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ARM Platform for Assisted Parking

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***Abstract*—This paper presents a novel approach to automate vehicle parking for enhanced vehicle safety using ultrasonic sensors under the control of an ARM Cortex M3 kit. Parking safety remains a paramount concern in automotive applications, necessitating continuous advancements in obstacle detection technologies. Leveraging the effectiveness of ultrasonic sensors in detecting obstacles across a wide range, the proposed system offers real-time distance measurements between the vehicle and nearby objects. This data is communicated to the driver via a UART terminal, while status indicators, such as LEDs, provide immediate alerts when the proximity to obstacles breaches a predefined threshold. By harnessing the capabilities of ARM Cortex M3 technology and ultrasonic sensors, the system aims to significantly mitigate the risk of collisions during parking maneuvers. Its ability to provide accurate, real-time information empowers drivers to navigate parking spaces more safely and efficiently, thereby contributing to a smoother and more secure parking experience. experience.**

***Keywords*- ARM Cortex M3, Ultrasonic sensor, Parking Assistance.**

I. INTRODUCTION

In response to the growing demand for innovative solutions in urban mobility, this report presents a comprehensive analysis of the ARM platform's role in facilitating assisted parking systems. As cities worldwide grapple with increasing traffic congestion and limited parking spaces, the integration of advanced technologies becomes paramount in optimizing vehicular movement and enhancing driver convenience. Through an exploration of ARM-based assisted parking solutions, this document aims to elucidate the capabilities, benefits, and challenges associated with such systems. By examining key technical aspects, market trends, and potential applications, this report seeks to provide valuable insights for stakeholders in the automotive industry, urban planning authorities, and technology developers alike.[1].

In response to the imperative of ensuring safe and efficient parking experiences, automotive manufacturers have consistently prioritized the development of parking assistance systems. Aligned with this commitment to safety, regulatory bodies governing transportation have mandated specific safety standards for parking assistance features to be integrated into vehicles from the initial design phase. Complementing these regulations, governmental initiatives focus on enhancing parking infrastructure, offering training programs for drivers to foster safer parking practices, disseminating educational campaigns to raise awareness about parking safety, and implementing measures tailored to safeguard pedestrians and other vulnerable individuals in parking areas. [2].

Automobile manufacturers are steadfastly dedicated to advancing the safety infrastructure of forthcoming vehicles. Presently, a myriad of technologies have been developed and integrated, including but not limited to Adaptive Cruise Control (ACC), Lane Departure Detection, Automated Parking Systems, Advanced Driver Assistance Systems (ADAS), Fatigue Detection, Anti-lock Braking Systems (ABS), Blind Spot Detection, and Electronic Stability Control. [3]. Numerous companies are currently focusing their research efforts on advancing autonomous control systems for vehicles, employing a variety of sensors. These vehicles can be categorized based on the degree of human intervention required during operation

This paper is centered on the development of a cost-effective Safe Parking Assistance system by leveraging the rapid interrupt response capability of the ARM Cortex-M3 microcontroller. Research indicates that human reaction times in maneuvering vehicles during potential collision scenarios tend to slow with age [4]. The selection of ultrasonic sensors was based on their high resolution for accurately measuring surrounding distances. The processor analyses sensor data to determine if distances fall below or exceed predefined thresholds. The paper is structured into five sections: Introduction (Section I), Related Works (Section II), Methodology (Section III), Implementation Procedure (Section IV), and Conclusion drawn from the results (Section V).

II. RELATED WORK

In their research [5], the authors focused on addressing potential collisions during parking maneuvers by introducing automation to aid vehicles in avoiding obstacles. They achieved this by embedding intelligence into microcontrollers, which are then linked to the core components of the car's parking system, including sensors and actuators. This automated response is activated when the driver fails to respond to warning signals. Unlike fully autonomous parking systems, this proposed approach can be integrated into traditional vehicles to enhance safety while maintaining the enjoyment of parking. Features such as comprehensive parking alerts with LCD displays can be easily realized through this method. By offering collision forecasts, this implementation assists in minimizing accidents, thereby ensuring the safety of both passengers and vehicles. A realistic simulation environment to test the parking system has been proposed. In this model, the vehicle dynamics and control advice are viewed as a combined program, allowing both discrete system decisions and continuous vehicle dynamics to be modeled. Verification of collision avoidance while parking consists of rigorous, computer-verified mathematical proofs of its ability to avoid a collision under sufficiently clear and unambiguous conditions of the vehicle's kinematics and parameters. This maneuvering system has proven that the vehicle will not hit any fixed obstacles [6].

