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VEHICLE SPEED MEASUREMENT USING

DOPPLER EFFECT

Technology and Communication

2021

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UNIVERSITY OF APPLIED SCIENCES

Information Technology

ABSTRACT

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Title	Vehicle Speed Measurement Using Doppler Effect
Year	2021
Language	English
Pages	41 pages
Name of Supervisor	Jukka Matila

The dramatically increasing number of vehicles leads to many problems, and one of the most comment problems is Overspeed by driver intentionally or not. To help the driver and the police have a better control and safety, speed measurement devices have been built to solve these problems.

This thesis was built around the project, carried out as a research Vehicle Safety Features in Vietnam by Radar-SDK team of FPT Software. The primary purpose of this thesis was to give an understanding of building a speed measurement device with high accuracy, which can be applied in real-life to measure and used as a study case for later development.

In this project, specific circuits, Radar sensors, and microcontrollers were used to record and collect speed from high to low-speed vehicles. This data was analyzed and show the speed of the specific will be shown on vehicle to the monitor and the system will capture the photo of the vehicles with their speed.

Keywords: Speed measurement devices, Radar sensors, microcontroller

ABBREVIATIONS

CW   Continuous Wave

GPIO   General-purpose input/output

I2C   Inter-Integrated Circuit

IC   Integrated Circuit

IDE/IDLE Integrated Development Program

LCD   Liquid Crystal Display

LIDAR   Light Detection and Ranging

RADAR   Radio Detection and Ranging

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FIGURES AND TABLES

1. INTRODUCTION

Nowadays, the traffic has always been an issue. The number of people and vehicles participating in traffic is increasing day by day. Besides, the awareness of most drivers in traffic remains poor, leading to unpredictable consequences. The leading cause of tragic accidents is speeding. Only the traffic police force cannot be well managed, so determining the speed of the vehicle based on automatic equipment serving the handling and management of speed violations is essential.

There are many methods that scientists around the world have researched and applied in practice to help track vehicle speed. Among plans for detecting vehicle speed, Radar-based object detection systems have been deployed for centuries for various purposes such as aircraft detection, spacecraft, terrain mapping and weather forecast. With the advent of better design technology and signal control circuits, radars have become compact and affordable, providing relatively lower-cost solutions than other systems. The vehicle velocities were collected in the form of a continuous wave Doppler Radar. This system consumes very little energy and operates on the Doppler Effect principle by detecting Doppler changes in microwaves reflected from a moving object. The Doppler displacement received by the radar is proportional to the speed of the item.

2.LITERARY REVIEW

Vehicle speed measurement systems are significant parts of monitoring and handling vehicles that violate traffic laws. Traffic state estimation parameters play a significant role in the development of intelligent traffic systems. Usually, this information is collected by different types of sensors to give traffic status updates.

Advanced technology provides different means for collecting traffic data. However, the other methods often result in an accuracy that differs from the actual speed of the vehicle. Some of the techniques below discuss the most accurate traffic data processing between a measuring device and the driver's actual speed.

2.1 Detection by Radar Wave

Detection by Radar wave is a method of using radar waves based on the Doppler effect. The Doppler effect is a physical effect named after Christian Andreas Doppler. The frequency and wavelength of sound waves, electromagnetic waves, or waves, in general, are altered as the source moves relative to the Observer. [3]

2.1.1 Mathematical Expression

In normal conditions, wave sources and observers can both move relative to the environment. The Doppler effect is then the combination of two different products caused by these two movements.

$$f = \left(\frac{v + v_r}{v + v_s} \right) f_0$$

(1)

v: Speed of propagation of waves in the medium

Vr: The relative speed of the Observer concerning the environment.

Vs: The relative velocity of the source to the environment
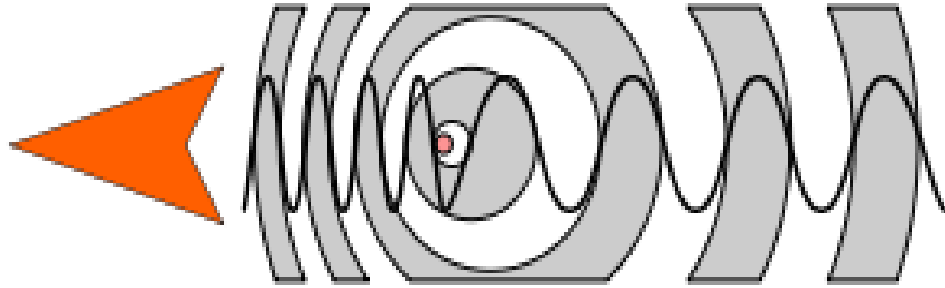
Figure 1: The Doppler effect follows the eye of the Observer [3]

Specifically, if the mobile source in the medium emits a wave with the frequency at the source f0, an observer standing still in the medium will receive frequency f:

$$f = f_0 \left(\frac{1}{1 + v/c} \right)$$

(2)

For c, the propagation speed of the wave in the environment, v is the component of the velocity of the source relative to the medium pointing to the Observer (negative if going towards the Observer, positive if the opposite). [2]

2.1.2 Doppler Examples

The siren on an ambulance approaching us will have a higher frequency (brighter) when the vehicle is stationary. This frequency decreases (lower) as the car passes and is lower than average when the vehicle passes away.

In other words, if the car is going straight towards you, the frequency will remain the same (since the velocity components v in the direction pointing at you stays constant, until they pass you, then immediately change to frequency. The difference between the high frequency on the approach and the standard frequency of the horn is precisely equal to the difference between the low frequency when going away compared to the reference frequency. When the vehicle does not hit the subject, it just passes the subject. The speed components in the direction pointing to the subject do

not remain the same because this direction always changes depending on the position of the vehicle:

$$v = v_0 \cdot \cos \theta$$

(3)

Where v is the vehicle's velocity component in the direction pointing to a subject, v0 is the speed of the vehicle and the angle between the direction of travel of the vehicle and its path to the subject. [2]
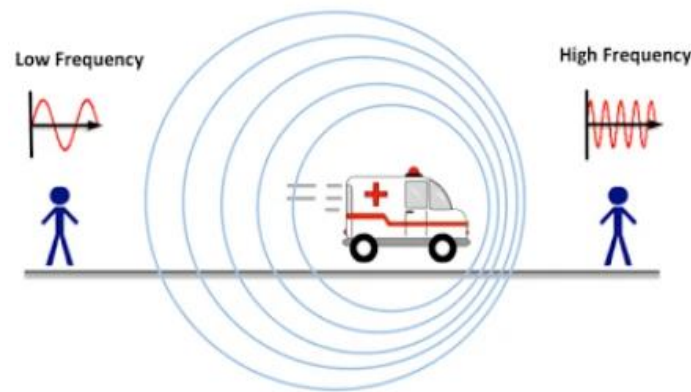
Figure 2: The Doppler effect on listening frequency [14]

2.2 LiDAR Detection

LIDAR started appeared in the early 1960s, shortly after the advent of lasers. At that time, the combined laser beam image recognition technology simulated the ability of the radar to measure distances and detect objects. This distance is calculated based on when the light ray started emitting from the light source and hit the item to be measured and reflected.

