Research Article

Implementation of Speed Measurement and Speed Limit System on Motorcycles Based on Global Positioning System

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Abstract: The Indonesian National Police Traffic Corps (Korlantas Polri) recorded many traffic accidents in 2022, with hundreds of lives lost. High riding speed was identified as a contributing risk factor to these accidents. Uncontrolled motorcycle conditions and the lack of rider focus while riding were also identified as potential causes of accidents. Therefore, researchers designed a solution by creating a device to address these issues. The device to be discussed here is a GPS-based speed-measuring and limiting device. This device aims to reduce the risk of accidents by controlling riding speed. The speed sensor utilizes GPS, with the function to temporarily stop the motorcycle when it reaches a speed of 48 km/h, preventing riders from riding at high speeds. The speed limitation at 48 km/h is expected to reduce the risk of traffic accidents. Based on the analysis and calculations of this GPS-based motorcycle speed-limiting device, it is ensured that the motorcycle will not be damaged when the ignition coil is disrupted for 1 second to temporarily turn off the motorcycle upon reaching the specified speed.

Keywords: Traffic Accidents; Motorcycles; GPS; Speed Measurement; Motorcycles devices.

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1. Introduction

The Indonesian National Police Traffic Corps (Korlantas Polri) noted that the number of traffic accidents in 2022 was still quite high. where the traffic accident statistics throughout 2022, including 6,707 cases with 452 people dying, 972 people suffering severe injuries, and 6,704 people with minor injuries, with material losses totaling more than IDR 13 billion. Low traffic awareness is one of the main causes of accidents, and it needs attention and continuous evaluation [1].

One of the inappropriate behaviors that often involves teenagers is illegal motorcycle racing. Although, in reality, activities like this are highly risky in public areas rather than in official racing venues or facilities. From these illegal racing activities, accidents often occur, leading to significant expenditures for medical treatment, as well as the risk of death or physical disabilities such as brain injuries, fractures, or even amputations. However, in Indonesia, illegal racing is considered a traffic violation, as it has the potential to cause disturbances and accidents that harm not only the participants but also spectators and other road users [2].

Three main factors cause dangerous traffic accidents for individuals according to WHO in 2004 such as human error, machine error (vehicle error), and road and environmental conditions. Among these three factors, human error is identified as the most dominant factor in the occurrence of traffic accidents [3].

Riding at high speeds can increase the risk of traffic accidents. Accidents can occur due to the vehicle losing control or riders paying insufficient attention to traffic situations when riding at high speeds. There is a possibility that a motorcycle may lose balance at any moment, causing the rider to skid or fall, which can result in serious injuries. In addition to potentially endangering personal safety, high speeds can also threaten the safety of other road users. Therefore, riding at high speeds is considered an imprudent act [4].

The highest speed limits are set based on the category of the area, such as residential areas, urban areas, intercity roads, and highways. For highways, the minimum speed limit is 60 (sixty) kilometers per hour under free-flowing conditions, while the maximum speed limit is 100 (one hundred) kilometers per hour. On intercity roads, the highest speed limit is 80 (eighty) kilometers per hour. In urban areas, the maximum speed limit is 50 (fifty) kilometers per hour, while in residential areas, the highest speed limit is set at 30 (thirty) kilometers per hour [5].

Law No. 22 of 2009, which replaces Law No. 14 of 1992, is designed to realize the security, safety, order, and smooth flow of traffic and road transportation. Every individual using the road, whether with a vehicle or on foot, expects a safe condition where they are free from the threat of criminal acts or social disturbances while on the journey. Road users also hope for a safe and accident-free traffic journey, enabling them to reach their destination safely. The smooth flow of traffic is the expectation of every road user [6].

2. Theory

2.1 Global Positioning System (GPS)

GPS is a satellite-based navigation and position monitoring system owned and operated by the United States. GPS can provide position data with an accuracy that varies from a few millimeters to tens of meters [7]. The GPS Neo 6mv2 module can detect almost any location which can pick up signals from 22 satellites. However, it requires low power consumption, making it suitable for projects with minimal power requirements.

2.2 Relay

A relay is a type of switch that is activated by electrical power and included in an electromechanical component consisting of two main parts, namely the electromagnet (coil) and the mechanical part (switch contacts). The principle applied by relays is using electromagnetic effects to move the switch contacts. Thus, a relatively small electric current (low power) can conduct electricity at a higher voltage. In general, relays are equipped with a coil made of iron, and when the coil is electrified, the coil becomes magnetized and attracts the switch contacts so that there is a connection. magnetized and attracts the switch contacts so that connection occurs. When the contacts are connected, electric current can flow [8].

