Department of Electrical and
Electronic Engineering

Embedded Systems Project 2022-23

Proposal Document

Title: White-Line Following Buggy

Group Number: 4

Group members:	ID Number	I confirm that this is the group's own work.
Asim Zubair	10541694	☒
Doruk Tan Atila	10866352	☒
Muhamad Muhamad Asri	10915564	☒
Muhammad Bin Suratman	10869503	☒
Zhixin Chen	10816322	☒

Tutor: Dr. Laith Danoon

Date: 10/02/2023

Contents

1. Introduction, Aims and Objectives

This report explains group 4's technical decisions from semester 1, along with the team management rules set by the group for the Embedded Systems Project. The project aims to fabricate a white line following buggy that can complete the track as quickly as possible. To overcome specified obstacles on the track, such as the maximum slope, turn angle, line breaks and potential problems such as ambient lighting, group 4 conducted two labs and wrote relevant design reports.

The first design report dealt with the mechanics part of the buggy. The motor was closely examined in the lab and the required gearbox ratio was calculated. The second design report dealt with the sensor design, chassis design and software design. Several line sensors were tested in the lab and relevant designs were made using the outcomes of the lab.

To complete the project, group 4 made detailed plans for every aspect of the buggy by successfully completing the previous milestones such as the design reports. In semester 2, the group will start to execute those plans and build the buggy. The milestones for semester 2 are the three technical demonstrations that require the following deliverables respectively: motor control, sensors, control/steering. Successful completion of the fourth technical demonstration, which is the heat race, is the main aim of the project.

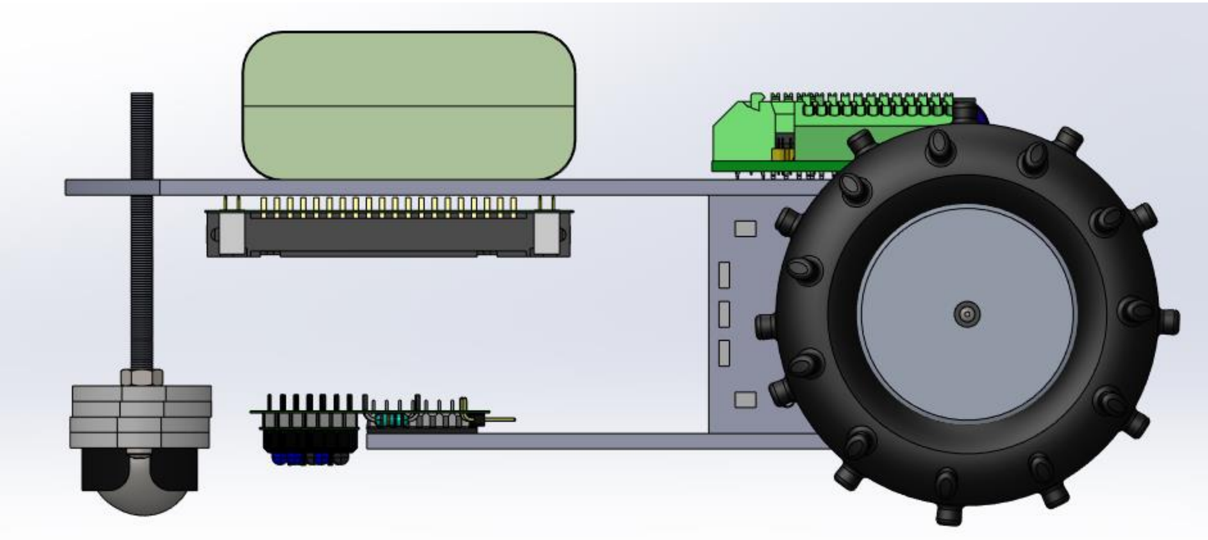


Figure 1 – Side View of Buggy

The side view of the constructed buggy is shown in figure 1 above. The chassis has been constructed such that its width does not exceed the width of the track. The chassis has also been built such that its length does not collide with the track wall while turning the buggy around when there is an interruption in front of the buggy. The sensor PCB (Printed Circuit Board) is situated at the bottom to distinguish the white line from the black track.

2. Technical Overview

The purpose of the design reports was to identify and characterize certain known problems and unknown problems. Design report 1's intent was to characterize a motor and figure out if it would deliver tasks such as moving the buggy on flat and sloped surfaces. The torque required to climb the slope at a max incline of 18° is 0.133 Nm, where the buggy's weight is 1.5 kg. For the motor to deliver this torque, it would require working with a current of 22.167 A, which is unrealistic since the maximum current recommendation is 1.4 A. The motor failed to deliver enough torque required to climb an 18° sloped surface thus needing the assistance of a gearbox [1].

