DRIVER AUDACITY EVALUATION BASED ON ENVIRONMENT-SPECIFIC EMBEDDED CYBER-PHYSICAL SYSTEMS USING LOW-LEVEL COMPUTATION PLATFORM.

by

Md. Asifuzzaman Khan (170021005)
Md. Arean Ashfaq (170021043)
Md. Kazi Sazzad Ahmed (170021147)

A Thesis Submitted to the Academic Faculty in Partial Fulfillment of the Requirements for the Degree of

BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING

Department of Electrical and Electronic Engineering
Islamic University of Technology (IUT)
Gazipur, Bangladesh

10th May, 2022

DRIVER AUDACITY EVALUATION BASED ON ENVIRONMENT-SPECIFIC EMBEDDED CYBER-PHYSICAL SYSTEMS USING LOW-LEVEL COMPUTATION PLATFORM.

Approved by:

Dr. Golam Sarwar

Supervisor and Professor,
Department of Electrical and Electronic Engineering,
Islamic University of Technology (IUT),
Boardbazar, Gazipur-1704.

Date: 10th May, 2022

Declaration of Authorship

This is to certify that the work in this thesis paper is the outcome of research carried out by the students under the supervision of Dr. Golam Sarwar, Professor, Department of Electrical and Electronic Engineering (EEE), Islamic University of Technology (IUT).

Authors

Md. Asifuzzaman Khan

ID-170021005

Md. Arean Ashfaq

ID-170021043

Md. Kazi Sazzad Ahmed

ID-170021147

Table of Contents

List of Figures

List of Hardware & Cost

MPU 6050 IMU …………………………………………………………..BDT 250

IRF9540 MOSFET x 4……………………………………………………BDT 90 x 4

IRF540 MOSFET x 4……………………………………………………..BDT 70 x 4

HC-05 BT Module x 2…………………………………………….......BDT 345 x 2

Motor driver PCB………………………………………………………..BDT 410

Arduino Nano ……………………………………………………………..BDT 600

Wemos D1 mini ………………………………………………...................BDT 440

Breadboard x 2……………………………………………………………BDT 170 x 2

RC model Car……………………………………………………………..BDT 650

Wires………..…………………………………………………………….BDT 120

Op Amps………..…………………………………………………………..BDT 50*6

List of Acronyms

IMU	Inertial Measurement Unit
MEMS	Micro-ElectroMechanical System
MOSFET	Metal-Oxide-Semiconductor Field-Effect Transistor
RF	Radio frequency
OTG	On The Go
BT	Bluetooth
GPS	Global Positioning System
ML	Machine Learning
DMP	Digital Motion PRocessor
DLPF	Digital Low Pass Filter
SOC	System On Chip
PCB	Printed Circuit Board
RT	Real Time
OP AMP	Operational Amplifier

Acknowledgements

All praises are for **Allah** for blessing us with the knowledge and ability to do this thesis. He is the Most Benevolent and the Most Merciful and our utmost gratitude must be to Him.

We wish to express our deepest gratitude to our academic and research supervisor Dr. Golam Sarwar, Professor, Department of EEE, IUT for his constant guidance, supervision and invaluable life lessons and suggestions during the entire thesis work.

Abstract

Reckless driving of public transport in third world countries like Bangladesh has long been an unsolved issue. One of the reasons being the lack of constant monitoring of the driver's driving style. Present solution to this is to use a constant monitoring device onboard the vehicle to assess the driver's performance. They use onboard neural networks to analyze various driving data pattern collected from the suite of sensors on board the car. However the use of onboard neural network increases the computational complexity and demands for expensive processor. Moreover the suite of sensors used such as GPS, Steering angle sensor, IMU adds to the cost. This makes them a not so viable option for mass use in the roads of a underdeveloped country like Bangladesh. Here in this paper we propose a plug and play device that can analyze the driving behavior in real-time using an onboard low level processor and 2 low cost sensors. This process eliminates the need of onboard neural network. A test bench is setup for simulating the various driving patterns and the collected data is compared with the published studies to validate the method. Then the methodology is explained in details. Finally the whole system is tested with the collected data and result is analyzed. .

Chapter 1

Introduction

Low income countries like Bangladesh faced lack of governing bodies due to the privatization of public transportations. Emergence of tough competition for profit, lack of lability and unpredictable road conditions make it unrealistic for evaluation on law enforcement basis by the limited number of traffic police stationed on duty. So an automated system that constantly monitors the public transports is a situation demanded.

1.1 Traffic and road situation

Generally speaking, Bangladesh now has one of the most difficult driving conditions in the entire world. Dense population plays a key role in this regard and is critical for the current conditions now seen on the road.

Secondly, there is a lack of road planning and traffic infrastructure. Major city roads are met with unsafe and erratic junctions. Insufficient number of lanes in major connecting roads chokes even if they barely reach rush-hour traffic.

Lane allocation is non-existent or very poorly managed given that it does exist. This imposes a key role in the non stationary clogs we see in everyday traffic. The streets are filled with vehicles with different movement characteristics, size or propulsion method. Leg-cranked rickshaws occupy many of the major roads in dhaka. Disruption caused by a swift lane change thus results in a dommonio effect among vehicles that translates to major delay in junction clearance or systematic discharge of vehicles.

All these factors with uneducated public bus drivers and personal chauffeurs makes roads of Dhaka a very unsafe place to drive or commute.

1.2 Condition of public transports

Shifting our focus on the biggest contributors of traffic jams and road casualties in Bangladesh. Bangladesh has developed a privatized public transportation scheme from the dawn of its independence. That means each route is served by different privately owned companies who run multiple vehicles traversing the entire route for passengers on every major point on the basis of vacancy within the vehicle. Here, the issues related to this systems are,

- unpredictable bus schedules
- no guarantee of vacancy
- cramped seating arrangement with passengers standing
- unsafe boarding and unboarding of passengers
- toxic competition for passengers and racing mentality
- no regulation for passenger comfort

Buses are the mostly used public transport of the masses in Bangladesh. There are generally 2 types of buses that roam the roads of the Capital. One is the European Standard 8M_Mid-Bus and the other is the City Bus. Their respective properties are given below in table 1.1.

Table 1.1

Properties	**8M_Mid Bus**	**City Bus**
Passenger capacity	16 - 26 seats	38 - 42 seats
Chassis	FAW CA6730CRD21	HINO RK8JRSK
Average Length	7, 865 mm	11,850 mm
Average Width	2,220 mm	2,470 mm
Average Height	2,950 mm	

A typical scenario inside the public transport of Bangladesh is shown in figure 1.1

Figure 1.1

1.3 Background and Motivation

The sheer spectacle Dhaka shows during rush hours and the countless hours spent motivated us to indulge in the topic to find a suitable solution for traffic in this city. Our research hopes to imply a proper governing scheme that will enforce drivers to follow a few basic rules.

There have been many incidents shaking the entire country involving public buses and daily commuters. Like many other families from our country, we were not different. Our friend's loss on december of 2019, inspired us to do proper work on this particular road condition and traffic law situation.

Chapter 2

Literature Review

2.1 Situational Incompatibility Of Existing Models

Nearly all of the behavior recognition models require complex computation making the need of expensive hardware mandatory. Moreover, the acceleration data from the vehicles are considered to be obtained from a smooth surface road. that does not incorporate road condition based driving modulation and dependency on passenger comfort.

Audacity is based on many factors other than erratic accelerating tendency. But it is a mathematical function with variable dependency like lane blocking, stop elongation, unsafe boarding. Lanes of a particular road are not strictly regulated. Sudden lane changes, many times with intent to block, is a major contributor in traffic jams if we evaluate the matter on a cause and effect basis.

We had to come up with a solution that will incorporate these factors in our final audacity score evaluation. This score will directly reflect on the contribution to road congestion. Other models, especially neural networks[1], tend to be very effective in recognizing faulty patterns on the basis of a singular sensor parameters, sometimes a handful together[2]. But either way, they recognize the discrepancy in the maneuvering to identify faulty ones. They have, now at this point, become very effective in identifying dangerous, harmful, and not exaggerating, lethal patterns, none can be directly related to the amount of congestion they impose on the road.

Moreover, the system is to be fitted on every public transport on the street, in a low income country like Bangladesh. So, it is crucial that we keep the unit cost to be bare minimum. Thus, we were to optimize our algorithm to run on an entry level microcontroller or SOC.

2.2 Our Sensor Suites

2.2.1 MPU 6050 MEMS IMU

MPU 6050 is a MEMS 3 axis (X,Y,Z) accelerometer and 3 axis (X rotation, Y rotation, Z rotation) gyroscope manufactured by InvenSense™. It includes a digital motion processor (DMP) and a digital Low pass filter (DLPF). A MEMS IMU works on the simple basis of Newton's third law, that is every action has an equal and opposite reaction. When the module is accelerated in positive direction it logs an equal acceleration in the negative direction. So a vehicle's acceleration can be measured by setting the IMU aligned with the corresponding axis of the vehicle. The onboard Low pass filter can be programmed to set necessary filtration parameters. For this project the DLPF Bandwidth was set to 5Hz. This value is chosen considering the vibration from the IC engine and road vibration. The onboard DMP helps to read absolute acceleration on the 3 Axis. Absolute acceleration ensures that the acceleration value is compensated for gravitational acceleration on the 3 Axis. This is done by calculating the gyroscopic correction angles by the DMP and the corresponding acceleration values.

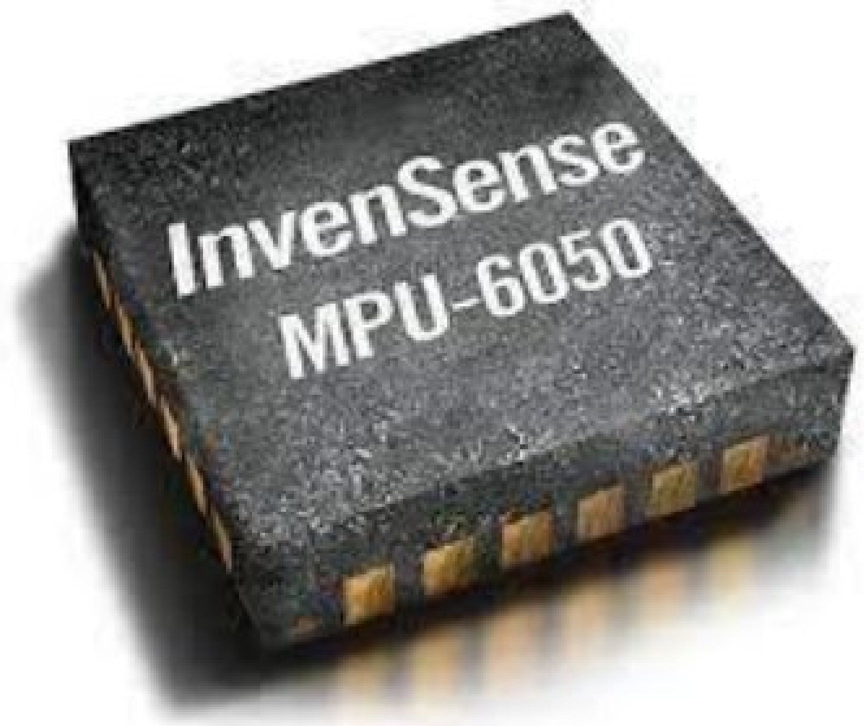


Figure 2.1 (a)
InvenSense chip

Figure 2.1 (b)
MPU6050 Module

2.2.2 RF Transceiver Module

This module is a custom made device that enables lane detection. It consists of a 1.413 KHz transmitter and receiver module. The transmitter module creates radio frequency of 1.413 KHz. When the receiver module is within a certain range of the transmitter it detects the RF signal and latches a digital output indicative of the proximity. The TX module is set on the guard rail of the roads and the receiver is setup onboard the vehicle. This allows the detection of vehicles on the right or left-most lane. The Transmitter and Receiver is shown in figure 2.2 (a) and (b) respectively

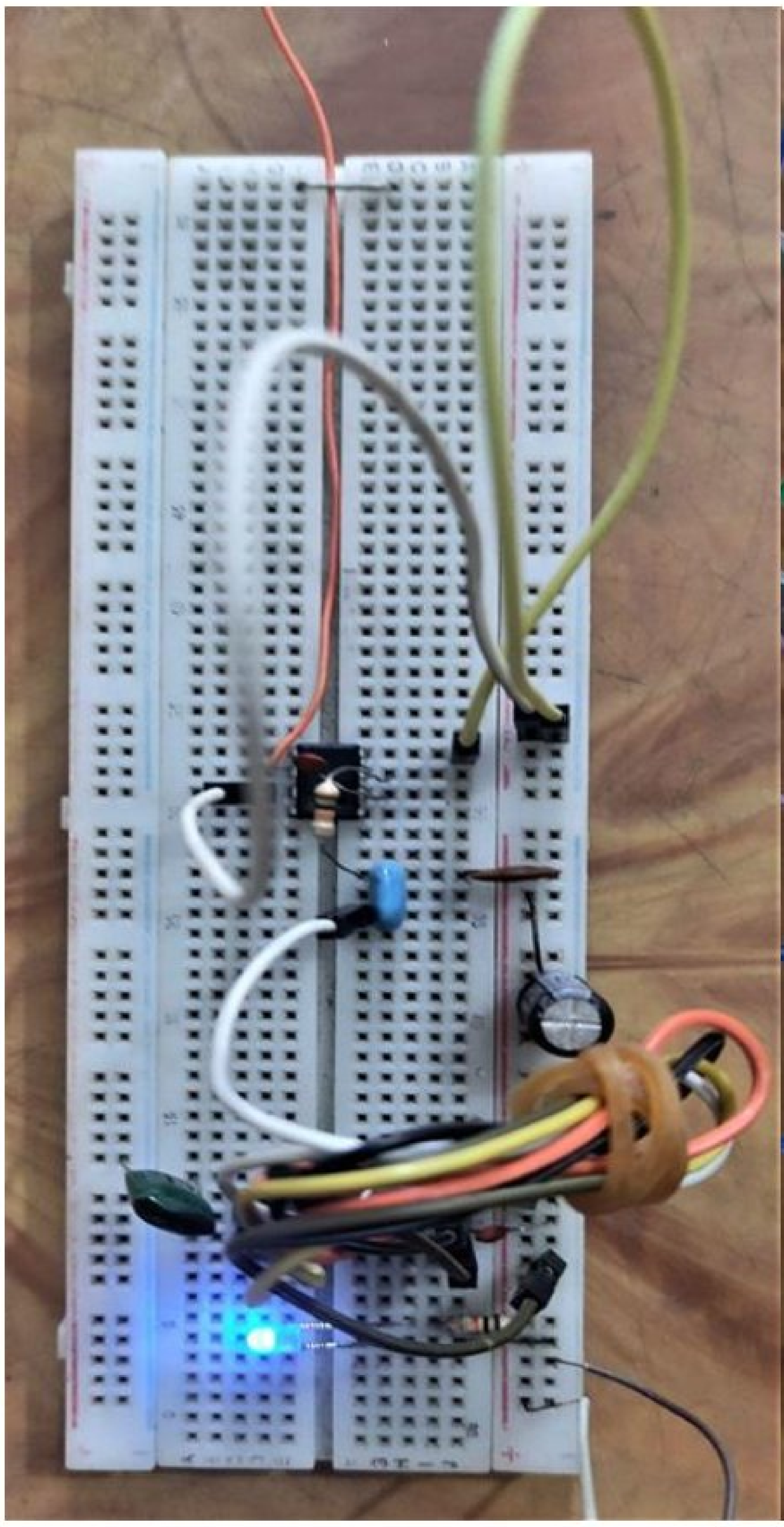


Figure 2.2 (a)