2.3 Buzzer

Buzzer is an electronic device that converts electrical vibrations into sound vibrations. In principle, the way a buzzer works is almost similar to a loudspeaker, where the buzzer consists of a coil mounted on a diaphragm. Buzzers are often used as indicators to signal the completion of a process, an error in a device, or a warning that a certain event has occurred [9].

2.4 Liquid Crystal Display

LCD is a type of electronic display designed using CMOS logic technology. This screen operates without generating its light, but rather reflects light from the surroundings for front-lit or transmits light from back-lit. LCD is used to display a size or number so that it can be seen and known through its crystal display screen [10]. I2C/TWI LCD is a module to reduce the number of pins required on the LCD. This module consists of 4 pins that will be connected to the Arduino. Arduino Uno supports I2C communication with I2C LCD modules, so it can control 16x2 and 20x4 Character LCDs using only 2 Pins, namely Analog Input Pin 4 (SDA) and Analog Input Pin 5 (SCL) [11].

3. Method

3.1 Flowchart System

The flowchart for the design research of the speed measuring system and speed limit on a motorcycle based on the Global Positioning System can be seen in Figure 1. This flowchart can briefly illustrate the process of exploration configuration, and the sequence of checks to be completed is as follows.

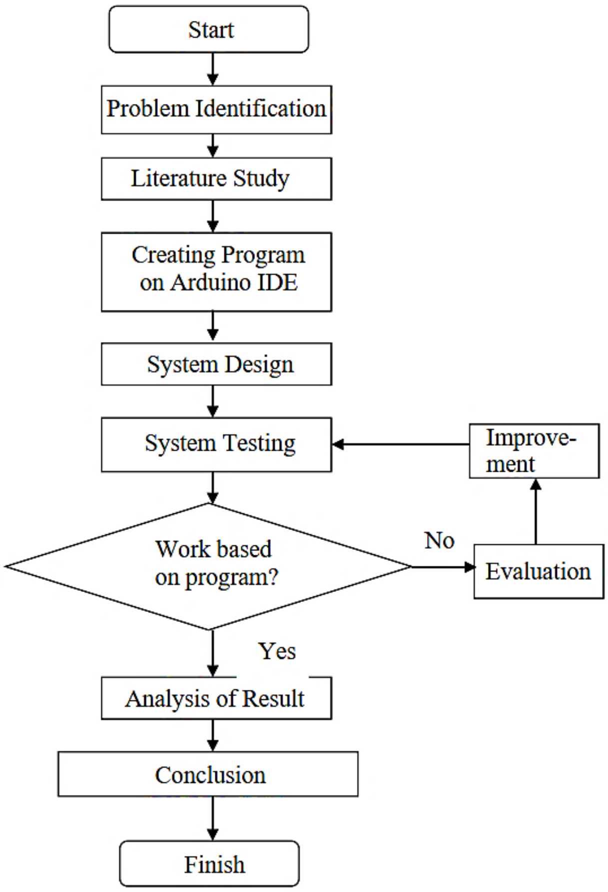


Figure 1. Flowchart Design Research

3.2 System Design

Programming in the Arduino IDE application is used to read the speed from the GPS module as input speed data and simultaneously display the speed data from the GPS on the LCD. The program also determines the set point value to activate the buzzer as a rider reminder and activates the relay to temporarily turn off the motorcycle as a speed limiter [12-25]. The system design aims to assemble a speed measuring tool and speed limit for motorbikes based on GPS. A Block diagram can be seen in Figure 2.

