Department of Electrical and
Electronic Engineering

Embedded Systems Project 2022-23

Proposal Document

Title: ESP Proposal Document

Group Number: 12

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1. Introduction

The Embedded Systems Projects (ESP) is a project that aims to create a white-line following buggy that is fully capable of autonomously navigating itself through a predesigned environment that is filled with various obstacles. This project could serve as the foundation/prototype for autonomous vehicles in the very near future, as technology advances. Modern transportation has not adapted fully autonomous vehicles due to the fact that there is not a stable and efficient way to guide the vehicle closely towards a predetermined path. The project models this problem with fewer constraints and gives insight into the most crucial part of an autonomous vehicle, its control and steering. The following proposal report describes the various aspects of the project, showing the way the project would be executed. The technical overview section describes the various technical decisions made on the design of the buggy to tackle all the problems faced on the obstacle track, which includes the selection of the motor/gearbox, software system design, sensor selection, control algorithm selection as well as the design of the chassis. The team organisation section describes the roles and responsibilities of the team as well as other aspects of teamwork to deliver the project efficiently. The planning and budget section describes the planning of the project, such as the project plan, project Gantt chart, health and safety assessment, schedule of the project and budget to build the buggy. The key milestones of the project would be the motor control demonstration, sensor demonstration, control/steering demonstration, final demonstration, the design and final reports and the final aim of producing a white-line following buggy.

The CAD of the buggy is shown in Figure 1.1. The chassis of the buggy is split into two layers. The top layer includes the NUCLEO-F401RE and the battery pack. The bottom layer includes the gearbox, the motor driver board, the sensor board and the castor wheel. Finally, both layers of the chassis and of all of the buggy's components excluding the battery back are held together with nuts and bolts. The battery pack will be attached to the top layer of the chassis using Velcro straps that will be inserted through the slits.

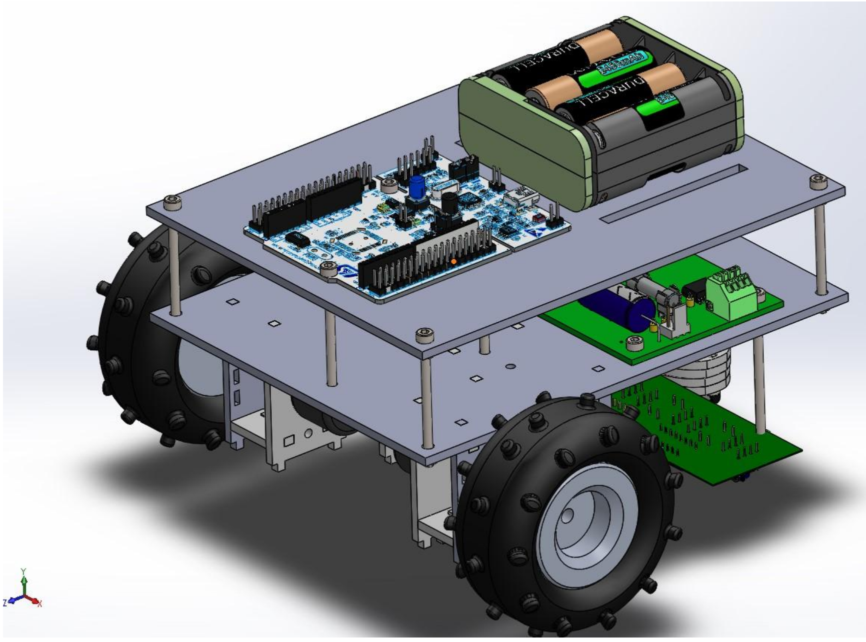

Figure 1.1: 3-D CAD model of the buggy design

2. Technical Overview

2.1 Motor and Sensor Characterisation

The gearbox is an important component of the buggy as it provides additional torque required for the buggy to climb the slope along the race track. Hence, motor characterisation is done to determine the torque that the motor provides and load measurements are done to determine the minimum torque required by the buggy to overcome the slope.