Tx Module

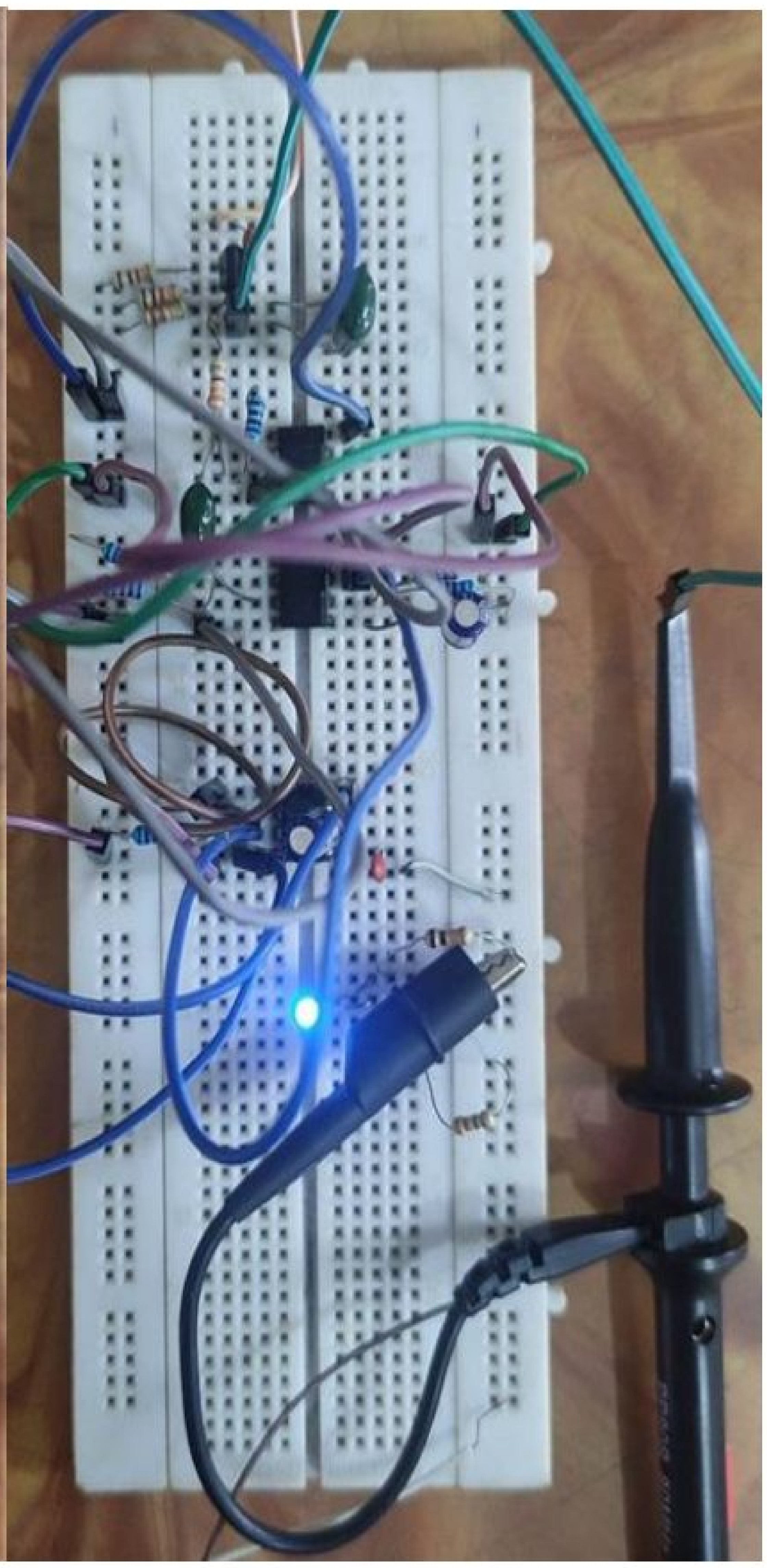


Figure 2.2 (b)

Rx Module

Chapter 3

METHODOLOGY

Our goal is to implement the modular CAN BUS setup at every vehicle at a very wide scale (nationwide in most cases). So, affordability, scalability, robustness, reliability. The system must withstand roads with little to no network availability and ever changing road conditions. Not to mention the on board module as well as the total infrastructure should be very affordable.

Inclusion of a powerful onboard computer will increase the price of each onboard unit drastically. Thus we skip mass calculation to the servers, not the onboard system. Need of network access, GPS and big unfiltered dataset may limit the network/processing bandwidth. questioning the future option for scalability.

By using off the shelf parts and incorporating modular design schemes we plan to maximize robustness and repairability.

By making data-driven decisions through algorithmic procedures we plan to increase accuracy of stamped driving cases.

3.1 System Overview

At a single system cycle, our system,

1. acquires data
2. filters data
3. checks previous holding conditions
4. sets threshold
5. compares data
6. calculates penalty score

The audacity evaluation is based on the amount of accumulated penalty score over a specified period of time defined by the governing authority. Preferably in a month due to the small size of stored data and comparable complexity in data collection for archiving.

Many factors are individually identified and weighted depending on the majority of the fault. (eg. the maximum acceleration in a faulty turn). And class based penalty score depending on that. Then all the penalty scores of different conditions are accumulated at the end of the universal loop.

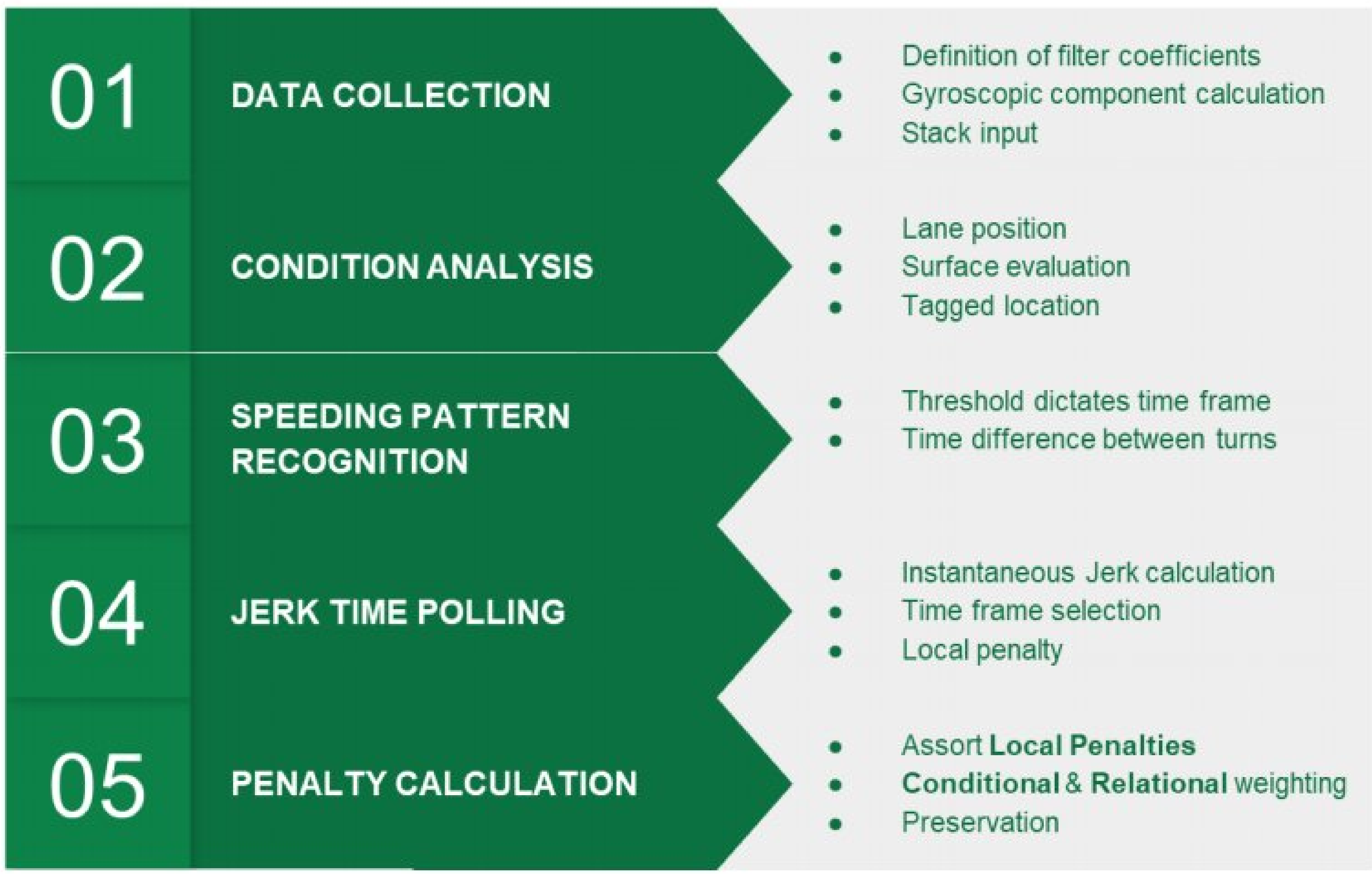


Figure 3.1

3.2 Test bench setup

Most of our research period was occupied by a nation-wide lockdown due to Covid-19 pandemic. So, for the ease of convenience, a test bench shown in Figure 3.2 was set up where various road conditions could be simulated in real life in a miniature scale 60:1.To make matters reliable an RC vehicle was constructed with realistic motion characteristics. Then the obtained data was compared with the published data to assess the feasibility of the test bench and comparing figure 3.6 with figure shows that the test bench behaves similarly to the real vehicle

3.2.1 Miniature vehicle assembly

Features of the miniature vehicles are

1. Non-binary steering control for angle of attack selection. Rock and pinion assembly was implemented. The angle was actuated with a servo with a resolution of 256 steps within 160 degree of angular displacement
2. Regenerative braking system for simulation braking patterns close to the actual drum brakes usually used in local buses
3. Custom preset drive path encoded within the controller for reliable filter variable calculation
4. Suspension modification

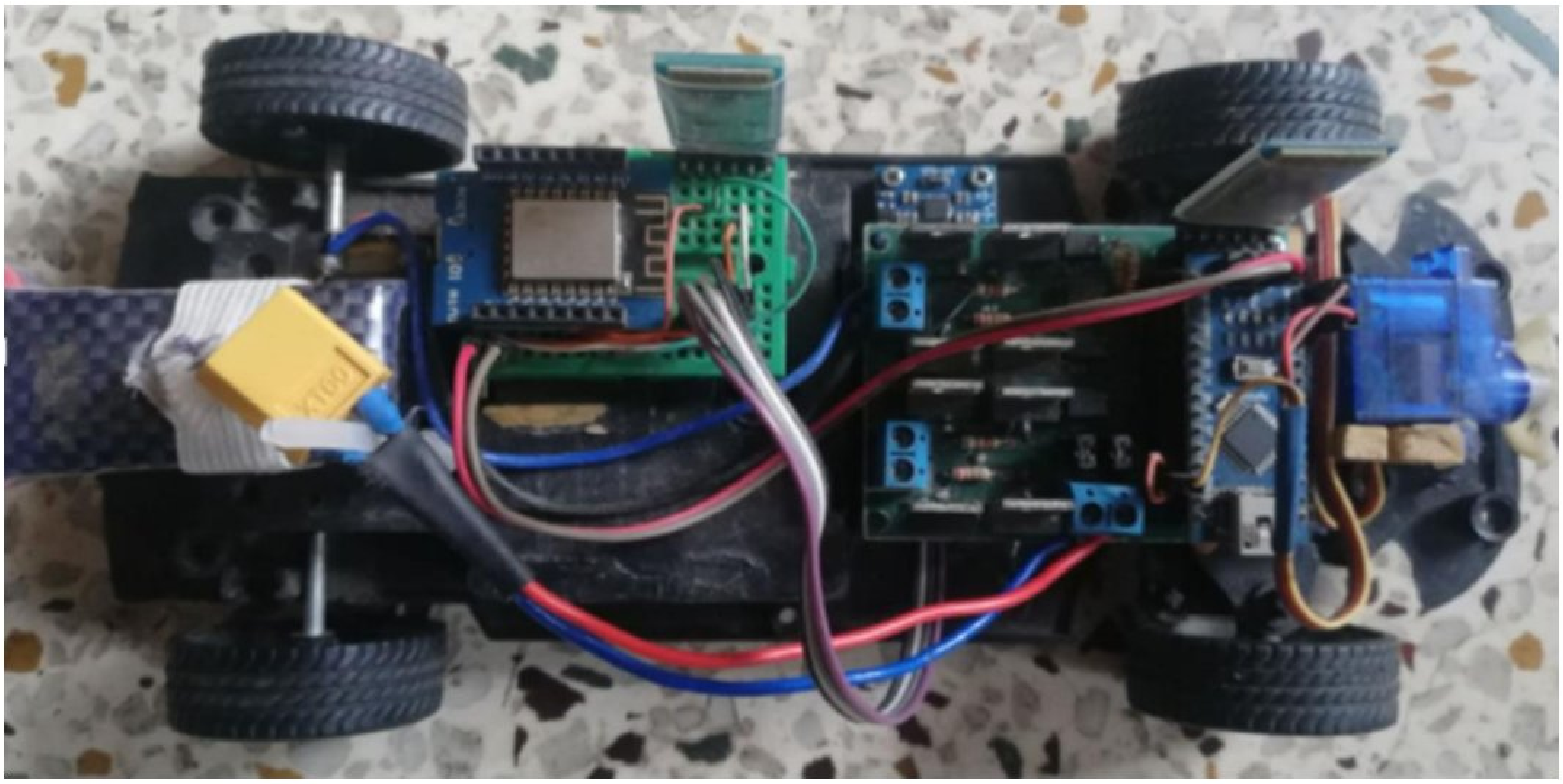
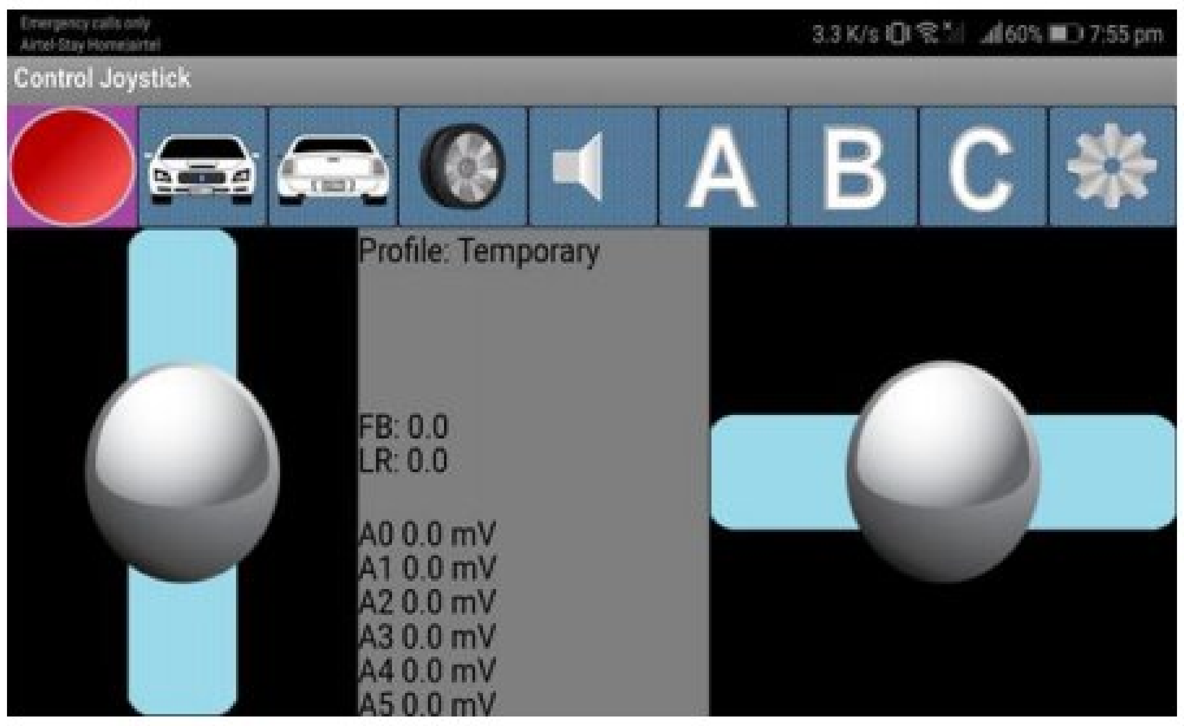


