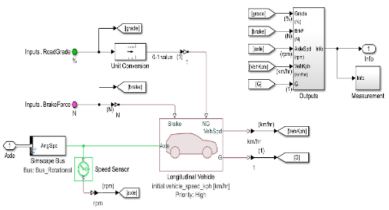
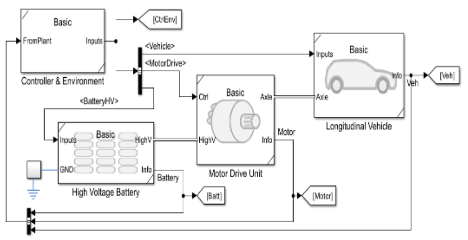
Data and Telemetry Award

Team Averera (ID: IN0014001)





Battery Electric Vehicle Model for Simulation

Executive Summary

We have implemented a telemetry approach that includes the collection and analysis of vehicle sensor data, such as vehicle speed, energy usage, and context data like track maps. By leveraging these data points, we gain valuable insights into our vehicle's performance, allowing us to make informed decisions to optimize efficiency and speed.

Our information processes involve analysis, modeling, simulation, and machine learning techniques to develop a control strategy that keeps our vehicle near the optimum performance range. By simulating race scenarios and virtual testing, we can refine our control inputs, optimize parameters, and identify potential issues to enhance our strategy.

In addition, we consider context data, such as weather conditions, to understand how they impact energy consumption and efficiency. This knowledge enables us to adapt our driving tactics and make intelligent maneuvers to navigate specific driving situations and edge cases.

Our data-driven approach and strategic improvements aim to achieve the best possible on-track performance, balancing minimal energy consumption and competitive speed. We anticipate significant performance improvements, though the exact percentage will depend on various factors.

Introduction

Data and telemetry have emerged as critical components in various domains, revolutionizing industries and pushing the boundaries of innovation.

Data is the foundation for informed decision-making, enabling teams to optimize their race strategies, enhance vehicle performance, and strive for greater energy efficiency.

Telemetry plays a pivotal role in enabling teams to monitor and analyse key performance indicators as a means of collecting and transmitting data wirelessly from the vehicle to a centralized system. With telemetry, participants comprehensively understand their vehicle's performance, allowing them to fine-tune their strategies and make data-driven decisions that optimize performance and efficiency.

Data Points

This section explores the relevant data points, the telemetry approach, and the identification of crucial vehicle sensor data and context data that contribute to achieving our goals. This section explores the relevant data points, the telemetry approach, and the identification of crucial vehicle sensor data and context data that contribute to achieving our goals. The data strategy begins with data collection. Some data we have extracted from vehicles (like speed, current, voltage) and other forms of data (like Track Maps, Track Coordinates, Turns, ROC, etc.) using different software and the web. These data are highly relevant to our strategy and driving tactics.

- **Sensor data** We have attached a hall sensor on a vehicle on the back right side with four magnets attached at equally spaced distances. When the sensor encounters magnets, interrupt forms, sending this interrupt value inside Arduino and calculating speed and RPM values. With a bit of change inside the same Arduino code, we can also calculate the total distance traveled by the vehicle. We also have attached the current and voltage sensor on the back of the vehicle.

Fig 1. Hall sensor

Fig 2. Current sensor

The current and voltage sensor allows for calculating energy efficiency through straightforward formula. We can determine the power consumed by measuring the current flowing through the vehicle's electrical circuits and the corresponding voltage across these circuits. Energy Efficiency is then calculated by dividing the valuable output (mechanical work performed) by input energy (electrical energy consumed).