A total of three gearboxes were given as selection options.
The second gearbox was chosen since it had both enough speed and sufficient torque to climb the slope. With the second gearbox to successfully climb the slope, the torque applied by the motor needs to be 0.006 N with a current of 1.068 A. The other two gearboxes were not chosen as the first one had low torque thus requiring a current of 1.333 A to climb the slope but high speed, and the third one had high torque that required a current of 0.854 A to climb the slope but low speed. The second gearbox is versatile in both torque and speed without overheating the motor to its limit [1].

Design report 2's intent was to choose and characterize light sensors to be used for the line detection task, plan a software system design, plan non-light sensors that might aid the buggy in fulfilling the task, plan a control algorithm and design a chassis.

The line-following sensor is to allow the buggy to follow the white line and detect the edge of it during turns. Through testing dark current, background noise, variation with the height, and line spread function with different sensors, TCRT 5000 Sensor is the most appropriate one for the buggy. The TCRT-5000 was chosen because it was modular thus does not require extra work saving the group time that will be spent focusing on control algorithms. it can clearly differentiate when the white line starts and ends, it filters ambient light better than other available sensors to test with. The other sensors tested were a paring of TSHG6400 IR LED and BPW17N T3/4, TSHA4401 IR LED and TEKT5400S, OVL5521 WHITE LED and 5M OHM LDR. All these sensors did not show a sharp change in voltage when moving from white to black or vice versa. TCRT-5000 was configured with 91 Ω with the emitter and 10 KΩ with the receiver. The configuration enhanced the measurements [2].

The control algorithm is heavily dependent on the line sensors and non-line sensors. Non-line sensors are encoders, Bluetooth, voltmeter and amperemeter. The control algorithm will implement the PID control algorithm. The PID control algorithm will deliver smooth turns and fast responses to changes. Ambient light, direct sunlight and line-breaks will be mitigated as well. PID was chosen instead of the bang-bang alternative because it will complete the task quicker. This will require extra work and attention to details, but the upsides are enough to undertake such endeavour.

The software is designed to be the bridge between the sensors and the motors. The current software design allows the buggy to have three features: Line detection/tracking, speed sensing/adjusting and current sensing/adjusting. The buggy will be able to track the white line using the line sensors discussed. The buggy will turn using the PID algorithm discussed. Speed will be measured using the encoders. For the PID algorithm to run efficiently the speed will be held constant during the track. The current sensing is the safety feature of the buggy which will make sure the current on the motors does not go beyond 1.4 A. For all 3 features, the microcontroller will adjust the motor output using the input of relevant sensors.

According to figure 1, the buggy is assembled on two plates that serve as its top and bottom chassis. Factors like material selection, cost, density, Young’s modulus, and ultimate tensile stress must be considered in designing the chassis. Materials can be selected from acetal, Glass Reinforced Plastic (GRP) laminate, aluminium, and mild steel.

Mild steel is the best material for chassis since it is the least expensive, has the highest Young's modulus, and has the highest ultimate tensile stress. However, acetal was chosen as the chassis material since it had the lowest density when compared to other materials. The chassis must be as light as practical for this project's specific purpose. Acetal has sufficient ultimate tensile stress to handle the weight of the components mounted to the chassis [3].

The arrangement of the components affects the stability of the buggy. The mass of the front and rear end components should be the same, at 453 g and 509 g, respectively. It must be put at the opposite end of the chassis to improve load distribution. Gearboxes would be fitted by screwing the protruding piece of the gearbox into the square cuts on both the top and bottom chassis [2].

Group 4 is planning to use machine learning to optimize PID constants at different speeds. A reinforcement learning algorithm will be used to optimize the PID coefficients. The data will be transmitted to a pc via Bluetooth and the pc will run the algorithm to optimize constants. The coefficients will change in real time through PC’s output to the microcontroller via Bluetooth. In case this approach works and the PID coefficients can be optimized at different speeds, the software design of the speed sensing/adjusting feature will be altered.