*Figure**3.2***

Top View of the test bench



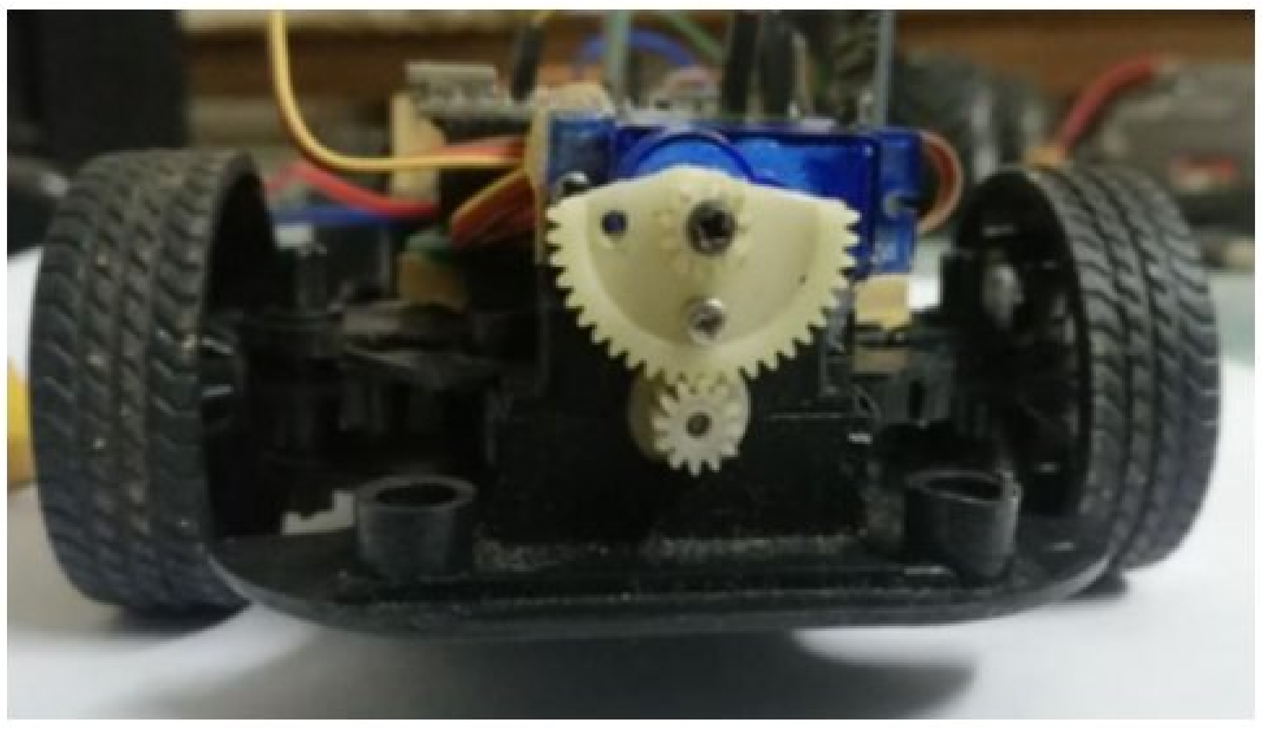


Figure 3.3

Proportional Control Interface

Figure 3.4

Rack and Pinion Based Steering

3.2.2 Axis of Accelerations and Sensor Orientation

Axes in the MPU6050 are defined and marked on the soc itself. Also the detection of turning is most sensitive near the front wheel base as it is due to the centrifugal force created when turning. With these in mind, the sensor was placed as shown in figure 3.5.

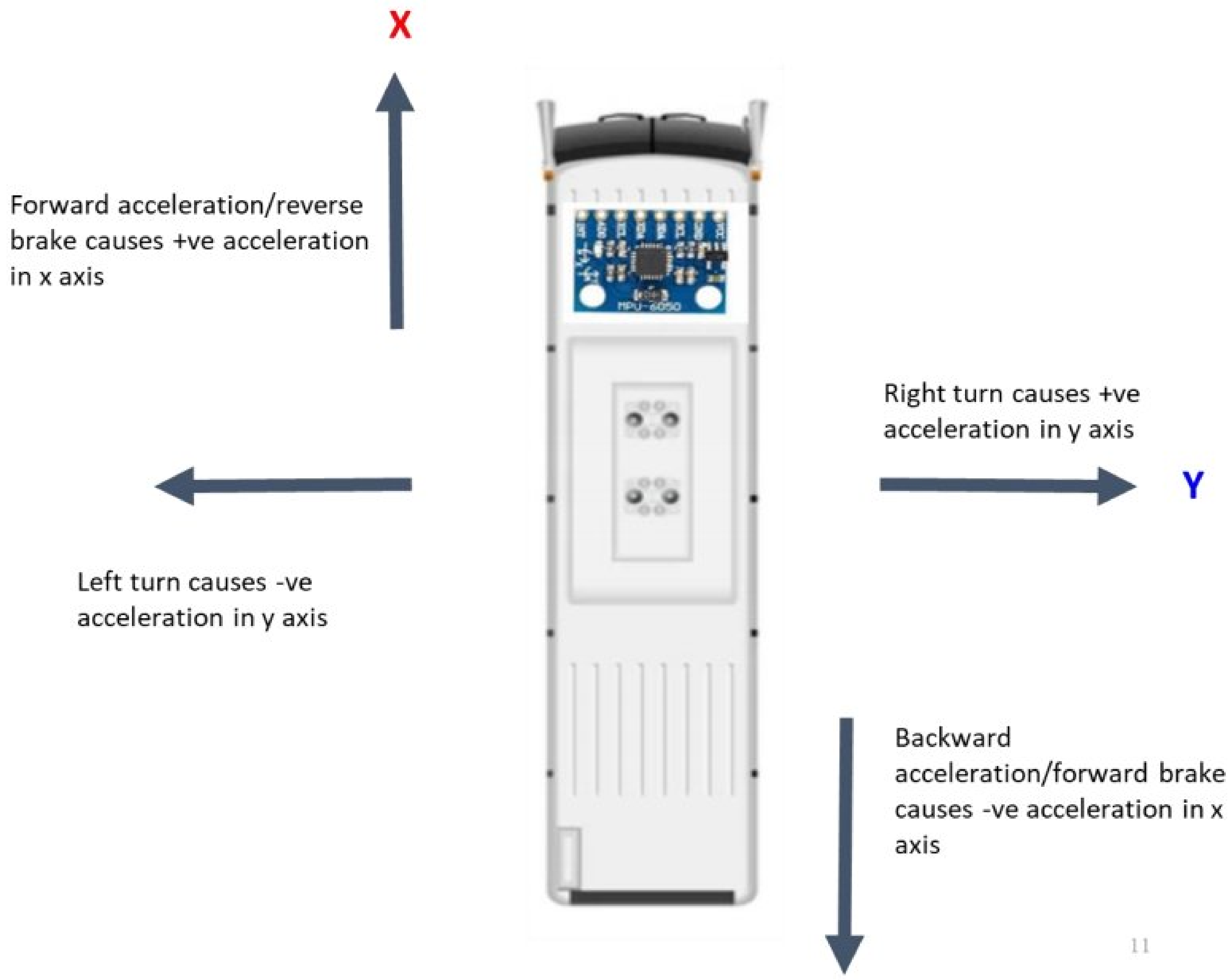


Figure 3.5

Sensor orientation in the vehicle

3.3 Maneuver Pattern Evaluation

Here in this document driving pattern is referred to the various patterns that are generated when acceleration is plotted against time for different driving maneuvers. For example: Braking, Turning, Lane changing etc. These types of patterns actually distinguish the different driving maneuvers and the extent of the maneuver.

As stated earlier, we have eliminated the need of neural networks to isolate significant time frames containing harsh movement from the total runtime.

For the flagged actions related directly to the vehicle movement we are considering lateral and longitudinal time series acceleration data as the key factor. Because it can tell a lot about the nature of the movement. The published pattern for Hard Braking vs Normal Braking is shown in Figure 3.6 (a) & (b).

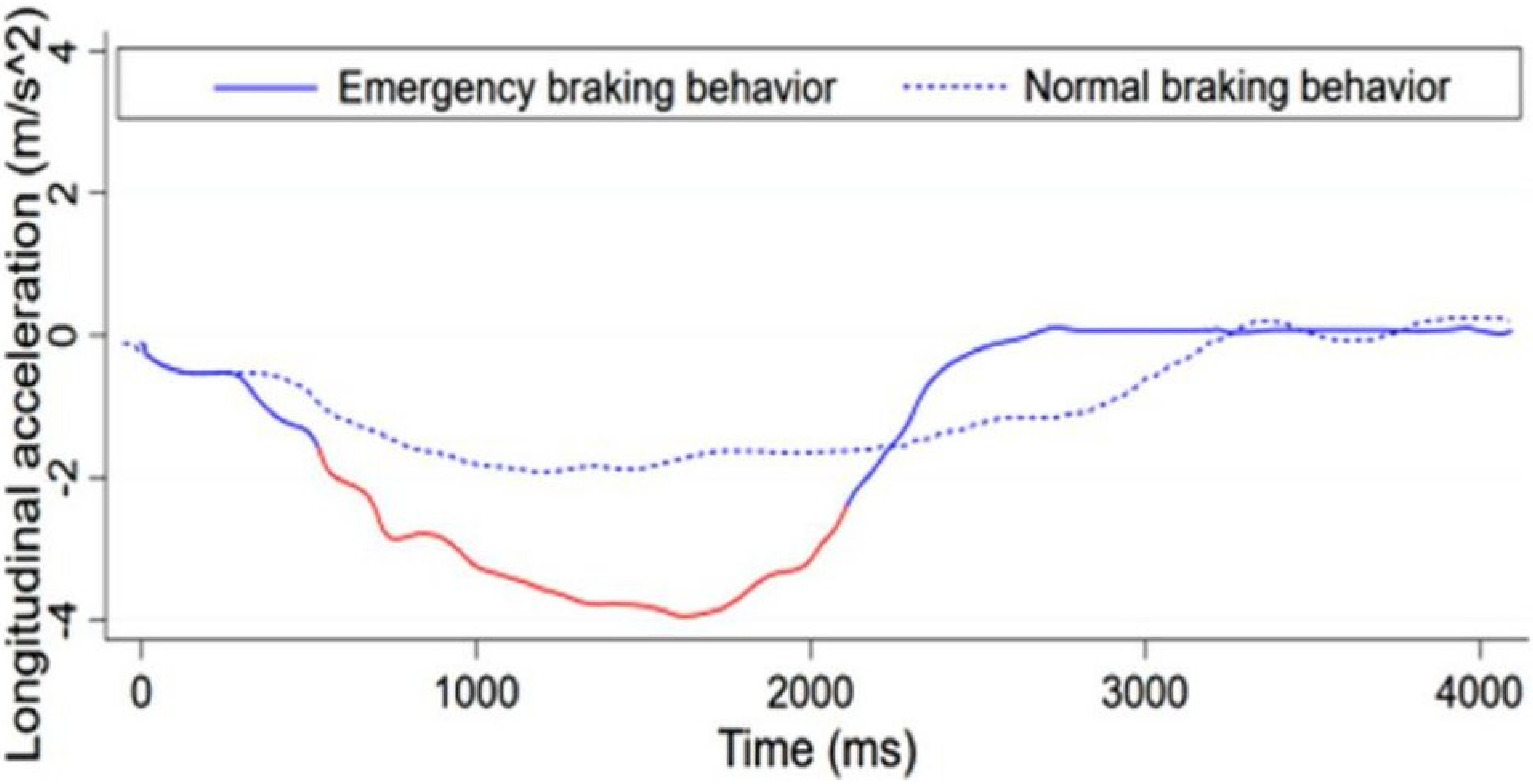


Figure 3.6 (a)