The gear ratios are obtained from the options of gearboxes and each their output torque is calculated so it can be compared with the needed torque. The current and voltage used by the motor with the gearbox is calculated as to not exceed the current limit of the motor drive board. Choosing the suitable gearbox is crucial in constructing an efficient and stable software system for controlling the buggy during the race.

From results obtained during the motor lab and the first design report [4], it was made clear through calculations of torque that gearbox 2 provided the buggy enough torque to climb the steepest slope on the track, whilst not compromising on speed. This is because the current used by gearbox 2 does not exceed the current limit of the motor drive board while providing the necessary torque and decent speed for the buggy.

2.2 Software System Design

The software system is a crucial part of the project, linking all the other sections together and providing the ability to control the buggy. There are multiple functions required for the external devices, including input and output functions used to measure from sensors and send output signals to motors.

This section links to the motor characterisation and sensor characterisation sections as results obtained from the motor characterisation section provide an understanding on how the motors work, so the software can be implemented in a way which controls these motors as efficiently as possible.

The software is going to contain multiple functions, such as providing PWM signals to the motors to power them in different ways to adapt to the track, however it also requires functions to read the line sensor values in order to calculate the required change in the motors' speed. Along with this, the software must be able to retrieve motor speed values and the battery energy level to ensure the buggy drives at the correct speed and has sufficient battery charge before the technical demonstrations.

2.3 Sensor Characterisation

The line sensor is the main component supporting the control section as it is an essential part of the input and output interfaces. The sensor characterisation directly links to the control algorithm, as its sensitivity determines the type of controller algorithm that can be used. To determine the most suitable sensor for the project, the characteristics of TCRT5000 and two additional sensor pairs built by the team were measured during the sensor lab [5]. The TCRT5000 was selected for its great sensitivity with respect to changing surface colours, making a clearer distinction between the black track and white line, but also providing a higher voltage than the other sensor pairs at the same height. The combination of these features makes it ideal for detecting the line and keeping the buggy on the track in the race. Another reason the TCRT5000 was selected is that, as a widely used and pre-built optical sensor, it is less likely to have connectivity or other issues than the sensor pairs built from discrete components and it is far easier to fit it into the system - its pre-built module provides an easier and less error prone way to install the line sensors to the PCB, reducing the risk of buggy failure.

2.4 Control Algorithms Selection

The control algorithm selection determines the steering and motions of the buggy and is the key towards a stable and efficient line-following buggy. The control algorithm is implemented in the microcontroller and controlled by the software system. It takes input from the line-sensors and calculates the necessary differential gain to apply to the wheels to steer it.

A Proportional Integral Differential (PID) controller will be used in the buggy, as it allows for swift realignment of the buggy to the line in a smooth motion and eliminates steady-state error, so that the line would always be centre to the buggy. In addition, it also applies a damping factor to the buggy, which allows for more efficient realignment. A PID controller requires the input sensors to be precise and does not fluctuate often, else the error propagation would be significant enough to reduce the performance of the buggy. Since the TCRT5000 is used, a PID controller could be used due to its accurate measurements.

This section is vital to the software system design section as it is the most important and difficult to program section of the software, which is required in order for the buggy to follow the white line correctly. It is also heavily linked to the sensor and motor characterisation sections as they provide the knowledge required to be able to operate a control algorithm involving those components.

2.5 Chassis Design

The chassis design of the buggy is intended to distribute the weight of the buggy evenly, use efficient hole placement to simplify mounting of the components and facilitate component access.

The design is a two-layer chassis of acetal plastic. Comparing acetal to other materials for the chassis design, it outperformed them in terms of price, weight and deflection calculations. The multi-layer design provides easy access to components for adjustments and replacements. The chassis has been designed to be large enough to accommodate all components without them obstructing each other.

The holes on both layers of the chassis are designed to be as efficient as possible. The front of the motor board and the sensor board will be using the same two holes when placed on the buggy. Each layer of the chassis will have four holes at its edges and screws will be inserted through each one connecting both layers together, contributing to the overall stability and rigidness of the buggy.

As seen in Figure 1.1, the battery pack is placed on the front of the top layer of the chassis, preventing the buggy from having excess weight on one side of the chassis, which could cause the buggy to fall backwards when reaching the peak of the ramp. Similarly, the rest of the components are placed specifically in a way that will balance weight distribution and maximise stability of the buggy.