3. Team Organisation

Table 1 – Team Roles and Organisation

Team Members	Roles	Design Report 1	Design Report 2
Asim Zubair	Secretary	Gearbox Ratio Selection	Non-line Sensor & Control
Doruk Tan Atila	Software Lead	Introduction	Software
Muhammad Bin Suratman (Mur)	Mechanical Lead	Load Measurement	Introduction & Circuit Diagram
Muhamad Muhamad Asri (Akmal)	Design Lead	Summary	Hardware Overview & Summary
Zhixin Chen	Electronic Lead	Motor Characterisation	Line Sensor Characterisation

Group 4 follows democratic principles which means everyone in the group takes the responsibility for the buggy work such as labs and reports. Among the group members, Asim is the group secretary who might help book the meeting rooms and summarise the project status in weekly journals; Doruk is the Software lead who concentrates more on software. Akmal is the Design lead who focuses on the buggy design such as the positions of sensors, motors, and batteries. Mur is the Mechanical lead who oversees soldering and assembling of components. Zhixin is the Electronics lead who is responsible for PCB and sensors.

All group members will confer notable events and make decisions together by vote. Most of the time, the work was assigned to members who joined the lab, although information and process were shared with members who cannot participate in the lab. For DR1, Zhixin, Asim, and Akmal joined the motor lab and Mur did the load measurement. Therefore, Mur took responsibility for load measurement in DR1. Asim did the gearbox ratio, and Zhixin did the motor characterisation in DR1. As Doruk did not join the lab, he took the responsibility for the introduction and Akmal did the summary. For DR2, Zhixin, Doruk, and Mur joined the sensor lab. Hence Doruk took responsibility for Software, Zhixin did the Sensor Characterisation and Mur did the Circuit Diagram and Introduction for DR2. The rest of the work is split by Asim and Akmal. Asim did the Non-line Sensor and Control and Akmal did the Hardware Overview and Summary.

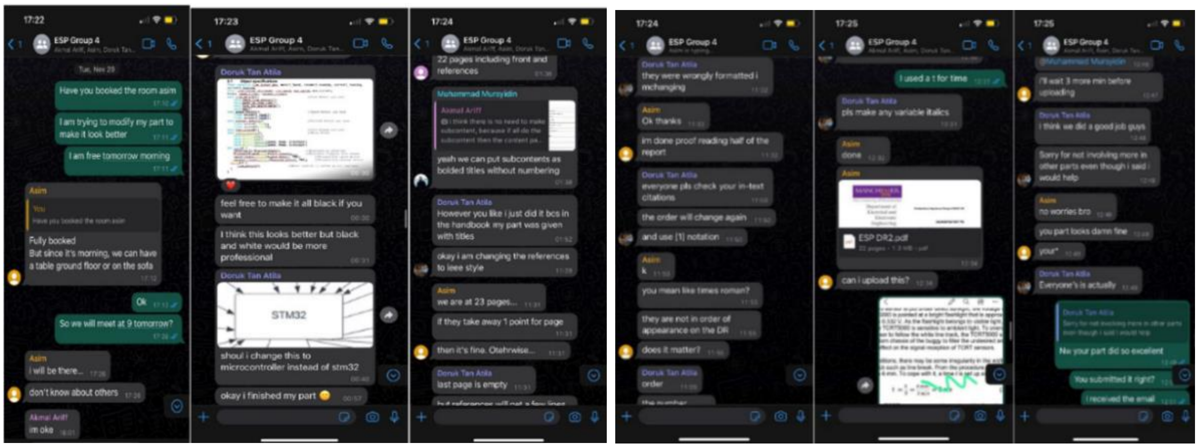


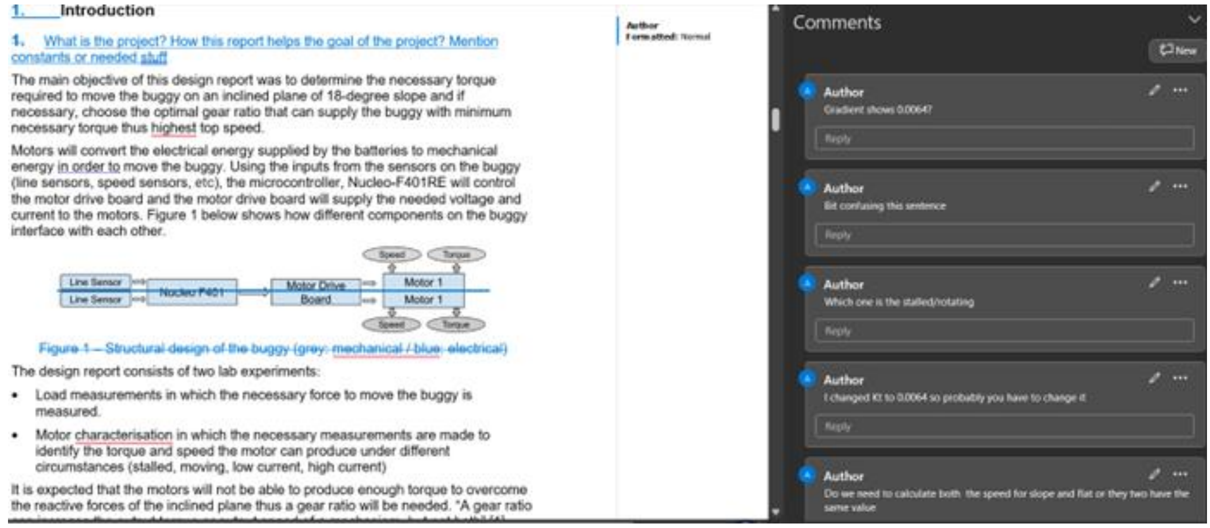
Figure 2 and 3 respectively – WhatsApp Group Chat

