Intelligent Road Safety Speed Governor

Team-18 - Anish Mulay ED21B011, Ankit Yadav ED21B012, Shishir Kulkarni ED21B037, Pranav Debbad ED21B046, Omkar Soni ED21B045[1]

[a]*Engineering Design , IIT Madras,*

Contents

1. Introduction

1.1. Problem Statement

Road safety is a critical concern worldwide, with overspeeding being a major contributor to accidents. In India alone, overspeeding accounts for a staggering 58.7% of over 3 lakh annual accidents. Existing solutions, such as speed cameras, speed bumps, police patrols, and Advanced Driver Assistance Systems (ADAS), present various drawbacks. Speed cameras primarily serve as revenue generators for authorities, speed bumps cause driver inconvenience, police patrols are manpower-intensive and inconsistent, and ADAS, though effective, is not universally available and is very expensive. Speed signs and police enforcement, have also been proven to be insufficient.

Recognizing this, the development of an Automatic Vehicle Speed Control (AVSC) system becomes imperative. The AVSC system aims to address the limitations of current solutions by automatically controlling vehicle speed in specific zones, such as school areas and construction sites, offering a comprehensive and efficient approach to road safety.

1.2. Objective

The primary objective of this project is to pioneer an Intelligent Road Infrastructure System, integrating radiated emission sources that interact with vehicles to dynamically adjust the speed governor based on relative velocity. This innovative approach aims to mitigate overspeeding incidents, a major cause of over 3 lakh annual accidents in India. The system's intelligence lies in its integration with the Electronic Control Unit (ECU), providing real-time prevention of overspeeding incidents.

In parallel, the project seeks to address the limitations of existing solutions, such as speed cameras and speed bumps, by creating an AVSC system based on RFID technology. The core objectives include designing and implementing an AVSC system capable of effectively controlling vehicle speed in predefined zones.

1.3. Literature review

In our pursuit to enhance road safety, a thorough examination of prevailing Automatic Vehicle Speed Control (AVSC) systems unfolds a diverse array of technologies, ranging from radar to sonar and cameras. Yet, amidst these options, RFID technology emerges as a cost-effective, reliable, and practical choice,

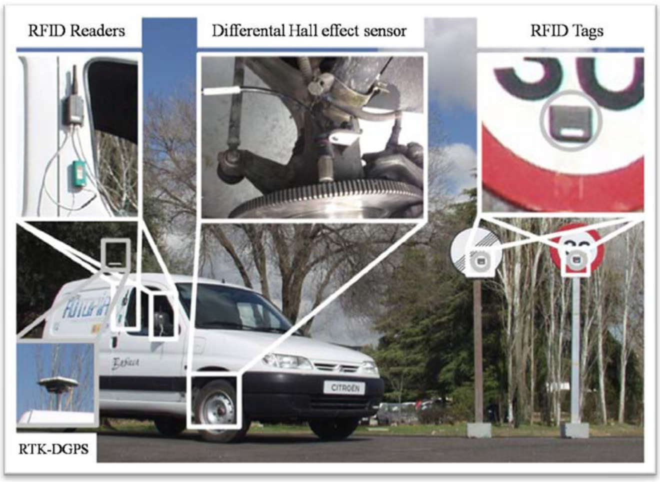

Figure 1: Traffic Signal posts equipped with RF-transmitter and Automobile equipped with the RF-receiver

showcasing its significance in the evolution of AVSC systems. AVSC systems, pivotal in addressing road safety concerns and traffic congestion, leverage various technologies to govern vehicle speed, particularly in demarcated zones. This literature review sheds light on the ascendancy of RFID technology, acknowledged for its affordability, extended range, reliability, and respect for user privacy.

1.3.1. *RFID-based AVSC Systems:*

Delving deeper into RFID-based AVSC systems reveals a structured framework involving a transmitter unit strategically positioned at traffic signal points and a receiver unit seamlessly integrated into vehicles. This setup facilitates the seamless broadcasting of speed limit signals for restricted zones, utilizing RFID tags and readers to establish effective communication. As vehicles, equipped with RFID tags, traverse these areas, the system ensures compliance by dynamically adjusting vehicle speed.

1.3.2. *Advantages of RFID-based AVSC Systems:*

The pragmatic advantages of RFID-based AVSC systems are succinctly outlined. Their cost-effectiveness renders them economically feasible for widespread adoption. The expansive detection range, spanning several meters, ensures efficient vehicle identification and precise speed control. The inherent reliability of RFID technology underscores its capacity to perform consistently in varied environmental conditions. Crucially, the privacy-centric attributes of RFID tags address pertinent concerns related to user data security.

1.3.3. *Literature Review Findings:*

Our exhaustive scrutiny of literature pertaining to RFID-based AVSC systems echoes promising outcomes, showcasing the technology's potential in bolstering road safety. A multitude of studies consistently demonstrates the effectiveness of RFID-based AVSC systems in regulating vehicle speed within restricted zones.

1.3.4. *Effectiveness in Speed Control:*

Research endeavors led by Rahim et al. (2018) and others corroborate the practical application and effectiveness of RFID-based AVSC systems in governing vehicle speed. These findings substantiate the technology's real-world utility, offering pragmatic insights for the design and implementation of intelligent road infrastructure systems. As we navigate the nuanced landscape of AVSC technologies, RFID emerges as a front-runner, aligning seamlessly with our project's overarching objective to redefine speed control for an elevated standard of road safety. This technology represents a pragmatic solution for implementing a speed governor in vehicles in India. By integrating the speed governor with the Engine Control Unit (ECU), it becomes inseparable, eliminating the possibility for drivers to simply visit any mechanic for its removal. Should a driver wish to eliminate the speed governor, they would also need to remove the ECU, a task that cannot be easily reversed.

2. Experimental Studies

Our comprehensive exploration of the proposed Automatic Vehicle Speed Control (AVSC) system extends beyond theory, delving into nuanced experimental studies designed to validate its efficacy in real-world and simulated environments.

2.1. ***Theoretical Study:***

Initiating our investigation, a meticulous theoretical study employed the Atmel's AVR microcontroller and AT86RF230 wireless module. This theoretical foundation, while addressing the intricacies of transmitter states and power optimization, served as a baseline for subsequent experimental validations. Simultaneously, MATLAB's Simulink played a crucial role in modeling and simulating the proposed system's behavior, aligning theoretical predictions with practical outcomes.

2.2. ***In-House Studies:***

In-house studies provided controlled environments to scrutinize the AVSC system's performance. Leveraging MATLAB Simulink, we replicated diverse traffic scenarios, evaluating the system's ability to detect, track, and control vehicle speed under varying conditions. The results not only validated the theoretical underpinnings but also showcased the robustness of the system in a simulated yet dynamic traffic landscape.

2.3. ***Simulation Studies:***

Simulation studies, a cornerstone of our experimental endeavors, utilized MATLAB Simulink to emulate a real life scenario where a car travelling on a road with a Government defined speed limit is overspeeding. In our model a transmitter sends a constant signal with has data encoded into it for the maximum speed limit on the road and that signal is fed into AVSC unit which intelligently decides how to decelerate the vehicle to not bring it under the speed limit.