In [7], the system is centered on vehicle tracking and monitoring, facilitated by the LPC1768 microcontroller. This setup collects various vehicle parameters, storing them in a database. Additionally, a graphical user interface (GUI) is developed to visualize the collected data for calculating factors such as velocity. Particularly beneficial for cargo vehicles, this system offers effective monitoring capabilities. A cost-effective solution to automotive control challenges is presented, detailed at the block level. Comprising two components, the system includes a Vehicle-to-Vehicle Collision Avoidance Unit (VVCAU) designed to prevent collisions between vehicles, while the Black Box (BB) records pertinent vehicle data such as speed, braking status, accident direction, date, temperature, and distance. The microcontroller employed in this system is the LPC1768 [8]

III. METHODOLOGY

A. ARM CORTEX M3

The ARM Cortex M3 processor(Fig 1) is well-known for its outstanding efficiency and flexibility, specifically designed for tasks that demand quick responses and minimal power usage. It's part of the ARM Cortex™ processor family, which uses a consistent design to meet a wide range of performance needs across different technologies. Within this family, processors are based on three distinct ARMv7 architecture configurations: A-profile for complex modern applications, R-profile for real-time systems, and M configuration, which is aimed at cost-effective microcontrollers and applications. As the first processor from ARM to use the ARMv7-M architecture as shown in fig 2, the Cortex-M3 is built to provide strong performance in embedded applications, especially in environments where power and cost are critical factors. It's used in various applications such as microcontrollers, vehicle systems, industrial controls, and wireless networks, and it also simplifies ARM's Alternate Programmability Architecture for less complex tasks. Introduced in 2006, the Cortex-M3 marks the beginning of the Cortex processor series, offering impressive performance at a low threshold and bringing many features previously found only in high-end processors to a wider audience. Overall, the Cortex-M3 meets the demands of the 32- bit embedded processor market effectively and possess key attributes: High performance: Achieve increased productivity without the need for higher frequencies or increased power consumption. Low power consumption: Extend battery life, particularly crucial in mobile products and wireless network applications. Enhanced determinism: Ensure critical and interrupt tasks are processed promptly and consistently within a known number of cycles. Improved code density: Optimize memory usage by ensuring code fits into the smallest memory footprint possible.

A wide array of development tools is available for microcontrollers powered by the Cortex-M3 processor, ranging from free or inexpensive compilers to comprehensive development kits offered by various tool vendors. These microcontrollers offer numerous advantages, notably their seamless programmability using the widely-used C language and their adherence to a robust and established architecture. This adherence ensures that application code can be easily transferred and utilized, promoting easy reuse and reducing development timelines and testing efforts. Additionally, the Cortex processor introduces a range of advanced features and technologies designed specifically for microcontroller applications. For example, the ability to mask interrupts for critical tasks ensures uninterrupted operation of essential functions, while precise nested vector interrupts enable intricate and finely-tuned interrupt handling mechanisms. These advanced functionalities, combined with the inherent efficiency and reliability of the Cortex-M3 processor, make it an attractive choice for a wide range of users. It appeals not only to experienced professionals familiar with ARM processors but also to newcomers looking to incorporate powerful 32-bit microcontrollers into their products. The combination of user-friendly programming, architectural compatibility, and tailored features positions the Cortex-M3 as a versatile and indispensable solution poised to enhance innovation and efficiency across various microcontroller applications.[9].