Published data of Normal Vs Hard Braking behavior

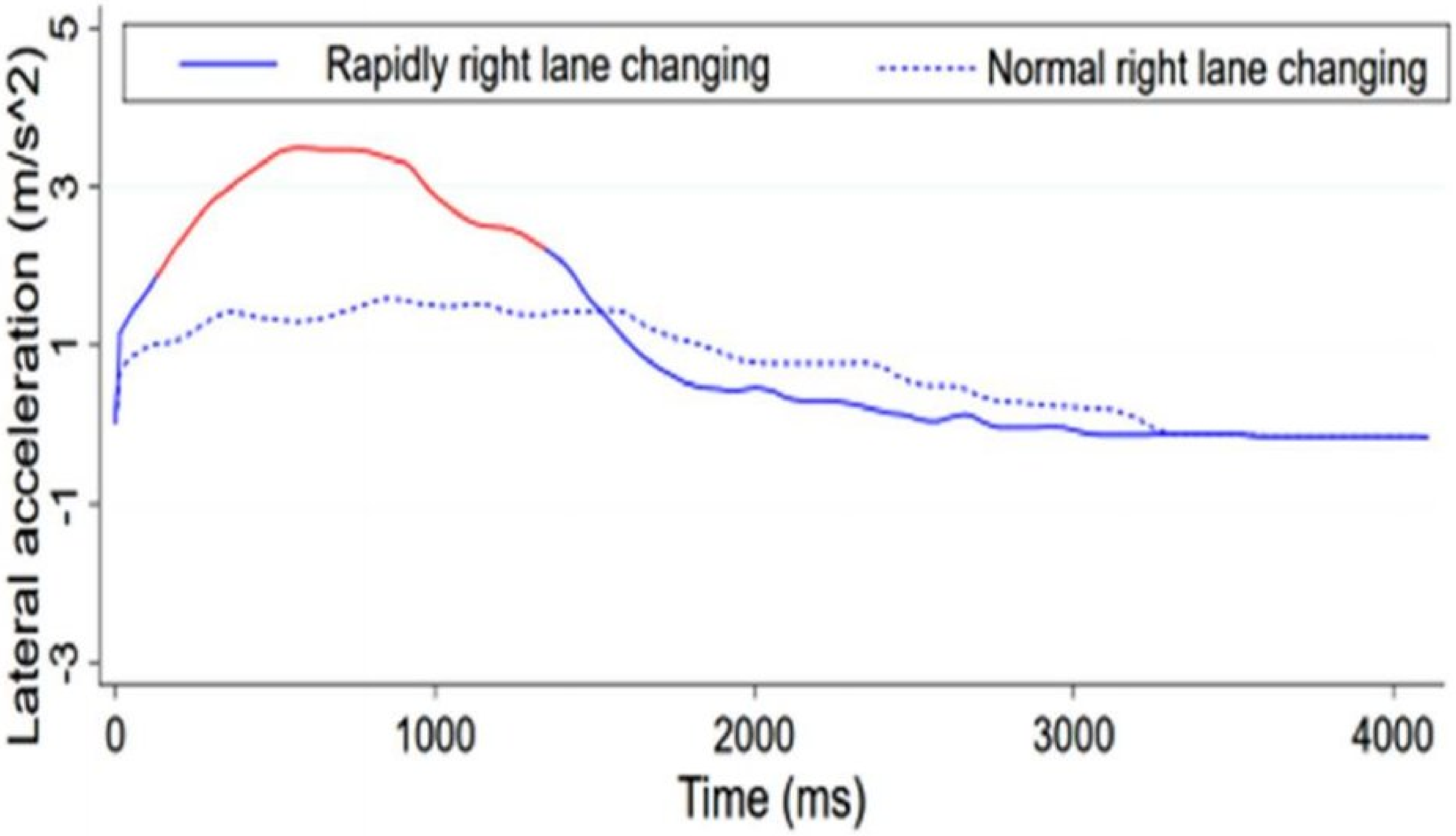


Figure 3.6 (b)

Published data of Normal Vs Sharp right turn

From the figure we can see that the only way a hard/emergency brake differs from a normal brake is that the hard brake's longitudinal acceleration curve has a deeper valley compared to the normal one. And the depth of the valley directly gives us information about the hardness of the brake along with the jerk. Similarly for the case of hard acceleration the condition would be similar. Instead of a valley there will be a peak, and the height of the peak will talk about the hardness of acceleration.

Similarly lateral acceleration data can be used to process flagged actions related to sharp turn and abrupt lane changes.

So using a neural net for detecting the flagged actions related to vehicle movement is not necessary as all the flagged action gives a basic shape when acceleration is plotted against time. The shape is so basic that it can be processed using an algorithm only. So there is no need to invest heavy computational power for machine learning algorithms.

3.3.1 Slope Of Acceleration Time polling

Slope of acceleration is known as jerk. This parameter plays a crucial role in the overall comfort of a ride and may indicate many driving practices in a long referencial time frame. This parameter also imposes a great mathematical relation to the fuel consumed, thus this parameter was taken into consideration and identified and separated not differently from the acceleration patterns.

The algorithm also neglects the gear shifting delays and transmissional thrust. The process calculates,

1. Duration of the faulty jerk (neglecting the transitional periods)
2. Maximum amplitude of the jerk within that instance
3. Elimination of the frame and archiving with RT stamp

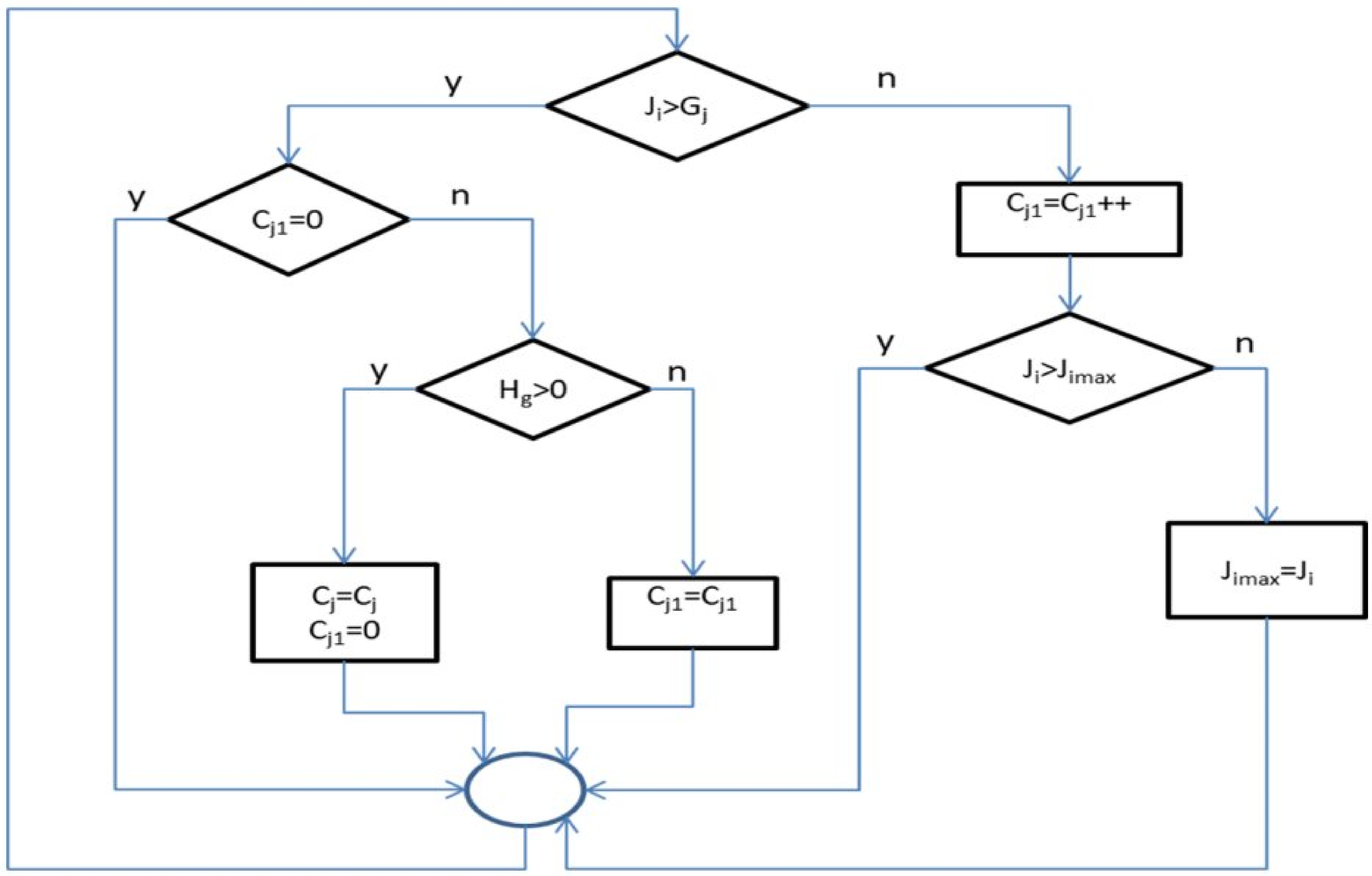


Figure 3.7 (a)

Time polling algorithm for jerk assessment

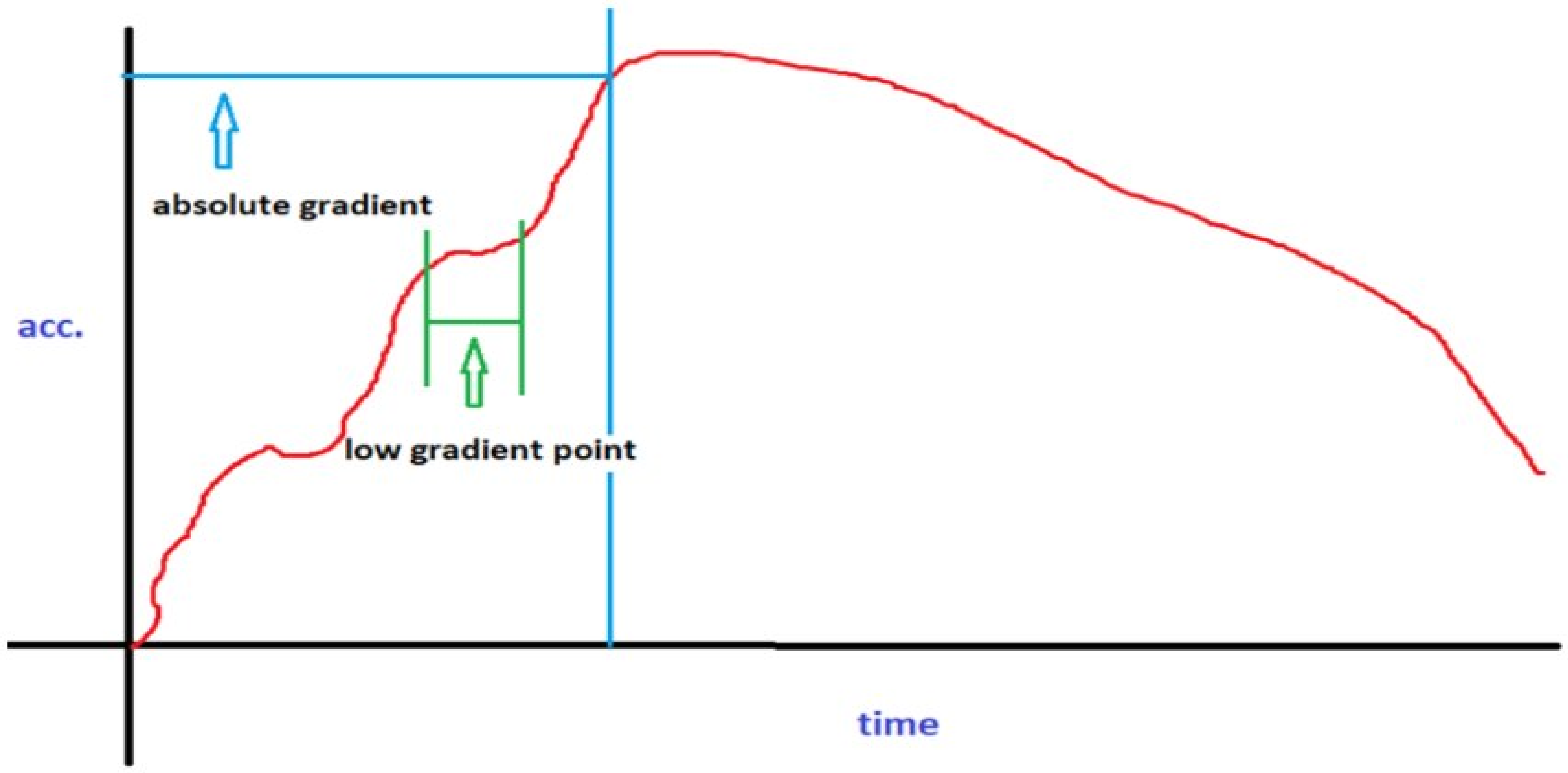


Figure 3.7 (b)

Curve of jerk

Here, G' = weight for normalized max jerk

G'' = weight for polling time

Gj = Permissible max jerk

3.3.2 Harsh Brake, Turn & Collision assessment algorithm

This algorithm constantly monitors the acceleration reading from the X and Y axis of the accelerometer detect Harsh Brake, Turn & Collision assessment algorithm. The algorithm shown in figure is only for braking assessment. However, the algorithm is same for the turning assessment portion also. Here the governing variables are:

1. AT = Acceleration Threshold
2. CTRT = Cost to time Ratio Threshold
3. time = elapsed time after threshold is crossed

AT is set by the standard described in www.copradar.com[3]. It is subject to change according to law and vehicle types. For example the handbrake threshold for a mini bus and an intercity bus may not be the same. For Brake and collision assessment the threshold relates to breaking acceleration threshold and for turning it relates to centrifugal acceleration threshold due to turning.

Cost to time ratio is an experimental value and subject to change according to law and vehicle type.

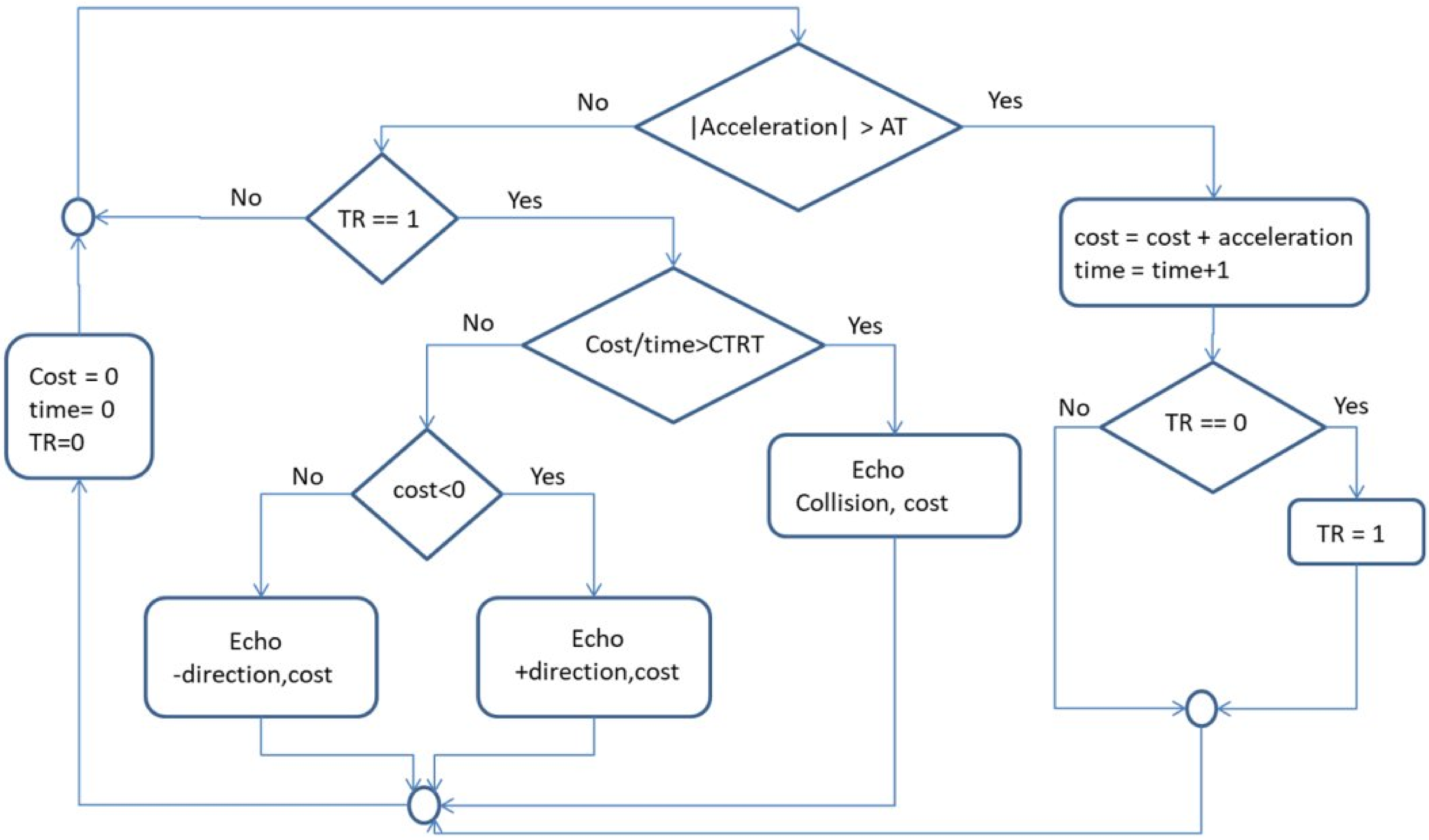


Figure 3.8
Harsh Brake assessment algorithm

3.4 Lane Detection

GPS data was not suitable for accessing the relational position of the vehicle with respect to each lane. So, a system was to be designed to determine the lane position of the vehicle along the entirety of the routes at a specific interval. The optimized interval in this case could not be determined due to the imposed regulated transport law due to Covid-19 pandemic.