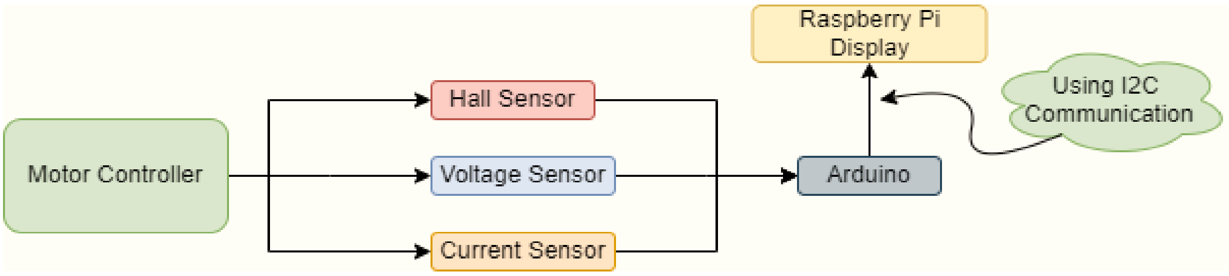


Fig 3. Flow Chart of Data Transfer.

- Context Data Some other forms of external data we found are necessary for better race strategy and will affect our energy efficiency and consumption.

    1. **Track Info** We have used software named *QGIS* (geographic information system) to study the Pertamia Mandalika International Street Circuit thoroughly also looked up on the web for some extra information regarding tracks.

Fig 4. Mandalika Track (Used QGIS)

Fig 5. Mandalika Track (Web)

The track is 4310 m long and has no change in the elevation profile. An official track completion is recorded only when the vehicle covers four complete laps (12,930 m) in less than 30 minutes. Hence the average speed is 26 Km/h.
Here we calculated ROC (radius of curvature) for all 17 turns (6 left and 11 right turns). The purpose was to predict when to apply brakes during the turns, as using breaks during a run heavily affects efficiency. And we also calculated the distance between two consecutive turns to know how long we had to press the throttle and when to leave the vehicle to freewheel.

    2. **Weather Conditions** Extreme temperatures, whether hot or cold, can increase resistance and reduce efficiency in components such as batteries and motors. Winds can create aerodynamic

drag, a significant factor affecting energy consumption. Rainfall and wet road conditions can affect the vehicle's traction causing increased rolling resistance. That is why we analyze historical weather data and incorporate weather forecasting to develop strategies for adapting to weather scenarios.
The temperature during June at which we conducted the vehicle test, the average daily temperature high/low, used to be **40°C/29°C**.

Fig 6. 4 to 8 June temperature data (UP, India)

The temperature during July at which we will be testing our vehicle, i.e., during competition time, the average daily temperature high/low, will be **28°C/24°C**.

Fig 7. 4 to 8 June temperature data (Lombok, Indonesia)

We can safely conclude the fact that If our components can withstand this much heat during testing, they can also easily survive the temperature during competition.

- Telemetry Approach We have used to transmit the data from the vehicle to the driver using a Raspberry Pi 5-inch HD display mounted on the vehicle's dashboard. The driver can make informed judgments based on real-time conditions by providing immediate access to critical data. They can analyse trends, identify potential areas for optimization, and react swiftly to changing circumstances.

Fig 8. GUI on Raspberry display

Fig 9. Raspberry display

The parameters we have included in this display are a speedometer, odometer, energy efficiency data, headlight, indicators, wiper, and hazard lights. We have attached two Arduino in the vehicle, one in the back and another one in front of the vehicle. Back Arduino intakes the sensor data (hall, current, etc.). On the other hand, the front Arduino controlled all the neo-pixel lights around the vehicle.

The basic flow chart of the setup discussed above is shown in Fig 10.