2.2.1 LiDAR Application to Find Ranges and Mappings

LIDAR was first used in meteorology when the American Center for Atmospheric Research used it to measure clouds. This technology began to spread and gain more recognition when NASA astronauts used it to map the moon's surface during the Apollo 15 mission.

As explained by the US Department of Meteorology and Hydrology, a LIDAR system usually includes:

Laser generator: often use wavelengths from 600 to 1000nm because it is cheap. In return, it is harmful the eyes, so that regulations will limit energy. The 1550nm wavelength is safe for the eyes at high points, but the receiver is not as modern, so it is usually only used for long-range and lower accuracy. [4]

Scanner: components used to control the laser to rotate around the environment.[4]

Receiver: the laser signal is reflected back.[4]

A positioning device can be a GPS sensor and a gravity sensor to know the direction and scan position.

Figure 3 illustrates the LIDAR system simulation. When the laser goes from the emitter, it will hit the scanner. Here used a rotating mirror to guide the laser around. When the laser beam hits the wall, it is reflected and recorded by the receiver, thereby calculating the distance of the transmitter to the wall. Similarly, when there is an obstacle in the middle of the room, the laser will come and be reflected again in a shorter time, i.e., the distance to the transmitter is shorter. Because the laser is rotating continuously, the image of the whole room can be synthesized.[4]
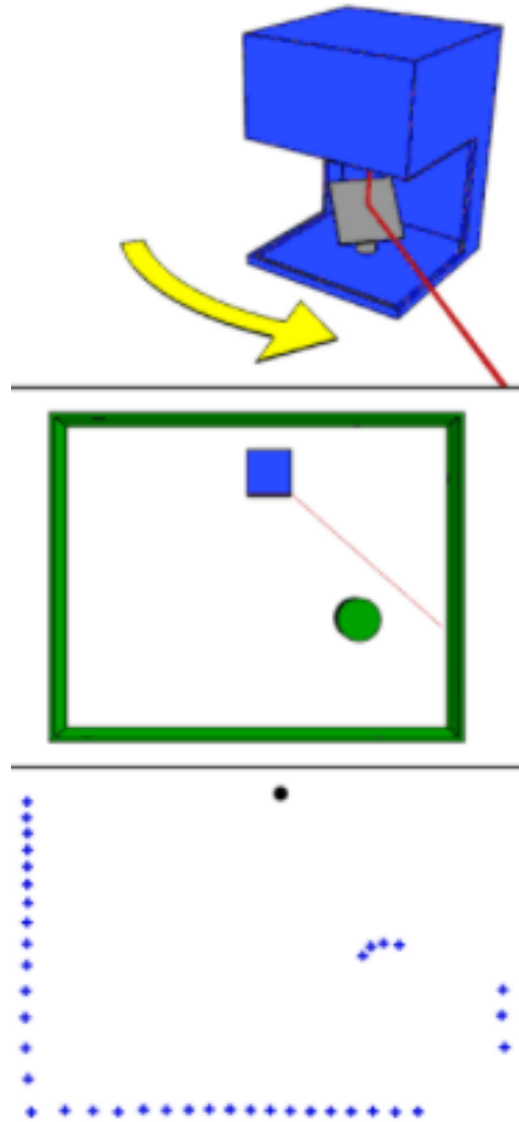
Figure 3: LiDAR system simulation [15]

2.2.2 Speed Measurement by LiDAR
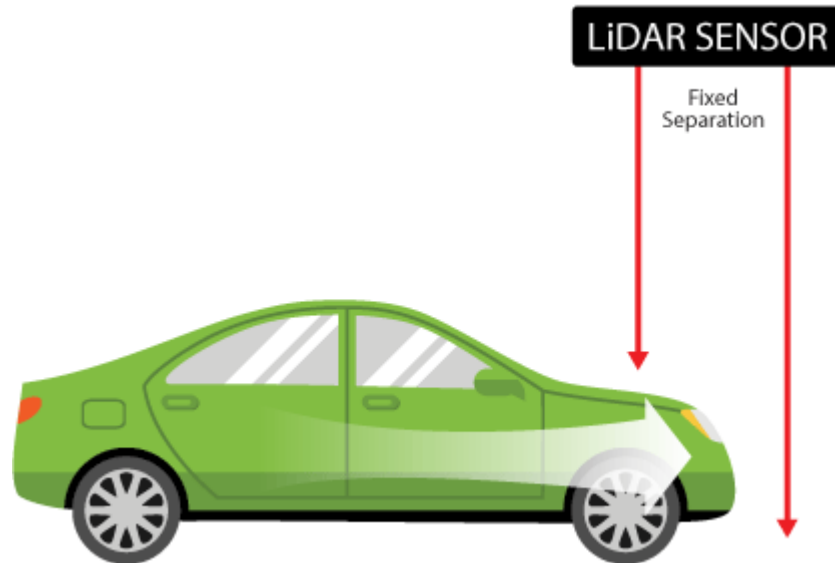
Figure 4: Speed measurement simulation using LIDAR [13]

When a vehicle passes through or breaks the first beam, the microprocessor inside records the time, the beam was disconnected. When the car cuts the second beam, the moment of the second interrupt is recorded. The sensor will calculate the passing speed of the passing vehicle based on the distance between the two beams on the road and the intervals.

By placing sensors on the road surface, it is possible to accurately measure all speed of all vehicles in multi-lane environments - virtually eliminating the possibility of sensor clogging. Furthermore, the sensors can simultaneously measure the speed of vehicles moving in the same or opposite direction. [15]

2.3 GPS Based Speed Measurement

The speed measurement in a GPS-based system based on a calculation between satellites and ground devices such as smartphones or GPS trackers. By sending a signal from the device to satellites and back, GPS based system can measure the speed of the object at quite an accuracy speed.
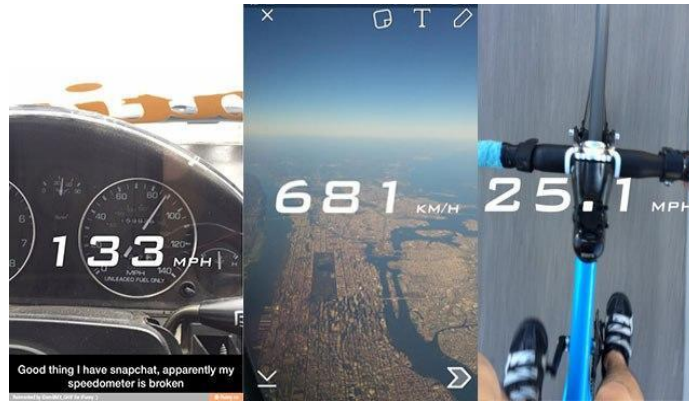
Figure 5: GPS Based Speed Measurement example [16]
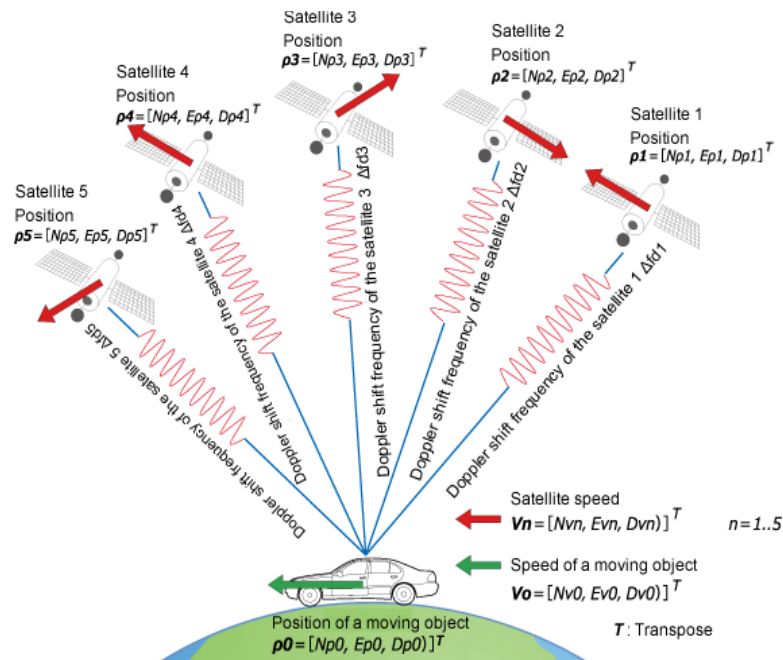
Figure 6: How GPS based system works [17]