One side (Suitably left side) will be decorated with RF transducers which will radiate a synchronous 1.413 KHz sinusoidal EM wave continuously. Every participating vehicle will be fitted with a receiver tuned to that particular frequency. The amplitude of the received signal will translate to the relational distance between transducer pairs according to a predefined reference value.

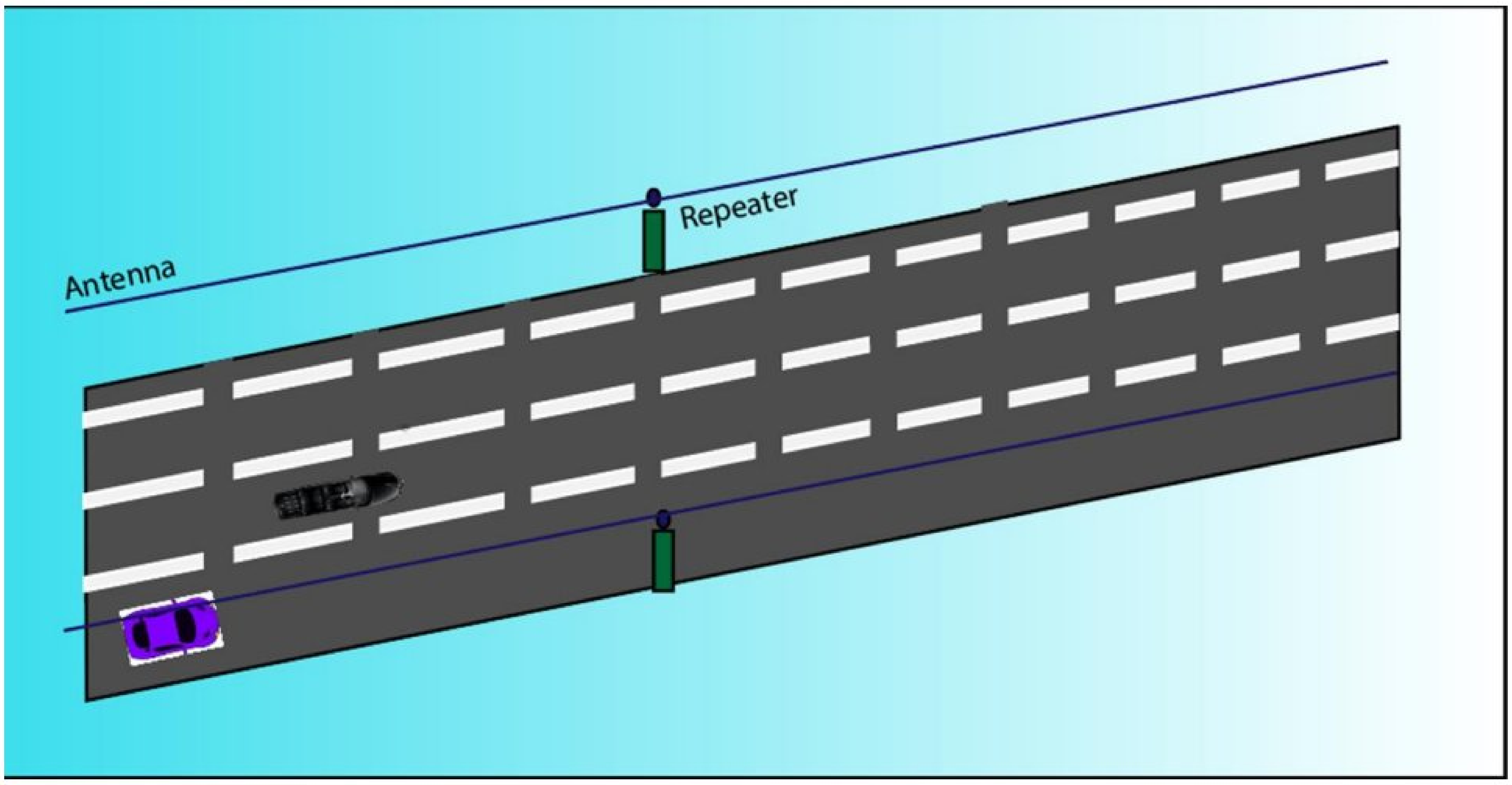


Figure 3.9

Placement of transmitter wire along roadside

3.4.1 RF BEACON (Transmitter)

Each transmitter unit is constructed with two ics and a few auxiliary components. Its purpose is to regulate the input voltage and emit a sinusoid of 1.431 KHz through an antenna built into the PCB.

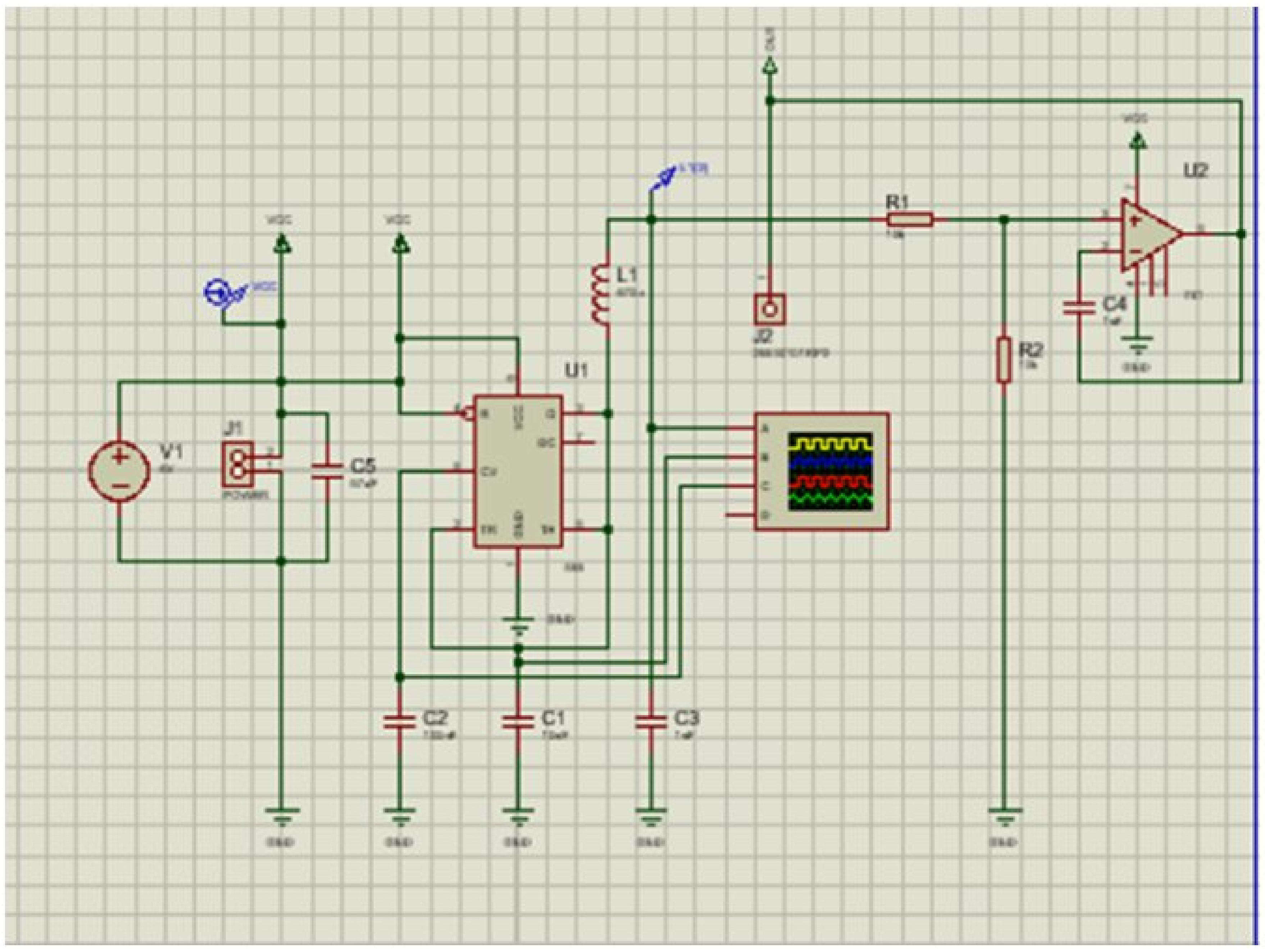


Figure 3.10

Circuit diagram of the transmitter

Firstly, we regulate the input voltage to the total circuit. The oscillator circuit is an NE555p timer chip working in astable mode. Thus input voltage regulation is crucial as it changes the charge and discharge time of the capacitor.

Next, the 1.413 KHz square wave is fed to an RLC chain with its natural frequency tuned to that one.

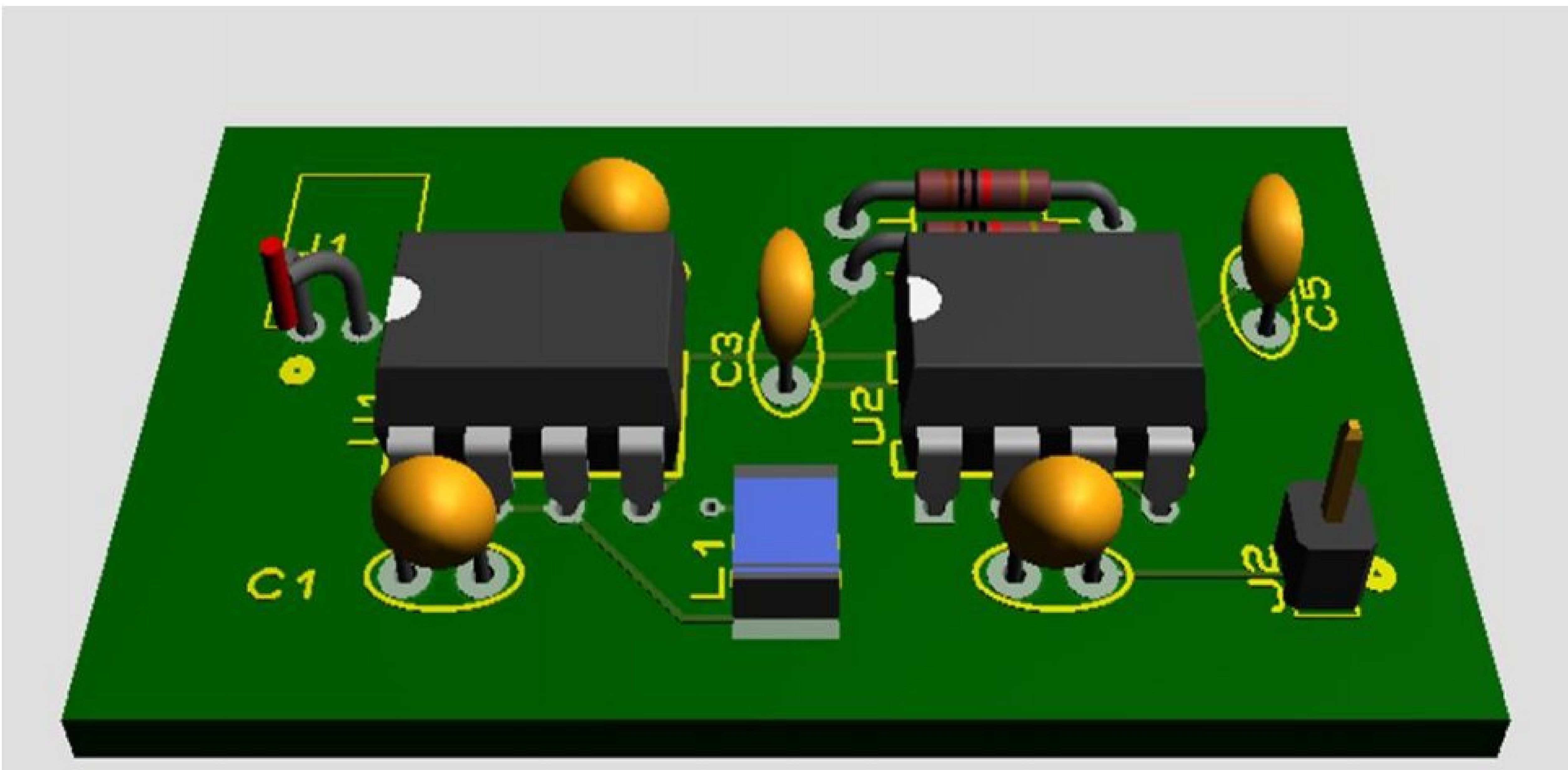


Figure 3.11

PCB design of the Transmitter module

3.4.2 RF Decoder (Receiver)

Special care was given to keep the cost to the absolute minimum. We also had to decode the received signal with respect to the amplitude on the module itself to reduce the computation time in the SOC. So, the receiver module is able to output a logic level digital signal according to the proximity from the beacon. Thus, making the microprocessor's job much easier.