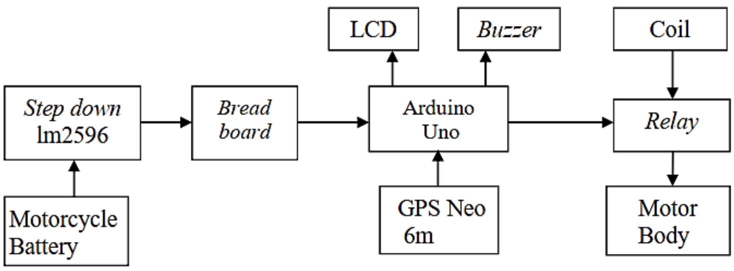


Figure 2. Design System Block Diagram

Based on Figure 2, it can be seen that the Arduino Uno serves as the brain of the entire speed limiter system [8]. The motorcycle battery functions as the power supply [9]–[10] for the system, with a step-down module used to reduce voltage [11] from the battery to the breadboard. The breadboard serves as the connector for all system components [12]. The LCD is connected to the Arduino to display speed data [13], and the buzzer serves as an output from the Arduino to warn when the speed limit has been reached [14]. The GPS Neo 6m is an input to the Arduino for reading speed [15]–[17]. The relay is an output from the Arduino used to connect and disconnect the current from the coil to the motorcycle chassis [18]. While the coil is connected to the motorcycle chassis, the motor will turn off.

3.3 System Testing

The next step is to conduct a system test to determine whether the device works properly. In this phase, the researcher will test the system by verifying the operational functions of the GPS to ensure it is working correctly, confirming that the buzzer has operated, ensuring that the relay has functioned, verifying that the step-down can lower the voltage effectively, and ensuring that the motorcycle used has a good motorcycle battery. If successful, the process will proceed to the next stage; however, if unsuccessful, an evaluation will be conducted on the device and program, followed by necessary corrective measures. Subsequently, the researcher will analyze the data from this research to find the solutions.

3.4 Motorcycle Speed Limiter System

The following is a flowchart of the motorcycle speed limiter system based on the Global Positioning System, shown in Figure 3

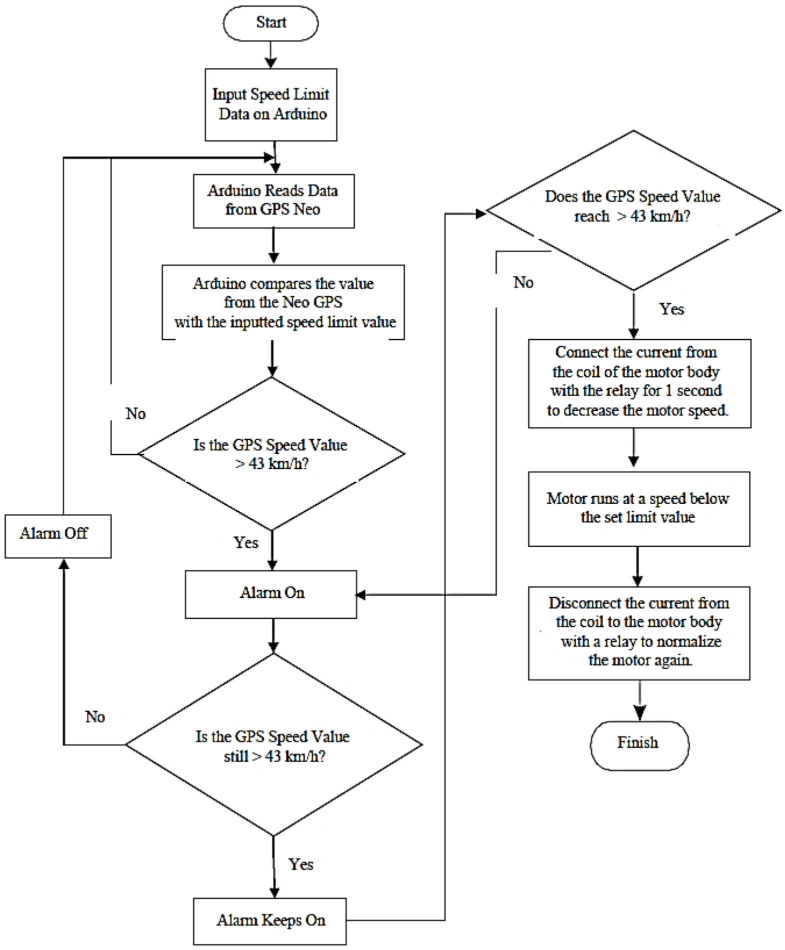


Figure 3. Motorcycle Speed Limiter System

Arduino is used to input speed limit data for motorcycles, with the input value set at 43 km/h as an alarm sign and 48 km/h as the maximum speed limit for motorcycles. The tool used to measure speed is the GPS Neo 6m. Then, Arduino compares the GPS value with the input of the speed limit value. If the data received by Arduino does not match with the input of speed limit data, the motorcycle will continue to run as usual. However, when the speed data received by Arduino reaches 43 km/h, the alarm will sound every 0.3 seconds as a reminder that the speed has exceeded the input limit. If the speed decreases, the alarm will stop, and the motorcycle will not turn off. If the motorcycle speed does not decrease and reaches 48 km/h, the relay will connect the current from the coil to the motorcycle body every 1 second as long as the speed value is still above 48 km/h, similar to the situation of a motorcycle running out of fuel.