Figure 4 – Weekly Journals

All valuable information is shared face-to-face during the group meetings or by WhatsApp. WhatsApp's chat is used for quick decision making or discussion, for instance, the room booked for meetings, the work separated to each member, how the work is implemented and asking for help as shown in figures 2 and 3. The weekly journal is the conclusion for members about what to do during the week. It is shared on WhatsApp once members finish individual work. It is submitted onto the Blackboard after everyone agreed on the content as shown in figure 4. In contrast, meeting face-to-face is used to discuss critical and essential information or modify and integrate the design reports.

Table 2 – Partial Attendance List for Meetings

Team Member	Date						
	5/10/22	11/10	14/10	16/10	17/10	19/10	24/10
Asim	X	X	X	X	X	X	X
Doruk	X	X	X	X	X	X	X
Mur	X	X	X	X	X	X	X
Akmal	X	X	X	X	X	X	X
Zhixin	X	X	X	X	X	X	X



1. Introduction

1. What is the project? How this report helps the goal of the project? Mention constants or needed stuff

The main objective of this design report was to determine the necessary torque required to move the buggy on an inclined plane of 18-degree slope and if necessary, choose the optimal gear ratio that can supply the buggy with minimum necessary torque thus highest top speed.

Motors will convert the electrical energy supplied by the batteries to mechanical energy in order to move the buggy. Using the inputs from the sensors on the buggy (line sensors, speed sensors, etc), the microcontroller, Nucleo-F401RE will control the motor drive board and the motor drive board will supply the needed voltage and current to the motors. Figure 1 below shows how different components on the buggy interface with each other.

Figure 1 – Structural design of the buggy (grey: mechanical / blue: electrical)

The design report consists of two lab experiments:

- Load measurements in which the necessary force to move the buggy is measured.
- Motor characterisation in which the necessary measurements are made to identify the torque and speed the motor can produce under different circumstances (stalled, moving, low current, high current)

It is expected that the motors will not be able to produce enough torque to overcome the reactive forces of the inclined plane thus a gear ratio will be needed. "A gear ratio

Author
Formatted: Normal

Comments

New

Author
Gradient shows 0.0064?
Reply

Author
Bit confusing this sentence
Reply

Author
Which one is the stalled/rotating
Reply

Author
I changed Kt to 0.0064 so probably you have to change it
Reply

Author
Do we need to calculate both the speed for slope and flat or they two have the same value

Figure 5 – Making Comments on Each Other's Parts

In addition to the tutorial meetings on Monday, there are at least two additional meetings that all members need to attend to discuss the work or feedback from others about how well the report has been working. Table 2 is the attendance list for members who joined the meetings. At the beginning of each experiment, the team members discuss what part they need to be responsible for in the design report and decide on the people in charge of each experiment. In the following meetings, the team members report their progress on their parts, put forward their challenges and discuss solutions. After everyone finishes his part of the report, the purpose of meetings will be to make comments on each other's part and deliberate report drafts that might need to be modified. Figure 5 is how group members make comments and modify the report. In the last meeting, the team members review the whole report. Finally, the person in charge of submission compiles the last version and uploads it to WhatsApp's group chat, which is submitted after confirmation by all team members.

From the first meeting, the team was unanimous that the appropriate work distribution is an essential factor for the project's efficiency. Workload distribution and sharing are essential points used to build the project's Gantt chart. The work will be distributed to the right person in the right place as each member has unique strengths and weaknesses, as known that the buggy project held several aspects, such as software, hardware, calculations, assembling, etc. Therefore, each member will take the part that they are skilled in so that the work will be done efficiently and comprehensively, and the member will be able to demonstrate his part clearly to other members. Therefore, the work was split efficiently, and the team could finish the report and make modifications repeatedly before the due date. For example, in DR1 and DR2, each part has different grading. Grading is one of the critical points that help in the work distribution. Therefore, the team tries to distribute the work evenly among the members according to the marks. If some of the members noticed that they took less effort than other team members, they help other team members or be responsible for the presentation and comprehensive proofreading.

