Working of ultrasonic sensor with FPGA

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Documentation

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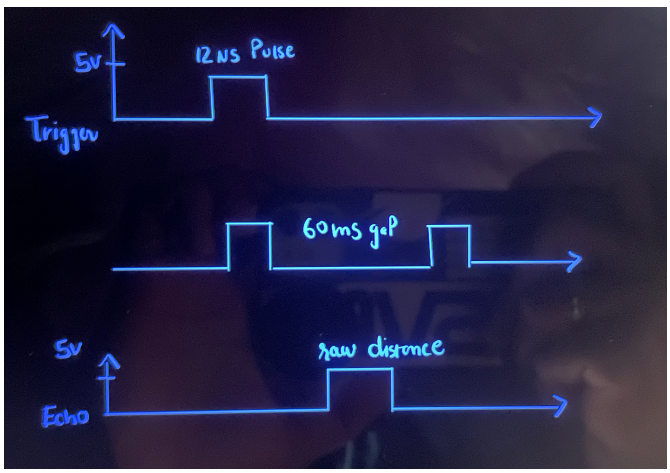
2. Ultrasonic Sensor

How the Ultrasonic Sensor Works
The ultrasonic sensor emits high-frequency sound waves (ultrasonic waves) and listens for their echoes. Here's how it operates:
Trigger Pulse: The sensor sends a short burst of ultrasonic waves by generating a trigger pulse.
Echo Detection: These waves travel until they hit an object. When they do, they bounce back as echoes.
Echo Reception: The sensor listens for these echoes, measuring the time it takes for the waves to return.
Distance Calculation: By knowing the speed of sound (approximately 343 meters per second or 0.0343 cm/μs), the sensor calculates the distance to the object using the formula: Distance = (Time * Speed) / 2.



3. Ultrasonic Module (`ultrasonic.v`)

The `ultrasonic.v` module controls the ultrasonic sensor and handles distance measurements. It features a finite state machine **(FSM)** to manage states such as idle, trigger, waiting for the echo, measurement, and measurement completion.
Key Components:
State Machine: Manages the sensor's operational states.
Counter: Keeps track of time intervals.
Measurement Logic: Captures the distance measurement when the measurement is complete.

4. Top-Level Module (`ultrasonicLED.v`)

The top-level module, `ultrasonicLED.v`, is the central component of the project. It interfaces with the FPGA board and connects the ultrasonic sensor to the LEDs for distance indication. Here's why we need a top-level module:

What Is a Top-Level Module?

A top-level module is the highest-level component of a digital design. It serves as the entry point for the entire system and interfaces with external components such as sensors, LEDs, and user inputs. In this project, `ultrasonicLED.v` acts as the top-level module.

Why Do We Need It?

- System Integration: The top-level module integrates all the lower-level modules and components, creating a cohesive system. It defines how different parts of the design work together.
- External Interface: It provides the interface to connect the FPGA board with external hardware, making it suitable for real-world applications. In this project, it connects the ultrasonic sensor and LEDs.

- Control and Coordination: The top-level module initiates and coordinates actions within the system. It controls when to trigger distance measurements and how to interpret measurement results.

5. How the Modules Work Together

- The `ultrasonicLED` module initialises the system and periodically triggers the `ultrasonic` module to measure distances.
- The `ultrasonic` module controls the ultrasonic sensor, sends trigger pulses, and processes echo signals.
- When a measurement is complete, the `ultrasonic` module calculates the distance and sends it to the `ultrasonicLED` module.
- The `ultrasonicLED` module interprets the distance measurement and updates the LEDs accordingly. It also monitors for timeouts.

6. Conclusion

The Ultrasonic Distance Measurement System demonstrates how to interface an ultrasonic sensor with an FPGA board and create a functional distance measurement system. The project combines hardware control and digital signal processing to accurately measure distances and provides a valuable learning experience in FPGA-based embedded systems.
This documentation provides a comprehensive understanding of the project's components, functionality, and how the ultrasonic sensor operates. It also highlights the role of the top-level module in system integration and external interfacing. It serves as a valuable resource for both understanding and implementing the project successfully.