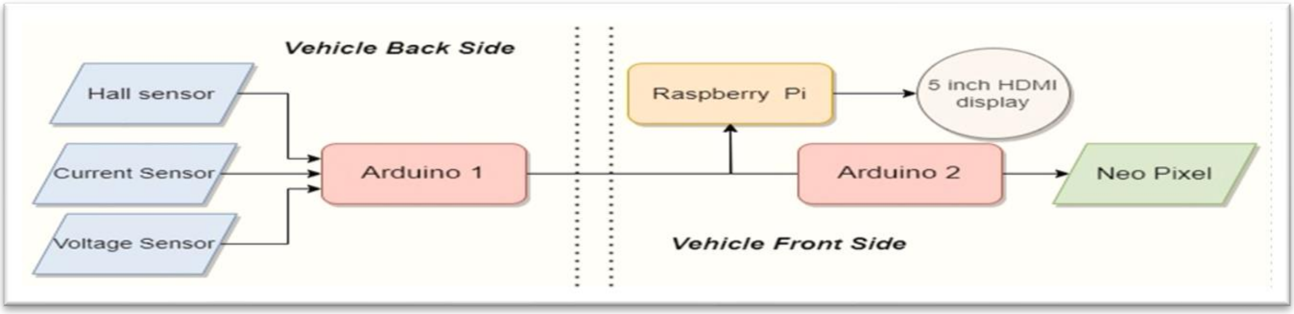
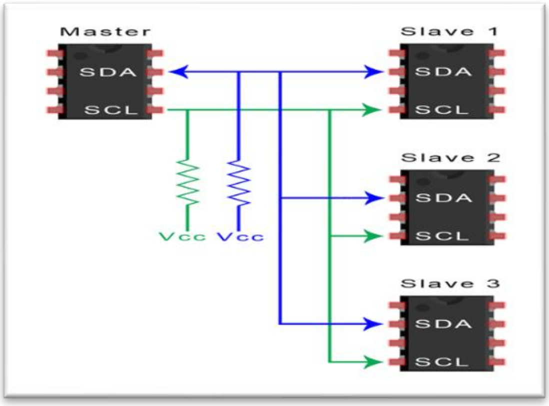


Fig 10. Flow Chart of Data transfer from Arduino to Raspberry Pi.



All the data is now transferred to the raspberry pi using ***I2C** (Inter-Integrated Circuit)* ***Communication***.

We have used multiple slaves (Arduino) and a single master (Raspberry Pi). At first, we were using a USB cable to communicate, so the communication part was simple, but the vast demerit was that all the Arduinos were getting powered through raspberry pi. So we went for this approach instead, powering both components separately and using wires between them only for communication.

Information Processes

After the data collection, we tried to model those data to develop the best driving strategy. The main target for the team is to cover a certain distance for a set amount of time by using minimal energy with the highest possible energy efficiency.

Simulation Overview

We tried to make a model in *SIMULINK* that follows our vehicle and simulate the model by feeding all the data we have collected. In generating different driving strategies and comparing energy efficiency, it is essential to set proper simulation limitations. Hence, the results are realistic, and the plans are not only feasible but also fulfilling the rules of the competition.

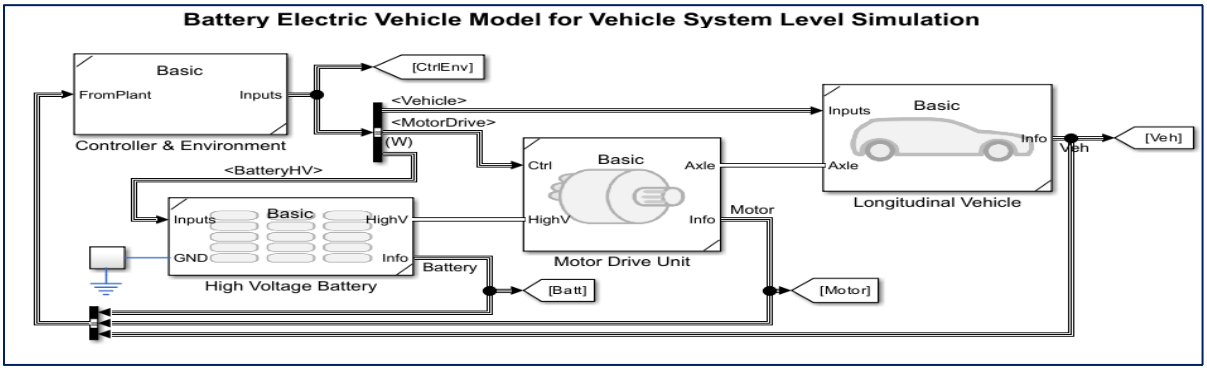


Fig 11. Model of Vehicle (SHIVAAY)

We are starting by feeding the model our vehicle's mechanical parameters like weight, drag, rolling radius, frontal area, etc.