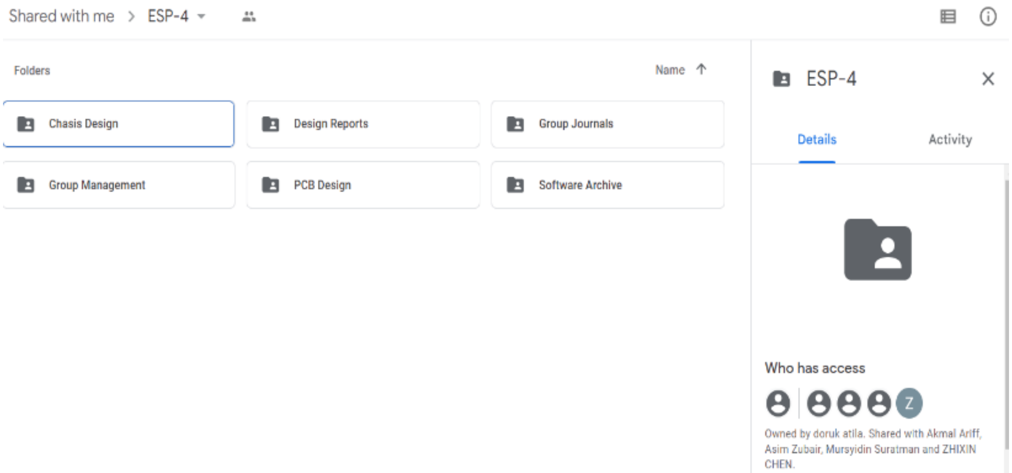


Figure 6 – Shared Google Drives

To facilitate the transmission and sharing of files, and to prevent the loss of files due to device failure, the team used the Google Drive folder shown in figure 6 and Google Documents. The folder is shared by all group members, which stores important files' backups. The required public files can be invoked from other members' files when necessary. Google Documents are updated by the person in charge of the experiment or used for report modification following the suggestions of other members.

4. Planning and Budget

This section is dedicated to review the time-based plan and the overall budget for the whole project. The project plan is the explanation of the main deadlines and deliverables for the upcoming semester. To make planning simpler, a Gantt chart is produced with a brief discussion on each Technical Demonstration. A Health and Safety Risk Assessment is also included in this section along with another paragraph of explanation. Then, each component of the buggy is taken into consideration to total the cost of the buggy.

Technical demonstrations will be reviewed throughout this semester's embedded systems project, and submissions must be completed by the deadlines. Motor control, sensors, control/steering, and heat & racing are among the demonstration categories. A proposal (10/2/23), final PCB (24/3/23), laser cutting & order (21/4/23), peer review form (5/5/23), and final report (12/5/23) are all required to be submitted before the deadlines.

All team members in the second semester are required to attend technical demonstrations 1-4, which have a direct impact on the module evaluation. They must be able to provide documents and respond to inquiries regarding their approach. Each team member should have a basic understanding of the project, with the members responsible for a particular area possessing more specific knowledge.

