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Automatic Braking System Using CAN Protocol

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Abstract: This project is about creating an automatic braking system (ABS) for vehicles using the Controller Area Network (CAN) protocol for communication. The system uses an ultrasonic sensor to detect objects in front of the vehicle. The data from the sensor is sent to a microcontroller (STM32F407) that processes the information. If an obstacle is detected, the microcontroller sends a signal over the CAN network to another microcontroller, which controls the vehicle's brakes through a motor drive circuit. The CAN protocol helps ensure that all parts of the system communicate reliably and quickly, which is important for safety. The system also has a buzzer that sounds an alert when there's danger. This project shows that a simple and effective ABS can be built using common parts and the CAN protocol, improving vehicle safety and reducing the risk of collisions. In the future, more sensors could be added for better awareness of the surroundings, and smarter control systems could improve braking performance.

***Index Terms* - Controller Area Network, STM32F407.**

I. Introduction

Accidents occur due to technical problems within the vehicle or due to mistakes of the driver. Sometimes the drivers lose control over the vehicle, and sometimes accidents occur due to rash driving. When the drivers come to know that the vehicle is going to collide, they become nervous, and they don't apply the brakes. The majority of the accidents occur this way. The system designed will prevent such accidents. It keeps track of any vehicles in front. It will continuously keep track of the distance between the two vehicles. When two come dangerously close, the microprocessor in the system activates the brakes, and it will stop the vehicle. The Automatic braking system is introduced for providing safety and comfort to the driver during driving. The main aim of the system is to avoid critical damage to the vehicle during driving. Most of the time, the driver is unable to judge the proper distance between the car and an obstacle, so this system will be helpful as well as important in car safety. As the requirements of human beings for comfort and safe driving increase, this system is an addition to the regular safety system and also increases the demand for vehicles in the market view.

CAN Protocol:

The CAN bus was developed by BOSCH as a multi-master, message broadcast system that specifies a maximum signalling rate of 1 megabit per second (bps). Unlike a traditional network such as USB or Ethernet, CAN does not send large blocks of data point-to-point from node A to node B under the supervision of a central bus master. In a CAN network, many short messages like temperature or RPM are broadcast to the entire network, which provides for data consistency in every node of the system. CAN is an International Standardisation Organisation (ISO)-defined serial communications bus originally developed for the automotive industry to replace the complex wiring harness with a two-wire bus. The specification calls for high immunity to electrical interference and the ability to self-diagnose and repair data errors.

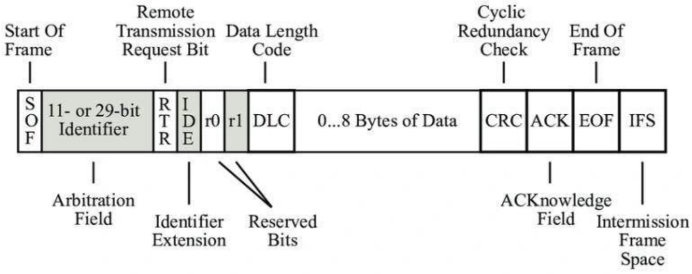

Fig 1.1 CAN Frame Format.

CAN Frame Format:

- SOF (Start of Frame): A dominant bit that marks the beginning of a message, used for synchronization among all nodes on the bus after being idle.
- Identifier: The 11-bit identifier in the standard CAN frame defines the message's priority. Lower binary values indicate higher priority messages.
- RTR (Remote Transmission Request): A dominant bit when a node requests information from another node. All nodes receive the request, but only the node with the matching identifier responds.
- IDE (Identifier Extension): A dominant bit indicates that a standard CAN identifier without extension is being transmitted.
- ro (Reserved): A reserved bit for future use in possible standard amendments.
- DLC (Data Length Code): A 4-bit code specifying the number of bytes of application data being transmitted.
- Data: The actual application data being transmitted, up to 64 bits in length.
- CRC (Cyclic Redundancy Check): A 16-bit field (15 bits plus delimiter) used for error detection, providing a checksum of the preceding application data.
- ACK (Acknowledgement): An error-free message indicator. Nodes receiving the message overwrite the recessive ACK bit with a dominant bit. If an error is detected, the bit remains recessive, and the message is discarded. This is a 2-bit field: one for the acknowledgement bit and one for the delimiter.
- EOF (End of Frame): A 7-bit field marking the end of the CAN frame. It disables bit-stuffing and indicates a stuffing error when dominant. Bit-stuffing inserts an opposite logic level bit after five consecutive bits of the same level.
- IFS (Inter-frame Space): A 7-bit field specifying the time needed for the controller to move the correctly received frame into its buffer area.