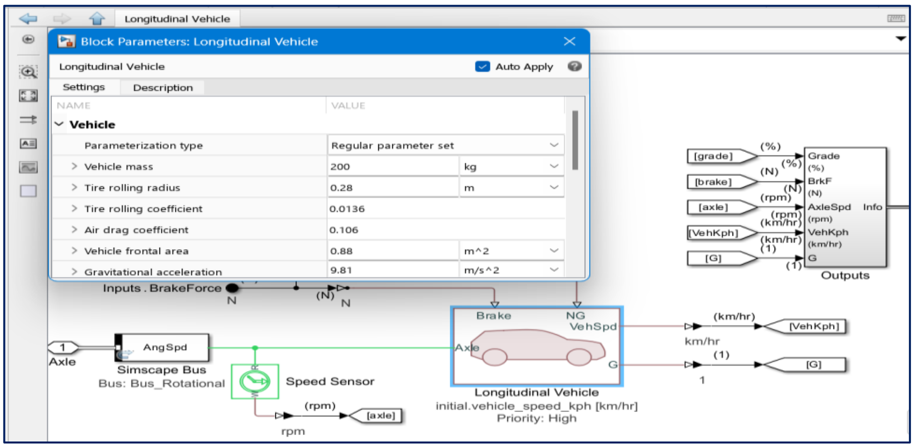
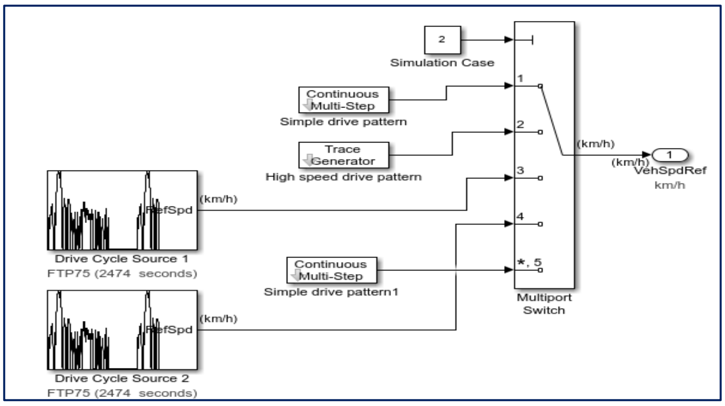


Fig 12. Parameter Insertion



In the next step, we provided different driving strategies to examine how efficiency varies with other speed-time graphs.

Different speed data feed to check the model; here, we have provided two driving cycles of the same time interval (2474 seconds). We also offer our constant speed and speed data during freewheeling, as shown below in Fig 13 and 14.