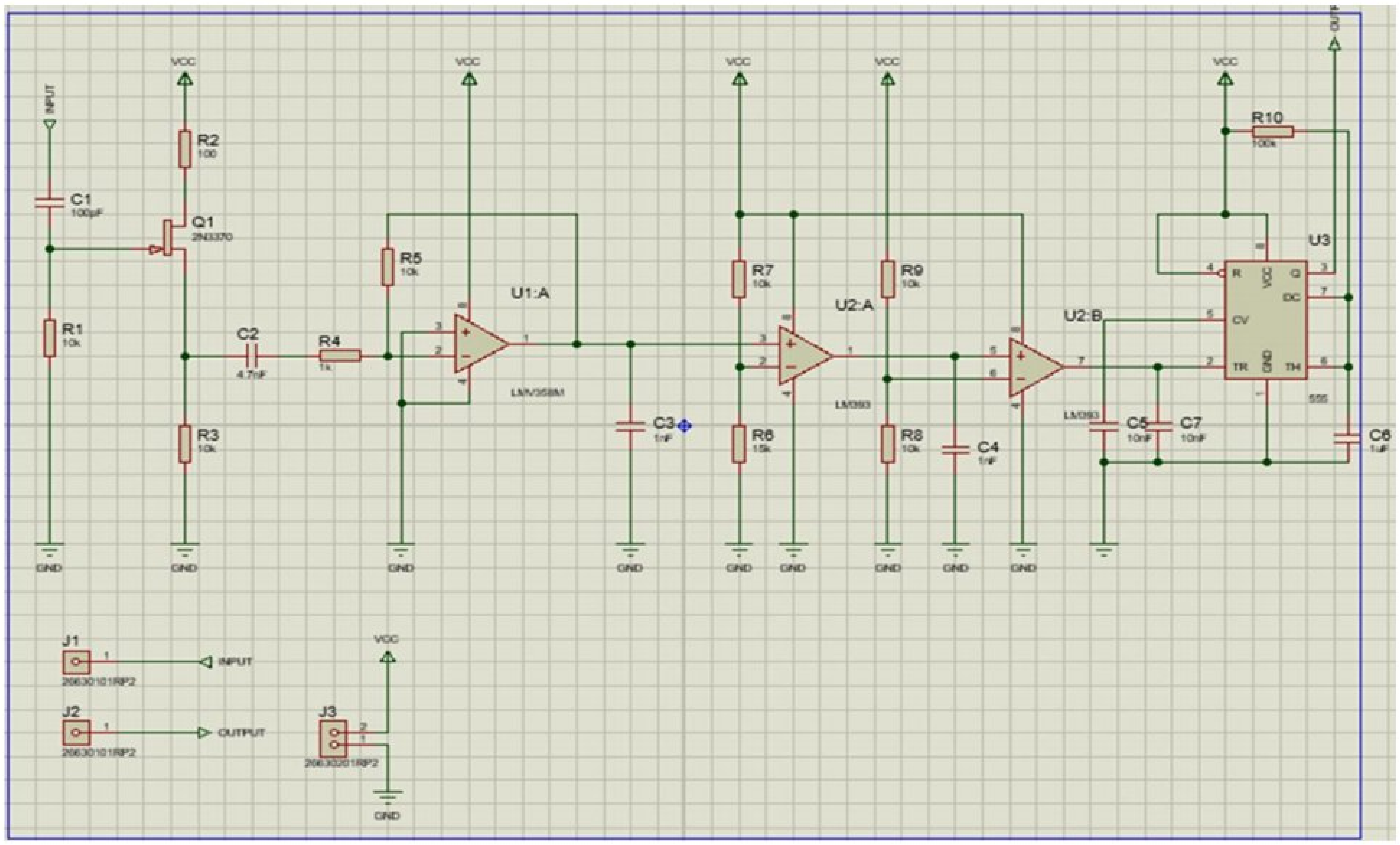


Figure 3.12
Circuit diagram of the Receiver

The signal enters the first stage of amplification from the antenna through the signal level NPN transistor. The next stage of amplification is done by an OP AMP in inverting configuration. We have used an LM 741 for our use due to its availability.

After amplification, the pulse is directly routed to a NE 555P IC's trigger pin. The universal loop in the system has a duration of approximately 80 ms. The latching timer circuit latches the signal for another 110 ms. Giving the microprocessor enough time to pole its input.

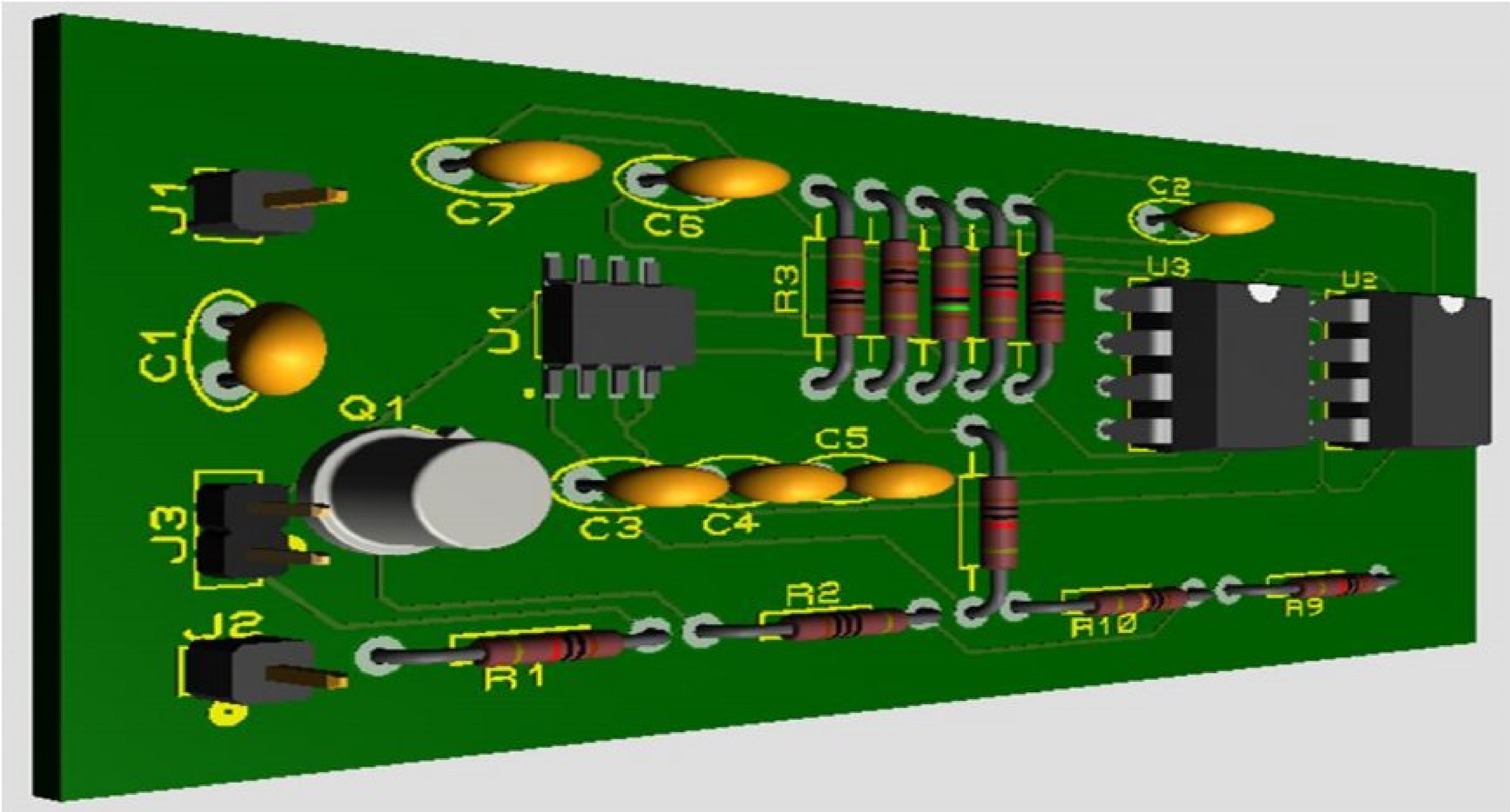


Figure 3.13
PCB design of the Receiver module

Chapter 4

Result Analysis

4.1 Rc model curve vs real car-mounted curve

The published data [1] of a braking maneuver pattern was shown previously in figure 3.6 (a) and turning behavior in figure 3.6 (b) . The braking pattern from our test bench is given in figure 4.1 (a) and sharp turning behavior is given in figure 4.1(b) . We can see the pattern shapes are similar. So the two curves are very comparable for both cases although the test bench data is less filtered. General discrepancy due to noise between the readings is canceled out since we are taking the area under the curve and is negligible**.** The portion of filtration is kept as a scope of future work.

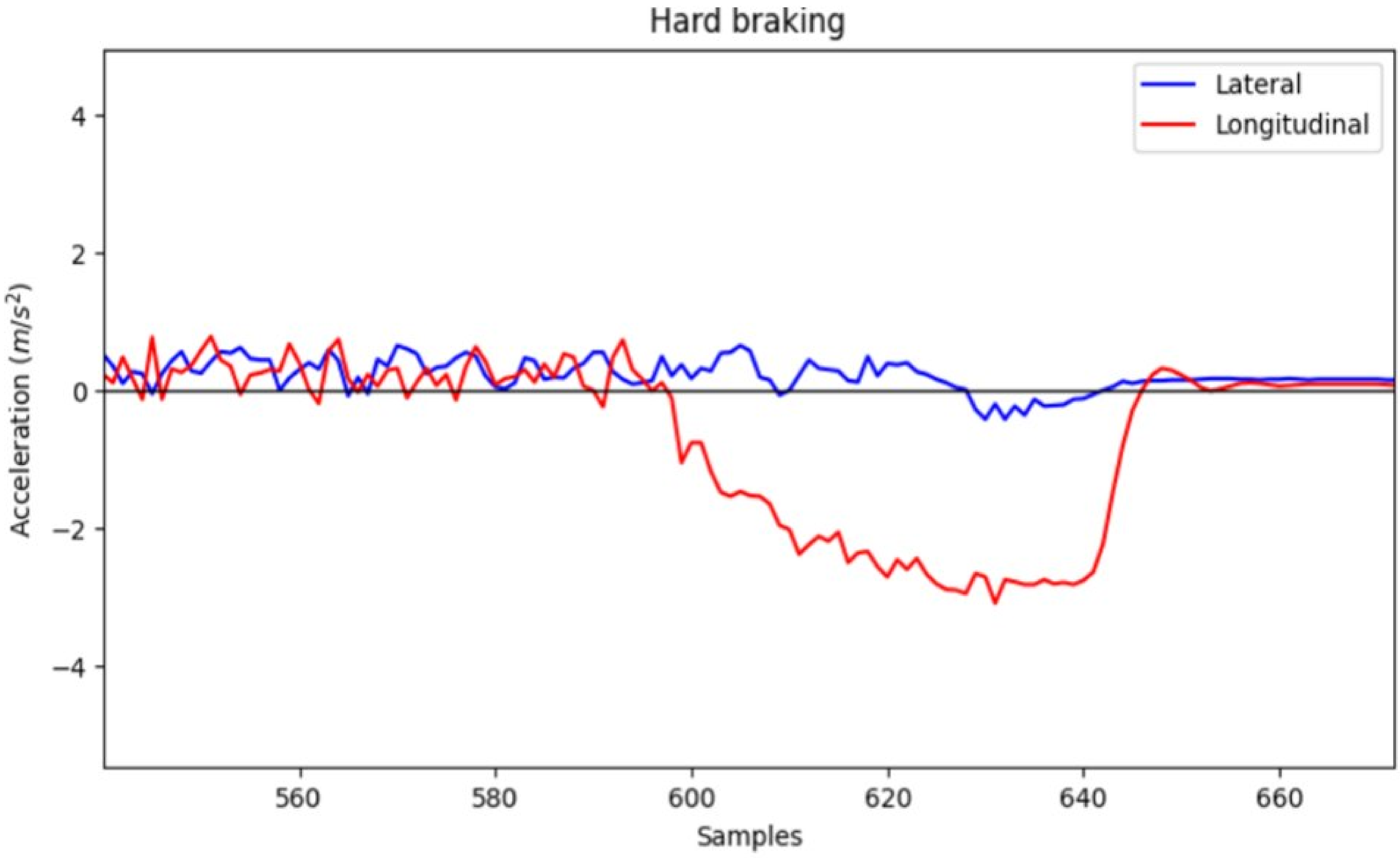


Figure 4.1 (a)

Braking maneuver pattern in test bench

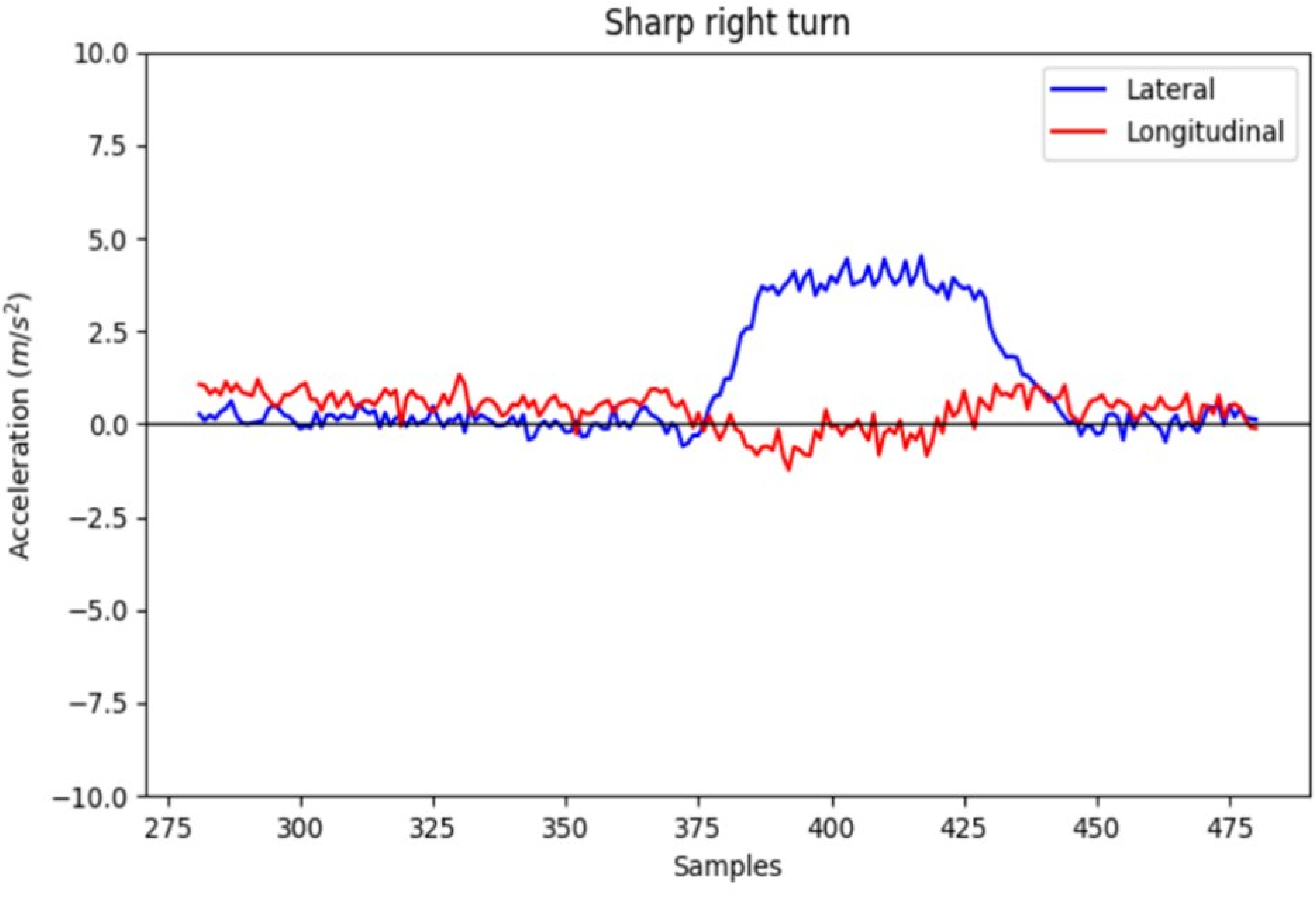


Figure 4.1 (b)

Turning maneuver pattern in test bench

4.2 Rc model curve vs real carmounted curve

There was little room to get onboard data due to the pandemic. But the speed curve of the test bench was modded in such a way that it matches the real life conditions. The acceleration data collected from the real vehicle is given in figure 4.2 (a) and from the test bench is given in figure 4.2 (b). The patterns matches , but the testbench is noisy while the real car data is filtered with a software lowpass filter.

