Theoretical description

Project: Smart Parking System with Ultrasonic Sensors

Components:

- **NEXYS A7 50T Board**

FPGA development platform designed by Digilent. It includes Axtix-7 FPGA which provides a balance of processing power and I/O capabilities. Board contains several built-in peripherals, including an accelerometer, temperature sensor, MEMs digital microphone, a speaker amplifier, and several I/O devices allow the Nexys A7 to be used for a wide range of designs without needing any other components.

Ports:

- Power jack
- Powe switch
- USB host connector
- VGA connector
- Audio connector
- UART
- Ethernet connector
- Pmod ports

All Nexys A7 power supplies can be turned on and off by a single logic-level power switch (SW16). An external power supply can be used by plugging into to the power jack (J13) and setting jumper JP3 to “WALL”.

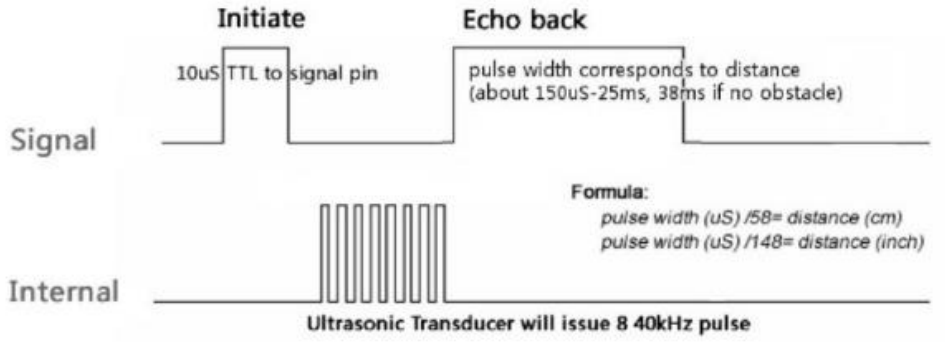
Thanks to its features and performance, A7-50T is a suitable also in the development and testing of digital systems.

- **HCSR04 Ultrasonic Sensor**

The HC-SR04 is measuring sensor module that uses sonar to determine distance to an object by sending out a sound pulse and timing how long it takes for the pulse to bounce back after hitting an object.

Ports:

- VCC = 5V
- Trig = Trigger input of Sensor
- Echo = Echo output of Sensor
- GND = GND

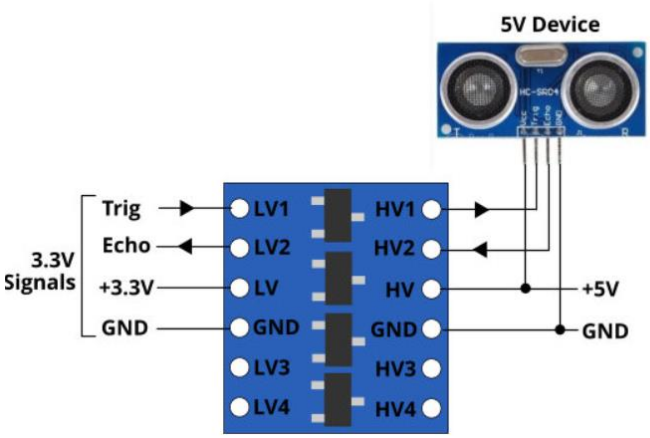


To start measurement, Trig of SRO4 must receive pulse of high (5V). for at least 10us, this will initiate the sensor will transmit out 8 cycle of ultrasonic burst at 40kHz and wait for the reflected ultrasonic burst. When the sensor detected ultrasonic from receiver, it will set the Echo pin to high (5V) and delay for a period (width) which proportion to distance. To obtain the distance, measure the width (Ton) of Echo pin.

Time = Width of Echo pulse, in uS (micro second)

- Distance in centimeters = Time / 58
- Distance in inches = Time / 148
- Or you can utilize the speed of sound, which is 340m/s

Since the HC-SR04 is powered from 5V and the NEXYS A7-50T board uses 3.3V, we used a logic level converter for the connection. The use of a logic converter ensures that the FPGA operating at 3.3V communicates safely with the HC-SR04 sensor, which needs 5V. This avoids the risk of damaging the FPGA due to too high a voltage.