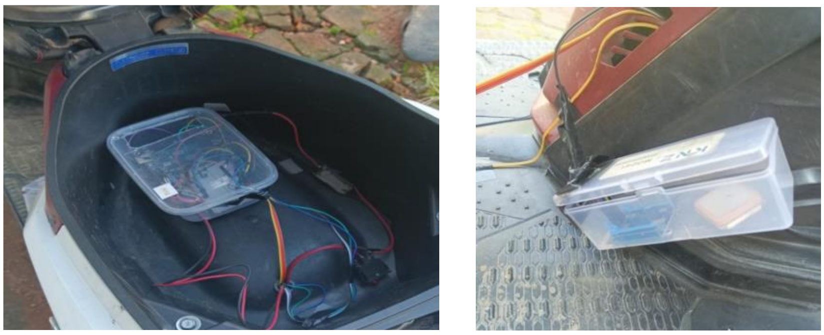
When the current from the coil is connected to the motorcycle body, it will cause the motorcycle to turn off because the motorcycle body serves as the grounding. When connected, the coil will be deactivated, leading to the motorcycle's turn-off. Hence, the cable from the coil is first connected to a relay before being connected to the motorcycle body. When the motorcycle speed has decreased, the relay will reconnect the current from the coil to the motorcycle body, restoring the motorcycle to normal. However, if the speed is still above 43 km/h, the buzzer will continue to stay on.

The system for measuring the speed and speed limit of this motorcycle cannot be implemented on all types of motorcycles. The motorcycles that can be used for this tool are automatic motorcycles with a well-functioning electrical system or a still good motorcycle battery. This tool cannot be used on motorcycles with unstable electrical systems or a damaged battery. If the battery is damaged, the power supply entering all components will be disrupted, leading to errors in the system, resulting in tool damage.

4. Result and Analyzes

4.1 Results of Speed Limiter System

The motorcycle speed limiter is applied in two places on the motorcycle, namely inside and outside the motorcycle trunk. In the design inside the motorcycle trunk, a transparent box protects the Arduino and interconnected cables on the breadboard from being easily unplugged and secure when placing other items in the trunk. The components inside the box include Arduino Uno, a breadboard, and a relay. From the outside of the box, there is an LM2596 step-down converter to lower the voltage from the motorcycle battery, and a switch to turn on and off this motorcycle speed limiter device. Meanwhile, the components outside the motorcycle trunk include the Neo 6m GPS, LCD, and buzzer. The Neo 6m GPS is placed outside the motorcycle trunk for easy reception of satellite signals, the buzzer is positioned outside the motorcycle trunk for easy hearing by the rider, and the LCD is placed below the motorcycle speedometer to view the motorcycle speed data from the designed device.



(a) (b)

Figure 4. (a) Design of a motorcycle speed limiter system, (b) GPS Neo 6m placed under the motorcycle seat

(a) (b)

Figure 5. (a) buzzer placed in front of the motorcycle seat, (b) LCD placed under the motorcycle seat

4.2 Results of GPS Sensor Testing

Sensor testing carried out in this research is GPS Neo 6m sensor. The testing aims to determine the time it takes for the GPS to receive signals from satellites with various time differences. The testing data can be seen in Table 1.

Table 1. GPS Sensor Test Data Capturing Signals

Number of Testing	Testing Time	Time Range of Each Test	The time it takes for GPS to receive signals
1	11.00	-	5 seconds
2	11.15	15 minutes	5 seconds
3	11.40	25 minutes	8 seconds
4	13.00	80 minutes	9 seconds
5	15.00	120 minutes	13 seconds

GPS can be said to have captured a signal when it has successfully decoded the unique code transmitted by satellites and determined the location. Subsequently, GPS utilizes this data to calculate the user's GPS position. Essentially, the GPS receiver calculates the distance to each satellite based on the time it takes to receive the signal transmitted by the respective satellite. By measuring the distance from several other satellites, the receiver can determine the accurate position of the user.