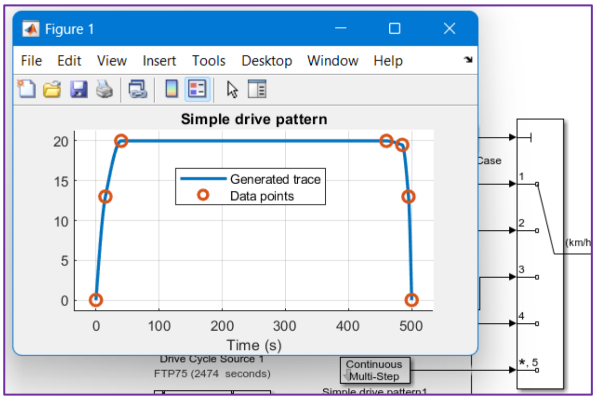


Fig 13. Constant Speed Data

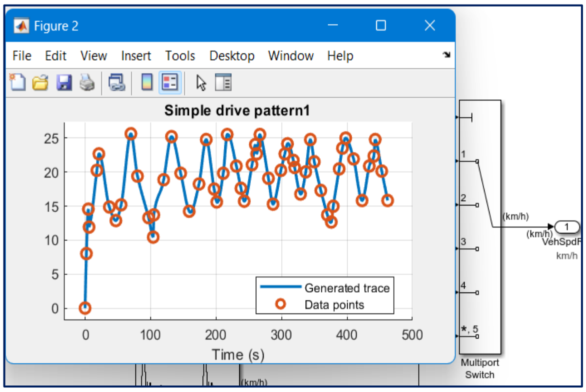
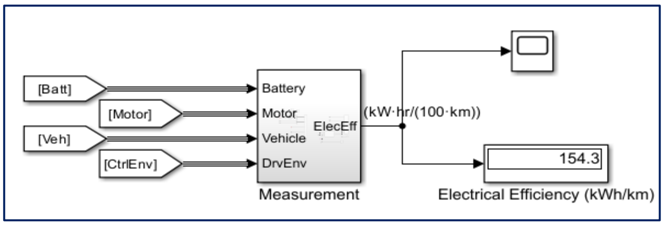


Fig 14. Speed Data from Free-Wheeling



The efficiency value we obtained from inputting these above-mentioned speed profile data, average current, time, etc, in the simulation is shown in the diagram.

Let us further explore the data we have generated so far. To increase efficiency, the two best methods we come up with are:

- Use the *free-wheeling technique* to let the vehicle glide (let the vehicle move with its inertia). So instead of applying brakes just before the turns, leave the throttle free a certain distance before the turn such that the vehicle would have enough velocity at the time of the turn.
- Move the vehicle with *constant speed* throughout the whole course and use braking just before the finish line. Still, this case is ideal. It is only possible when the vehicle would not meet traffic and would not have to undertake unscheduled manoeuvres such as sudden acceleration or braking.

On June 6, we performed two test runs inside the campus of our college, and we tried to implement the points mentioned above during our test run.

First Test Run (Using 1st Method)- We implemented the free-wheeling technique, as shown in Fig 10. A total of 517 sec of data were collected with an average speed of 20 km/h. Maximum speed reached 26 Km/h, and minimum speed was 12 Km/h.

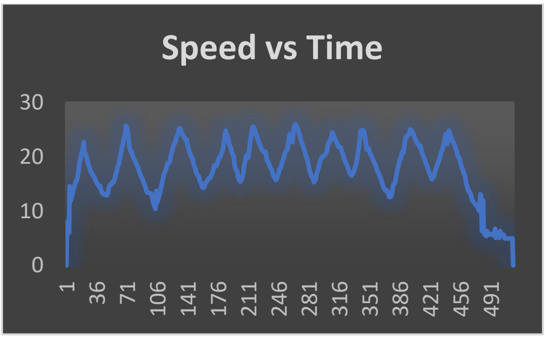


Fig 15. Speed vs. Time Graph (Free-Wheeling approach)

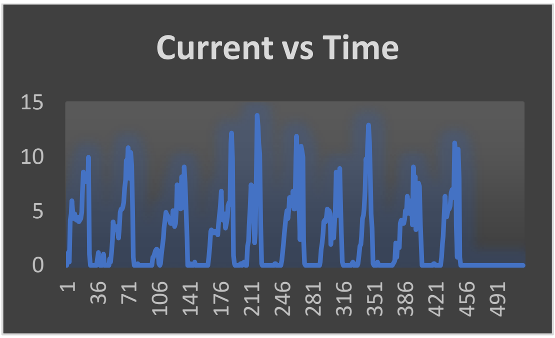


Fig 16. Current vs. Time Graph (Free-Wheeling approach)

There needs to be more than the speed vs. Time graph to discuss which method we should use to give higher efficiency. Another parameter we studied is the current graph changing with the throttle. Current behaviour with throttle can be seen here during the acceleration part vehicle intaking current, and no current flows during gliding. The Current average consumption during this whole test run was 2.462 Ampere.