Table 1: Literature Review

No.	Citation / Title of Research Paper	Learning Outcomes
1	A. Adarsh et al., ”Integrated Real-time Vehicle Speed Control System using RFID and GPS,” 2020 Second International Conference on Inventive Research in Computing Applications (ICIRCA), Coimbatore, India, 2020, pp. 194-200, doi: 10.1109/ICIRCA48905.2020.9182925.	This paper suggests an innovative approach to road safety by integrating RFID and GPS to dynamically control vehicle speed based on location-specific speed limits, enhancing overall safety near restricted zones.
2	A Design Model for Automatic Vehicle Speed Controller	The paper introduces a novel automobile speed control design, emphasizing a theoretical analysis focused on a single vehicle. Acknowledging potential signal interference from nearby vehicles, further research is warranted for real-world applicability.
3	M. K. Telaprolu, K. Varun, S. N. Rao, V. V. Sarma, E. K. Ratnakanth and V. Banda, ”Microcontroller based automation of variable electronic speed governor,” 2009 IEEE International Conference on Vehicular Electronics and Safety (ICVES), Pune, India, 2009, pp. 151-155, doi: 10.1109/ICVES.2009.5400228.	This research proposes a practical solution for global traffic issues, suggesting a zone-based speed control system using transmitters, microcontrollers, and solenoid valves. The low-cost, adaptable system aims to enhance road safety.

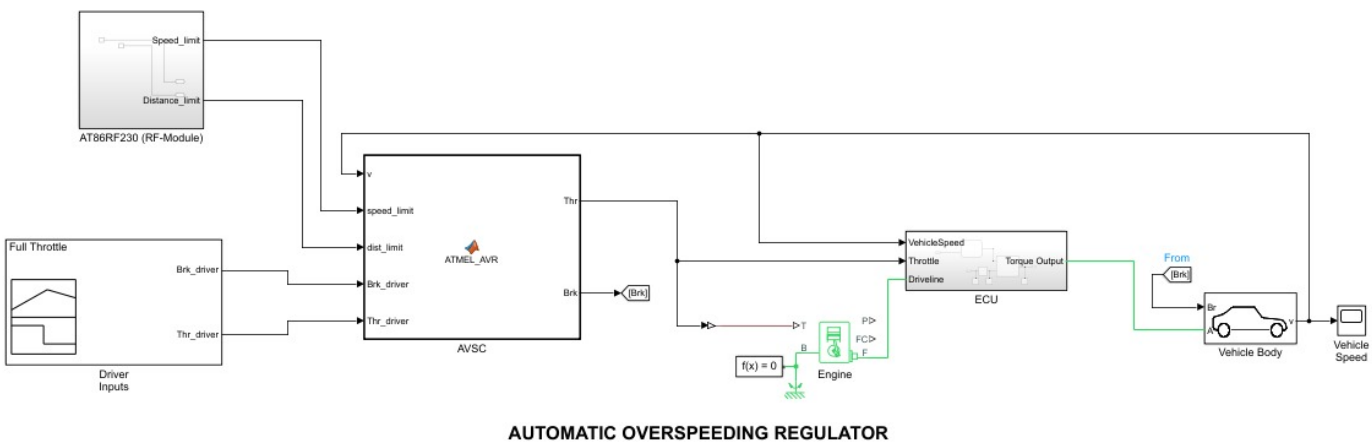

Figure 2: Simulink Model for Controlling Overspeeding

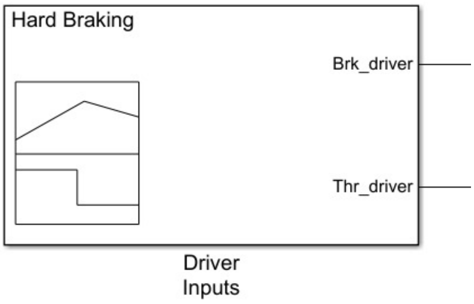

Figure 3: Driver Inputs

2.4. *Our Simulation Models:*

This is the model made by our team for implementing the vehicle speed control. There are various parts and parameters in it:

1. Driver Inputs (*Figure-3,4*): These correspond to the throttle and brake inputs provided by the driver via accelerator and brake pads.
2. RF Module (*Figure-5,6,7,8*): This module is for transmitting the signal frequency corresponding to the road speed limit to the receiver in the car. The transmitter-receiver module used for this purpose is called as AT86RF230 it is a 2.45GHz radio transceiver. It can operate in the temperature range of -40 degree centigrade to 85 degree centigrade. AT86RF230 in the transmitter section will be either in the transmission state or sleep state and the AT86RF230 in receiver section will be in the Receiving state. Datasheets of AT86RF230 shows that transition time from state to sleep state take 1.1milliseconds and from the sleep state to transmission state takes 48 micro seconds. It takes 224 micro seconds to transmit a frame of 1 byte. Since the frame size in the proposed design is 7 bytes it takes 1.792 milliseconds to transmit the frame.
3. AVSC (*Figure-9*): This is the Automatic Vehicle Speed Controller. It takes The shown inputs and then decides on the outputs that are provided to the ECU and the brake module to make sure that the vehicle speed stays inside the provided limit.
4. ECU (*Figure-10*): This is the Electronic Control Unit of the vehicle. It takes in the inputs from the driveline, throttle and the value of the vehicle speed and via transmission module it gives an output torque to the wheels.

2.5. *Gaps in Studies*

While our studies yielded promising results, acknowledging the need for continued research is imperative. In-depth analyses revealed avenues for further exploration, emphasizing the significance of long-term performance evaluations under diverse weather conditions and traffic scenarios. Research efforts were also directed towards refining the AVSC system's scalability and cost-effectiveness, informed by insights gained from a synthesis of various research papers.

In conclusion, our experimental studies, rooted in a theoretical foundation and augmented by MATLAB Simulink simulations, validate the efficacy of the proposed AVSC system. The integration of insights from diverse research papers ensured a robust approach, addressing real-world challenges and paving the way for advancements in road safety through sophisticated speed governors.

3. Methodology

The methodology employed in the development and assessment of the RFID-based Automatic Vehicle Speed Control (AVSC) system revolves around meticulous system design, wireless module integration, and operational modes.

3.1. *System Design*

The foundational phase focused on a detailed system design, delineating the architecture and functionalities of the AVSC system. Comprising two pivotal components — the transmitter unit and the receiver unit — the system utilizes RFID technology for effective communication. The transmitter unit, positioned strategically at calculated distances on major traffic roads, broadcasts speed limit signals. It encompasses an RFID tag reader, a microcontroller, and a transmitter module. The RFID tag reader identifies vehicles equipped with RFID tags, and the microcontroller processes this information, generating speed limit signals. The transmitter module then broadcasts these signals within the designated coverage area.

The receiver unit, mounted on vehicles, plays a crucial role in implementing the speed control measures. Comprising an RFID tag antenna, a microcontroller, and an actuator interface, the receiver unit interprets the signals from the transmitter unit. The RFID tag antenna receives the signal, and the microcontroller processes it to determine the appropriate speed limit. This information is then communicated to the AVSC designed by our team. This AVSC takes four inputs which are throttle input by the driver, brake input by the driver, vehicle speed at the instant, the speed limit for the road, and the desired distance over which the vehicle speed should be brought under the road speed limit. By calculating the necessary deceleration required to control the vehicle speed within he desired distance, the AVSC gives two outputs to the engine that govern the actual throttle and brake inputs going to the prime mover.

3.2. *Wireless Module Integration*

Integral to the AVSC system is the wireless module, embedded in both the transmitter and the vehicle. The transmitter, affixed at locations necessitating speed control, transmits frames that specify the maximum speed limit and the duration for which this limitation must be implemented. The receiver in the vehicle detects these frames, processes the information, and enters an active mode to implement speed control measures. The frame structure includes synchronization headers, frame length, and data units specifying maximum speed and time to live values. The synchronization header ensures effective communication between the transmitter and receiver.