The time required for GPS to acquire signals depends on the device's location. The GPS Neo-6M will more easily capture satellite signals outdoors or in open areas. However, the GPS Neo-6M will struggle to capture satellite signals when located indoors or in a garage. This is because signals transmitted from satellites face difficulty penetrating buildings or trees, making it challenging for the GPS to detect signals sent by satellites. Consequently, it will take a significant amount of time for the GPS to acquire signals if activated within a garage.

4.3 Tool Accuracy Testing Results

This test is conducted to observe the differences in GPS accuracy compared to a motorcycle speedometer to analyze the causes and factors influencing GPS accuracy. The testing table can be seen in Table 2. As seen in Table 2, testing conducted over 4 days during daylight hours revealed differences between the motorcycle speed and GPS speed at various velocities. In the test video, at low speeds (<15 km/h), the GPS speedometer can match the motorcycle speed when the motorcycle maintains a constant speed. However, the GPS speedometer lags behind the motorcycle speed because the Arduino requires a delay to display changes in GPS speed on the LCD, causing the GPS to lag in matching the motorcycle speed. However, at speeds above 15 km/h, the GPS can't match the motorcycle's speed. In the test video, it is evident that the GPS cannot keep up with the motorcycle's speed even when the motorcycle is moving at a constant speed. This is due to a phenomenon known as Doppler shift. Doppler shift is a phenomenon where the satellite signal moving toward the GPS receiver experiences a frequency change due to the movement of the GPS receiver. This makes it difficult for the GPS to calculate speed. The faster the movement of the GPS receiver, the more challenging it becomes for the GPS to process signals received from satellites, resulting in lower accuracy at higher speeds.

Table 2. Tool Accuracy Testing Results

Date	Time	Weather	Motorcycle Speedometer	GPS Speedometer	Difference
November 9, 2023	13.00	Sunny	21 km/h	19 km/h	2 km/h
			27 km/h	23 km/h	4 km/h
			30 km/h	25 km/h	5 km/h
			40 km/h	35 km/h	5 km/h
			41 km/h	36 km/h	5 km/h
November 10, 2023	13.24	Sunny	30 km/h	27 km/h	3 km/h
			35 km/h	30 km/h	5 km/h
			40 km/h	36 km/h	4 km/h
			43 km/h	40 km/h	3 km/h
			50 km/h	46 km/h	4 km/h
November 11, 2023	12.00	Sunny	10 km/h	10 km/h	0 km/h
			12 km/h	12 km/h	0 km/h
			14 km/h	13 km/h	1 km/h
			20 km/h	18 km/h	2 km/h
			22 km/h	21 km/h	1 km/h
November 12, 2023	14.15	Sunny	26 km/h	22 km/h	4 km/h
			29 km/h	25 km/h	4 km/h
			30 km/h	27 km/h	3 km/h
			32 km/h	29 km/h	3 km/h
			36 km/h	31 km/h	5 km/h

During the daytime, the influence of solar activity on the atmosphere can also lead to inaccuracies in GPS signals. Although this influence is minor, it can still disrupt the accuracy of GPS signals. Therefore, during the daytime, the accuracy of GPS signals may be slightly lower.

4.4 Overall Test Results of the Tool

Overall testing consists of buzzer testing and relay testing to ensure that the device is working properly. The buzzer is considered to be working well if its on-and-off cycles are by the programmed settings, and the sound of the buzzer is audible to the rider. The relay is deemed to be working properly if its on- and off cycles match the programmed settings, and the relay can accurately interrupt and connect the electrical current according to the programmed settings, allowing the motorcycle to turn off when the speed limit is reached.

4.5 Buzzer Testing Results

In this test, observations were made on the buzzer to ensure that the buzzer lights up properly according to the programmed settings, to verify that the buzzer operates within the specified speed limits, and to ensure that the buzzer sound is audible to motorcycle riders. The results of the buzzer test can be seen in Table 3.

Table 3. Buzzer Testing Results

Number of Testing	GPS Speed	Median Speed Limit	Buzzer condition	Audible to riders?
1	41 km/h	43 km/h	Off	No
2	42 km/h	43 km/h	Off	No
3	43 km/h	43 km/h	On	Yes
4	44 km/h	43 km/h	On	Yes
5	45 km/h	43 km/h	On	Yes

From Table 3, when the GPS speedometer speed has not reached 43 km/h, the buzzer is still not active, because the speed limit value to activate the buzzer is 43 km/h, by the median value in the previous calculation. When the GPS speedometer speed reaches 43 km/h, the buzzer is active, indicating that the speed limit warning has been reached. This means that the buzzer is working properly according to the programmed settings.