FSM

Abstract machine that can be in exactly one of a finite number of *states* at any given time. In this project we use Moore machine which output depends only on state. The FSM consists of 5 unique states, each performing a specific function:

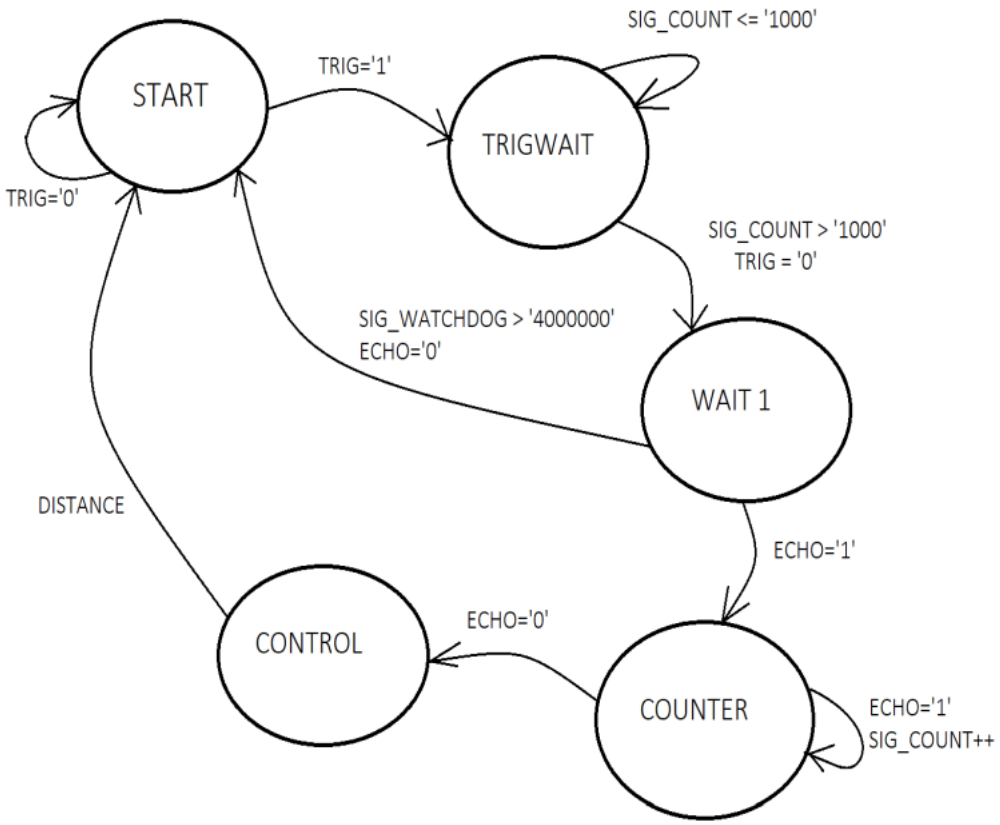
START - initial state of the measurement. By changing the TRIG signal to a value of 1, the transition to the TRIGWAIT state occurs.

TRIGWAIT - manage the duration of the trigger pulse that initiates the ultrasonic signal. Signal sig_count determine how long the TRIG pulse has been active. Once the sig_count exceeds 1000, the TRIG signal is set to '0', indicating the end of the ultrasonic pulse. After the TRIG pulse has been correctly terminated, the FSM transitions to the WAIT1 state.

WAIT1 - detects the ECHO signal, waits for the state to change to '1', which means that the echo signal has been caught. While waiting for ECHO, the sig_watchdog timer is activated, which increments with each clock cycle. This timer helps to identify when the ECHO signal does not arrive at the expected time (ECHO=’0’). When the ECHO signal changes to '1', FSM goes into the COUNTER state.

COUNTER - measuring the duration of the ECHO. This represents the duration of the ultrasonic signal from sending it to the sensor until it returns. Signal sig_count continues to increment while the ECHO signal is active. It records the total length of the active ECHO signal. When the ECHO signal changes to '0', the measurement process is finished and FSM goes into the CONTROL state.

CONTROL - distance calculation based on the time data obtained in the previous state. It ensures that the calculated distance does not exceed the maximum range of the sensor (for example, 0 to 100 units). If the result of the calculation is greater than the maximum range,the distance output will be set to the largest possible value (99). After calculating the distance, FSM automatically returns to the initial START state, where the system is ready to start the next measurement cycle.



design of the used FSM

Resources:

- https://digilent.com/reference/_media/reference/programmable-logic/nexys-a7/nexys-a7_rm.pdf
- https://web.eece.maine.edu/~zhu/book/lab/HC-SR04%20User%20Manual.pdf