Extended CAN Frame Format: In the extended format, there are additional bits:

- SRR (Substitute Remote Request): Replaces the RTR bit in the standard format, serving as a placeholder in the extended frame format.
- IDE (Identifier Extension): The recessive IDE bit signals that additional identifier bits are following. The extension consists of 18 more bits.
- r1: A reserved bit added after the RTR and r0 bits, placed ahead of the DLC bit in the extended frame format.

II.HARDWARE REQUIREMENTS

1. STM32F407 Discovery Board

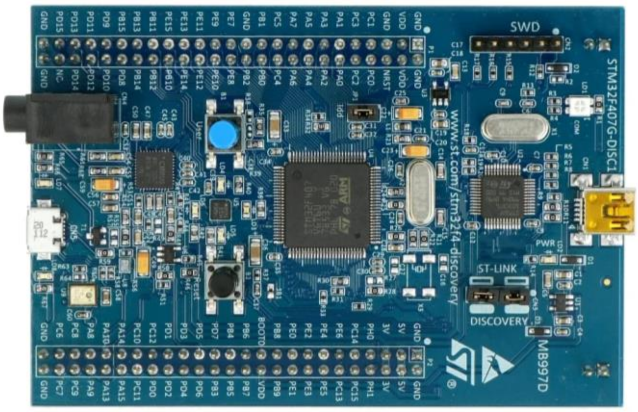

Fig 2.1 STM32F407 Discovery Board

The STM32F407G-DISC1 Discovery Kit is a development board designed for exploring the STM32F407/417 series microcontrollers. It features the STM32F407VGT6 microcontroller with a 32-bit ARM Cortex-M4F core, running at up to 168 MHz, and includes 1 MB Flash and 192 KB RAM. The board also integrates an ST-LINK/V2 debug tool, MEMS sensors (3-axis accelerometer and digital microphone), LEDs, push buttons, and a USB OTG connector. It can be powered through USB or an external 5V supply and supports debugging and programming through ST-LINK using IDEs like Keil or STM32Cube IDE. The board is available in two versions: the newer "DISC1" (MB997D) and an older version (MB997C). Additionally, the STM32F4 Discovery board offers modules for communication and interface design with support for various IDEs like IAR Embedded Workbench®, MDK-ARM, and STM32CubeIDE.

2. MCP2551 CAN Transceivers:

The MCP2551 is a high-speed, fault-tolerant CAN transceiver that connects a CAN protocol controller to the physical bus. It is fully compliant with the ISO-11898 standard, supporting 12V and 24V systems and can operate at speeds up to 1 Mb/s. The device provides differential transmit and receive capabilities, ensuring reliable data transmission even in the presence of high-voltage spikes on the bus. It also offers features like ground fault detection, power-on reset, voltage brown-out protection, and protection against short-circuit conditions. The MCP2551 can connect up to 112 nodes, operates with low current in standby, and has high noise immunity. It is available in industrial (-40°C to +85°C) and extended temperature ranges (-40°C to +125°C).

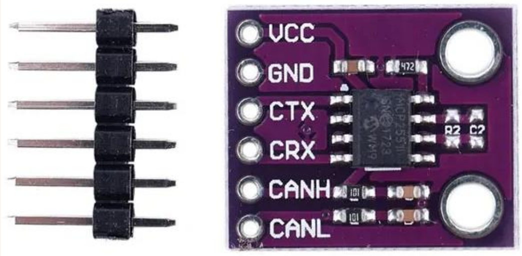

Fig 2.2 MCP2551

3. L298N Motor Drive Module.

The L298N Motor Driver Module is a high-power motor driver designed for controlling DC and Stepper Motors. It incorporates the L298 motor driver IC and a 78M05 5V regulator. The module can control up to four DC motors or two DC motors with both direction and speed control using PWM signals. The pinout configuration includes inputs (IN1, IN2 for Motor A and IN3, IN4 for Motor B) for controlling motor direction, ENA and ENB for enabling PWM signals, and output pins (OUT1, OUT2 for Motor A and OUT3, OUT4 for Motor B) to drive the motors. It is powered via a 12V input for the motors, while a 5V supply powers the logic circuitry of the L298N IC. The module also features a ground pin (GND) and provides a power-on LED indicator. The L298N motor driver supports motor supply voltages up to 46V and can handle up to 2A of current per motor. It operates within a driver voltage range of 5-35V and provides a maximum power output of 25W. Additionally, the module includes current sensing for each motor and comes equipped with a heatsink for effective thermal management.