The weight distribution of the buggy is related to the torque of its motors, as a high torque motor coupled with a rear-heavy buggy would likely result in the buggy flipping over when going up the slope.

This section of the design is fairly dependent on the motor characterisation section as the torque calculated for the motor and its chosen gearbox dictate the maximum weight the buggy can be whilst still having enough power to climb the steepest slope on the track.

2.6 Winning Features

The winning feature of the buggy is that it is designed to deliver consistent performance. The simplistic design of the buggy means that the respective components can work together at its best without overcomplication. It is also cheap so there would be an abundance of budget left for any last-minute changes or repairs. The two-level design allows all the components to fit properly and also allows for easy and safe connections of the components, reducing the chances of a wire blow-out. In addition, the buggy's mass is distributed evenly to prevent any tip-overs which may send the buggy off track, guaranteeing a more consistent performance. The gearbox selected provides the greatest speed whilst also meeting the torque requirement to drive the buggy up the track’s slope, making it power efficient and more consistent in speed. The use of a PID controller along with precise line sensors also further improves the power efficiency of the buggy by creating a proportional response to changes in the buggy’s direction.

3. Team Organisation

3.1 Roles and Responsibilities

The main named roles within the group are the Project Manager, Secretary and Safety Officer. The Project Manager manages the Gantt chart and monitors the progress of the project using this tool, updating it and using it as guidance to ensure the project runs as expected. The Secretary is in charge of communications in the group, making sure meeting logs are updated to maintain clarity and provide evidence of communication between the members of the group. The Safety Officer ensures that any hazards are accounted for, ensuring the safety of the group members during laboratory sessions and technical demonstrations. This is done using a health and safety risk assessment which identifies health risks and allows for mitigation planning, in order to reduce the likelihood of these risks occurring.

3.2 Communications and Record-keeping

The team has had 3 methods of communicating since the start of the academic year. WhatsApp, Zoom and Discord. WhatsApp is used for arranging meetings and discussing small issues, Zoom was the team’s former way of conducting meetings, and Discord is the team’s current way of conducting meetings. The team preferred Discord over Zoom as it has the same capabilities of Zoom but arranging meetings is easier as there is no need for a room ID and all members can be alerted with a single notification. Communications evidence of the WhatsApp and Discord group is provided below in Figure 3.1 and Figure 3.2 respectively.

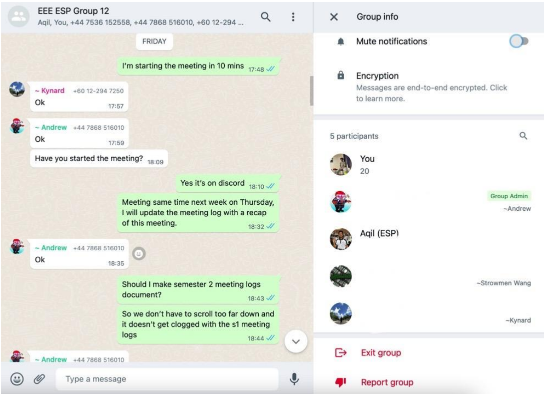

Figure 3.1: WhatsApp group chat

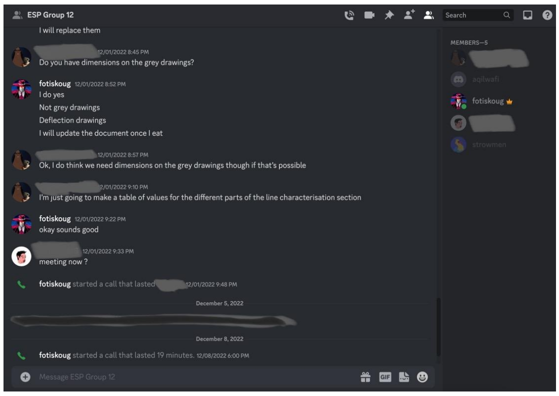

Figure 3.2: Discord group chat

All of our documents are kept in a google drive named 'ESP Group 12' for which only members who have been sent the link have access to. Members can edit documents freely. By using shared documents, each team member can see what edits to the documents have been made, at what time and by which member, maintaining clarity in communications and work. A list of our record-keeping documents of meetings include:

- Meeting Logs Semester 1
- Meeting Logs Semester 2
- Weekly Journals (different document for each week, all kept in one folder)
- GanttProject Gantt chart

When a team member updates a document, he must inform all other team members of the changes he has made via WhatsApp or another communication method, to make sure all team members are aware of the task's progress. This helps team members avoid work duplication. The Weekly journal is completed by a different member each week, with each team member adding their individual contribution.