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Fig 1: ARM Cortex M3 (LPC1768)

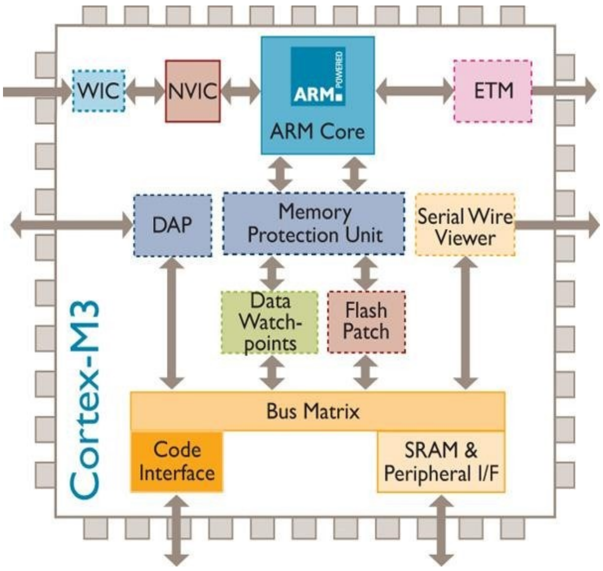

Fig 2: Architecture of Cortex-M3

B. Ultrasonic Sensor (HC-SR04)

Ultrasonic Module HC-SR04 which is in below fig 3 works on the principle of SONAR and RADAR system. It can be used to determine the distance of an object in the range from 2 cm to 400 cm.

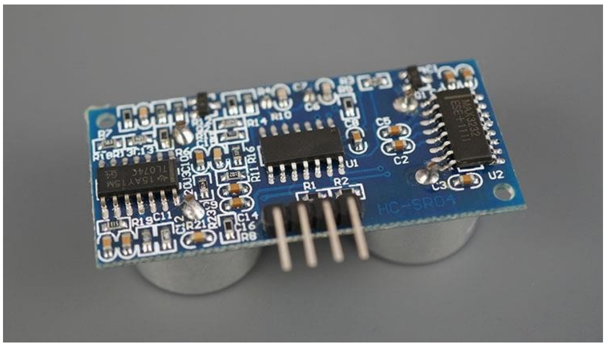

Fig 3: HC-SR04 Ultrasonic Sensor

The module has only 4 pins, VCC, GND, TRIG and ECHO. Trigger pin is activated to generate a burst of signals. After this the Echo pin is made high by the control circuit in the module. Echo pin remains high till it gets echo signal of the transmitted pulses back. The time for which the echo pin remains high, i.e., the width of the Echo signal, which indicates the time it takes for the generated ultrasonic sound to travel to and from the obstacle. Using this time and the conventional value of the speed of sound in air, we can find the object's distance using a simple formula for distance using speed and time [10].

VS = 343 m/s = 0.0343 cm/s (speed of sound in air) (1)

DT= 0.0343 cm/s x T sec (total travelled distance) (2)

D = $(0.0343 \times T)/2$ cm (Actual distance of separation) (3)

Fig. 4 is a depiction of sound waves generated by the sensor and receiving after rebound. Ultrasonic Distance/Ranging Sensors are based on similar working principle to what is used in sonar. Ultrasonic sensors emit sound waves at a frequency that exceeds the range of human hearing. The probe sensor acts as a microphone to receive and transmit ultrasound. It has two transducers, one for transmitting ultrasound and one for receiving echoes. Based on the time it takes for the echo to arrive, we can calculate the distance. By calculating travel time and speed of sound, the distance can be calculated. It emits an ultrasonic pulse that travels through the air and bounces back to the sensor if there is an obstacle or object. Whenever an object is near, the ultrasonic sensor detects the object and gives a signal.

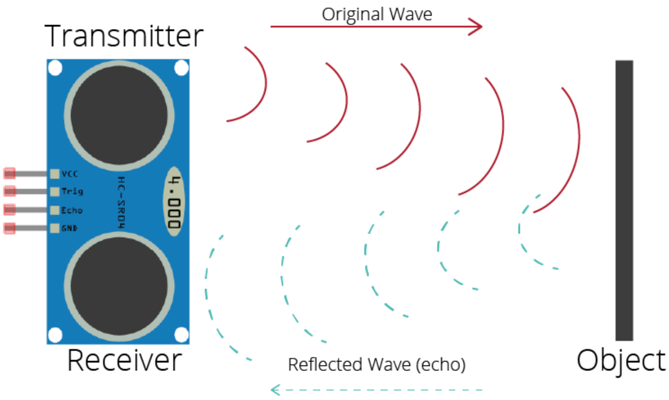

Fig 4: Soundwave Generation from HC-SR04 module

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C. Distance Caluculations:

We know speed of sound in air,

$$V_s = 343 \text{ m/s} = 0.0343 \text{ cm/us}$$

We also know the time it took for sound waves to emit and echo back, let's call this time taken T. Now, by using basic distance formula we can find the distance as:

$$\text{Distance Travelled} = \text{Speed x Time taken}$$

$$D_s = 343 \text{ m/s x } T_{seconds}$$

Now, since we will be measuring ECHO ON-Time in microseconds and also to get distance in centimetres we can change the units as follows:

$$D_T \text{ in cm} = 0.0343 \text{ cm/us x } T_{us}$$

After this we divide the computed value by 2 since the waves have travelled double distance.

$$D = D_T/2 = 0.0343XT/2 \text{ CM}$$

IV. IMPLEMENTATION

The ALS Development board under consideration is powered by the LPC1768 microcontroller, which belongs to NXP Semiconductor's esteemed family of ARM Cortex-M3 microcontrollers. Noteworthy for its high degree of integration and remarkable efficiency, the LPC1768 operates at a clock speed of 100 MHz while maintaining low power consumption— a crucial factor in today's energy-conscious design landscape.

Programming for this sophisticated microcontroller is facilitated through an integrated development environment (IDE) known as Keil uVision v4. This IDE provides developers

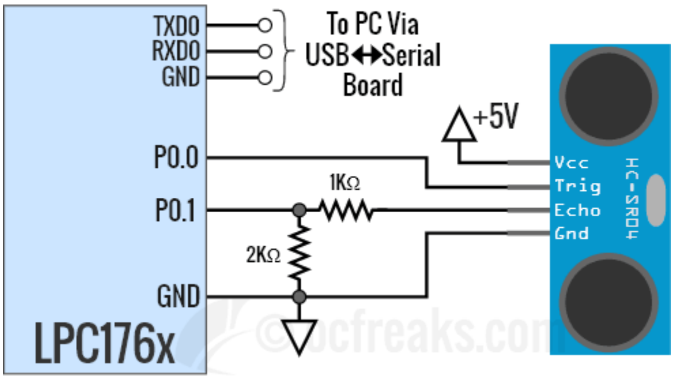

Fig 5: Circuit Diagram

with a comprehensive suite of tools and features tailored for Cortex-M3 microcontrollers, enabling efficient and streamlined development processes. With Keil uVision v4, programmers can harness the full potential of the LPC1768 microcontroller, leveraging its advanced capabilities to bring their innovative ideas to life while ensuring optimal performance and reliability. [11].

ARM's Keil uVision software is used to write the desired program to operate the sensor. The compiler and linker make the program to a machine-readable format. Building the project would lead to generation of hex files which is pushed into the microcontroller storage. The µVision IDE combines project

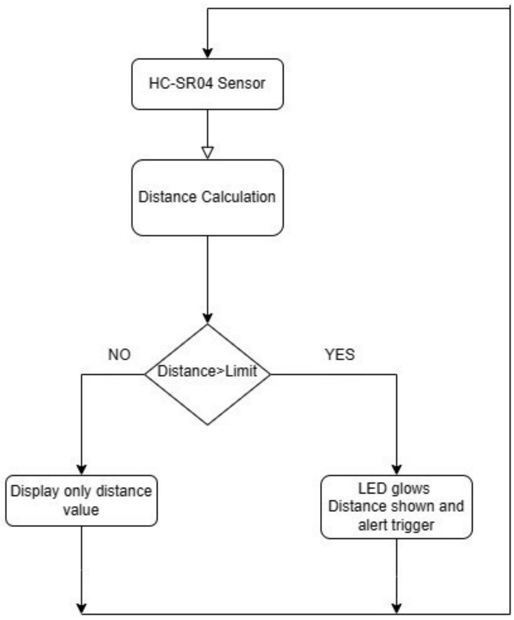

Fig 6: Flowchart of Implementation

management, production facilities, source code editing, program debugging and full simulation in one powerful environment. The platform is simple and easy to use, helping to create functional embedded programs [12].

