CMPE 663 Project G

Ultrasound

Andrei Tumbar

Instructor: Wolfe
TA: Nitin Borhade

By submitting this report, you attest that you neither have given nor have received any assistance (including writing, collecting data, plotting figures, tables or graphs, or using previous student reports as a reference), and you further acknowledge that giving or receiving such assistance will result in a failing grade for this course.

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Analysis/Design

This project looked at operating an ultrasonic sensor for distance detection. Operation of the ultrasonic involves input capture for echo timing as well as polling for accurate pulse widths. `TIM2` was used to operate the timing of input and output to the sensor. The UART was used to take user as usual. While taking sensor measurements, UART input can halt the measurements if any input is detected. To implement, a non-blocking check for UART input can be embedded into the loop for taking sensor measurements.

Ultrasonic sensor signals

Other than the voltage and ground wires, the ultrasonic sensor operates with two signals: trigger and echo. The trigger is an input to the sensor which tell the sensor when to fire its output pulse. The echo pin is an output from the sensor that will notify when the output ping is sent and when it returns.

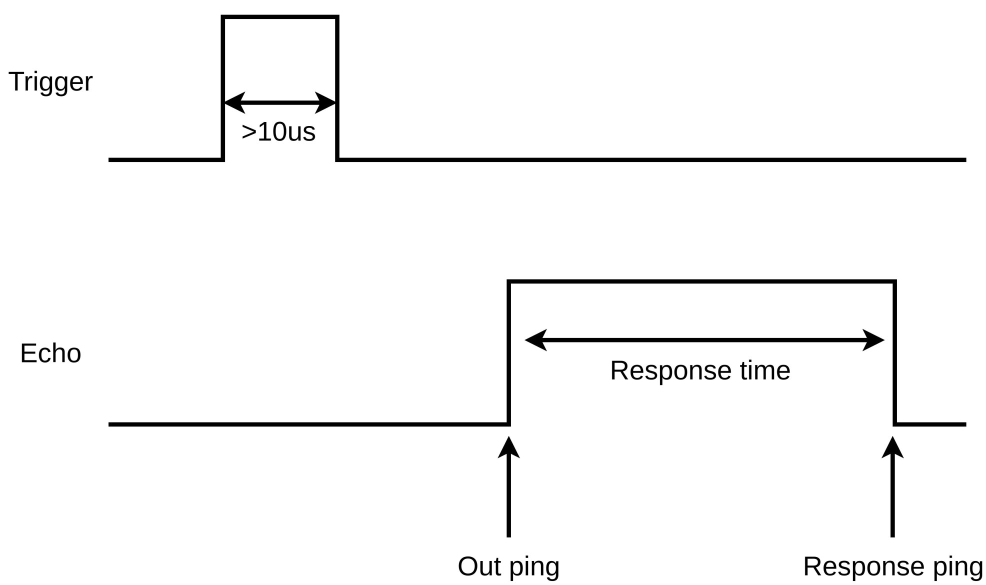

Figure 1: Ultrasonic sensor inputs and outputs

Figure **??** shows the pin operation for the input and output to the sensor. The output trigger can be easily implementing by setting the trigger pin high, waiting for ∼20 µs and then setting it back to low. The echo pin timing can be implemented by enabling input capture with both rising and falling triggers. The first event on the timer will provide a reference count to substract the second event from. The counter different will tell us how long the signal took to return. The speed of sound can be used to calculate the distance the sound wave travelled.

Distance calculation

Calculating the distance between detected surface and the sensor is fairly straight forward. I used a prescaler of 79 on `TIM2` with a system clock of 80 MHz. This means that each count on the timer represents 1 µs. Using this informating, we can derive an expression.

$$
\begin{aligned}
c &= 343\,\mathrm{m/s} && \text{Speed of sound in air} \\
\mathrm{t_{response}}\,\mathrm{\mu s} &= t_{reply} - t_{reference} && \text{Elasped time of wave travel} \\
\mathrm{d_{travel}}\,\mathrm{mm} &= \frac{\mathrm{t_{response}}\,\mathrm{\mu s}}{1000\,\mathrm{\mu s/ms}} \cdot \mathrm{c}\,\mathrm{m/s} && \text{Total travel of distance in mm} \\
d &= \frac{d_{travel}}{2} && \text{Travel is round trip distance}
\end{aligned}
$$

Using this conversion with a system clock and timer prescaler as stated above, the expression was verified to be correct by placing the sensor a known length away from a surface.

Test Plan

Testing the program involved pointing the sensor at a wall and testing the readings at varying distances. I implemented a "live" feed before the 100 measurements are taken to make creating the CSV easier. The ultrasonic sensor outputed values that were consistent with visual inspection. This confirmed the functionality of the sensor was correct. Testing revealed that my equation to convert timer ticks to distance was incorrect. I was not taking into account the fact that the travel time is a *round-trip* time. This means that you must divide this time by to calculate the distance the sound wave travelled.

Project Results

When testing the sensor measurements on different surfaces, we can see a varying standard deviation. For softer surfaces like a pillow or clothing, the deviation was significantly higher than for smooth and hard surfaces like a wall. The accuracy of the sensor was fairly high for distances between 100 mm and 3 m. At distances that were out of range, the pulse width was capped off by the hardware. When measuring larger distances, $> 1\,\mathrm{m}$, a large surface is needed because the cone radius rises as the distance away from the sensor increases.

Lessons Learned

This project was fairly straight forward. The code to implement this project was very similar to the first project. One difference between the two was the fact that this one required a timing output signal. I implemented this in the simplest form possible, setting the pin high, polling the timer counter, setting the pin to low. Before this project I was not familiar with the operation of the ultrasonic sensor.