3.3 Meetings and Decision Making

The team meetings are usually short and concise. An idea or plan is proposed and members are asked one by one for their input and once the team has come to a consensus, the focus of the meeting is shifted to another important topic. For a decision to be made, all team members must be in agreement. If a person is unhappy with a team decision, they should argue their point and if all team members agree that it is valid, the decision is discussed further and a common ground is reached. All team members attend the meetings as they are always arranged at a suitable time for everyone. If a team member is unable to join a meeting, they must inform the team members of the reason for their absence.

3.4 Effectiveness of Meetings

The meetings have been successful as there hasn't been any conflict between group members. Each member contributes in team meetings. Everyone has been working on their assigned tasks effectively and there hasn't been duplication of work due to the planning done in advance for each task.

3.5 Workload and Spread of Workload

Workload is spread fairly evenly using a Resources chart, containing the workload per group member for each task. The main focus was to provide a large section to each group member to complete in order to spread the workload evenly, with all group members providing input to these sections if required. All group members then proof-read each section. In Design Report 1 and 2, the group members each completed a specific section of the reports, to act as a basic way to spread workload, with each group member then proceeding to cross-check the other sections, providing improvements to those sections. Sections such as the introduction and summary were completed initially as a group to evenly spread the workload, as these sections were linked to all of the sections our group members individually created.

3.6 The Team's Learning Styles

There are four learning styles as listed in the technical handbook [1] - Activist, Reflector, Theorist and Pragmatist. At the beginning of the project, the team members discussed and informed the team of their preferred learning styles. Knowing and comparing the members' learning styles at early stages of team working lets the team capitalise each member's strengths and abilities and allows the team to recognize the most effective way of communicating and working with each other. This helped in assigning team roles to each member and dividing the workload of the project to the appropriate team members in order for the project to run smoothly. Learning styles may overlap between team members and it may change along the course of the project no matter how small. Nevertheless, the team always discusses the best way to distribute workload evenly and each member keeps the team informed of any changes in their learning styles for the team to work efficiently.

3.7 Meeting Frequency

Meetings are hosted every Monday and Thursday at 6 or 6:30 pm. During weeks before a report is due, additional meetings are arranged to discuss the report's progress.

4. Planning and Budget

4.1 Project Plan

The most important aspects of the project for semester 2 consist of the four technical demonstrations and the final report [2]. Each of these activities have their own deliverables which vary depending on the activity's content. For the technical demonstrations, all four include either buggy assembly and/or programming, with working code and an assembled buggy being deliverables for these activities. Each technical demonstration involves a different part of the coding, whilst the first two technical demonstrations require more assembly. There are additional deliverables for the second and third technical demonstration, the system diagrams. The final report requires a completely different set of tasks and deliverables as it involves the entire project. The table below provides a summary of the main activities, further detailed in the Gantt chart.

Table 4.1: Summary of main activities

Team Activity (Date)	Milestones	Deliverables	Individual Activities	Responsible Group Members
TD1 - Motor	1. Set up microcontroller	1. Working code for PWM	1. Program microcontrolle	1. Andrew, Tingxuan.