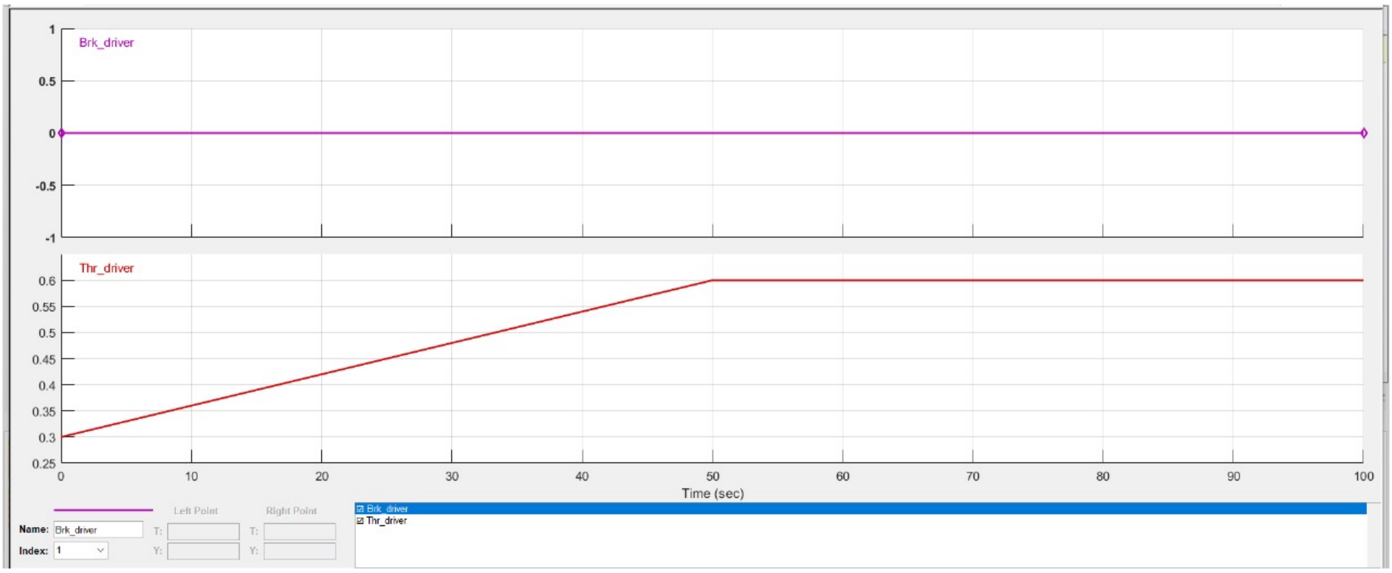

Figure 4: Driver Inputs for Brakes and Throttle

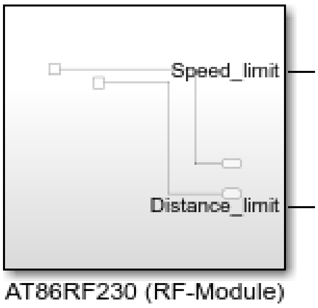

Figure 5: AT86RF230

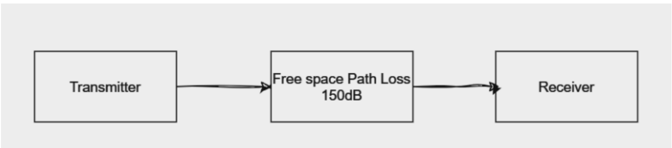

Figure 6: Transmitter Receiver Path Loss

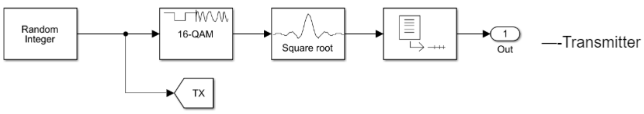

Figure 7: Transmitter Module

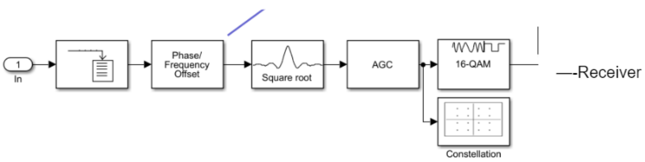

Figure 8: Receiver Module

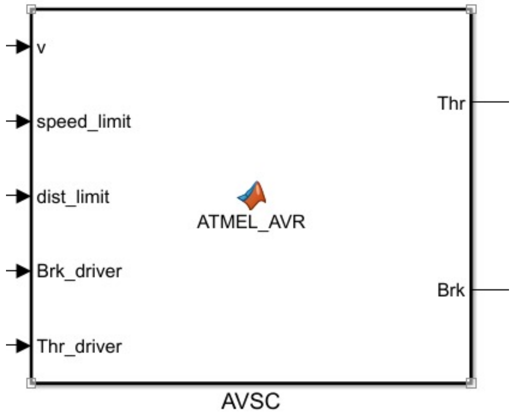

Figure 9: ATMEL-AVR -Micro-controller

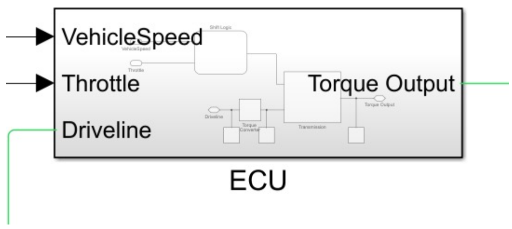

Figure 10: ECU Module in the car

3.3. *Modes of Operation*

The AVSC system operates in two primary modes:

1. **Normal Mode:** During normal mode, the system receives pedal position values from sensors and transfers them to the Electronic Control Unit (ECU). In this mode, the AVSC system operates passively, awaiting data from the transmitter.
2. **Active Mode:** In active mode, the microcontroller continuously monitors the vehicle's speed. Employing fuzzy logic, the system assesses if the speed exceeds the maximum limit. If the speed surpasses the set limit, a signal is sent to the ECU, initiating speed control measures in terms of controlling the throttle and brake signals. This active mode ensures real-time responsiveness to dynamic speed scenarios.

This methodology ensures the AVSC system is rooted in a robust theoretical foundation, effectively utilizing RFID technology and wireless communication. The integration of the wireless module, operational modes, and precise speed control mechanisms highlights the system's adaptability and efficacy in dynamically controlling vehicle speed, ultimately contributing to enhanced road safety. The careful consideration of these elements underscores the practicality and relevance of the AVSC system in real-world applications.

3.4. *Flow of the Methodology*

(Refer Figure-11) The block diagram shows the main components of the automatic speed controller that takes the speed limit and the distance range in which the speed limit needs to be achieved from a transmitter placed on the road. The speed sensor measures the vehicle's speed and sends gives this as an input to our controller. The RF module receives the vehicle's speed signal from the transmitter and sends it to the controller. The controller compares the vehicle's speed to the speed limit signal received from the roadside transmitter. If the vehicle's speed is above the speed limit, the ECU sends a signal to the throttle body to reduce the engine's power output. The throttle body reduces the amount of air entering the engine, which reduces the engine's power output and the vehicle's speed.