When the vehicle travels on the road, the data from transmission device will send data to GPS satellites and received data back on the location and condition in real-time. More data sent out leads to more location received back. Based on time and location point, the device will calculate the speed.

2.4 Vision Based System for Speed Measurement

This system uses an optimized motion detector and a novel text detector t efficiently locate vehicle plates plate regions, tracked across multiple frames, and rectified for perspective distortion. Vehicle speed is measured by comparing the trajectories of the tracked features to known real-world measure.[8]

tion of Camera

Figure 2. Position of Camera

Figure 7: Vision based system [8]

2.5 Image Processing Techniques

Vehicle speed measurement based on image detection is one of the most convenient methods for speed detection. New algorithms are introduced to calculate vehicle speed by comparing two consecutive frames. Its principle is that both images are converted from a 2D image plane to 3D coordinates based on a calibrated camera. Secondly, the difference of two consecutive frames is calculated, resulting in the background being removed and the media in the two structures mapped onto an image. Finally, the vehicle mass performance closest to the ground is compared to estimate its distance and speed. Vehicle speed detection is based on a video in urban intersections in calculating vehicle speed equal to the width of the detection area and its time to go through that detection area [8]. The vehicle velocity estimator to monitor traffic system calculates the vehicle speed based on the shift of gravity center of the vehicle. Most of the speed estimation methods is based on visibility estimate the average traffic speed over a while with an error rate of more than 10% of the actual value. Such an error rate is considered large for any practical use. Errors due to external conditions such as the time of day or night or the changing weather can be substantial, requiring frequent updates at the expense of computational complexity.

3. METHODS

Arduino ESP32 WeMos D1 R32 will be the center of the system, to collect images from ESP 32 Cam and data from Radar HB100 to show the speed and the measure subject to LCD 16x2 screen and then save to SD card.

3.1 Components

3.1.1 KIT Arduino ESP32

The center of the vehicle speed monitoring system is built on the KIT Arduino ESP32 WeMos D1 R32 platform (core is the ESP32-WROOM-32 chip). ESP32 KIT is used in a compatible system and recognized by the Arduino IDE under the name ESP32 Dev Module (Note: select ESP32 Dev module when connecting the ESP32 Kit with the computer running Arduino IDE).

Figure 8: KIT ESP32 WeMos D1 R32 [18]

ESP32 Dev Board PINMAP

				3.3V		**GND**							
(pu)			RESET	EN		GPIO23	VSPI MOSI						SPI MOSI
SVP		ADC0		GPIO36		GPIO22							Wire SCL
SVN		ADC3		GPIO39		GPIO1	TX0						Serial TX
		ADC6		GPIO34		GPIO3	RX0						Serial RX
		ADC7		GPIO35		GPIO21							Wire SDA
	TOUCH9	ADC4		GPIO32		**GND**							
	TOUCH8	ADC5		GPIO33		GPIO19	VSPI MISO						SPI MISO
DAC1		ADC18		GPIO25		GPIO18	VSPI SCK						SPI SCK
DAC2		ADC19		GPIO26		GPIO5	VSPI SS					(pu)	SPI SS
	TOUCH7	ADC17		GPIO27		GPIO17							
	TMS	TOUCH6	ADC16	HSPI SCK	GPIO14	GPIO16							
(pd)	TDI	TOUCH5	ADC15	HSPI MISO	GPIO12	GPIO4		ADC10	TOUCH0		(pd)		
					GND	GPIO0	BOOT	ADC11	TOUCH1		(pu)		
	TCK	TOUCH4	ADC14	HSPI MOSI	GPIO13	GPIO2		ADC12	TOUCH2		(pd)		
				FLASH D2	GPIO9	GPIO15	HSPI SS	ADC13	TOUCH3	TDO	(pu)		
				FLASH D3	GPIO10	GPIO8	FLASH D1						
				FLASH CMD	GPIO11	GPIO7	FLASH D0						
				5V		GPIO6	FLASH SCK						

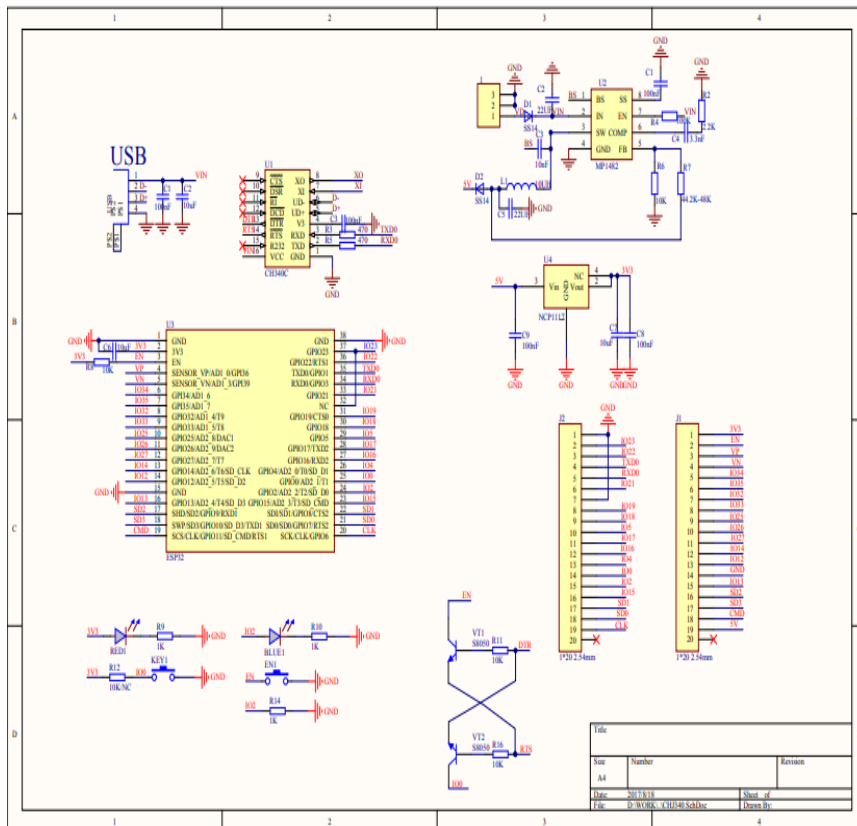**Figure 9**: Name and function pins on KIT ESP32 [19]