Flash Magic is a PC tool for programming flash-based microcontrollers from NXP using serial bus, Ethernet, CAN or SWD in target hardware [13]. The first step is to select the communication port to communicate with the card. The baud rate is set to 115200 bps and oscillator frequency set to 12 MHz The build process of Keil software outputs a hex file which is selected to program the microcontroller.

The ultrasonic sensor emits sound waves to detect nearby objects, assuming a speed of sound in air of 343 m/s. Upon receiving a trigger pulse, the HC-SR04 Module releases a burst of 8 ultrasonic pulses at 40 kHz frequency[14]. Subsequently, it listens for the echo, which corresponds to the time it takes for the sound wave to return after hitting an object. The duration of the pulse being HIGH is measured, and this value is then used to calculate the distance between the vehicle and any obstacles. In the parking scenario, the aim is to ensure that the vehicle maintains a safe distance from obstacles while maneuvering into a parking space. A predetermined safe parking distance is set using the LIMIT macro. If the calculated distance between the vehicle and an obstacle falls below this limit, it indicates that the parking space is too confined or there is an obstacle in the way. In such cases, a warning signal is activated, such as an LED light, to alert the driver to adjust their parking trajectory and avoid potential collisions with surrounding objects. This functionality helps drivers park their vehicles safely by providing real-time feedback on the proximity to obstacles, thereby reducing the risk of accidents and minimizing damage to both the vehicle and surrounding structures. accident.[15]

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Circuit Diagram

In the interfacing example given fig 5, P0.0 of LPC176x is configured as output and connected to TRIG pin and P0.1 is configured as input and connected to ECHO pin of the Ultrasonic Distance sensor. Timer0 module is used for generating delays with 1 us resolution. It is also used to measure time for ECHO pulse using two simple functions viz. startTimer0() & stopTimer0(). The distance data is sent to Terminal via UART0. The HC-SR04 Ultrasonic module operates on 5 Volts and hence the output HIGH on ECHO pin is also 5V. We can directly interface this on any of the GPIO pin which has a 5V tolerant pad. But it's better to use a voltage divider (using 2K and 1K resistors) to get input from ECHO pin for additional safety. Note that we don't need to translate 3.3V to 5V for TRIG pin since 3.3V is already a HIGH for TTL compatible input pins.

CONCLUSION AND FUTURE SCOPE

The integration of ARM platform technology in parking systems has brought about significant advancements in efficiency, reliability, and user experience. By leveraging the power and versatility of ARM processors, parking systems have become smarter, more responsive, and capable of handling complex tasks with ease. The ARM platform has enabled seamless integration with various sensors, actuators, and communication protocols, allowing for real-time monitoring, automated payments, and intelligent decision-making processes. Moreover, the scalability and cost-effectiveness of ARM-based solutions make them accessible to a wide range of parking facilities, from small lots to large multi-level garages. The proposed system lays a solid foundation for enhancing parking safety, but there are several avenues for future exploration and development:

Advanced Sensor Technologies: Investigate the integration of advanced sensor technologies such as LiDAR and radar to enhance obstacle detection accuracy and range.

Integration with Vehicle-to-Everything (V2X) Communication: Explore the integration of V2X communication capabilities to enable real-time data sharing with other vehicles and infrastructure, further enhancing situational awareness and accident prevention.

Machine Learning and Artificial Intelligence: Utilize machine learning and AI algorithms to improve the system's ability to detect and respond to complex driving scenarios, such as unpredictable pedestrian behavior or adverse weather conditions. Autonomous Driving Features: Extend the system to incorporate autonomous driving features, such as automated emergency braking and lane-keeping assistance, to provide a higher level of driver assistance and safety. Cybersecurity Measures: Implement robust cybersecurity measures to safeguard the system against potential cyber threats and ensure the integrity and reliability of the safety-critical functionalities. User Interface Enhancements: Enhance the user interface with intuitive controls and visualizations to improve the user experience and promote widespread adoption of the system. Regulatory Compliance and Standardization: Stay abreast of evolving regulatory requirements and industry standards related to vehicle safety systems and ensure compliance with relevant regulations. By exploring these avenues, the proposed system can evolve into a comprehensive and sophisticated safety solution that not only prevents accidents but also contributes to the advancement of autonomous driving technology and the overall improvement of road safety.

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