4. Implications of this model on the Road Safety:

Implementing a speed governing mechanism in vehicles can have several implications for road safety:

1. **Compliance with Speed Limits:** A speed governing mechanism ensures that vehicles adhere to predetermined speed limits. This can contribute significantly to reducing the likelihood of accidents, as excessive speed is a major factor in many road incidents.
2. **Prevention of Reckless Driving:** By limiting the maximum speed of a vehicle, the mechanism discourages reckless driving behavior. Drivers are less likely to engage in dangerous practices such as speeding, aggressive overtaking, leading to a safer road environment.
3. **Reduction in Severity of Accidents:** Even if accidents do occur, the severity of the impact is likely to be lower when vehicles are traveling at lower and controlled speeds. Lower speeds can mitigate the extent of damage and reduce the likelihood of fatal injuries in the event of a collision.
4. **Enhanced Pedestrian Safety:** Controlled vehicle speeds contribute to safer conditions for pedestrians. Slower-moving vehicles are easier for pedestrians to anticipate and react to, reducing the risk of accidents involving vulnerable road users.
5. **Improved Road Infrastructure Resilience:** Limiting speeds can result in less wear and tear on road infrastructure. This is particularly relevant in regions with challenging terrain or varying road conditions, where maintaining controlled speeds helps preserve the integrity of the road network.
6. **Positive Impact on Insurance and Liability:** Reduced speeds may lead to lower accident frequencies and severity, potentially resulting in decreased insurance claims. This can positively influence insurance costs and liabilities for both individual drivers and the broader community.
7. **Environmental Benefits:** Controlled speeds often lead to more fuel-efficient driving, contributing to lower emissions and improved fuel efficiency. This aligns with broader environmental goals and regulations.
8. **Standardization of Safety Measures:** A speed governing mechanism promotes standardization in safety measures across the automotive industry. This consistency can lead to more predictable road behavior and facilitate the development of advanced safety technologies.

In summary, the implications of a speed governing mechanism on road safety are generally positive, encompassing reduced accidents, improved compliance with speed limits, and overall safer road conditions. However, careful consideration and comprehensive strategies are necessary to address potential challenges and ensure effective implementation.

5. Human Factors Consideration in the Deployment of this Speed Governing Mechanism:

Taking human factors into account, an effective overspeeding alert system should consist of a combination of visual and auditory feedback to optimize the driver's awareness and response.

1. **Visual Alerts for Quick Recognition:** Humans are naturally attuned to visual stimuli. Utilizing visual alerts, such as a conspicuous change in the speedometer display or a flashing light, captures driver's immediate visual perception, ensuring quick recognition of the overspeeding situation.
2. **Accommodate Variability:** Recognizing individual variability in driver responsiveness, a system that integrates both visual and auditory alerts provides a better solution. This ensures that the overspeeding message is effectively

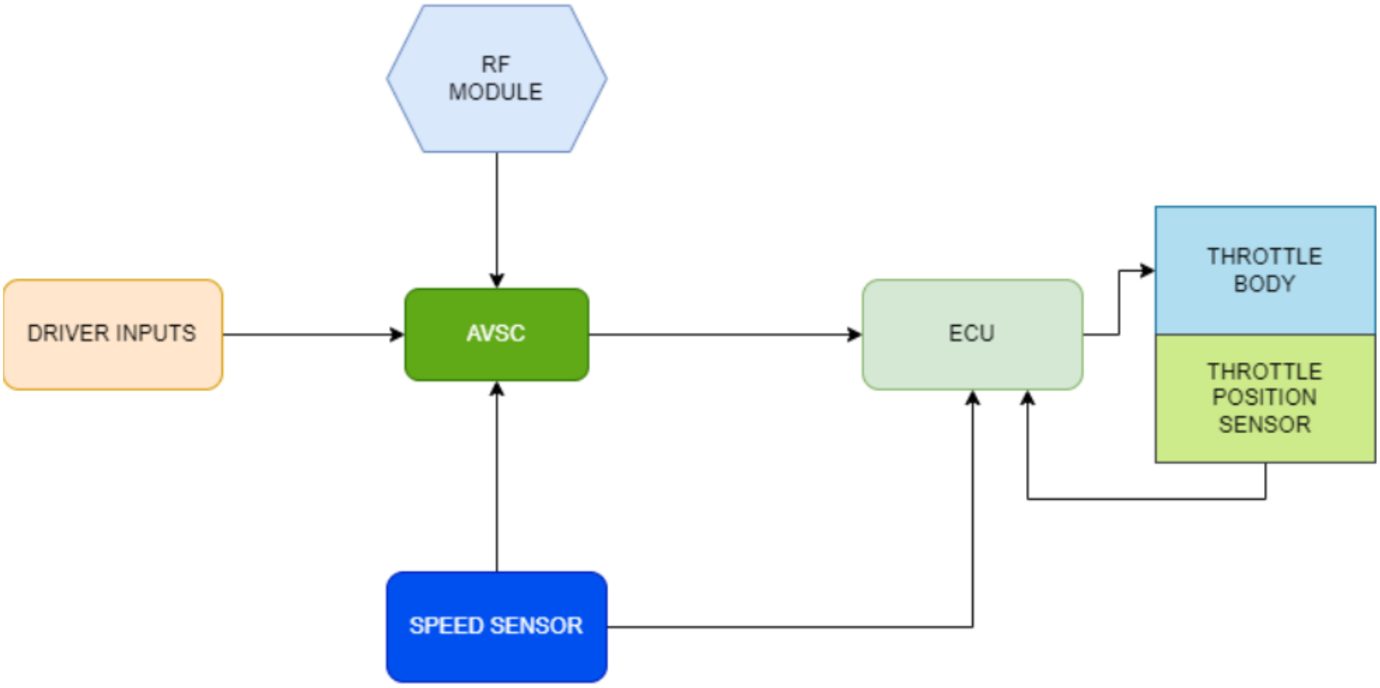

Figure 11: Methodology Flow

conveyed, even in situations where attention may be divided. Acknowledging the diverse ways drivers respond to alerts, a user-friendly system should allow for customization. Drivers should be able to choose and adjust the visual and auditory feedback based on their preferences.

3. **Auditory Alerts:** Auditory signals too help in capturing attention. Incorporating shrill sounds or spoken warnings ensures that the alert is attention-grabbing, particularly in instances where the driver may be visually distracted or in environments with elevated ambient noise levels. Google maps uses a similar technique.
4. **Comprehensive Warning Experience:** Human cognition benefits from multi-modal information processing. By combining visual indicators with auditory alerts, the overspeeding system offers a comprehensive warning experience. This can include displaying the specific speed exceeded visually while reinforcing the urgency through clear and immediate auditory messages.

Making a model which considers human factors in its design helps in enhancing the effectiveness of the technology and helps it communicate with the humans better ultimately leading to safer driving practices on the road.

6. Results

In the simulation of our model we have designed a microcontroller unit which takes in the inputs from the driver in form of throttle and brake padel position converts it to the speed of the vehicle. If the speed is above the certain decided threshold which is unique to every road, the microcontroller controls the throttle and brake outputs to the ECU and the brake module.

We have used a RF Module named AT86RF230 to work as a transmitter and receiver module. According to our model, a signal transmitter will be emitting frequencies corresponding to the maximum assigned speed limit on the road, the RF Module will help capture those signals and decode it to know the speed limit of the road and this output is fed into the AVSC (Automatic Vehicle Speed Controller) which processes the signal and sends an appropriate output to the ECU. If the vehicle speed is above the speed limit, then the AVSC controls the throttle and brake output to keep the speed under control and if the speed is under the speed limit, it passes on the signal to the ECU as it is.

Taking an example, if the speed limit on an IIT Madras road is 30 KMPH, and a car with this speed governor installed is travelling on the road, following are the speed characteristics in different scenarios:

Scenario 1: Initially, the car is within the speed limit, but the driver persists in applying throttle continuously.

