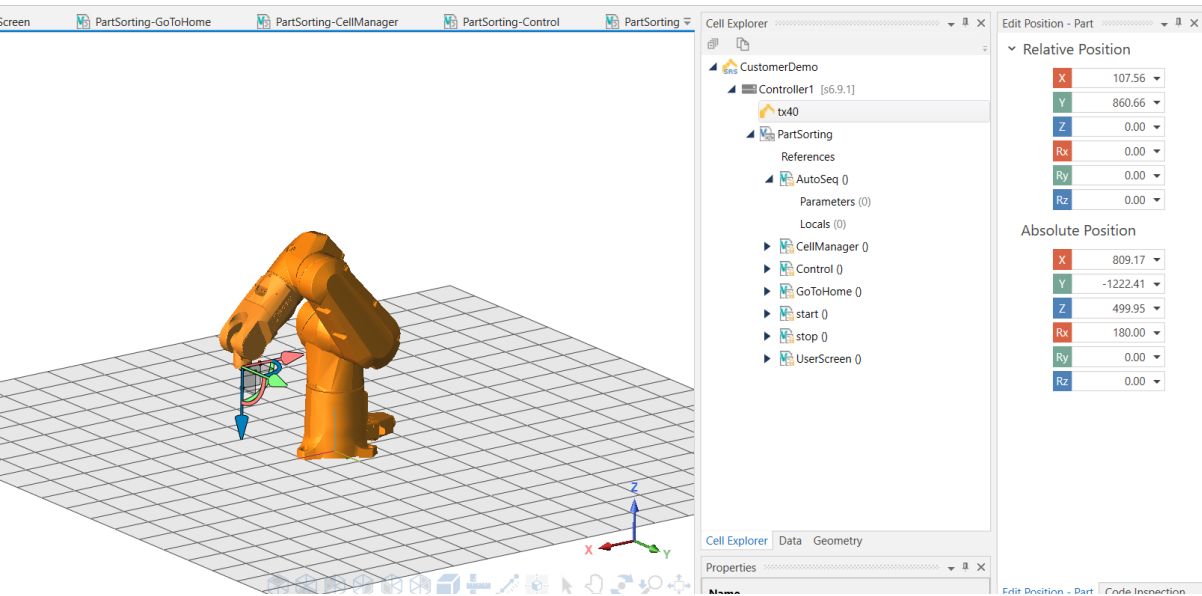
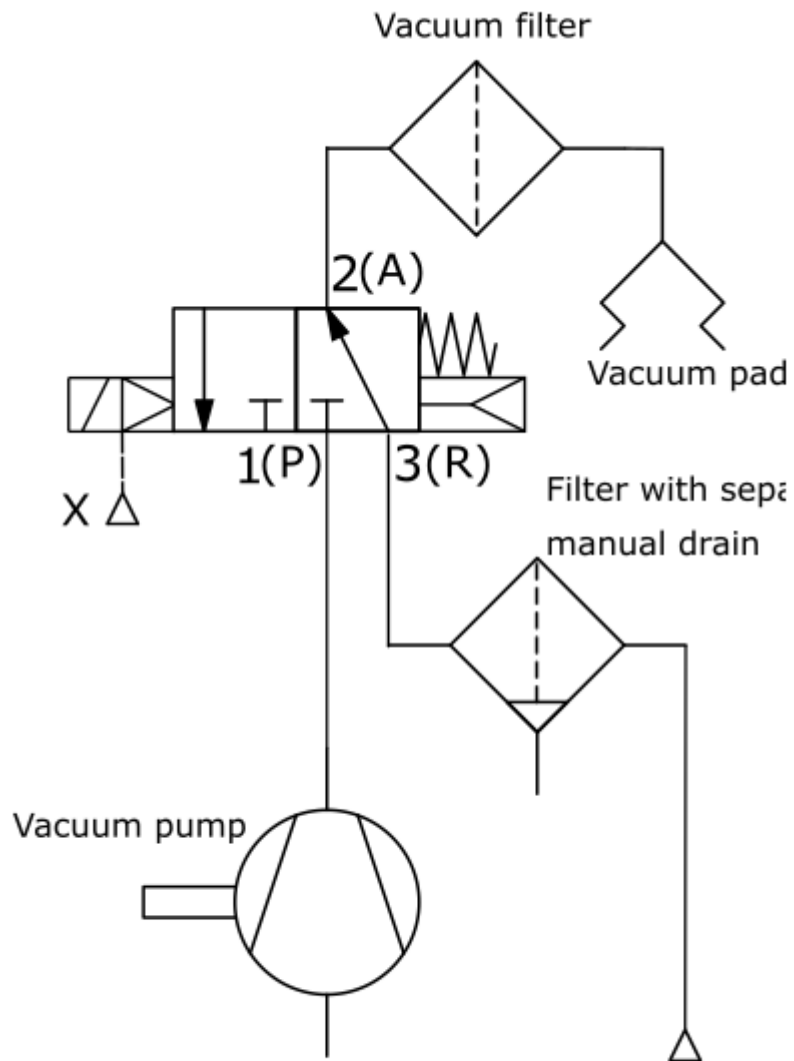


Figure 37 Robot simulation



Externally piloted vacuum control valve for vacuum pad

Figure 38 Vacuum valve concept (tameson, 2021)



Figure 39 Robot Cell Current