Figure 10: Schematic of KIT ESP32 WeMos D1 R32 [19]

This module contains the following features:

- Central core: Wireless Module - ESP-WROOM-32 based on Espressif ESP32 dual-core Tensilica LX6 processor with 802.11 b / g / n Wi-Fi and Bluetooth 4.2 LE. [19]

- Operating frequency up to 240Mhz. [19]

- 448 KB ROM for booting and chip core features. [19]

- 8 KB SRAM in RTC (called RTC SLOW Memory) for access by the co-processor. [19]

- 8 KB SRAM in RTC (called RTC FAST Memory) is used for data storage, accessed by the CPU when RTC is booting from Deep-sleep mode. [19]

3.1.2 Radar HB100

This is a small motion sensor module using a 10,525 GHz frequency. It belongs to the X-Band Bi-Static Doppler transceiver category. Inside, the radar obstacle sensor contains a Dielectric Resonator oscillator (insulating material is usually ceramic to create microwave waves) and a pair of Microstrip patch antenna. The antenna type is like a PCB antenna on the circuit but often built into the sensor. Generates sound waves for motion detection based on a very high reliability doppler effect.

Figure 11: RADAR HB100 [1]
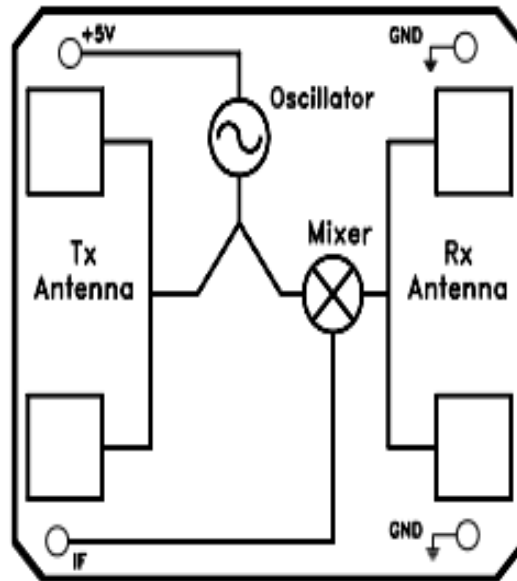
Figure 12: RADAR HB100 Diagram [1]

This module contains the following features:

- Non-contact detection [1]
- Regardless of temperature, humidity, noise, airflow, dust, light, suitable for a harsh environment. [1]
- Strong resistance to RF interference [1]

- The output capacity is small and does not endanger the human body. [1]
- Long-distance: detection range more than 20 meters. [1]
- Receiver: Sensitivity (10dB S / N ratio) 3Hz to 80Hz broadband: -86dBm 3Hz to 80Hz 10uV [1]
- Radiation pattern: Vertical beamwidth 3dB: 36 degrees, horizontal beam width 3dB: 72 degrees [1]
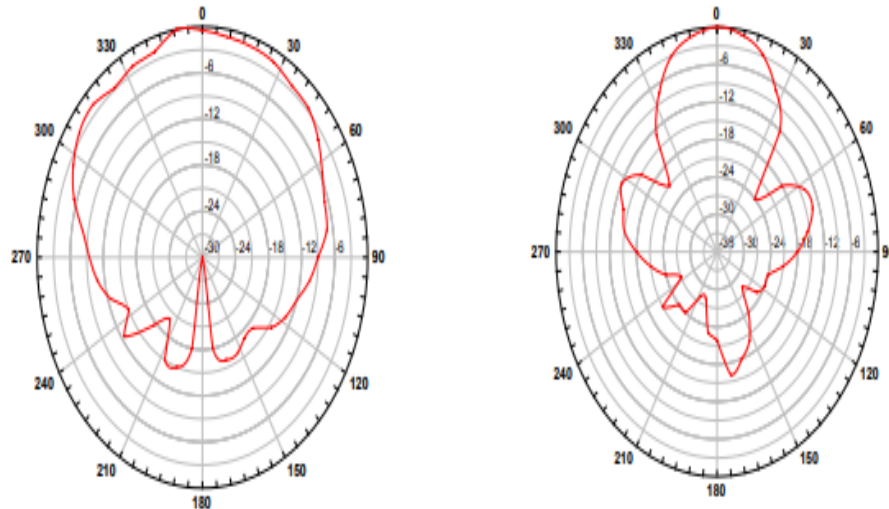
Figure 13: Horizontal and Vertical Beamwidth [2]