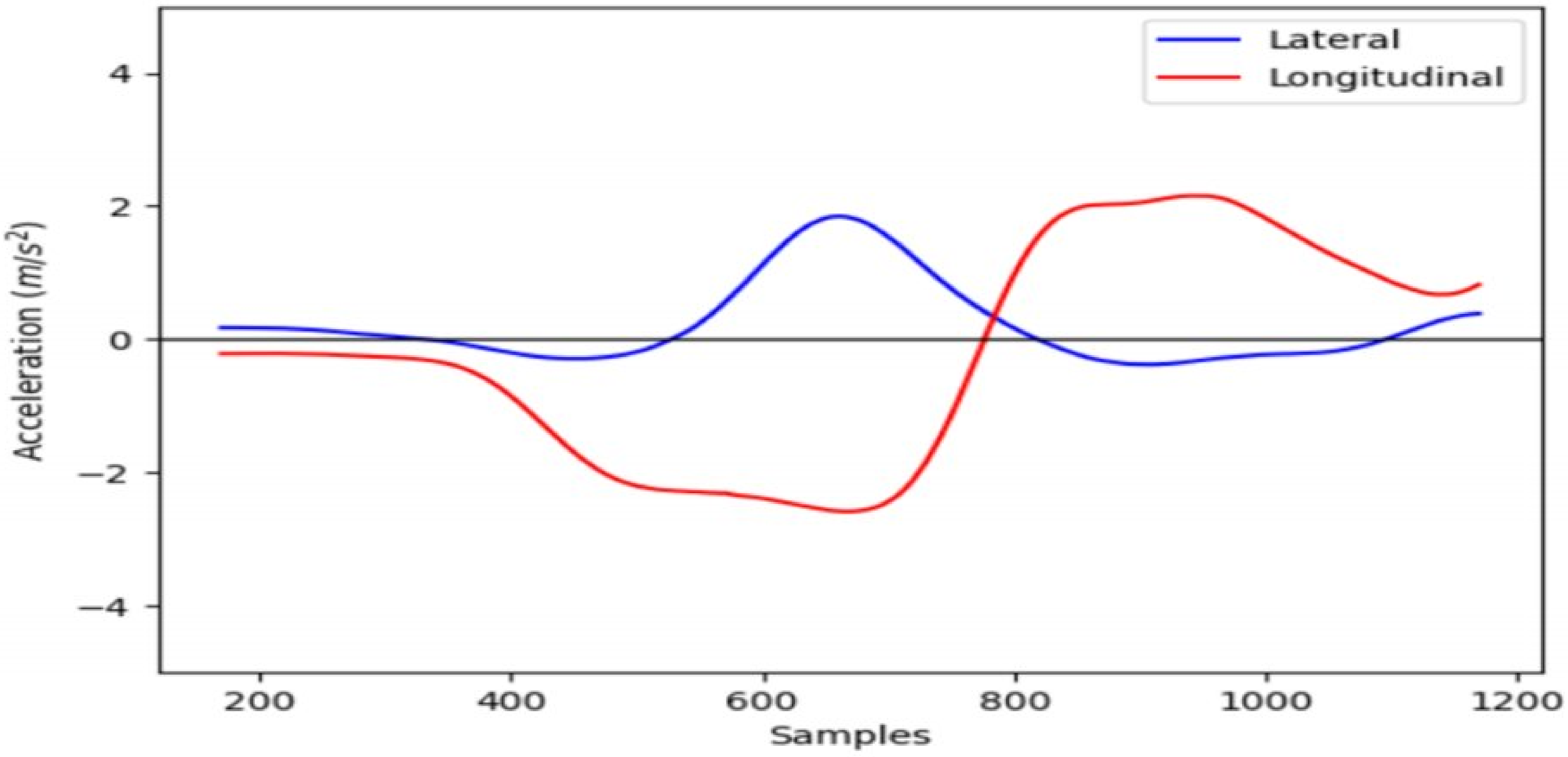


Figure 4.2 (a)

Accel followed by brake maneuver pattern in real car

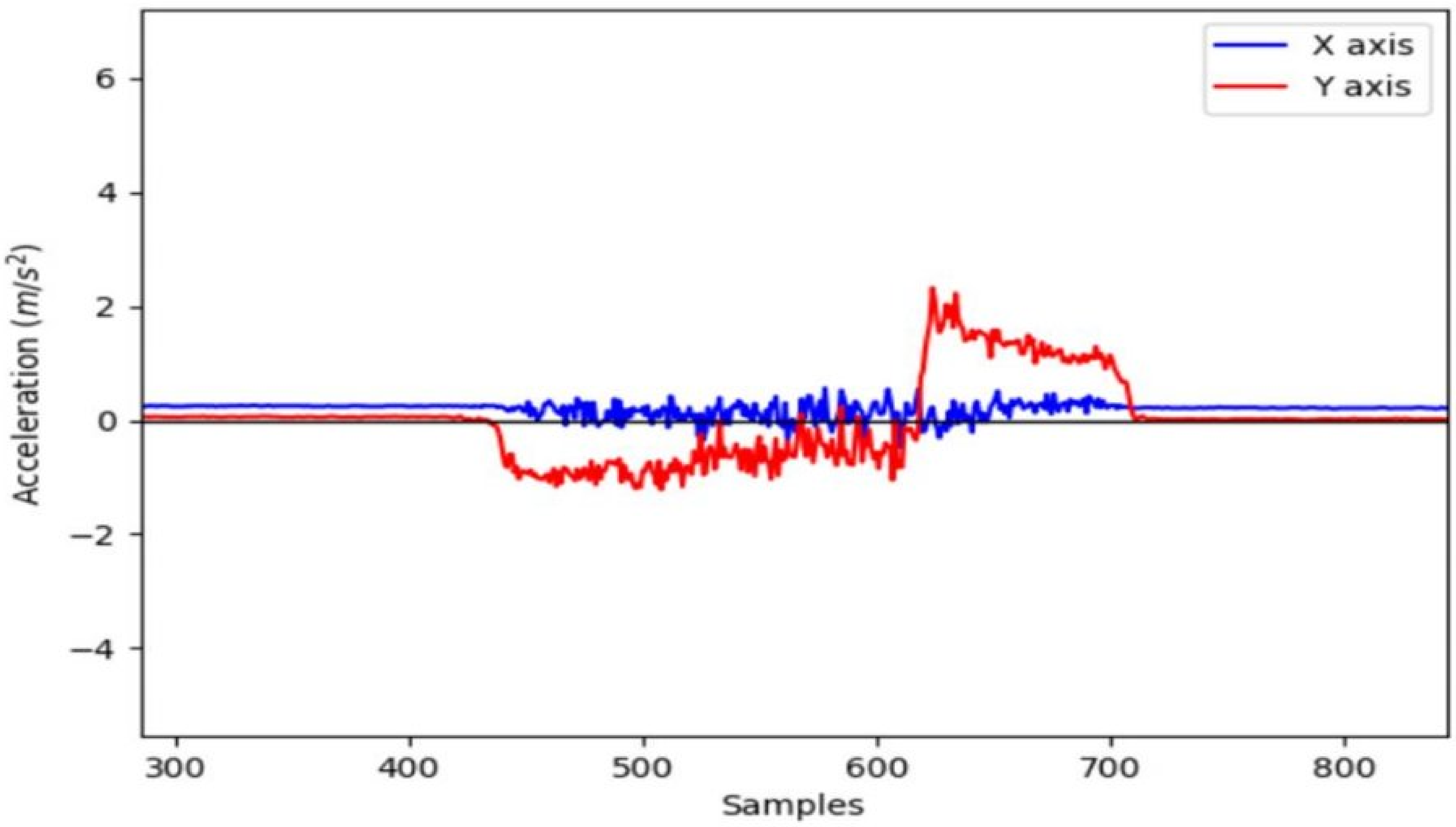


Figure 4.2 (b)

Accel followed by brake maneuver pattern in test bench

The turning data collected from the real vehicle is given in figure 4.3 (a) and from the test bench is given in figure 4.3 (b). They also match with each other. We have plans to further tune our governing variables to match the realistic curves more vividly.

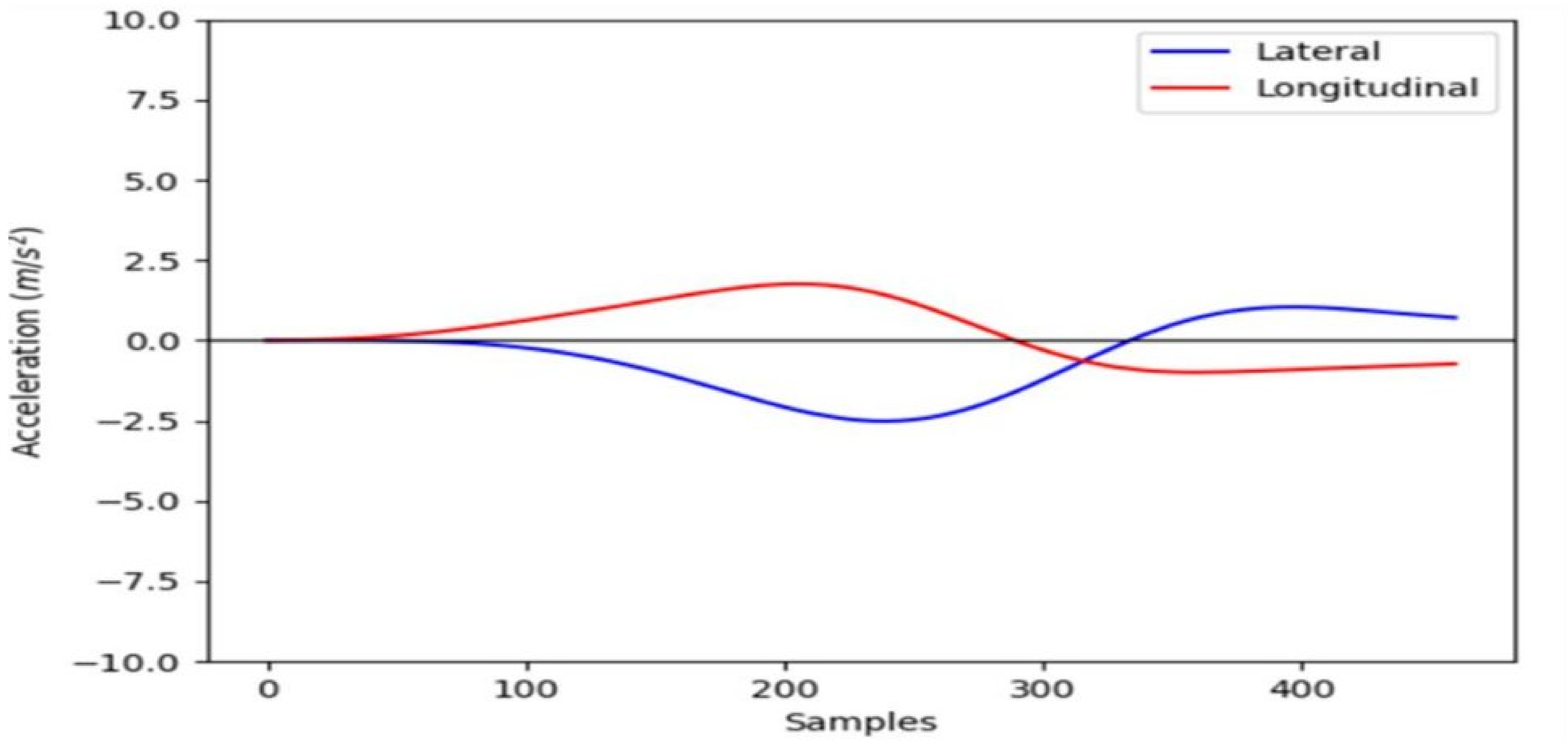


Figure 4.3 (a)

Turning curve with slight acceleration (Real car)

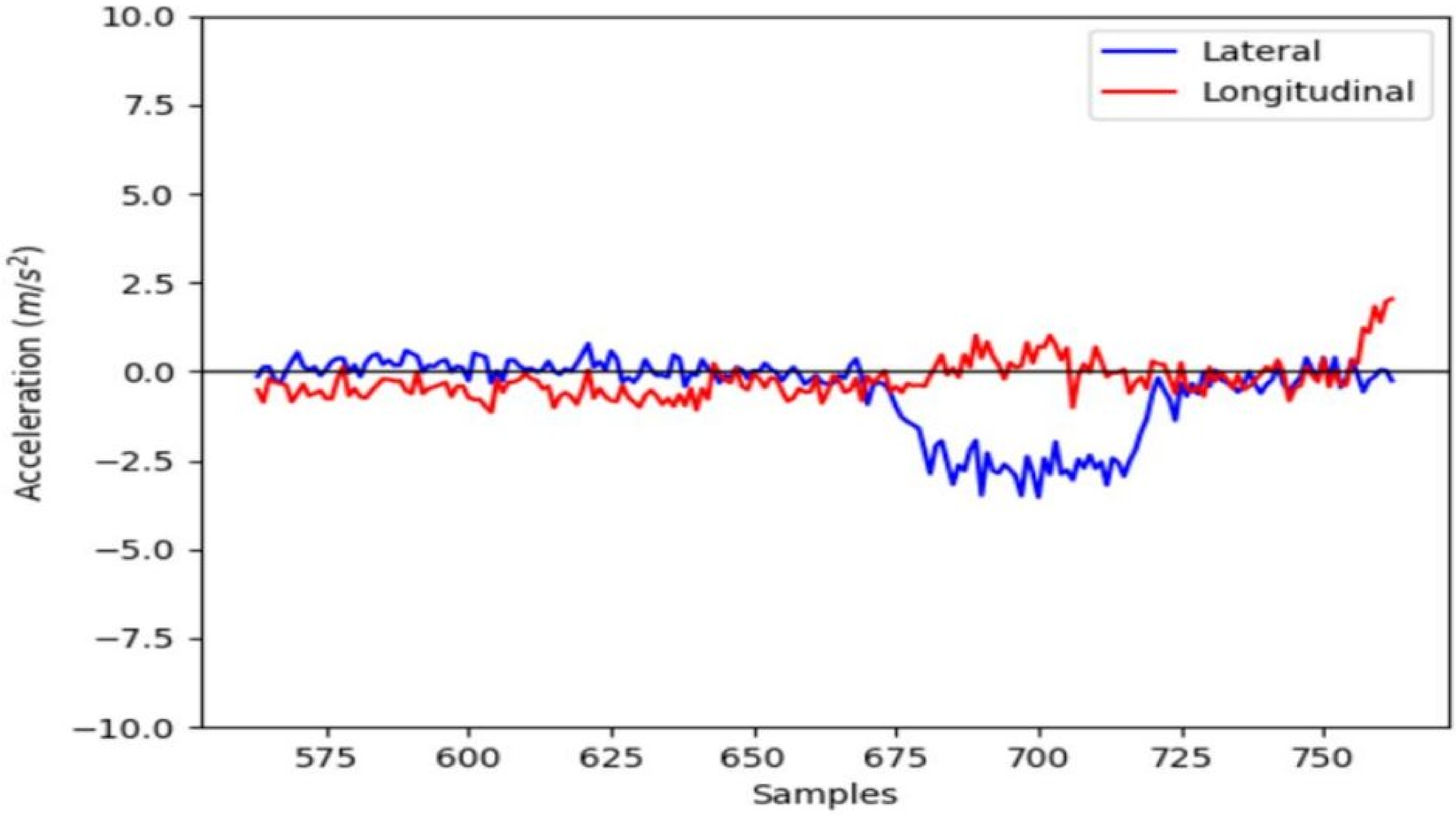


Figure 4.3 (b)

Turning curve with slight acceleration (Testbench car)

4.3 Rc model curve vs real carmounted curve

lane detection was successfully carried out results are stated below.