The duration of the buzzer activation when the GPS speed exceeds 43 km/h is 0.3 seconds, and it remains off for 0.4 seconds. Therefore, while the GPS speedometer indicates a speed above 43 km/h, the buzzer will stay active for 0.3 seconds and then turn off for 0.4 seconds. The purpose is to disrupt the rider's focus, making them aware that the buzzer is active and signaling that the motorcycle's speed is approaching the maximum limit.

4.6 Relay testing results

Relay testing is conducted to ensure that the relay has worked properly to turn off the motorcycle for 1 second while the motorcycle speed is still above 48 km/h until the speed drops below 48 km/h. The relay testing results can be seen in Table 4.

When the speed is still below 48 km/h, the relay is not active because it is set to activate when the speed reaches 48 km/h. At speeds from 48 km/h to 50 km/h, the relay becomes active and causes the motorcycle to turn off for 1 second. This means the relay works properly to disconnect and reconnect the coil current to the motor body to turn off the motorcycles for 1 second when the motor speed is above 48 km/h.

Table 4. Relay Testing Results

Number of Testing	GPS Speed	Speed Limit	Relay Condition	Motor engine condition (after the relay is active)
1	46 km/h	48 km/h	Off	-
2	47 km/h	48 km/h	Off	-
3	48 km/h	48 km/h	On	Off for 1 second
4	49 km/h	48 km/h	On	Off for 1 second
5	50 km/h	48 km/h	On	Off for 1 second

4.7 Results of Tool Testing at Different Speeds

Testing with different speeds aims to determine the differences in tool performance and the impact variations of the motor engine when the ignition on a motorcycle is turned off, whether the motorcycle is at high or low speeds. The speeds tested include 40 km/h, 50 km/h, 60 km/h, and 70 km/h. For more details, refer to Table 5.

Table 5. Tool Testing at Different Speeds

Number of Testing	Speed Limit	Buzzer condition	Relay Condition	Motor engine condition (after the relay is active)
1	40 km/h	On	On	Off for 1 second
2	50 km/h	On	On	Off for 1 second
3	60 km/h	On	On	Off for 1 second
4	70 km/h	On	On	Off for 1 second

From Table 5 data, in all speed tests, no issues were found with both the tool and the motorcycle. Whether at low or high speeds, the tool continues to work properly with no disruptions, such as the motorcycle engine shutting down completely, the Arduino system responding slowly to turn off the motorcycle when the speed limit is reached, and the motorcycle engine getting damaged due to sudden shutdown at high speeds. Therefore, it can be concluded that the tool performs well at low and high speeds and does not affect the motorcycle engine's performance.

In all the tests above, the sensation felt by the rider when the motorcycle is turned off for 1 second remains the same; the motorcycle will stall for 1 second, and the rider will feel their body pushed forward, similar to a sudden brake. Because it's only 1 second, it doesn't significantly impact the rider and passenger.

5. Conclusion

The conclusion that can be drawn from the results of this research is: [1] Arduino serves as the brain of the entire motorcycle speed limiter system. When the speed reaches 43 km/h, Arduino will command the buzzer to sound as a reminder that the speed limit is about to be reached. Subsequently, at a speed of 48 km/h, Arduino will instruct the relay to connect the current from the coil to the motorcycle's body, effectively shutting down the motorcycle for 1 second to reduce its speed. [2] Based on the analysis of GPS sensor testing regarding the time it takes for the GPS to become active, it depends on the device's location. The NEO-6M GPS is more likely to capture satellite signals easily when used outdoors or in open areas. However, it may face difficulties in capturing signals when placed indoors or in a garage. The GPS is active when the device successfully decodes the unique signal code and orbital parameters transmitted by the satellite. [3] Based on the results of the data analysis comparing the speedometer of a motorcycle with a GPS speedometer, there is a difference between the motorcycle speedometer and the

GPS speedometer. The GPS speedometer requires a delay to catch up with the motorcycle speedometer, resulting in a delayed display of speed on the GPS speedometer caused by the Doppler shift phenomenon. Doppler shift is a phenomenon where the signal from satellites moving toward the GPS receiver changes frequency due to the movement of the GPS receiver. This makes it difficult for the GPS to accurately calculate speed. The faster the movement of the GPS receiver, the more challenging it is for the GPS to process signals received from satellites, leading to a lower level of accuracy at higher speeds.

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