- In this situation, the driver consistently applies throttle, potentially causing the car to exceed the speed limit. However, our speed controller intervenes, maintaining the car speed at a constant 30 km/h. Simultaneously, it prompts the driver with a warning signal, advising them to release the throttle and ensure the car remains within the specified speed limit.

- The velocity graph (Figure-12) shows that the speed increases and finally becomes constant at 30kmph. There are small jerks in the speed, because the driver persistently tries to give the throttle but the controller successfully blocks this and keeps the speed at the speed limit.

- The acceleration graph (Figure-13) shows that the driver tries to continuously throttle which results is spikes.

- The brakes graph (Figure-14) shows the corresponding braking (decceleration) produced by the controller.

Scenario 2: Initially, the car is within the speed limit, and the driver is not giving any throttle above the speed limit.

- In this scenario, after receiving the warning (as described in the previous case), the driver takes no action to control the vehicle speed. Consequently, the car experiences a gradual reduction in speed due to factors such as frictional losses and air drag.

- The velocity graph (Figure-15) - The graph illustrates a decrease in velocity after reaching the speed limit, attributed to the influence of air drag and road friction. No additional throttle input is provided by the driver.

- The acceleration graph (Figure-16) - The acceleration graph indicates minimal changes after the car attains the speed limit, reflecting the absence of throttle input from the driver.

- (Figure-17) The controller intervenes by generating a braking response at the point when the car attempts to exceed the speed limit, ensuring that the speed is maintained within the specified limit.

Scenario 3: The car potentially tends to exceed the speed limit, and there is throttle given by the driver.

- In this situation, the driver consistently applies throttle, potentially causing the car to exceed the speed limit. However, our speed controller intervenes, maintaining the car speed at a constant 30 km/h. Simultaneously, it prompts the driver with a warning signal, advising them to release the throttle and ensure the car remains within the specified speed limit. Unlike the first case, here the jerks due to driver input are reduced by adaptive controlled output given by our speed controller, thus ensuring the comfort of the passengers in the car.

- The velocity graph (Figure-18) - The velocity becomes constant after reaching the speed limit, without any jerks

- The acceleration graph (Figure-19) shows that the driver tries to continuously throttle

- The Figure-20 shows corresponding constant braking force graph generated by the controller at the point the car tries to exceed the speed limit.

7. Inferences from the Results and Comparison with the Existing Solutions

From the results above we can infer that the Automatic Vehicle Speed Controller is an effective and easily implementable solution which can help reduce the road hazards related to overspeeding and ensure a safe journey for everyone.

Most of the modern speed governors are located in a vehicle such they can't be easily removed from the vehicle without damaging some other vital parts of the vehicle and also they are manufactured such that they can't be reprogrammed to adjust the speed limit which is a major advancement over the older static speed governors which could easily be removed from the cars.

Two of the majorly used speed governors are:

1. **Variable Speed Governer:** This speed governor uses the GPS system of the cars to locate its position and it has a database saved in it for the speed limits on various roads, so based on the car location it decides the maximum speed limit. The major set back of this speed governor is that, the GPS system is not always reliable so it can set a wrong speed limit for a wrong route. Especially on the narrow and empty roads which don't showup on GPS which seem harmless to drive fast but can have some factors due to which they have a speed limit.
2. **Adaptive Speed Governor:** This speed governor uses some pre-programmed speed limits of some specific locations like airports, factories etc. This speed governor is not at all scalable and is obviously not useful in most of the regions.

One of the major and common shortcoming in these governors is that none of them account for the jerks that the car can experience if the driver tries to cross the speed limit continuously. This model takes into account that case and this scenario is also taken care of.

8. Conclusions

In this project we presented a new approach to control the speed of the automobiles. We have presented a theoretical study and supporting MATLAB simulations on our proposed design. In our theoretical study, only one vehicle is considered. In normal driving situations, we can expect other vehicles circulating nearby and possibly blocking or attenuating RF signals.

9. References

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2. A Design Model for Automatic Vehicle Speed Controller