3.1.3 KIT ESP32 CAM

To be suitable for tracking and managing speed-breaking vehicles, this project uses the ESP 32 CAM Kit to record management images. The ESP32-CAM is a small size, low-power consumption camera module based on the ESP32. It comes with an OV2640 camera and offers an onboard TF card slot. ESP32-CAM can be widely used in smart IoT applications such as wireless video surveillance, upload Wi-Fi images, QR recognition.
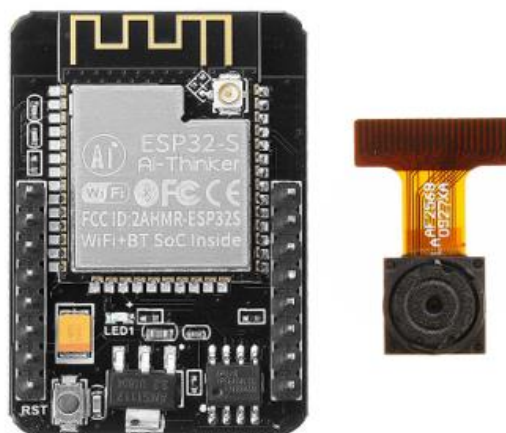
Figure 14: KIT ESP32 Cam [20]
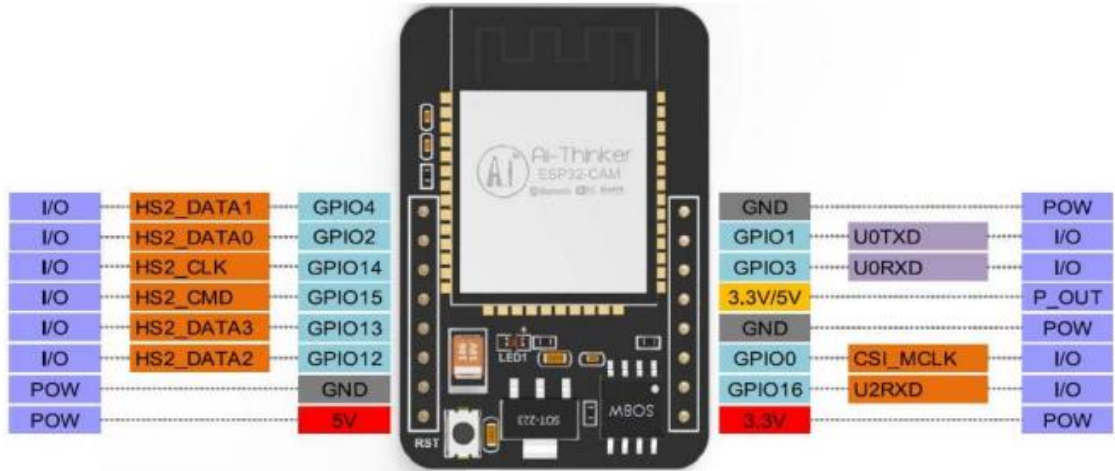
Figure 15: KIT ESP32 Map Pins [20]
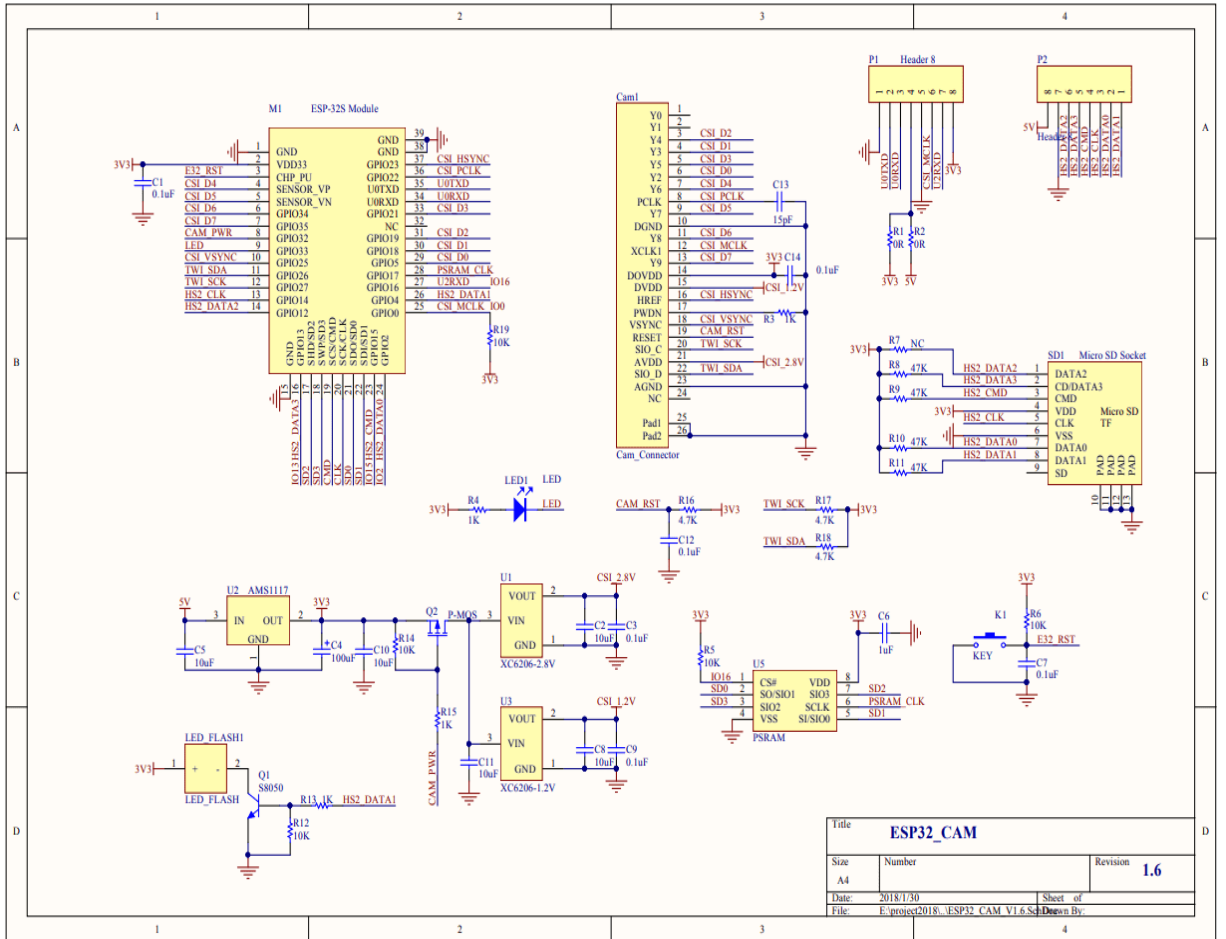
Figure 16: KIT ESP32 Schematic [20]

This module contains the following features:

- FPC connector. [20]

- Support OV2640 camera or OV7670 camera. [20]

- Output Image Format: JPEG (OV2640 only), BMP, GRAYSCALE. [20]

- Peripheral communication: UART / SPI / I2C / PWM. [20]

- UART baud rate: default 115200bps. [20]

3.1.4 LCD 16X2 Screen

LCD text 1602 is a familiar product inelectronic projects because it is easy to use and highly applicable.
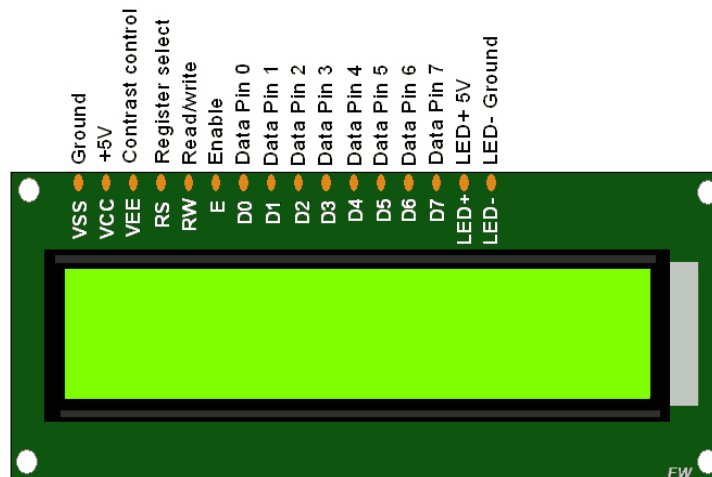
Figure 17: LCD Screen [21]

This module contains the following features:

- R / W selects read or write mode, high R / W activates read mode, low R / W activates write mode. [21]

- Operating voltage: 5V. [21]

- Vee: As a contrast adjustment pin, the contrast will change according to the voltage values applied in this; usually, the standard-setting is 0.4V to 0.9V. [21]

3.1.5 I2C Converter Circuit for LCD

LCD has too many pins, making it challenging to connect and occupy many microcontroller pins. The I2C converter module for LCD will solve this problem. Instead of using at least six microcontroller pins to connect to the LCD (RS, EN, D7, D6, D5, and D4), the conversion module only needs to Use two pins (SCL, SDA) for connection. The I2C converter module supports all kinds of LCDs using the HD44780 driver (LCD 1602, LCD 2004) connected to the microcontroller via I2C communication, compatible with most of today's microcontrollers.