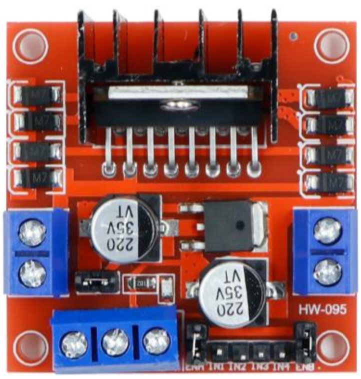

Fig 2.3. L298N

4. Ultrasonic Sensor (HC-SR04)

The HC-SR04 Ultrasonic Ranging Module is a non-contact distance measurement device that provides measurements from 2 cm to 400 cm with an accuracy of up to 3 mm. It consists of an ultrasonic transmitter, receiver, and control circuitry. The basic working principle involves using an IO trigger to send a high-level signal for at least 10 µs. The module then emits eight 40 kHz ultrasonic pulses and waits for a pulse to return. The time between sending and receiving the pulse is used to calculate the distance based on the formula:
Distance = (high-level time × velocity of sound (340 m/s)) / 2

Fig 2.4. HCSR04

5. USB to TTL UART serial converter.

The CP2102 USB to TTL UART Serial Converter allows embedded systems to establish a serial connection with a computer via USB. When connected to a USB bus, it appears as a standard COM port. It uses the CP2102 USB-to-UART bridge controller and is fully compliant with the USB 2.0 specification, supporting full-speed data transfer at 12 Mbps. The converter implements all RS-232 signals, including control and handshaking signals.

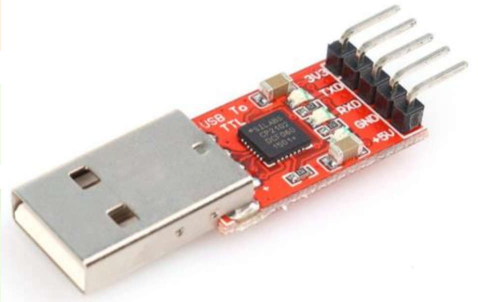

Fig 2.5. CP2102

III.DESIGN AND IMPLEMENTATION

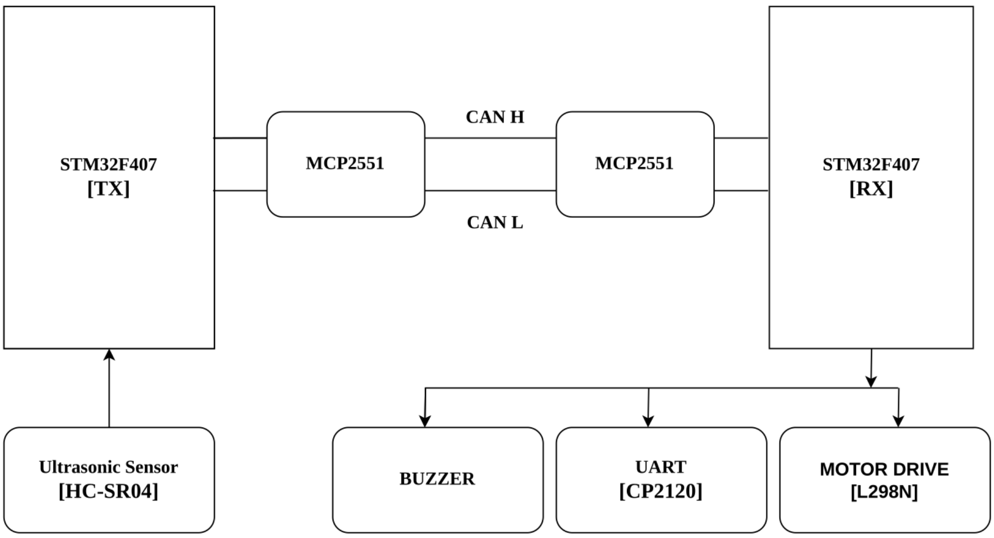

Fig 3.1. Block diagram.