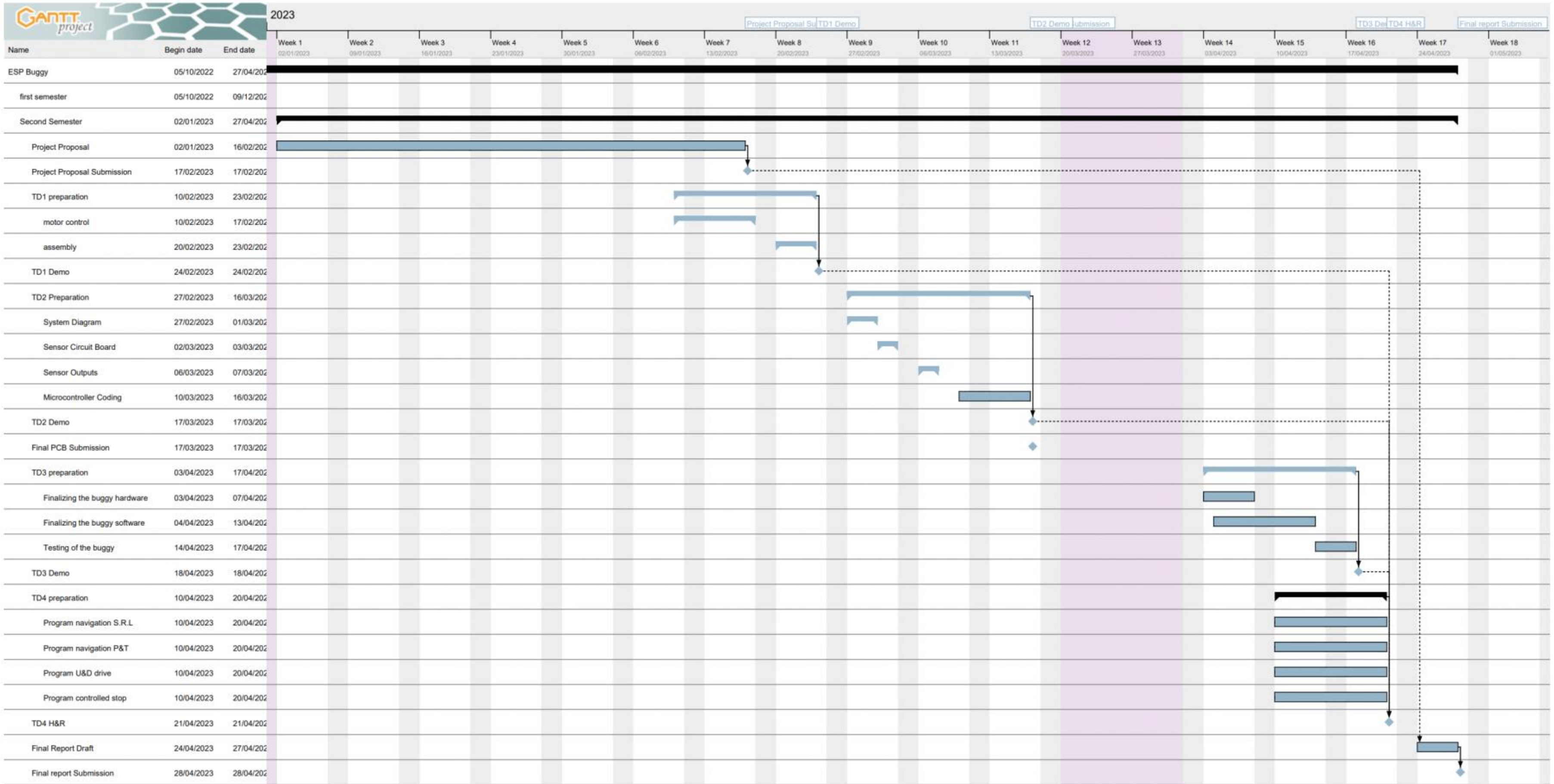
The Gantt chart shown on page 10 describes the planning for the group in a spread throughout the second semester. The former chart shows the deliverables of the team separated into weekly chunks. Each Technical Demonstration was set as milestones and then divided into smaller deliverables for each team member. The deliverable with the most allocated time was the Project Proposal since it spans into the examination period and the winter break. The team will then work on building the buggy prior to TD1, where the motor will be tested. A partly completed buggy with its sensors attached will be ready for the TD2 by 17th March. Then, the software will be finalised and readied in two weeks before completing the buggy. The completed buggy will then be tested for 4 days before it is ready for the third TD, as shown in Week 11 of the second semester. The final TD will be done on 21st April, where the task prior to the day will be carried on parallel to each other, as shown in Week 11 and 12 of the second semester. During this time, each team member will work on programming their own chunk of code for the same allocated time.

The latter is the resource chart, where the work distribution of the whole team is displayed with their allocated time. Each team member is assigned their own role with Asim as the Secretary of the team, Doruk as the Software Lead, Mur as the Mechanical Lead, Clark as the Electronic Lead, and Akmal as the Design Lead. As the names propose, everyone is focused on their own speciality, allowing better task distribution. The chart displays equal workload among team members apart from overloading in Week 3 of the second semester. This is the upcoming work distribution plan for the second semester, where all team members are used efficiently, consequently producing higher output during each task.

These are the proposed plans for the upcoming semester, where the Gantt chart clearly displays the efficient usage of resources and team members. It also shows a vivid diagram of each task to be done in chronological order, allowing the group to organise the tasks each week with little to no overloading. This Gantt chart is still flexible and free to allow changes in the future, as each task can still be separated into even smaller chunks. However, the milestones and deadlines will remain the same.

A risk register is a tool for identifying and assessing potential risks in a project and determining appropriate mitigation measures. Risks are classified into low, medium, and high levels based on the risk rating.