Second Test Run (Using 2nd Method)- Here, we tried to drive the vehicle at a constant rate as much as possible. 543 seconds of data were collected with a continuous average speed close to 19.5 Km/h.

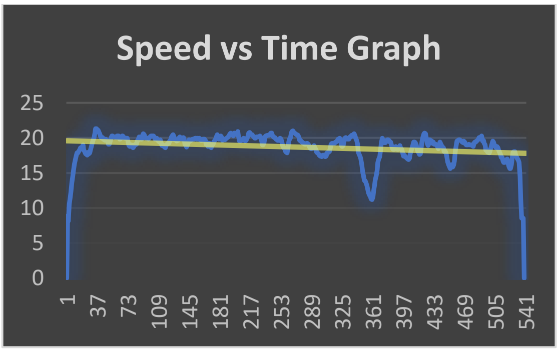


Fig 17. Speed vs. Time Graph (Constant Speed)

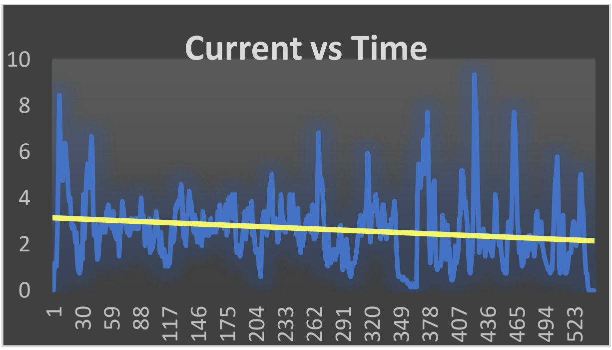


Fig 18. Current vs. Time Graph (Constant Speed)

Current values here are nearly constant, as one can expect due to the continuous throttle value. The average current consumption is 2.676 Amp, roughly close to the first run data.

Efficiency values in both cases is shown below in tabulated form.

	First Test Run	Second Test Run
Average Current (Amp-sec)	2.65	2.83
Voltage (V)	51.8	51.6
Distance Covered (m)	2761.65	3003.12
Total time taken (sec)	517	543
Efficiency (Km/KWH)	140.08	136.34

There are minor differences between the efficiency value we generated from the simulation and the calculated from actual data. These approximations are justified because of many conditions like tracks conditions we had performed our test on, the sensor's noise disturbance, and other external factors that could be the reasons for the difference between the efficiency value simulated and calculated from track data.

Strategy Development

This section will mainly revolve around analysing data we have collected and shown so far and will try to develop the best driving strategy possible. We primarily focus on which speed pattern (free-wheeling technique or constant speed) we should use.

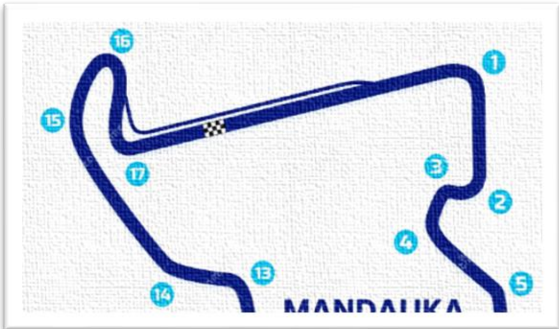
According to the calculations, the overall energy consumption of the driving strategy is better when starting to coast earlier and using braking just before the finish line, i.e., using the constant speed method throughout the course, than the free-wheeling technique. Still, the racing conditions must be better to perform this method efficiently. Hence, we decided to use both techniques according to the different situations.