Figure 18: I2C Module [22]

This module contains the following features:

- Operating voltage: 2.5-6V DC. [22]
- Monitor support: LCD1602,1604,2004 (driver HD44780). [22]
- Communication: I2C. [22]
- Default address: 0X27. [22]
- Built-in contrast-adjustable rotating resistor for LCD. [22]

3.2 System Building

3.2.1 System Diagram

Speed detection systems can be divided into two main categories: amplifier circuit and frequency counter for speed display. The proposed block diagram for a Doppler radar-based vehicle speed detection system is shown in Figure 13. The speed detection system will manage the speed limit of the vehicle on the road.
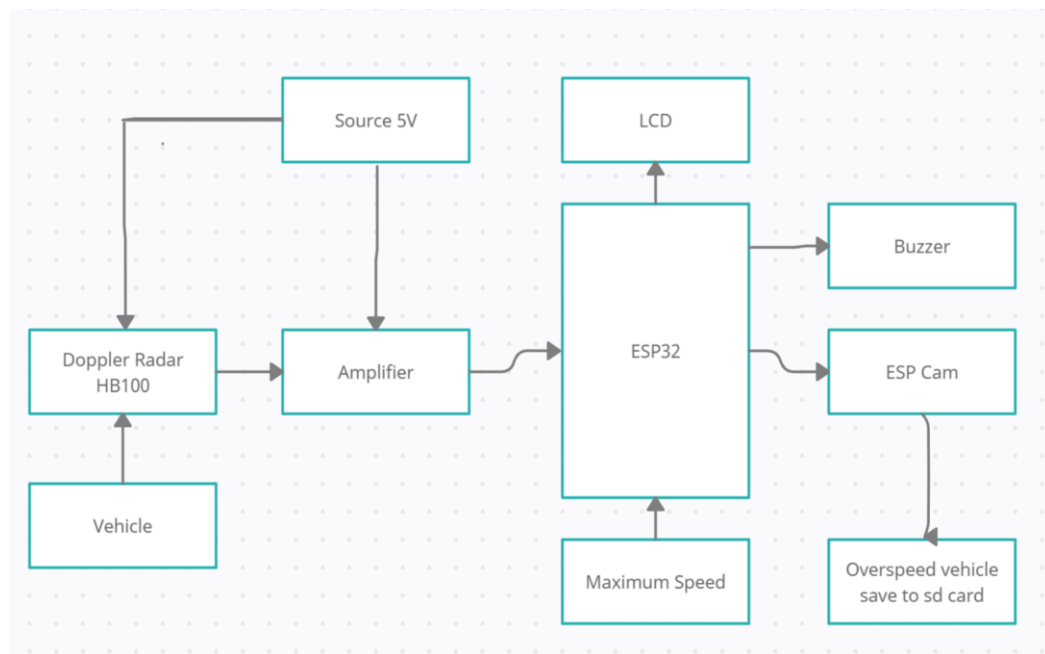
Figure 19: System Diagram

The speed of the vehicle is obtained from the continuous wave Doppler radar, which can detect moving the movement of the object or speed through the Doppler effect. The radar chosen for this system is HB100 with a transmitting frequency of 10.525GHz. The radar module operates at + 5Vdc for continuous-wave operation (CW). Therefore, the + 12V battery is used as a power source by converting it to + 5V through a voltage regulator using LM2596S. The output of a 12V to 5V voltage regulator circuit is connected to the + 5V pin of the module. After powering the radar module, the system starts to operate, and the module sends the transmitted signal from the antenna to the vehicle. Then, the reflected signal is returned to the transceiver antenna with a

variable frequency. The difference between the transmitted and received signals is called Doppler displacement. A microcontroller only works if its supply voltage is at least 3.5V. Hence, a high gain low-frequency amplifier is connected to the IF terminal to amplify the Doppler shift. The output of the amplifier is sent to the microcontroller. The purpose of the microcontroller is to calculate the speed of the vehicle through its frequency, which is the main factor that represents the speed. After performing the vehicle speed calculation, the LCD screen is used to display the vehicle speed. If the vehicle speed exceeds the permitted speed, the buzzer will sound. At the same time, the ESP32 CAM will take pictures and save them to the memory card.

3.2.2 Amplifier Circuit for Radar HB100

The radar doppler determines the frequency change in electromagnetic waves due to the movement of scattering closer to or away from the Observer by measuring the phase change occurring in electromagnetic waves in a series of pulses. The Doppler frequency is negative for objects too far away from the radar and positive for things in the radar detection area. The system can be used in real-time applications independent of temperature, humidity, airflow noise, dust, light. Since the sensor output is a sine wave with a minimal amplitude, it should be amplified by the amplifier before further processing.
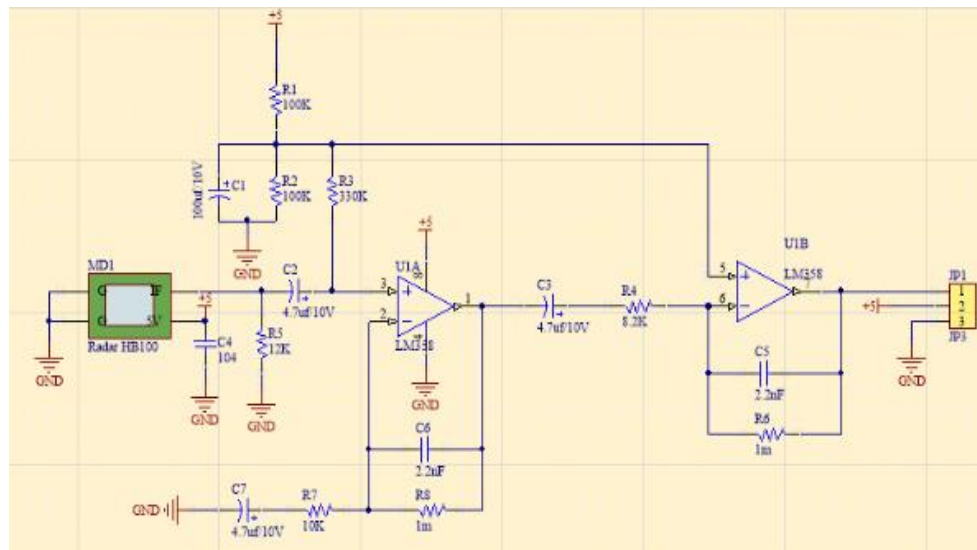

Figure 20: Amplifier Circuit Diagram
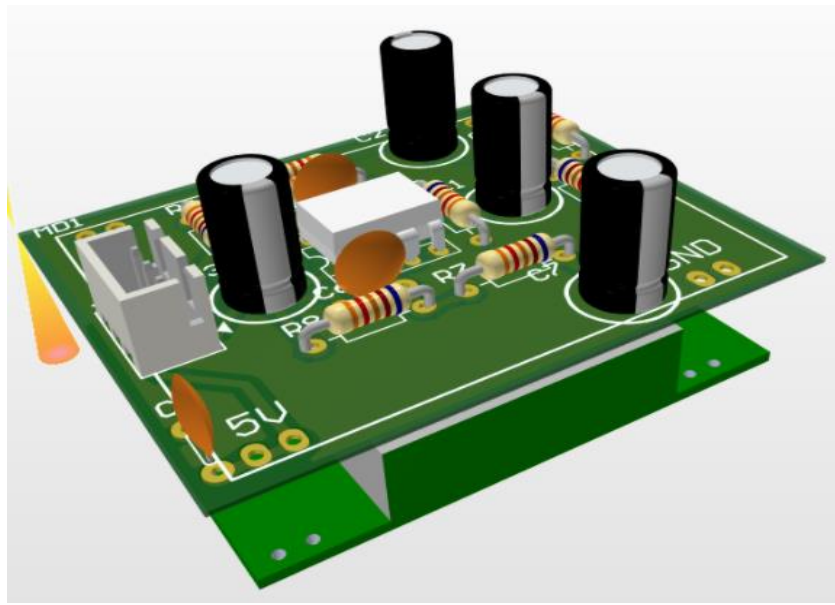
Figure 21: 3D Print Circuit