The risk assessment shown on pages 11 and 12 is a discussion between the group members of what will and might happen during the race day. The most prominent risk is by crashing the buggy, which would cause harm to the bystanders and the buggy itself. It is determined that the software piloting the buggy will play a vital role, therefore the software must be prepared meticulously to prevent this risk. Furthermore, four other low-level risks are identified, which are tripping over objects, flashing screens, short circuits, and sharp corners of the table. Respectively, these risks can be curbed by overtaking simple precautionary steps, which are tidying the items, wearing shades for epilepsy, double-checking each connection, and moving around carefully. As all these risks have been discussed and reviewed, they are all deemed acceptable by the group members.


GANTT project
2023
Project Proposal Su TD1 Demo
TD2 Demo Submission
TD3 De TD4 H&R
Final report Submission
Name
Begin date
End date
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Week 11
Week 12
Week 13
Week 14
Week 15
Week 16
Week 17
Week 18
ESP Buggy 05/10/2022 27/04/202
first semester 05/10/2022 09/12/202
Second Semester 02/01/2023 27/04/202
Project Proposal 02/01/2023 16/02/202
Project Proposal Submission 17/02/2023 17/02/202
TD1 preparation 10/02/2023 23/02/202
motor control 10/02/2023 17/02/202
assembly 20/02/2023 23/02/202
TD1 Demo 24/02/2023 24/02/202
TD2 Preparation 27/02/2023 16/03/202
System Diagram 27/02/2023 01/03/202
Sensor Circuit Board 02/03/2023 03/03/202
Sensor Outputs 06/03/2023 07/03/202
Microcontroller Coding 10/03/2023 16/03/202
TD2 Demo 17/03/2023 17/03/202
Final PCB Submission 17/03/2023 17/03/202
TD3 preparation 03/04/2023 17/04/202
Finalizing the buggy hardware 03/04/2023 07/04/202
Finalizing the buggy software 04/04/2023 13/04/202
Testing of the buggy 14/04/2023 17/04/202
TD3 Demo 18/04/2023 18/04/202
TD4 preparation 10/04/2023 20/04/202
Program navigation S.R.L 10/04/2023 20/04/202
Program navigation P&T 10/04/2023 20/04/202
Program U&D drive 10/04/2023 20/04/202
Program controlled stop 10/04/2023 20/04/202
TD4 H&R 21/04/2023 21/04/202
Final Report Draft 24/04/2023 27/04/202
Final report Submission 28/04/2023 28/04/202


GANTT project
2023
Project Proposal Submission
TD2 Demo Submission
TD3 Demo H&R
Final report Submiss
Name
Default role
Week 1
Week 2
Week 3
Week 4
Week 5
Week 6
Week 7
Week 8
Week 9
Week 10
Week 11
Week 12
Week 13
Week 14
Week 15
Week 16
Week 17
Week 18
Asim Secretary
Doruk Software Le...
Mur Mechanical ...
Clark Electronic L...
Akmal Design Lead
200%

MANCHESTER 1824

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
Race venue	Tripping over objects on floor	Anybody can fall and seriously hurt themselves	Attendees	Organize the stuff neatly and do not leave it on the floor	3	2	L	Y
Racetrack	Screens and LEDs flashing	May trigger epileptic seizure	Attendees	The person at risk should wear shades and keep their distance	2	2	L	Y
Racetrack	Short-circuit	Buggy catching fire	Bystander and buggy	Double-checking the connection and keeping extinguisher nearby	5	1	L	Y
Race venue	Sharp corners of tables	Group members can run into sharp edges	Group members	Taking extra care when moving around the racetrack	3	1	L	Y
Racetrack	Crashing the buggy	Damage to buggy or bystanders	Bystander and buggy	Ensure the software is sufficient before running the race	4	3	H	Y

Assessment ID Number (E&EE_Initials_DATE_Number)...**ESP 2022/2023 Group 4**........................ **Activity Location: Manchester**………..……………………………..

				THIS RISK ASSESSMENT WILL BE SUBJECT TO A REVIEW NO LATER THAN: (MAX 12 MTHS)
MANAGER/SUPERVISOR	NAME: Dr Laith Danoon	SIGNED:	DATE:6/2/2023	2 months
Student:	NAME: Asim Zubair	SIGNED:	DATE:6/2/2023	2 months

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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

Table 3 – Budget (Propose to Purchase)

Manufacturer Part	Qty	Seller	Seller Part	Cost Each
TCRT5000	4	RS	818-7524	£0.72
8 Pin IC Base	3	RS	1077344	£0.56
Sensor Mini PCBs	3	UoM	-	£1.00
6 Way SIL Header	2	Farnell	2751384	£0.21
Pan Head Screw	1 pack	Farnell	3666826	£2.35
Hex Female/Female Standoff	12	RS	222-395	£0.22
Velcro Straps	1	Farnell	2400992	£3.55
Total Cost				**£16.52**

The budget must be within £40.00 and should include the cost of purchasing the components for the buggy, excluding those that are provided for free. The table 3 above presents a list of items that our team would want to purchase for the project to run smoothly. Budget balance is around £23.48. The remainder is kept away for a future contingency that has not yet been defined.