When to use which method? And why? The track data we collected says there will be 17 turns (6 left and 11 right turns), so we decided to use the free-wheeling technique *during turns*. Because of two main reasons-

- we could not risk turning the vehicle during turns with the speed of 26 km/h when another vehicle is also present there.
- Our vehicle does not have any electronic differential, so during turns, both inward and outward tires will rotate at different speeds, and accelerating or using the constant speed method during that phase will harm our motor.

So, during turns, we decided to go with the *free-wheeling technique,* and during the rest of the time on the track, we will go with the *constant speed method*, maintaining an average speed of 26 Km/h. Even if other vehicles are present there, we have seen that the tracks are sufficiently wide enough to maintain our desired speed.

Let us discuss this strategy mentioned above more broadly on the Mandalika track and apply the parameters we collected above sections. So, this is what our strategy is looking like-



- Considering the track from **starting point to turn 1st (T1)** for analysis purpose. From *Fig 4,* we have the data of distance from starting line to the T1, which is approximately 431m.
- From our test run data, from *Fig 17*, the vehicle reached an average speed of 26 Km/h at 88.85 m from the rest position. *Using newtons laws of motion,* neglecting all other parameters like air drag, friction, etc., acceleration (acc) = 0.24 m/s^2.

• And the Vehicle reached from average speed to rest position in 43 seconds, deceleration becomes (decc=0.12 m/s^2).
• Inserting the value inside track conditions, we concluded that a total of 130 m will be needed for a vehicle to reach the average speed from starting line and 87.65 m from the average speed of 26 Km/h to 20 Km/h (assuming 20 Km/h would be a safe speed during the starting portion of the turn, even if there are some vehicles present there).

• We left with a total distance of 211 m between the distance we needed to make the vehicle reach average speed and slow down the vehicle before turning.

• Vague speed time profile is shown in *Fig 20*, where **Point A** is when the vehicle reaches its desired average speed of 26 Km/h, and **Point B** is the point till which we will be continuously going with the same speed. After that, we will leave the throttle for gliding to reach **Point C**, starting point of 1st turn (T1) with the speed of 20 Km/h, and the driving strategy is shown in Fig 21.

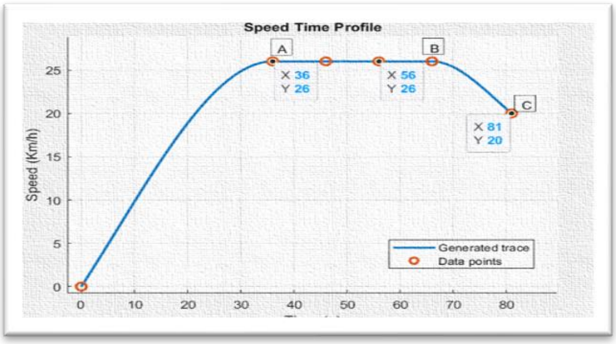


Fig 20. Speed Time Graph

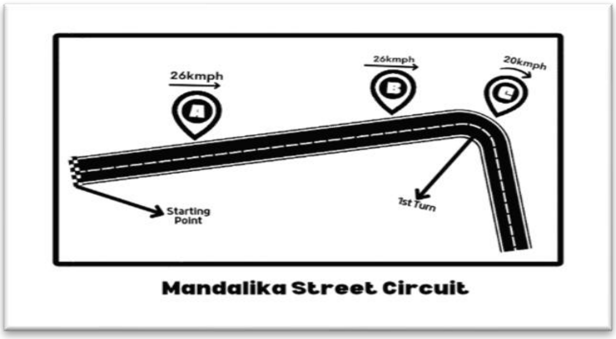
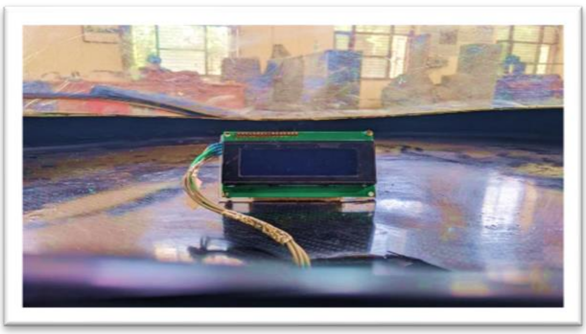


Fig 21. Pictorial representation

So, we have seen using the above analysis how we will implement both techniques of constant speed and free-wheeling method from time to time to increase our efficiency and ensure less energy consumption.