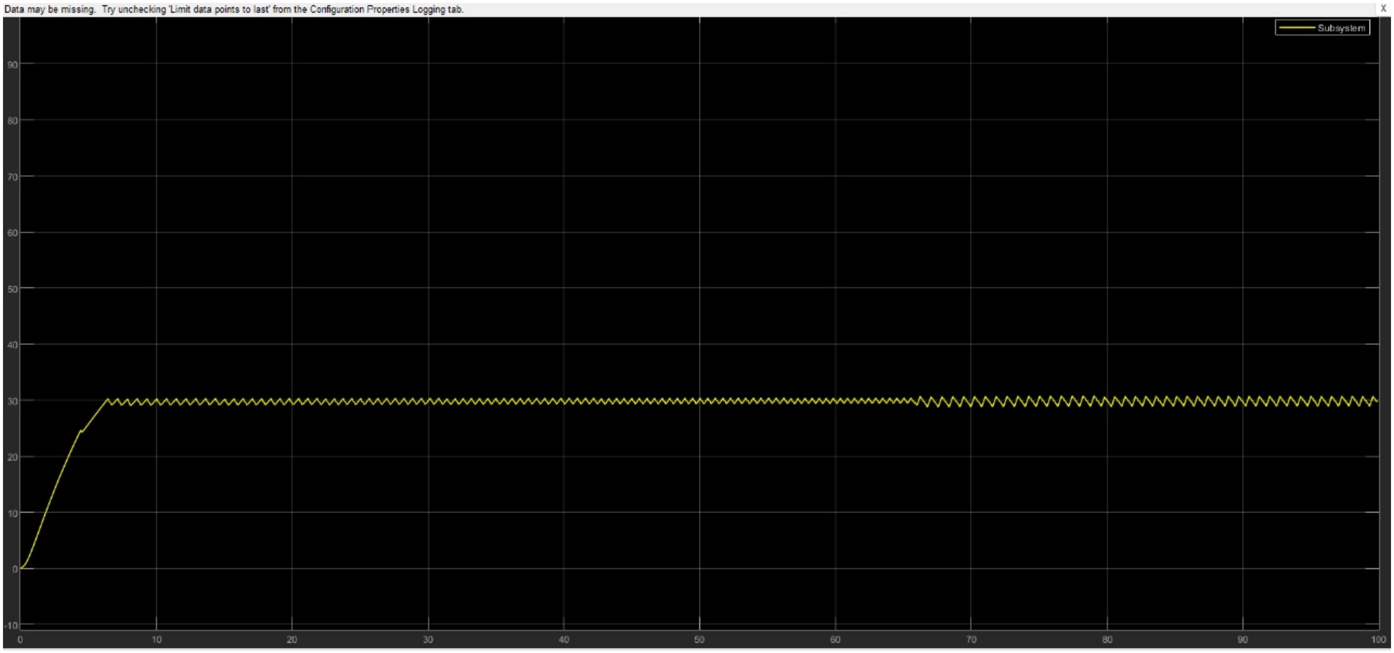

Figure 12: Scenario-1: Velocity Graph

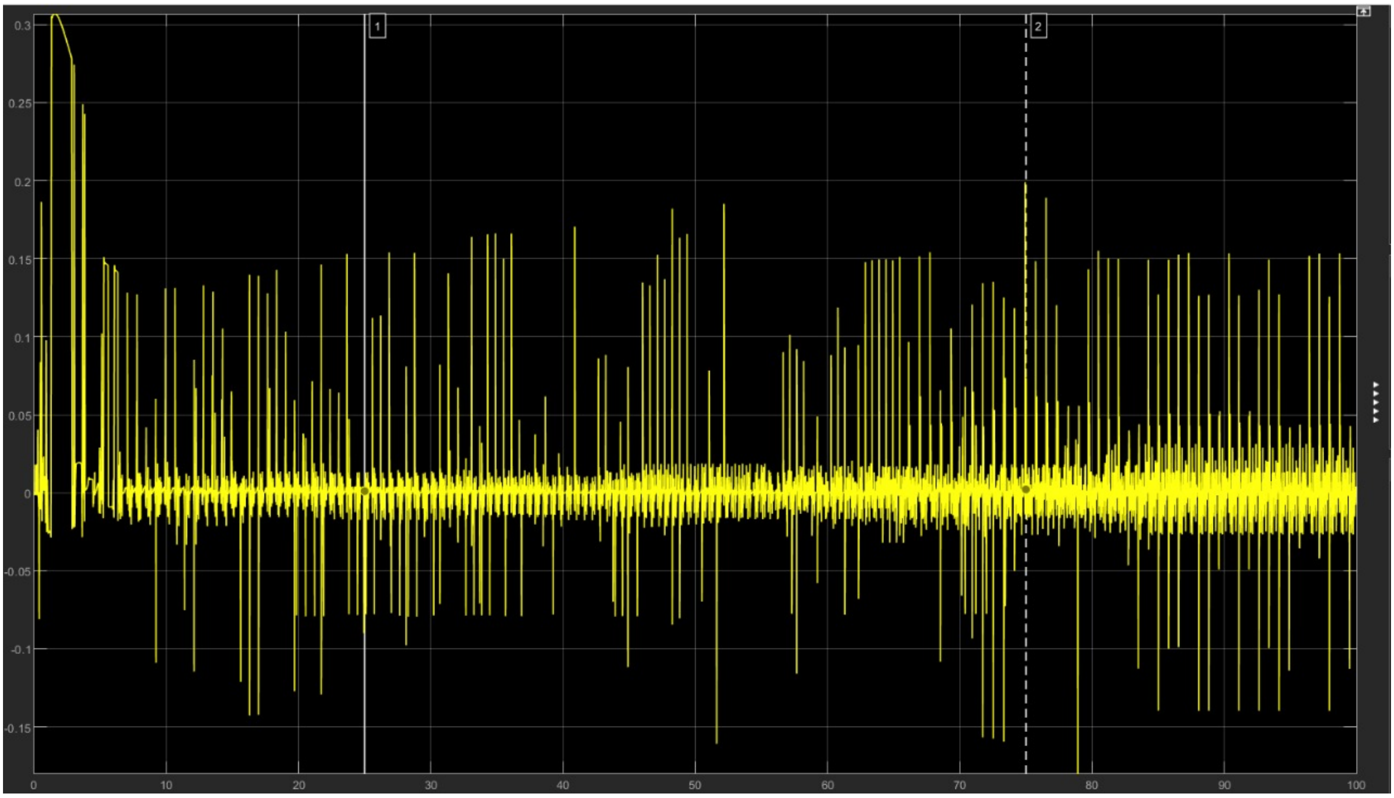

Figure 13: Scenario-1: Acceleration Graph

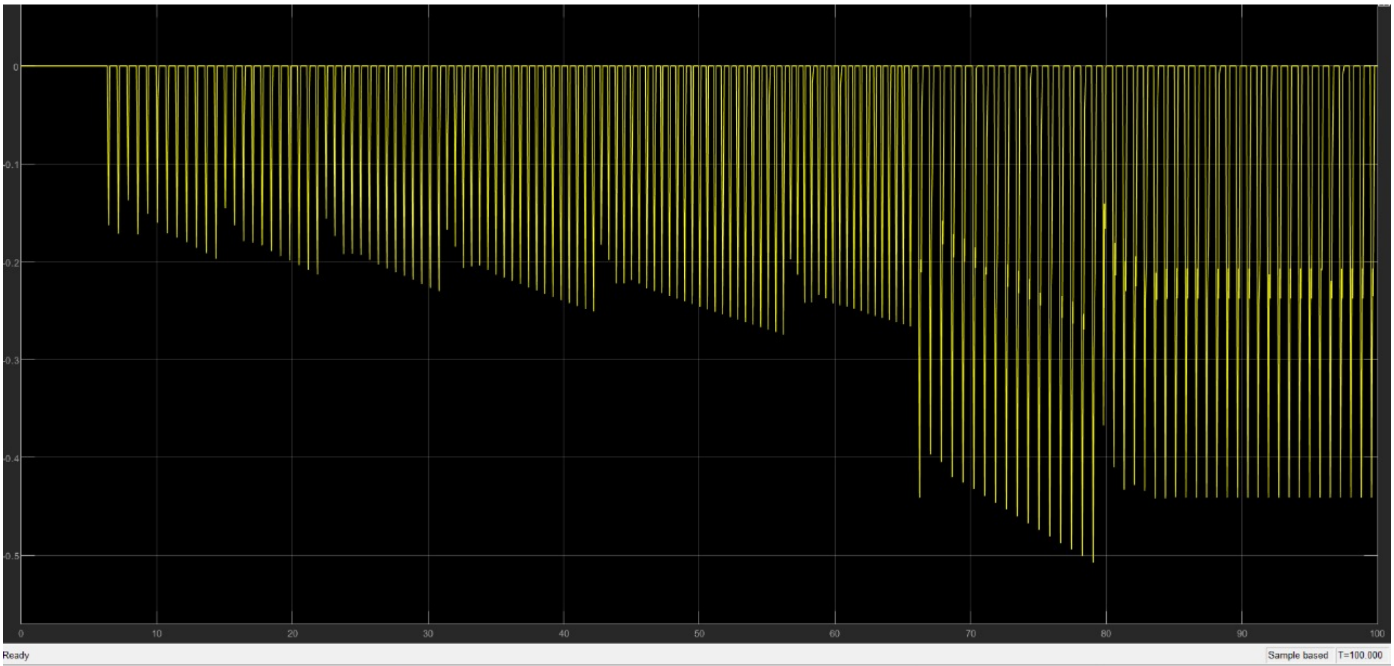

Figure 14: Scenario-1: Braking Graph