Table 4 – Total Cost of Buggy

Manufacturer Part	Qty	Seller	Seller Part	Cost Each
Resistor	12	-	Various	£0.10
ULN2003	1	RS	686-8209	£0.47
TCRT5000	6	RS	818-7524	£0.72
AEAT-601BF06	2	Farnell	2467469	£21.40
HM-10	1	RobotShop	RB-Suf-03	£13.53
Chassis	1	UoM	198.27 x 140.00 x 3.00 mm and 140.00 x 140.00 x 3.00 mm	£3.69
Front Wheel	1	Polulu	#955	£2.47
Rubber Tyre	2	Rapid	06-0654	£1.45
Motor A	2	RS	238-9737	£3.92
Gearbox Box	2	UoM	-	£7.00
NUCLEO-F401RE	1	Avnet	NUCLEO-F401RE	£15.00
MBED-016.1	1	Farnell	2468119	£42.54
STM Breakout	1	-	Proprietary	£10.00
I/O Board	1	-	Proprietary	£30.00
Controller Board	1	-	Proprietary	£30.00

Jumper Cables	1 bag	Farnell	2396416	£4.19
8 Pin IC Base	6	RS	1077344	£0.56
Sensor Mini PCBs	6	UoM	-	£1.00
4 Way SIL Header	2	RS	669-5314	£0.27
Battery Holder	1	Farnell	3829583	£2.28
Battery	8	Farnell	-	£2.00
Insulation Tape	1	RS	227-2976	£2.56
Stripboard	1	RS	286-5841	£4.16
6 Way SIL Header	2	Farnell	2751384	£0.21
Pan Head Screw	1 bag	Farnell	3666826	£2.35
Hex Female/Female Standoff	12	RS	222-395	£0.22
Velcro Straps	1	Farnell	2400992	£3.55
Total Cost of Buggy				**£268.81**

An estimate has been made for the total cost of the buggy, including both the planned budget spend and the value of the components that will be provided for free. Table 4 above shows the overall cost of the buggy. Manufacture part and cost per part can be obtained in the procedure handbook [3].

5. Summary

This report is the overview of ESP Group 4 compressed into a concise document. The technical overview summarises each physical aspect of the buggy. The buggy is currently at Technology Readiness Level 4, since some components are already available to the group. It will make use of the second gearbox as a compromise between speed and power. TCRT5000 sensor will be implemented, along with PID as its control algorithm. Acetal will be used as the chassis material since it is the lightest compared to others. Weight distribution is also discussed, and it is decided that the buggy will have the same mass at the front and rear chassis. This will keep the buggy extremely stable during motion.

The team is then introduced in the team organisation section, where all the roles and responsibilities are explained. Asim is the Secretary, and any other technical issues will pertain to other team members. Each role is explained, and the basic framework of the team is also laid out. The team connects with each other through WhatsApp, and each file is organized in a shared Google Drive. The group also facilitates improvements by encouraging comments on each other’s work. These comments are usually done on a shared document or during the weekly group meeting.

Furthermore, the group produces a Gantt chart to summarise all the important deadlines and deliverables. Every Technical Demonstration is set as milestones; therefore, the team can work on their own task with the same goal in mind. A Health and Safety Risk Assessment is also constructed, and each risk is discussed to be acceptable since none of it may cause any severe injury if mitigated correctly.

Lastly, A budget of £40.00 has been set down for the buggy project, which will be used purely to purchase components. The remainder of the money is set aside for any future situations. The projected cost of the buggy, including both the planned budget and freely given components, is £268.81.

6. Reference

1. A. Zubair, D. Tan Atila, M. Bin Suratman, M. Muhamad Asri, Z. Chen, "Design Report 1: Motor Characterisation." University of Manchester Department of Electrical and Electronic Engineering, Manchester, 2022.
2. A. Zubair, D. Tan Atila, M. Bin Suratman, M. Muhamad Asri, Z. Chen, "Design Report 2: Technical Characterisation." University of Manchester Department of Electrical and Electronic Engineering, Manchester, 2022.
3. "Procedure Handbook 2022-23." University of Manchester Department of Electrical and Electronic Engineering, Manchester.