1. STM32F407 [TX]: This microcontroller acts as the "transmitter" and is responsible for gathering data from the sensor and initiating the braking action. This unit is primarily transmitting data onto the CAN bus.
2. STM32F407 [RX]: This microcontroller acts as the "receiver" and is responsible for receiving the braking command and controlling the actual braking mechanism. This unit is primarily receiving data from the CAN bus.
3. MCP2551 are transceivers that convert the digital signals from the STM32F407 MCUs into the differential signals required for the CAN bus and vice versa. They act as a bridge between the microcontroller and the physical CAN bus. The two wires that make up the CAN bus. CAN H (High) and CAN L (Low) carry the differential signals that enable communication between the nodes.
4. Ultrasonic Sensor [HC-SR04]: This sensor measures distance to obstacles by emitting ultrasonic pulses and measuring the time it takes for the echo to return. This data is crucial for the automatic braking system to detect potential collisions.
5. MOTOR DRIVE [L298N]: This is a motor driver module that can control the speed and direction of a DC motor. In this system, it's used to control the braking mechanism
6. BUZZER: This is an audible alarm that can be used to provide warnings or alerts to the user about potential dangers or system status.
7. UART [CP2120]: This indicates a serial communication interface (Universal Asynchronous Receiver/Transmitter) using a CP2120 converter. This is used for distance for external devices.

System Functionality :

- The STM32F407 [TX] reads data from the Ultrasonic Sensor [HC-SR04] to determine the distance to any obstacles in front of the vehicle.
- The STM32F407 [TX] processes the distance data and determines if there's a risk of collision.
- If a potential collision is detected, the STM32F407 [TX] sends a message over the CAN bus via the MCP2551 transceiver. This message contains information about the urgency of the braking action required.
- The STM32F407 [RX] receives the CAN message via its MCP2551 transceiver.
- Based on the received message, the STM32F407 [RX] controls the MOTOR DRIVE [L298N] to apply the brakes.
- The BUZZER is activated by STM32F407 to warn the user.
- The UART [CP2120] interface is used for displaying distance between a system and an obstacle to an external device.

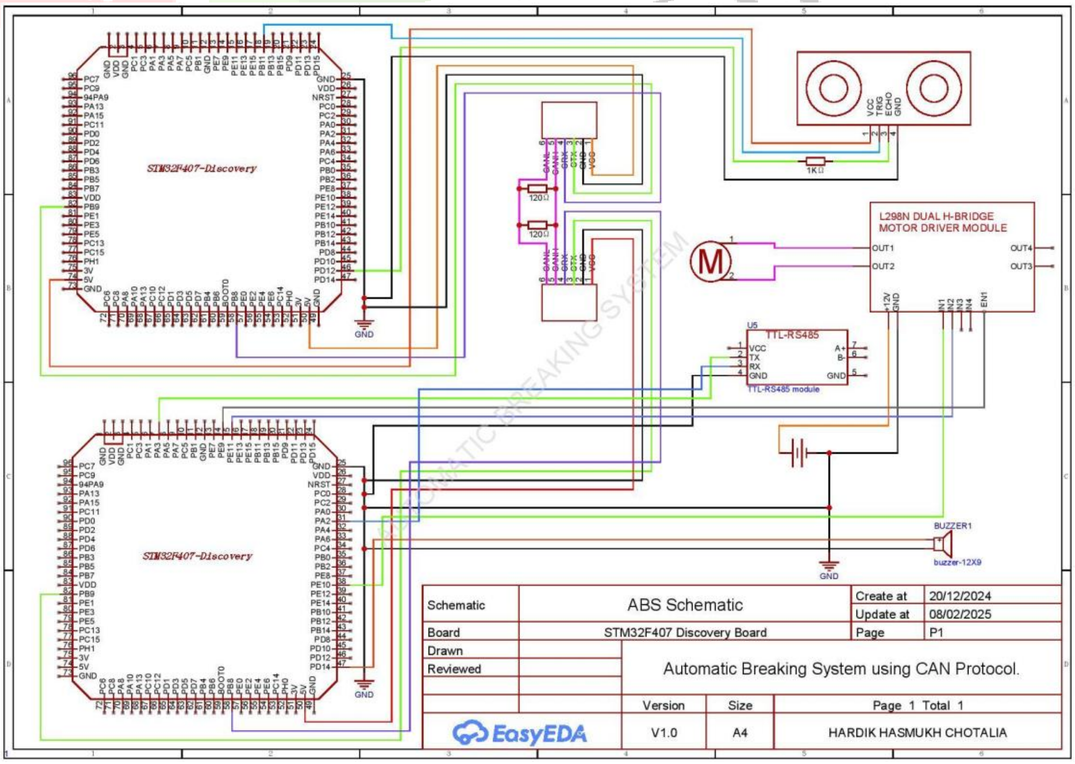

Fig 3.2. Circuit diagram.