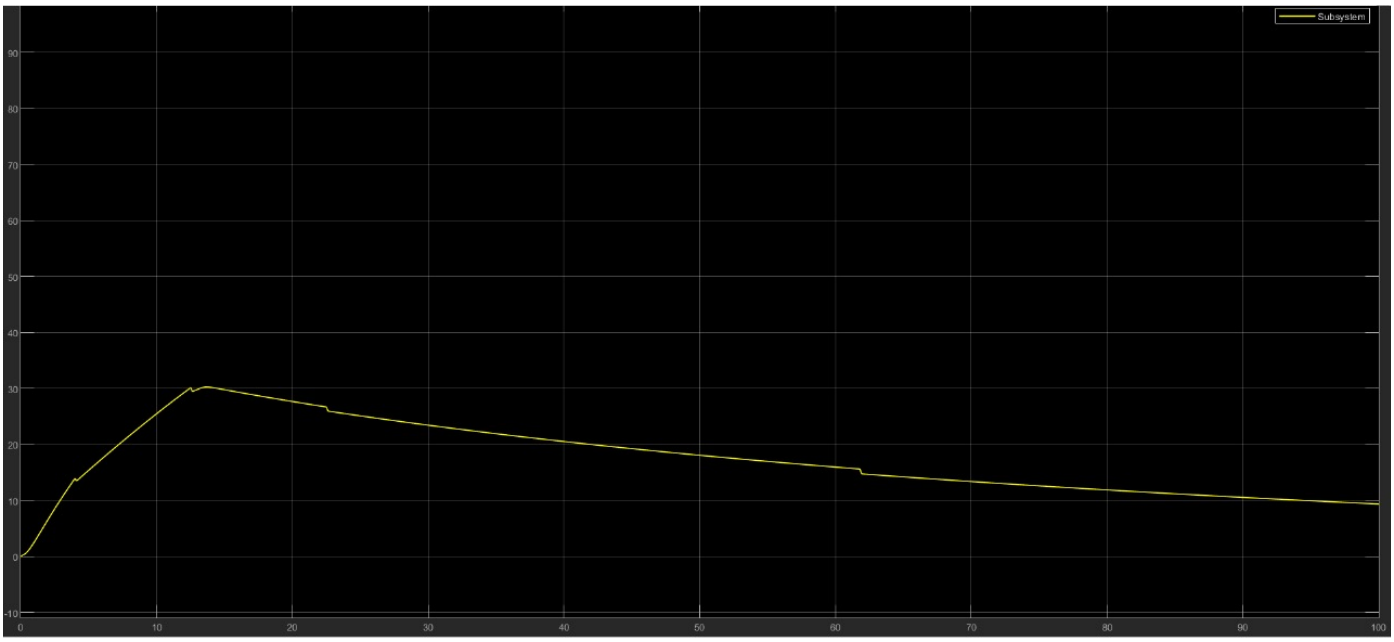

Figure 15: Scenario-2: Velocity graph

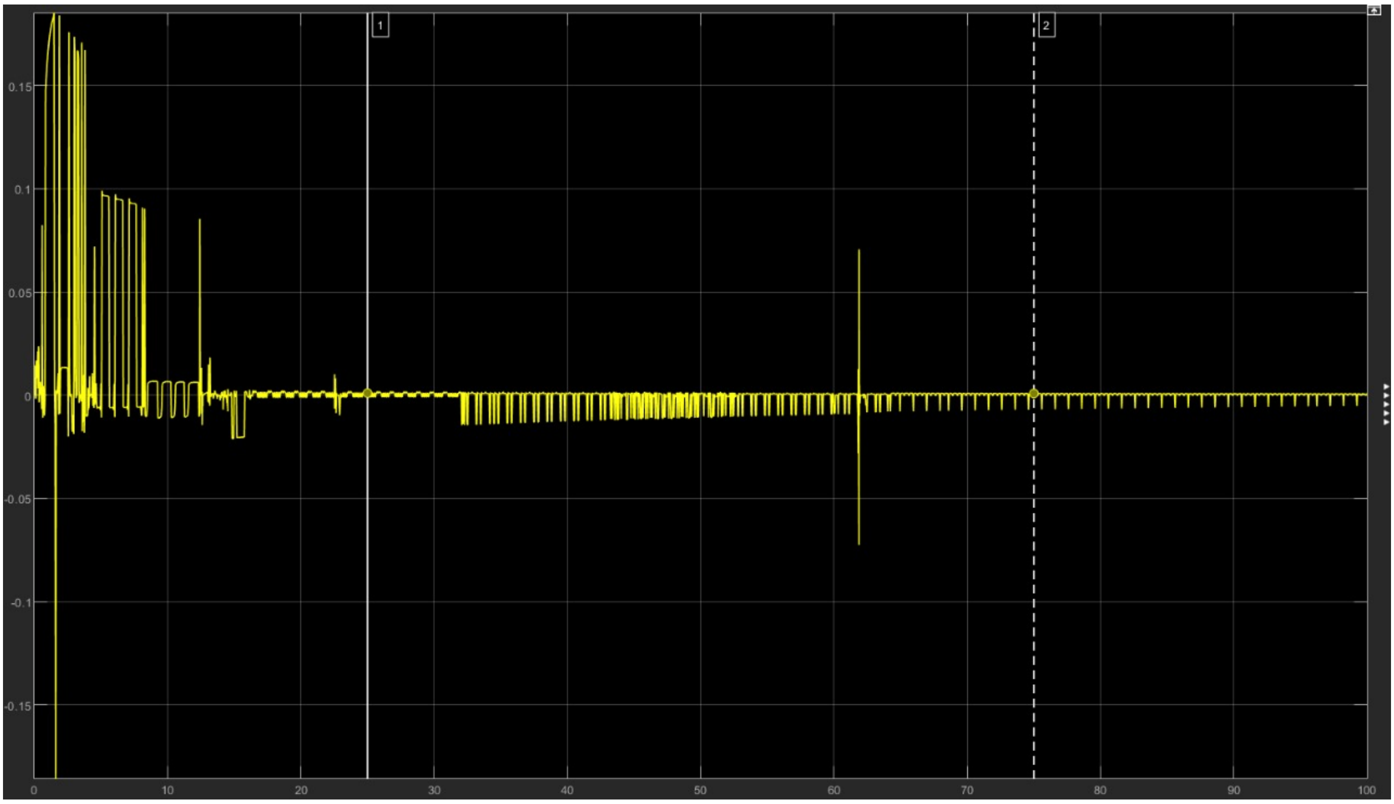

Figure 16: Scenario-2: Acceleration graph

Figure 17: Scenario-2: Braking Graph

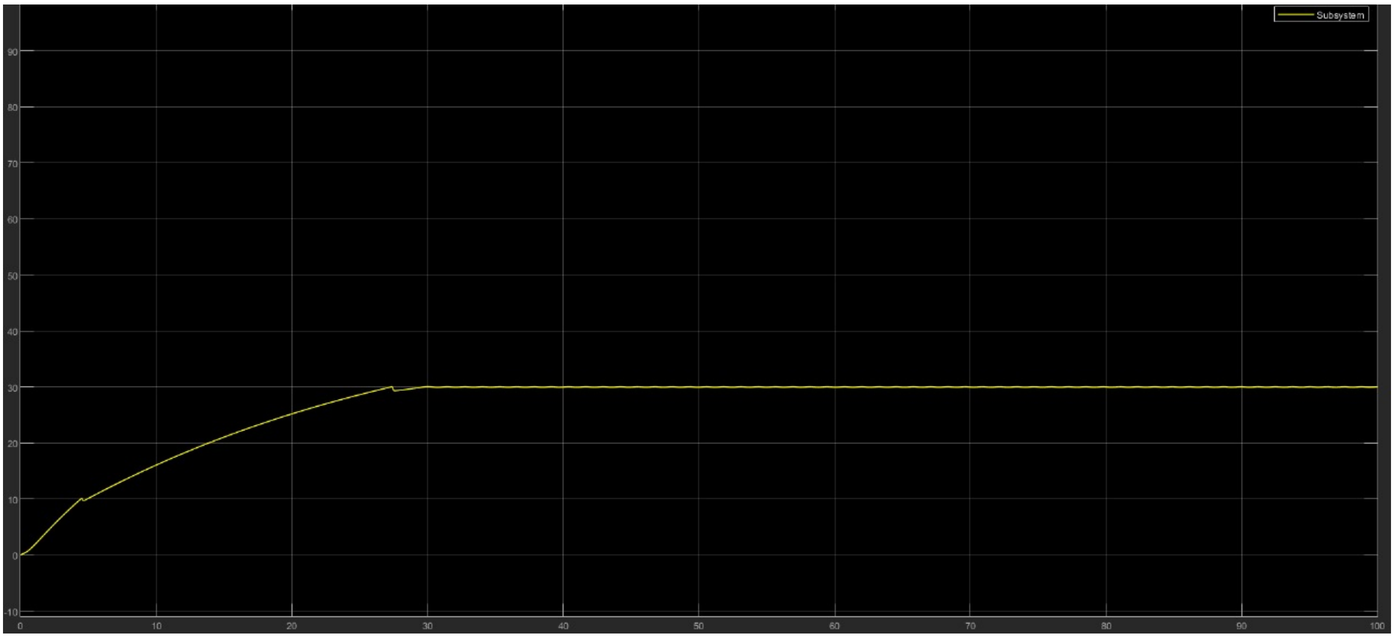

