Radar System with B-L475E-IOT01A board

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I. Introduction

This project aims to develop a radar system incorporating a Time-of-Flight (ToF) Sensor, QSPI Flash, UART, and a DAC Speaker. The primary objectives are accurate object detection and precise distance measurement.

II. Design Problem and Solution

A. *Design Problem*

ToF sensor has a limitation—it accurately detects objects within the range of 20mm to 2000mm, making it less effective for objects within 20mm or over 2000mm proximity to the device.

Moreover, in the context of a radar system, the mere provision of measured distance data, while accurate, may lack the necessary intuitive context for effective comprehension. Only presenting numerical distance values without additional information will limit its ability to interpret the significance of the data

B. *Solution*

To mitigate the impact of the ToF sensor's limited effective range, we have implemented a distance data filter. Specifically, any data indicating a distance of 20mm or 2000mm will be treated as invalid and, consequently, excluded from storage in the flash memory. This ensures that only reliable distance measurements within the sensor's range are stored, contributing to the accuracy of the collected data.

To provide a more intuitive interpretation of the data, we implemented a visual representation strategy. This involves graphical elements on a screen, specifically lines denoting the threshold and real-time data. By providing a clear and dynamic representation of both the predetermined threshold and the current real-time data, we can make our radar system more understandable.

III. Components

A. *Hardware*

- DAC Speaker: To enhance the practical utility of the radar system, instead of merely presenting raw real-time data, we incorporated a DAC speaker to introduce an alarm feature. In our case, a distance of 100mm serves as the minimum safe distance, effectively establishing the threshold for the radar system. When the real-time data indicate a distance less than this threshold, the speaker will be activated to generate an alarm, notifying an unsafe proximity to obstacles. By implementing an alarm functionality, we introduce a safety dimension to the system and creating a more secure operational environment.
- OLED Display Board: An OLED display board is used to make the radar system more intuitively understandable. This OLED visually displaying two lines—one indicating the predetermined threshold and the other representing the current distance to the detected obstacle. This visual representation significantly improves the system's overall practical utility

B. *Software*

The functionality of our radar system will be realized through C programming using STM32CubeIDE.

IV. Choice of Parameters

- Threshold: We have established a threshold of 100mm for our automatic radar system, considering the primary concern of minimizing false alarms. This decision takes into account the effective range of the Time-of-Flight (ToF) sensor, which operates optimally between 20mm and 2000mm. By setting the threshold at 100mm, we strike a balance that ensures the accuracy of alarm generation while providing users with enough time to respond to alerts.
- DAC value: We have incorporated a sine wave with a frequency of 1kHz as our DAC value for the alarm. The choice of frequency of the sound is aiming to create a noticeable and attention-grabbing alarm signal. This specific frequency, 1kHz, has been chosen for its perceptual characteristics, ensuring that it is harsh enough to effectively grab the user's attention in the event of an unsafe distance
- Delay time: The delay time is used to suspend the execution for a specified period (100 milliseconds according to our implementation). The delay is used to control the timing of sensor readings and display updates, ensuring that these operations occur at regular intervals rather than continuously. The 100 milliseconds is chosen to balance the accuracy of the reading while maintaining a relatively high OLED display frequency.

V. Evaluation Methods

To evaluate the performance of the system that integrates a Time-of-Flight (ToF) sensor, a DAC (Digital-to-Analog Converter) speaker, and an OLED display board, it is essential to conduct experiments to validate the performance of these components.

A. Time-of-Flight sensor evaluation

a) Accuracy test: The following experiment was carried out to test the accuracy of the Time-of-Flight sensor: obstacles were positioned at specific distances from the ToF sensor. The sensor's readings were then compared to these pre-measured distances to assess the accuracy of the ToF sensor in real-time object detection.

b) Environment influence test: The following experiment is aimed to test the influence of background light to the ToF sensor. Similar to the accuracy test, the sensor will measure the distance from obstacles but in different background light intensities.

B. DAC speaker evaluation

a) Alarm triggering test: Since we have established a threshold of 100 mm, the DAC speaker is expected to generate a noticeable alarm sound when the reading from the ToF sensor is below 100 mm. We should verify the alarm triggers at this distance.

C. OLED display board evaluation

a) OLED display test: The OLED should display two lines, one representing the threshold distance which is set to be 100 mm, the other line represents the current distance from the obstacle. To test the functionality of the design, we move the obstacle closer to the ToF sensor, the line representing the current distance is expected to move closer to the threshold line.

VI. RESULT AND BEHAVIORS

TABLE I. TOF SENSOR ACCURACY TEST RESULT

Actual distance/mm	*ToF sensor output/mm*	*Percentage of error/%*
1800	1790	0.56
900	896	0.44
100	99	1

The time-of-flight sensor provides an accurate and precise measurement of the distance from the obstacle with relatively low percentage of error.

TABLE II. ENVIRONMENT INFLUENCE TEST RESULT

Background Light	*Actual distance/mm*	*ToF sensor output/mm*	*Percentage of error/%*
strong	1800	1794	0.33
weak	1790	1782	0.45

It can be seen that background light has some impact on the performance of the ToF sensor. Strong background light will reduce the accuracy of the measurement..

TABLE III. ALARM TRIGGERING TEST RESULT

ToF sensor output/mm	*Alarm triggered*
45	yes
70	yes
110	no
150	no

OLED display test result: The OLED visually displays two lines—one indicating the predetermined threshold and the other representing the current distance to the detected obstacle. The photo below demonstrates this feature.

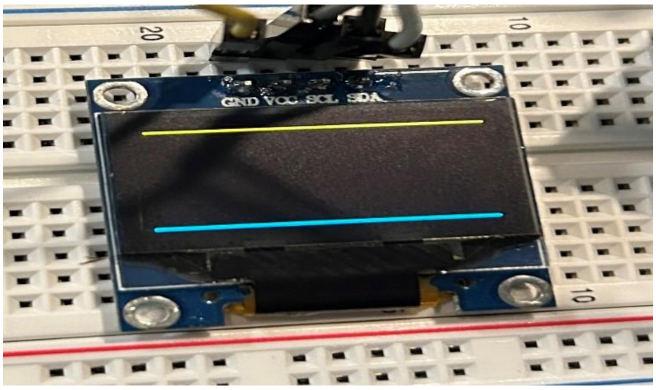

Fig. 1. OLED display

The orange line represents the threshold(100mm),while the blue represents the current distance to the detected obstacle. To test the functionality of the design, we move the obstacle closer to the ToF sensor, clearly it can be observed that the line representing the current distance will move closer to the threshold line.

VII. CONCLUSION

In summary, the team's objective is to incorporate a LiDAR system capable of detecting the range of objects and showcasing their positions on an LCD screen. Moving forward, enhancements will be made to introduce additional functionalities to this system. These upgrades encompass various alarm types, the integration of a board holder, and the development of a program designed to analyze previously recorded distance values. Ultimately, the team aims for a system that not only detects and displays object positions but also adapts to evolving needs through continuous improvement and analysis of collected data.