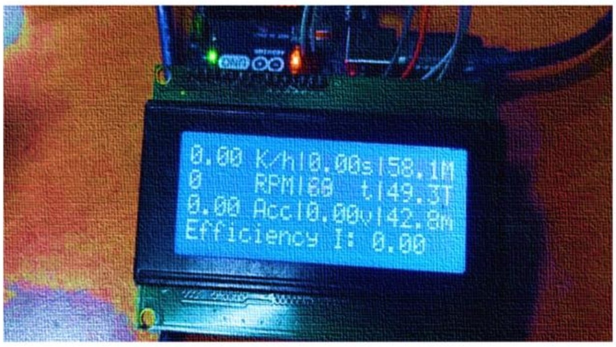
Driver Performance

Driver's sense of presence also plays a crucial role in better performance. We will not be using wireless communication between the driver and us. Instead, we have been using the telemetry approach to make transparent and clear communication between vehicles' performance and the driver by integrating a **24 x 4 LCD display** into our vehicle, providing the driver with a comprehensive and easily accessible view of crucial parameters during the competition.



The LCD display is designed to enhance the driver's decision-making process and enable them to adjust their strategy effectively. The driver can make informed judgments based on real-time conditions by providing immediate access to critical data. They can analyse trends, identify potential areas for optimization, and react swiftly to changing circumstances.

The data displayed acts as a valuable resource, guiding the driver's actions, fine-tuning their manoeuvres, and ensuring optimal performance on the track.



It presents essential parameters such as vehicle speed, RPM, distance travelled, battery voltage, acceleration, current consumption, etc.

Data flows into our display from I2C communication using SDA and SCL pins, where data from around the sensor gets captured inside Arduino. By I2C communication, it is transferred to the display.

By providing the driver with a comprehensive overview of critical parameters, we equip them with the tools to make intelligent decisions and adapt their strategy to changing conditions.

Result's Improvement

Does our above-mentioned data-driven approach provide us with the best possible on-track performance with a balanced minimal energy consumption? Maybe or maybe not, the data collection we had done, all the information process of all the data, are done on our track. We tried our best to replicate our track conditions to be as close as possible to the Mandalika street circuit, but we have yet to explore more of the Mandalika circuit to enhance our driving strategies and tactics.

We have identified several areas for improvement. These improvements aim to achieve a balanced minimal energy consumption and competitive speed.

- Tracks on which we had performed our test were not smooth and had many uneven surfaces and bumps, severely impacting our efficiency. Unlike in the Mandalika circuit, where the track surface is smooth and wide enough during turns, these factors might significantly increase our efficiency.

- Once we would perform a lap in the circuit, the data that will be collected at the end of the lap will be utilized to improve the driving strategy; this includes the value of acceleration that needs to be changed to reach the desired velocity, turn speed will be high compared to what we had here, constant speed can be maintained for long duration.

- The Temperature at which we performed our test run was relatively high compared to what we will be experiencing in Lombok, Indonesia. So, our electric components, motors, etc., will experience less resistance against heat, which may increase our vehicle performance.

Reference Links

- 5 Different Ways to Power a Raspberry Pi (makeuseof.com)
- Raspberry Pi (master) Arduino (slave) I2C communication with WiringPi - The Robotics Back-End (roboticsbackend.com)
- GitHub - RahulGoel2000/Torque-Vectoring-and-dashboard: The repository consists of code for implementation of a PID based electronic differential for a rear wheel driven Electric vehicle.
- Driving strategy for minimal energy consumption of an ultra-energy-efficient vehicle in Shell Eco-marathon competition - IOPscience