Control (09/02 to 26/02)	PWM peripheral registers. 2. Assemble the buggy. 3. Buggy ready for TD1.	outputs. 2. Assembled buggy. 3. Buggy tested for TD1.	r for TD1. 2. Main components and boards fitted. 3. Motor function tested.	2. Fotis, Aqil, Kynard 3. All group members.
TD2 - Sensors (26/02 to 19/03)	1. Create required schematics. 2. Sensor arrays complete. 3. Buggy ready for TD2.	1. Circuit schematic, board layout. and wiring diagram. 2. Assembled sensor array. 3. Buggy tested for TD2.	1. Fully design diagrams/layouts. 2. Build the sensor array PCB. 3. Perform required tests.	1. All group members. 2. Fotis, Aqil, Kynard. 3. All group members.
TD3 - Control/ Steering (19/03 to 22/04)	1. Set up code for controlling speed. 2. Buggy ready for TD3.	1. Working speed control code. 2. Buggy tested for TD3.	1. Program the speed control. 2. Perform required tests.	1. All group members. 2. All group members.
TD4 - Heats & Race (22/04 to 04/05)	1. Buggy travels around the entire race track.	1. Fully coded and assembled buggy.	1. Program any remaining required functions.	1. All group members.
Final Report (22/04 to 12/05)	1. First draft. 2. Final draft.	1. Completed first draft. 2. Completed final draft.	1. Complete all sections in the first draft. 2. Complete all sections in the second draft.	1. All group members. 2. All group members.

4.2 Gantt Chart

The Gantt chart is the most valuable tool used to track the project's progress, being formed from the project plan and improving on it by providing a more detailed and structured approach to the project. The milestones are more concise and exact in the Gantt chart, and the Gantt chart includes more individual tasks overall than the project plan it is formed from. The main activities from the project plan - the four technical demonstrations and the final report - are incorporated as main tasks in the Gantt chart, with the technical demonstrations also being grouped as part of the 'buggy construction' process. The proposal report was included in the Gantt chart as it is involved in both semesters, but isn't a focus for the majority of semester 2.