IV. ADVANTAGES , DISADVANTAGES & FUTURE SCOPE

- Advantages of Automatic Braking Systems:

1. Increased Safety : Automatic braking systems enhance safety by automatically applying the brakes when a potential collision is detected. This is particularly useful in situations where the driver may be distracted or unable to react quickly enough.
2. Reduced Driver Fatigue : These systems can alleviate some of the driving responsibilities, especially on long drives or in stop-and-go traffic, helping to reduce driver fatigue.
3. Improved Fuel Efficiency : By automatically applying the brakes, the system helps the car maintain a smoother and more controlled speed, which can improve fuel efficiency as less acceleration is needed after braking.
4. Reduced Insurance Costs : Many insurance companies offer discounts for cars equipped with automatic braking systems, as they lower the risk of accidents, potentially reducing premiums.
5. Increased Resale Value : Vehicles with automatic braking systems are often seen as more desirable, which can lead to a higher resale value.

- Disadvantages of Automatic Braking Systems:

1. Cost : The installation of automatic braking systems can be expensive, especially those utilizing advanced sensors and cameras.
2. False Positives : These systems can sometimes apply the brakes unnecessarily, due to factors like shadows, reflections, or other environmental conditions.
3. Dependence : Over-reliance on the system can cause drivers to become less attentive to their surroundings, which could be dangerous if the system malfunctions.
4. Maintenance : Automatic braking systems require regular maintenance to ensure proper functioning, which can increase the overall cost of vehicle ownership.
5. Cybersecurity Risks : Being connected to the car's computer network, automatic braking systems are vulnerable to hacking. A malicious hacker could potentially take control of the system, posing safety risks.

- Future Scope of Automatic Braking Systems:

1. Integration with Other Safety Systems : Future systems may integrate automatic braking with other safety technologies like lane departure warning and blind spot monitoring, creating a more comprehensive safety suite.
2. Artificial Intelligence (AI) : AI could improve the accuracy of automatic braking systems by enabling them to recognize various obstacles and predict collision risks more effectively.
3. V2X Communication : Vehicle-to-everything (V2X) communication will allow vehicles to exchange information with each other and infrastructure, enhancing the performance of automatic braking systems by providing more data about potential hazards ahead.
4. Autonomous Driving : As autonomous driving technology evolves, automatic braking systems will become more sophisticated and reliable, playing a crucial role in fully autonomous vehicles.
5. Personalized Braking : In the future, these systems may be able to adapt to individual driving styles and road conditions, offering a personalized braking response tailored to each driver’s habits and the environment.

V. CONCLUSION

The Automatic Braking system, if implemented can avert lots of accidents and can save invaluable human lives and property. Implementation of such an advanced system can be made compulsory similar to wearing of seat belts so that accidents can be averted to some extent. Our Automatic braking system provides a glimpse into the future of automotive safety, and how much more advanced these individual systems can be for avoiding accidents and protecting vehicle occupants when they are integrated into one system. The future of automotive safety is more than just developing new technology; it is shifting the approach to safety. Automatic BRAKING SYSTEM approach represents a significant shift from the traditional approach to safety, but it is fundamental to achieving the substantial benefits.

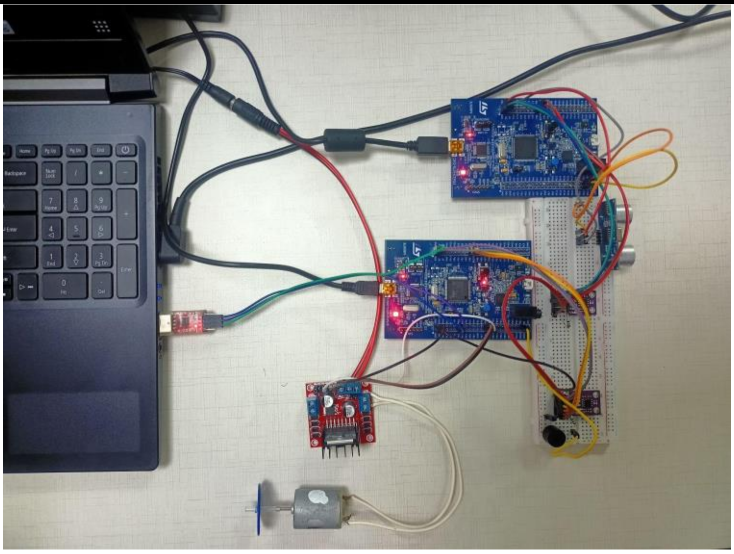

Fig 5.1 ABS using CAN

VI. ACKNOWLEDGEMENT

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