4.3.1 Transmitter

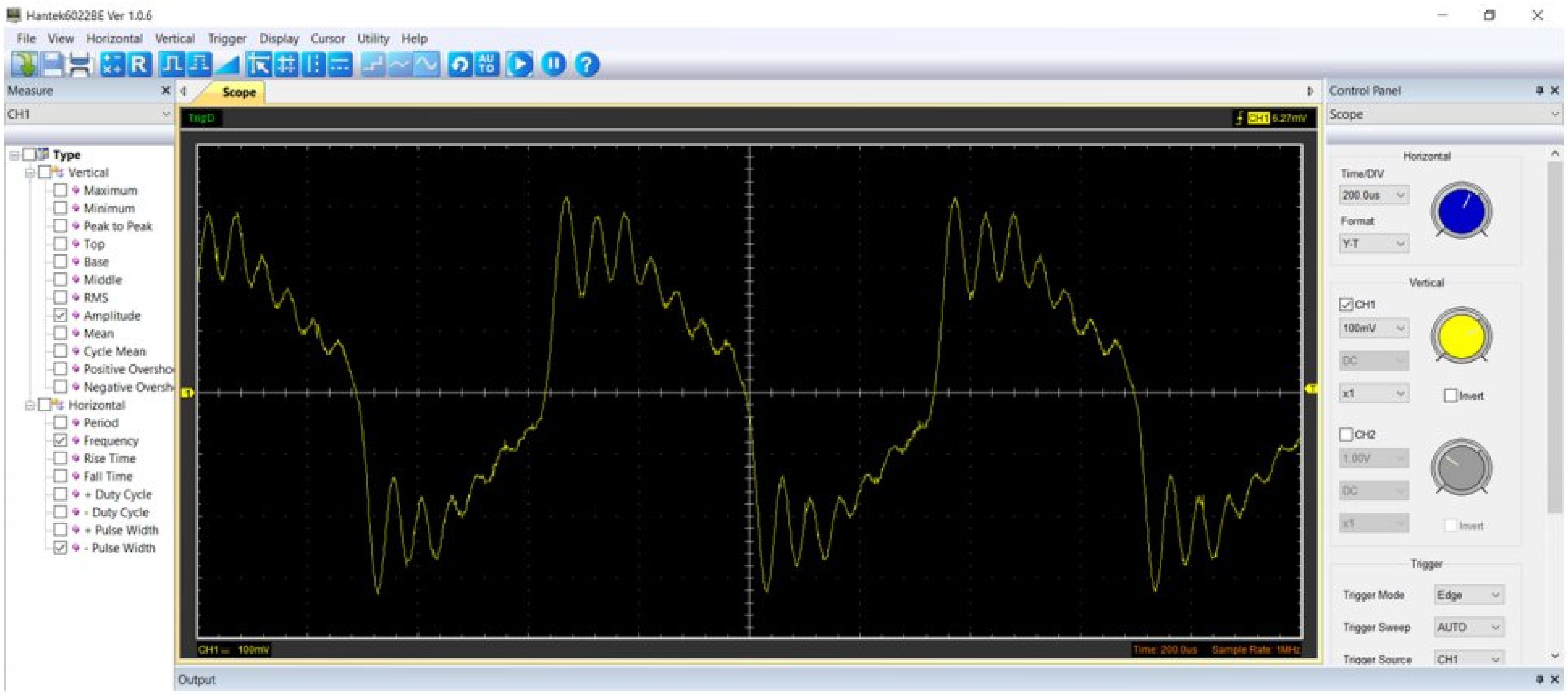


Figure 4.4
Transmitter wave shape

The scope used here is a HANTEK 22BE, running its native software version 1.0.4. We see the successful generation of a 1.402 KHz wave for transmission

4.3.2 Receiver

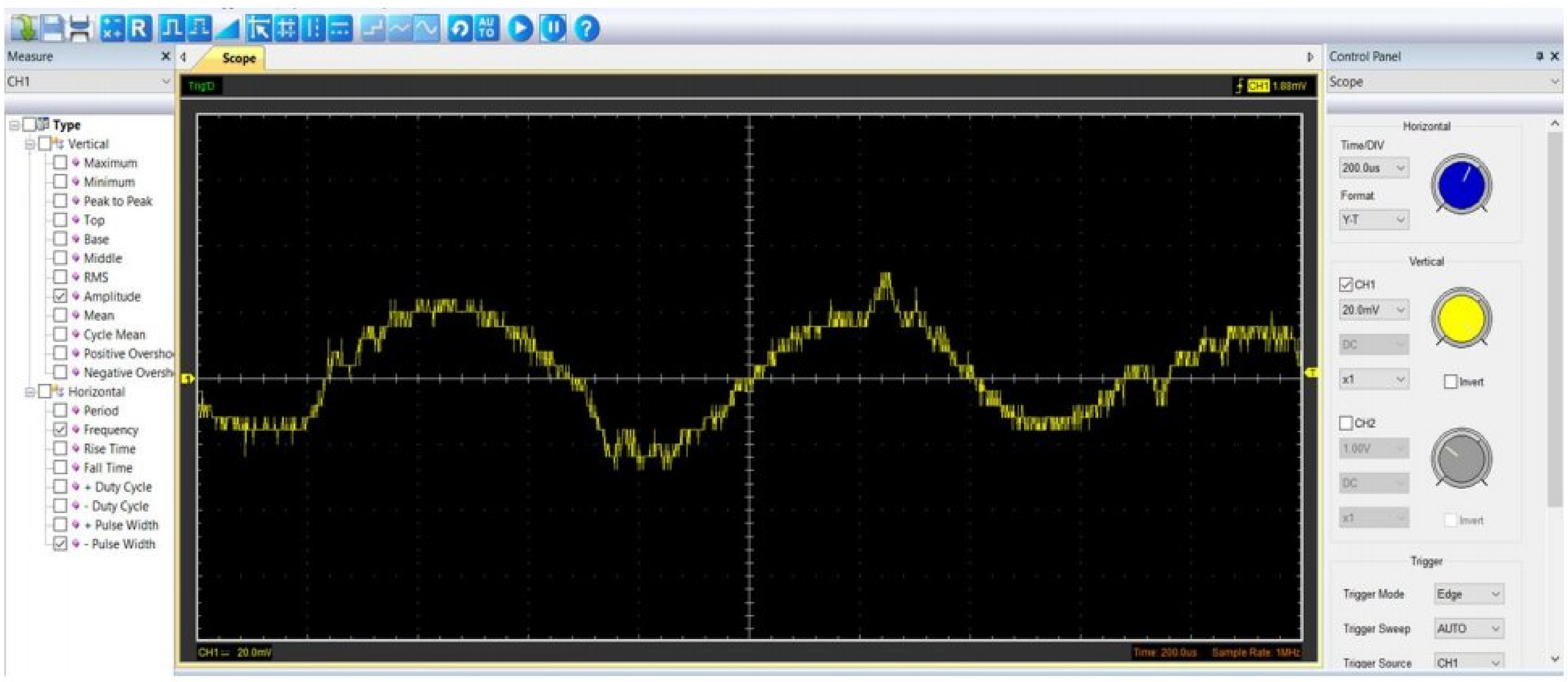


Figure 4.5
Transmitter wave shape

Here, The received signal was easily distinguishable from the noises. the reading here was after the first stage of amplification. Here we can see the amplitude of the received signal to be 63.4 mV.

4.3.3 RF ping test

the set up was placed in the manner shown in the figure below

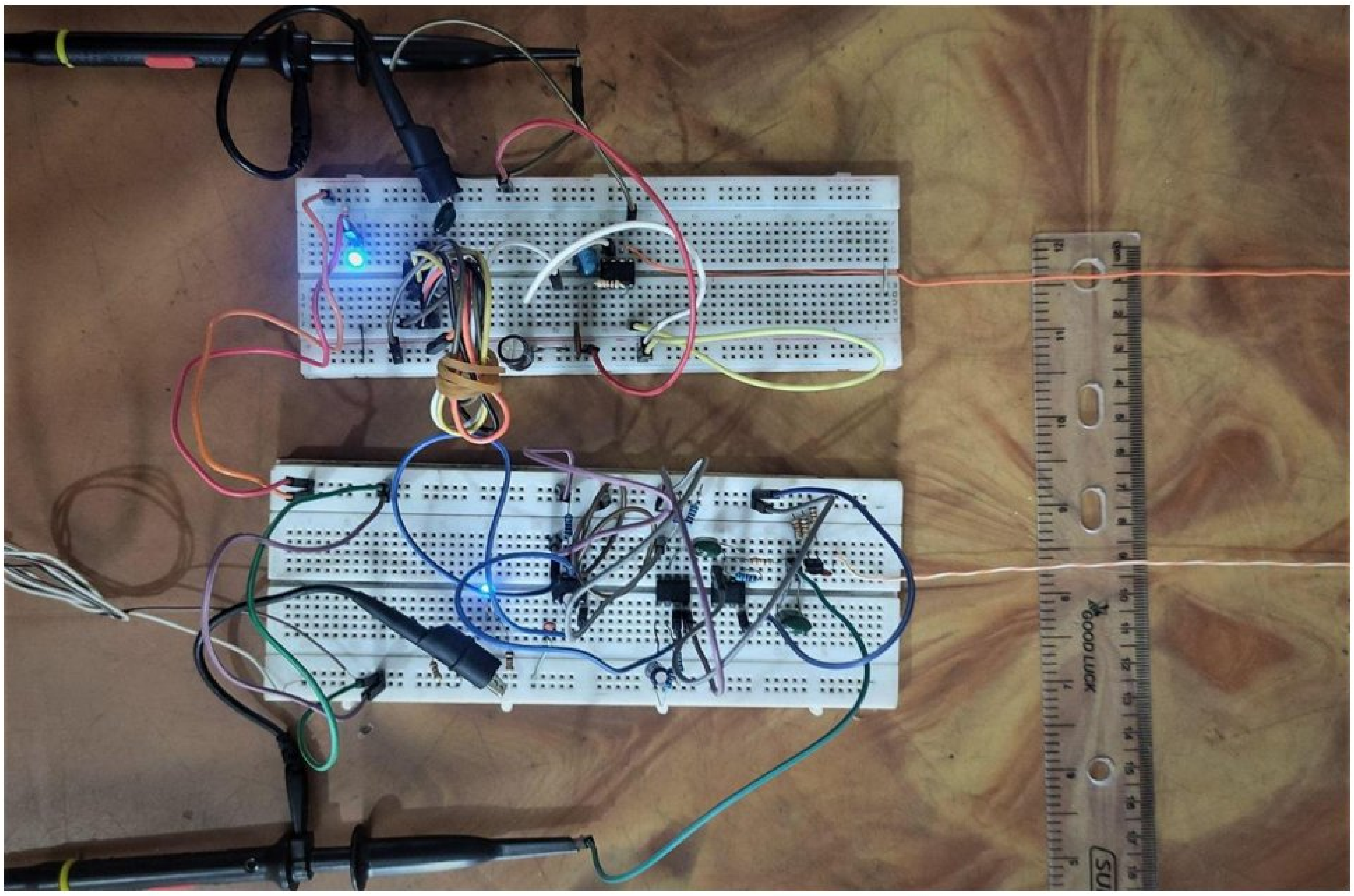


Figure 4.6

RF ping test setup

for our test they were set 0.5 Meter apart. and the probe attenuation set to 10X. IT was verified from multiple samples taken at multiple environmental and atmospheric conditions. The results deflected little.

Figure 4.7

RF ping test response

The module could generate a successful pulse from this 0.1 meter ping test. making lane detection a viable option for penalty calculation.

4.4 Jerk time polling

The governing parameters in this case are not tuned as per a humanitarian aspect with actual comfort level survey. The algorithm is thus implemented as a proof of concept. successful identification of the time frame was key to the aspect of the experimentation. The successful identification was achieved with any lever upper than the threshold.

Figure 4.8

Motion assessment result

Here we can see the successful detection of continuous faulty jerk. And experimental fault calculation.

Chapter 5

Conclusion

Our methodology incorporates Reduced cost, scaling opportunity, Minimal complexity & the elimination if variability. But there are significant room for improvements. In future we wish to work on

a. Better Data Filtration
b. Accumulation Strategy for Penalty Components
c. RT Data collection for Off-site neural net implementation
d. RT clock synchronization
e. Zonal transmission selection circuit

References

[1] **Long short-term memory and convolutional neural network for abnormal driving behaviour recognition**

Authors: Shuo Jia[1], Fei Hui[1] , Shining Li[1], Xiangmo Zhao[1], Asad J. Khattak[1,2]

[1]Department of Transportation Engineering, School of Information Engineering, Chang'an University, Middle-section of Nan'er Huan Road, Xi'an, People's Republic of China

[2]Department of Civil and Environmental Engineering, The University of Tennessee, 851 Neyland Drive, Knoxville, TN, US, E-mail: feihui@chd.edu.cn

Published: IET - Intelligent Transport Systems, 24th July 2019

[2] **Lightweight Driver Behavior Identification Model with Sparse Learning on In-Vehicle CAN-BUS Sensor Data**

Authors: Shan Ullah and Deok-Hwan Kim

Department of Electronic Engineering, Inha University, Incheon 22212, Korea; shan.ullah@iesl.inha.ac.kr

* Correspondence: deokhwan@inha.ac.kr; Tel.: +82-(0)32-860-7424

Published: MDPI - SENSORS, 4 September 2020

[3] **https://copradar.com/chapts/references/acceleration.html**