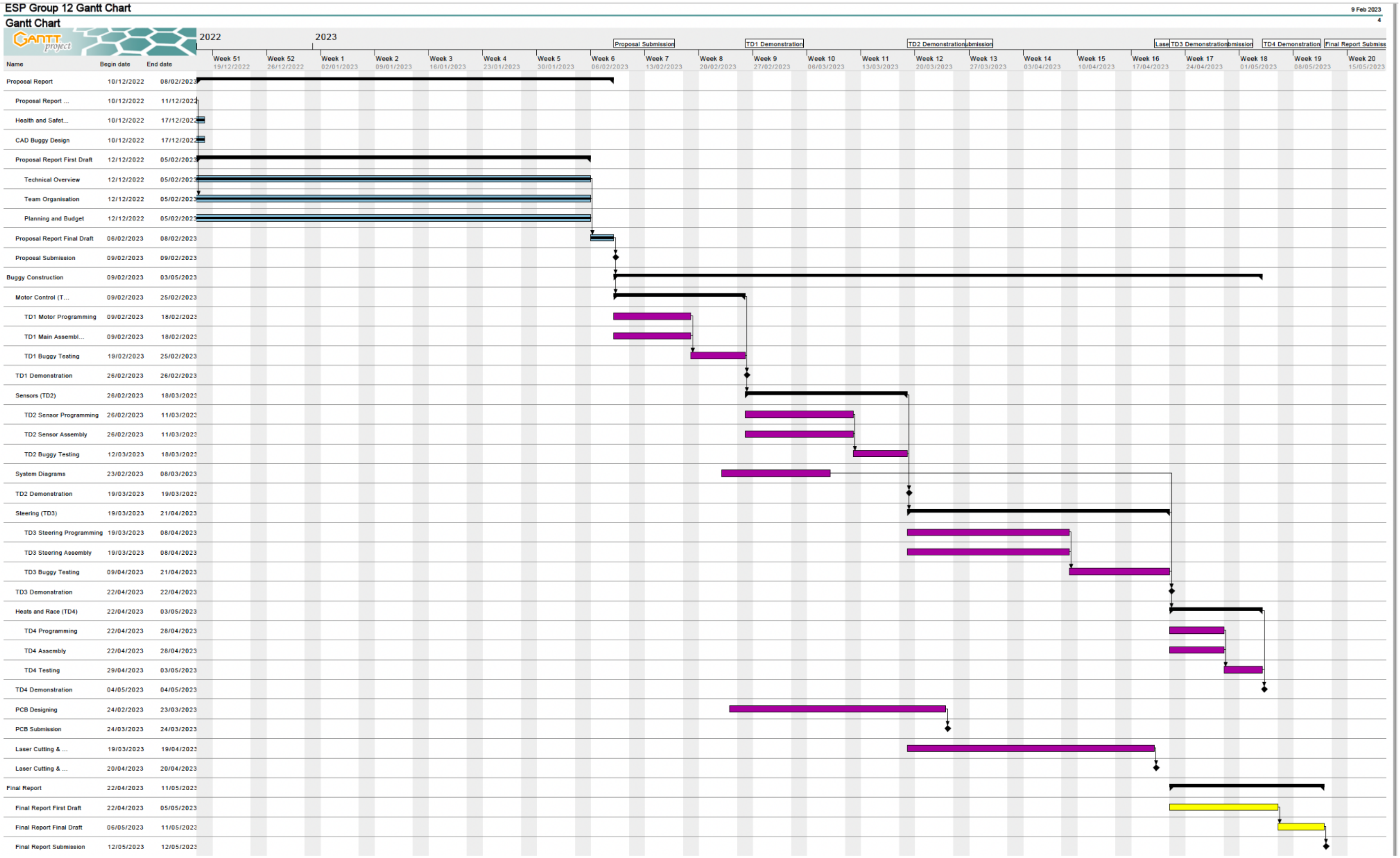

Figure 4.2 - Gantt chart outlining every key task for semester 2 of the project

Each technical demonstration follows the same base structure, consisting of a period of time for the system integration, at least a week for assembling and coding running concurrently, with a week of testing straight after. This is done purposefully to allow more flexibility to the Gantt chart as more specific sub-tasks can be added within these larger tasks when needed - making it easily modifiable. There is an additional task of the system diagrams which are incorporated in both TD2 and TD3 but are created during preparation for TD2. The final report is simply split into its first and final draft as designed in the project plan. The systems are integrated based on the requirements of each technical demonstration and the completed buggy system is completely assembled and tested to include in the final design report. The Gantt chart can then be further used to anticipate health and safety risks for the final race, using the knowledge of the activities completed beforehand.

These tasks also contain dependencies and make room for contingencies. For the four technical demonstrations, each demonstration is dependent on the previous one being completed as they involve parts used in the current technical demonstration which were assembled in the previous demonstration. Within each of these technical demonstration tasks, the coding and assembly are not dependent on each other and can run concurrently, with the team members' time being split between coding and assembling the buggy. The buggy testing is dependent on these previous sub-tasks and is then performed by the entire group. The final design report contains a final draft which is dependent on the first draft and the completion of the first three technical demonstrations, but can progress using a limited amount of the team's time until the final technical demonstration is completed, where it is then focussed on by the team. Each of these tasks can be completed by the designated team members or any other team members available, allowing for a contingency plan if a team member is ill whilst completing an activity. The 1-week testing times and assembly times also allow for emergency changes to be made to the buggy in time for the technical demonstrations, acting as another contingency to correct errors made with the buggy.

4.3 Health and Safety Risk Assessment

To ensure the safety of all participants and spectators on the final race day, a sufficiently detailed and complete health and safety risk assessment is vital. This risk assessment is easily created using the risk assessment template [3]. The final race day does not include any high-risk activities as there are few sources of risk, with the severity being mild for all of them. Unlike the construction of the buggy, which may have included higher risk activities such as drilling holes into the chassis, the final race day consists of smaller risks such as people tripping over the track or the buggy colliding with a spectator, both of which have a low severity and little risk of injury. Although they have a moderate likelihood the very low severity means they are low risks overall. Adjustments to the buggy and handling sharper parts of the buggy such as around the gears have a slightly higher severity but are less likely to occur, meaning they also share a low-risk rating. Each activity has existing control methods, such as an emergency stop to prevent the buggy from colliding with a spectator and a clear area for building the track. Other control measures include making sure the buggy cannot start moving when being assembled to protect the team members making any needed adjustments to the buggy, and covering exposed electrical wires which could have current flowing through when being handled.