Figure 18: Scenario-3: Velocity Graph

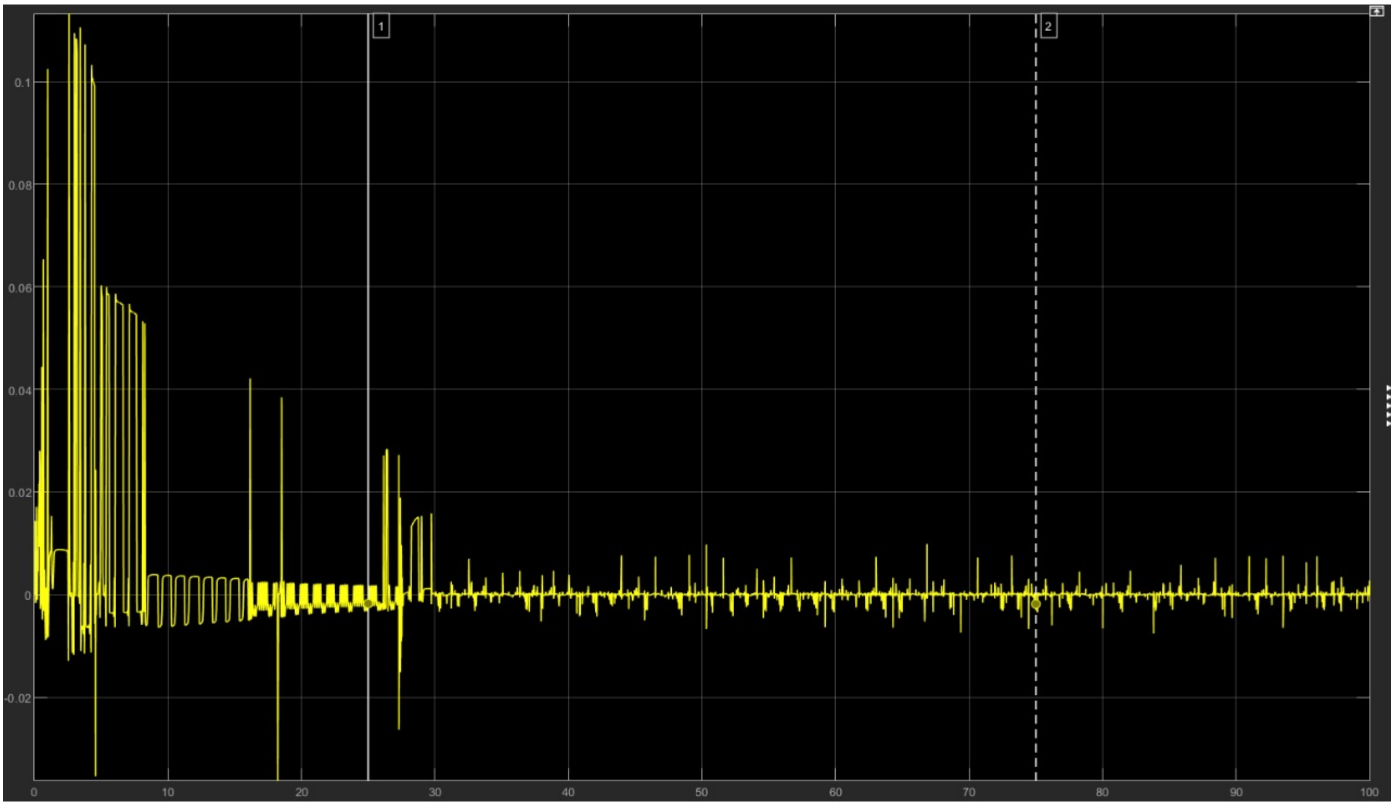

Figure 19: Scenario-3: Acceleration Graph

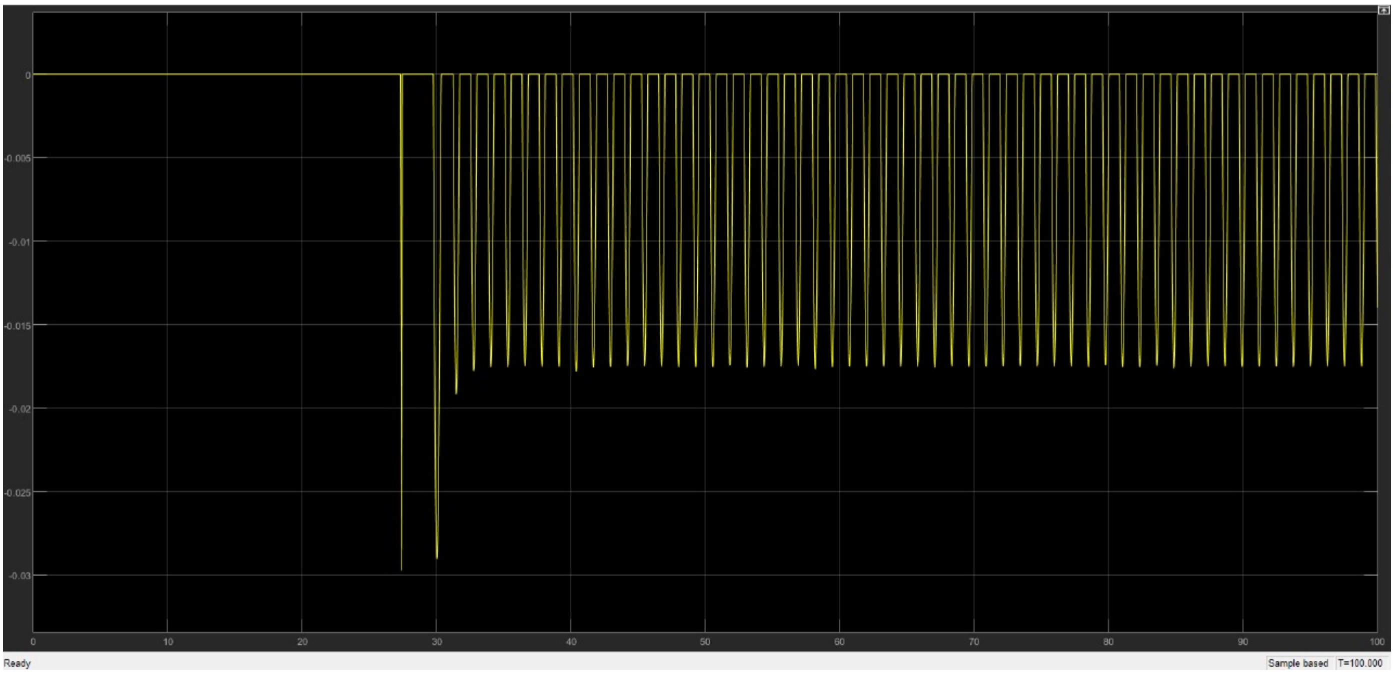

Figure 20: Scenario-3: Braking graph

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