In this system, the continuous wave Doppler (CW) radar is a sensor combined with the microcontroller to calculate the vehicle speed. Furthermore, the amplifier is used to amplify the voltage level to control the microcontroller since the sensor output is in the form of an analog signal. The sensor output is within the audio frequency range so that the frequency is below the speed limit, i.e., close to 1.1Khz. The amplifier IC used for this purpose is Quad LM358 op-amp. The output signal from the radar is in the range of a few millivolts, so an amplifier is needed to convert the voltage level to a point where a TTL logic can be controlled (Transistor Logic).

To minimize the effects of the noise, amplifiers need to be performed in two stages. The first stage is configured as a non-inverting amplifier. Since the sensor output is a small DC value (0.01 to 0.2Vdc), it is necessary to AC coupling of the output and amplified at least 100 times for microcontroller control. The output of the first stage is a sinusoidal signal with a small DC deviation. The capacitor filters the DC component at the output. Assume Av1 = 100, for a non-inverting amplifier:

$$A_{v1} = 1 + \frac{R_{f1}}{R_{in1}}$$

(4)

From the datasheet of LM358, choose Rin1 = 10kΩ so that the output voltage is about 5V.

$$100 = 1 + \frac{R_{f1}}{10k}$$

$$R_{f1} = 99 \times 10k = 990k\Omega \cong 1M\Omega$$

$$R_{f1} = R_{f2} = 1M\Omega$$

$$C_{in} = 4.7\mu F$$

$$R_{in} = 10k\Omega.$$

The second stage is configured as an inverting amplifier. The 2.2nF capacitor in the amplifier feedback line configures an active low pass filter. High-frequency interference is filtered, and the accuracy of the system is improved. The two stages are cascaded to achieve the overall result of the amplifier. The second stage acts as a comparator, and the output generated is the waveform received by the microcontroller.

$$f_c = \frac{1}{2\pi R_{in2} C_{in2}} \quad (5)$$

$$4Hz = \frac{1}{2\pi R_{in2}(4.7\mu F)}$$

$$R_{in2} \cong 8.4k\Omega$$

The design of the amplifier circuit uses the op-amp LM324 as the driver selected 5V as Vcc. For cascading stages, the Vbias for each stage should be 2.5V.

$$V_{bias} = \frac{R_2}{R_1 + R_2} \cdot V_{cc}$$

$$2.5V = \frac{R_2}{R_1 + R_2} \cdot 5V$$

$$\frac{R_2}{R_1 + R_2} = \frac{1}{2}$$

R1 = R2 = 100kΩ

For minimum error due to input bias, currents must be reduced to almost 0.01mA

3.2.3 Circuit Connection to the System

The Speed monitoring system is assembled of the following blocks:

- Power unit: provides 5V power for the whole system.
- Installation block: easily adjust the speed limit.
- Speed reading unit: get the required input data
- Display unit: shows the frequency and speed of the vehicle.
- Notification block: when a vehicle exceeds the permitted speed, the buzzer will signal.
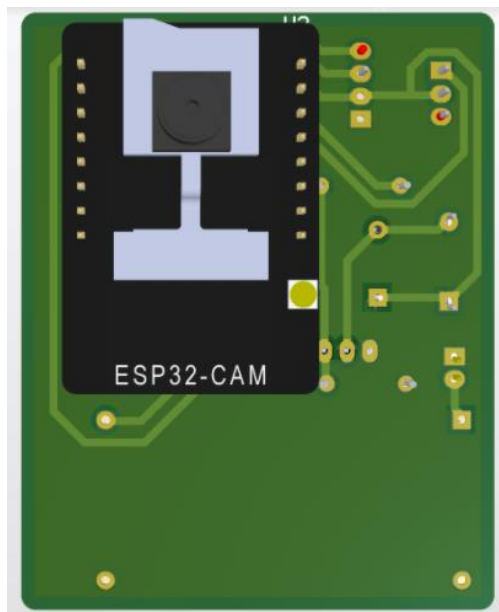
Figure 22: Front of Circuit
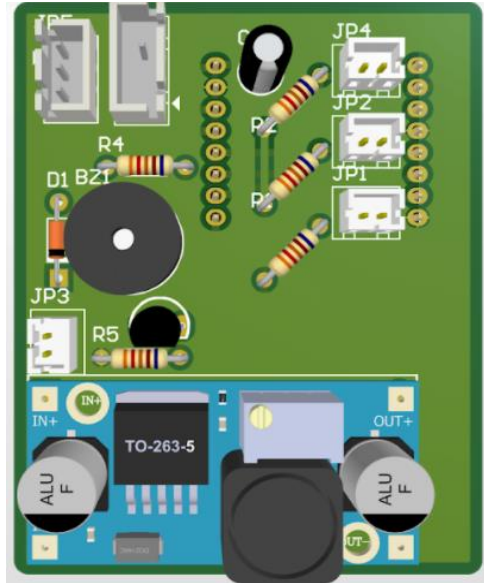
Figure 23: Back of Circuit

The doppler displacement equation is used to calculate the relationship between the frequency change and the speed of a moving object's speed.

$$fd = 2 * cosA * f * v / c \text{ (6)}$$

- fd: frequency change in Hz (i.e., frequency of the output signal from the radar)
- v: velocity of the moving object
- c: velocity of electromagnetic waves in vacuum
- f: frequency of wave transmitted from the sensor (10,525 GHz)

Assuming the object is in front such that the value of angle cosA = 1, the expression for the velocity of the object decreases to:

$$v = fd / 19.49074 \text{ (km / h)}$$

3.3 Software Building

There are several functions to explain in this project, but I will focus on four main function will be focus on.
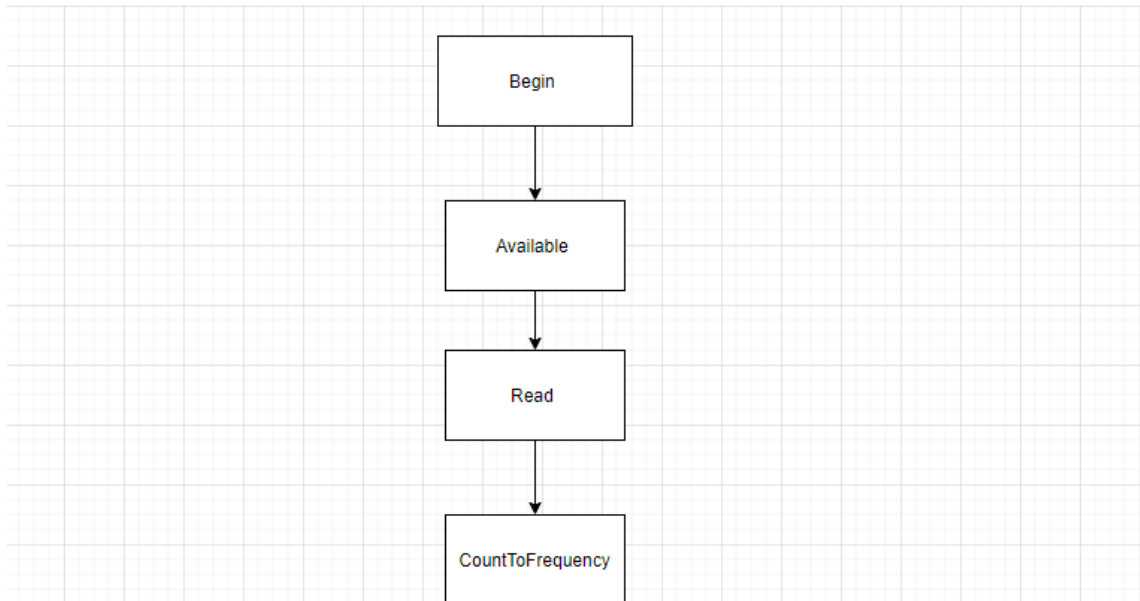
Figure 24: Function Flow

In the first block of function, the radar speed gun starts the Begin the shoot out and captures the frequency bounce back from the object, by setting capture measurement to zero, and begins the capture_start.

The second function Available, the function checks all frequencies and calculates the frequency sent out and bounces back from the object to the device.

Function Read starts by the time the frequency bounces back, the gun will read all the frequency from HB100, and starts to sort out.

Function CountToFrequency starts when function Read has been done. This function counts the Frequency bounce back from the object and counts it, then compares with the first frequency shoot out from the Begin.

```
ISR(TIMER_CAPTURE_VECTOR)
{
    uint16_t capture_lsw;
    uint32_t capture, period;
    uint8_t i;

    // get the timer capture
    capture_lsw = capture_read();
    if (capture_overflow() && capture_lsw < 0xFF00) {
        capture_overflow_reset();
        capture_msw++;
    }
    // compute the waveform period
    capture = ((uint32_t)capture_msw << 16) | capture_lsw;
    period = capture - capture_previous;
    capture_previous = capture;
```

Figure 25: Waveform Calculation

We used the Interrupt Service Routine(ISR) to capture the timer vector, also to handle the capture case and when overflow interrupts were pending(for example interrupts were disabled for a while), or where the overflow occurred while this ISR was starting up.

ISR also used timer to capture the signal from Radar HB100 and using that signal to calculate when the range of the wave have to be discontinued. We used the formular:

$$t = 1/f \text{ (7)}$$

Where t is the waveform period, and f is the length of two signal. After the calculation, the signal will be stored in a buffer and then compare with the first signal were generated from the Begin, from there the ESP32 can calculate the speed.

4. TESTING AND RESULT

4.1. Speed Calculation

If the 'f' is the value of the frequency of the microcontroller, the corresponding speed in Km / h is obtained by dividing it by a factor of 19.49. Some values for their respective frequencies and speeds are shown in the table below:

Table 1: Speed Calculation

Frequencies	Speed
0 Hz	0.00 km/h
100 Hz	5.13 km/h
400 Hz	20.52 km/h
800 Hz	41.04 km/h
1200 Hz	61.57 km/h

4.2 Accuracy when Measuring Speed.

Testing the overall system and sensor accuracy in speed measurement requires standard calibration equipment such as a speed gun to determine the speed of a moving vehicle. However, due to the lack of such resources available for testing, the system's accuracy of the system could not be accurately determined.

Table 2: Accuracy compare

Speed from the car meter	Speed from the system
0 Km/h	0 Km/h
10 Km/h	11 Km/h
17 Km/h	16 Km/h
20 Km/h	20 Km/h
25 Km/h	24 Km/h
30 Km/h	31 Km/h
35 Km/h	35 Km/h

The system accuracy is low. This could be due to several reasons:

- The direction between the motorcycle and the sensor is not perfectly aligned (i.e., angle A is not zero).
- The table is based on the observations of the motorcyclist and the observer looking at the LCD screen, making it difficult to synchronize the readings made by two observers.
- The output is affected by the number of objects that move around.

4.3 Comparison with Other Speed Measurement Method

4.3.1 GPS Based System

Figure 5 is shown an example of a GPS based system method using in an application called Snapchat. In ideal conditions, this application shows the speed of the vehicle or the speed of the person using that application in real-time with an almost accurate speed show on a vehicle.

We have tested this method again using the same application on a smartphone using a car in two conditions, normal weather and snowing day, and in the open road also inside the tunnel.

Table 3: Speed compare in open normal road and snowing conditions.

Speed by vehicle	Speed show on the app
10 km/h	9.54 km/h
20 km/h	19.7 km/h
30 km/h	29.8 km/h
40 km/h	39.6 km/h

Table 3 shows the speed comparison between the speed provided by the car and the speed on the application. As we can see, on the open road both in normal and snowing weather the speed provided by both systems has almost the same value.

After the open road test, we tried going into the tunnel to compare both systems again. This time we had different results.

Table 4: Speed compare inside tunnel road normal and snowing conditions.

Speed by vehicle	Speed show on the app
10 km/h	6.51 km/h
20 km/h	15.25 km/h
30 km/h	N/A
40 km/h	N/A

In this test, we are using the same speed as the test on the open road before. Table 4 has shown the result, the speed did not have the same numbers anymore, even if we run faster at 30 km/h and so on, the system even cannot measure the speed. This can be explained as the GPS-based system has to use many satellites to calculate and measure, one of the weaknesses of this system is an indoor condition or complicated environment such as jungle or caved. At this condition, the signal from both devices and satellites has been blocked, so the calculation or measurement is impossible or not accurate. Unlike GPS based system, the radar using the doppler effect has shown results in a very accurate way.

4.3.2 Speed Measurement Based on Image

This technic is based on a single frame or a single camera to calculate speeds. Unfortunately, we did not have the equipment to test, for more information, we can read more from Intraframe Scene Capturing and Speed Measurement Based on Superimposed Image. But as far as we know, this technic has been limited by the camera and environment such as when foggy weather or darkness, the ability of the camera has been limited in those conditions and leads to a false result.

5 CONCLUSION AND FUTURE WORK

The project introduces some speed measuring devices in traffic gives an overview of speed measurement methods.

Presenting the principles of building hardware circuit systems to measure vehicle speed and save captured images to memory cards.

The designed speed detection system is capable of continuously monitoring the vehicle's speed. The sensor works well for the car at a distance of about 7 meters.

The output is more accurate when there are no other moving objects around.

The value of each passing vehicle's speed is displayed on the LCD screen.

With each passing speed vehicle passing the sensor, the horn and the camera are activated, and the image is saved on the SD card.

The project camera used is a 2 Megapixel high-definition camera that communicates quickly, but the image quality is inferior and challenging to capture high-speed vehicles. Future development direction

Expanding the model with more optimized types of sensors and cameras Develop website system for easy data management.

Combine with image processing techniques to get high-quality data.

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