The University of Manchester

WORK ACTIVITY/ WORKPLACE (WHAT PART OF THE ACTIVITY POSES RISK OF INJURY OR ILLNESS)	HAZARD (S) (SOMETHING THAT COULD CAUSE HARM, ILLNESS OR INJURY)	LIKELY CONSEQUENCES (WHAT WOULD BE THE RESULT OF THE HAZARD)	WHO OR WHAT IS AT RISK (INCLUDE NUMBERS AND GROUPS)	EXISTING CONTROL MEASURES IN USE (WHAT PROTECTS PEOPLE FROM THESE HAZARDS)	WITH EXISTING CONTROLS			
					SEVERITY	LIKELIHOOD	RISK RATING	RISK ACCEPTABLE
Buggy Handling	The electrical wiring.	Small electrical shock from the electrical circuit if not handled correctly.	All group 12 members.	All exposed wires must be covered using electrical tape.	2	1	2	Y
Buggy Adjustments	The exposed gears used in the gearbox.	Fingers could get caught in between gears if the motors move unexpectedly whilst making sure the buggy is operational.	All group 12 members.	Ensure the buggy is unpowered when altering the buggy around the gear section.	2	2	4	Y
Buggy Driving	Collision with spectator.	The buggy could hit a spectator at a moderate speed.	Spectators.	Have an emergency stop mechanism for the buggy.	1	3	3	Y
Placing Test Track	Tripping over track pieces.	The person building the track could trip and fall, potentially causing injury.	Track builders.	Take care when placing track pieces.	1	2	2	Y

Assessment ID Number (E&EE_Initials_DATE_Number).. **Activity Location:**...

				THIS RISK ASSESSMENT WILL BE SUBJECT TO A REVIEW NO LATER THAN: (MAX 12 MTHS)
MANAGER/SUPERVISOR	NAME:	SIGNED:	DATE:	
Student:	NAME:	SIGNED:	DATE:	

IF THE ANSWERS TO ANY OF THE QUESTIONS BELOW IS YES THEN ADDITIONAL SPECIFIC RISK ASSESSMENTS MAY BE REQUIRED.

IS THERE A RISK OF FIRE?	**Y**/N	DOES THE ACTIVITY REQUIRE ANY HOME WORKING?	Y/**N**
ARE SUBSTANCES THAT ARE HAZARDOUS TO HEALTH USED?	**Y**/N	ARE THE EMPLOYEES REQUIRED TO WORK ALONE	Y/**N**
IS THERE MANUAL HANDLING INVOLVED?	**Y**/N	DOES THE ACTIVITY INVOLVE DRIVING	Y/**N**
IS PPE WORN OR REQUIRED TO BE WORN?	Y/**N**	DOES THE ACTIVITY REQUIRE WORK AT HEIGHT	Y/**N**
ARE DISPLAY SCREENS USED?	**Y**/N	DOES THE ACTIVITY INVOLVE FOREIGN TRAVEL	Y/**N**
IS THERE A SIGNIFICANT RISK TO YOUNG PERSONS?	Y/**N**	IS THERE A SIGNIFICANT RISK TO NEW / PREGNANT MOTHERS?	Y/**N**

***Severity value* = potential consequence of an incident/injury**

5 Very High Death / permanent incapacity / widespread loss
4 High Major Injury (Reportable Category) / Severe Incapacity / Serious Loss
3 Moderate Injury / illness of 3 days or more absence (reportable category) / Moderate loss
2 Slight Minor injury / illness – immediate First Aid only / slight loss
1 Negligible No injury or trivial injury / illness / loss

***Likelihood value* = what is the potential of an incident or injury occurring**

5 Almost certain to occur
4 Likely to occur
3 Quite possible to occur
2 Possible in current situation
1 Not likely to occur

risk rating = severity value × likelihood value

***risk ratings* are classified as *low* (1 – 5), *medium* (6 – 9) and *high* (10 – 25)**

Risk Classification and Actions:

Rating	Classification	Action
1 – 5	Low	Tolerable risk - Monitor and Manage
6 – 9	Medium	Review and introduce additional controls to mitigate to "As Low As Reasonably Practicable" (ALARP)
10 – 25	High	Stop work immediately and introduce further control measures

SEVERITY

LIKELIHOOD		1	2	3	4	5
	1	Low	Low	Low	Low	Low
	2	Low	Low	Medium	Medium	High
	3	Low	Medium	Medium	High	High
	4	Low	Medium	High	High	High
	5	Low	High	High	High	High

4.4 Budget

As each group is provided with a £40 budget, Table 4.2 below shows the additional components available to be purchased. The rest of them will remain available as a contingency in case unknown purchases need to be made in the future. Table 4.3 shows all the free issue components which are going to be used during the project. The price in the table is from the procedure handbook [2].

Table 4.2: Cost of the components to be purchased

Component	Description	Quantity	Seller	Cost Each (£)
TCRT5000	Reflective Optical Sensor	5	RS	0.72

Table 4.3: Cost of the free issue components

Component	Description	Quantity	Seller	Cost Each (£)
Sensors				
TCRT5000	Reflective Optical Sensor	2	RS	0.72
Mechanical Parts				
Chassis	600 x 900 x 3 mm acetal	1	UoM	42.00
Front Wheel	Ball Castor	1	Pololu	2.47
Rubber Tyre	80 mm Spiked Tyre	2	Rapid	1.45
Motor A	6-15V 8W DC Brushed	2	RS	3.92
Motor B	RS Pro DC Motor	2	RS	5.47
Gearbox Box	Acetal box + gears	2	UoM	7.00
Populated PCBs				
NUCLEO-F401RE	STM32F401RE Nucleo Dev.	1	Avnet	15.00
MBED-016.1	Mbed Application Shield	1	Farnell	42.54
STM breakout	STM32 Breakout board	1	-	10.00
I/O board	For PIC18F that you made	1	-	30.00
Controller Board	Motor Drive Board	1	-	30.00
Unpopulated PCBs & IC Sockets & Headers				
Jumper Cables	MM/MF/FF	1 bag	Farnell	4.19
8 Pin IC Base	2.54 mm pitch	3	RS	0.56
Sensor Mini PCBs	Created at UoM	3	UoM	1.00

4 Way SIL header	2.54 mm pitch	6	RS	0.27
Misc				
Battery Holder	Custom with fuse, 8-way	1	Farnell	2.28
Batteries	1.2 V, Rechargeable	8	Farnell	2.00
Insulation Tape	19 mm tape (white)	1	RS	2.56
Cable ties	-	3	RS	0.09
Stripboard	-	1	RS	4.16

The total cost of the buggy is the sum of the free issue parts and the ordered parts, which is £3.60 for the purchased part and £212.44 for the free issued one. Overall, the estimated cost of the baggy is roughly £216.04.

5. Summary

To summarise, the buggy was designed with the TCRT5000 as the sensors, along with gearbox 2 to drive the buggy. It would be controlled via a pre-designed software system, with the implementation of a PID controller algorithm. In addition, the buggy would have two levels in order to accommodate all the different components. The total estimated cost of the buggy including the testing of components would add up to £216.04 with £3.60 being the components that are purchased additionally to improve the performance of the buggy. There would be four demonstrations to test the functionality of the buggy shown above in the Gantt chart, with the final demonstration prior to closure of the project being 2nd May of 2023. The identification of the team's learning styles and assigning work accordingly has further improved coordination of the team, leading to greater performance. All members are active and contribute equally to meetings and reports. Communication between members is very good, leading to no work being duplicated. Detailed meeting logs ensure members are up to date, even on occasions where they can't attend the meeting.

6. References

[1] ESP Technical Handbook – EEEN21000 Embedded Systems ... (manchester.ac.uk), [Accessed 1st February 2023]

[2] ESP Procedures Handbook – EEEN21000 Embedded Systems ... (manchester.ac.uk) , [Accessed 1st February 2023]

[3] ESP Risk Assessment Template – EEEN21000 Embedded Systems ... (manchester.ac.uk), [Accessed 5th February 2023]

[4] ESP_Design_Report_1 2022-23.docx - Google Docs, [Accessed 3rd February 2023]

[5] ESP_Design_Report_2 2022-23.docx - Google Docs, [Accessed 3rd February 2023]