Check Your Distance

A Proximity Sensor Game

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Scope

Check your Distance is a game that utilizes a proximity sensor interfaced with a Nexys 4 DDR Artix-7 Field Programmable Gate Array. The 7-segment display on the FPGA board shows a value in centimeters and the user must place an object that far away. A point will should be awarded if the user is within 1 cm of the displayed value.

The problem

Clock Frequency

- Nexys Board - 100MHz
- Trigger - 10us TTL pulse
- Sonic Burst - 8 cycles at 40kHz
- Echo - width of the received pulse
- Combinational Circuits

Sensor Interfacing

Trigger input

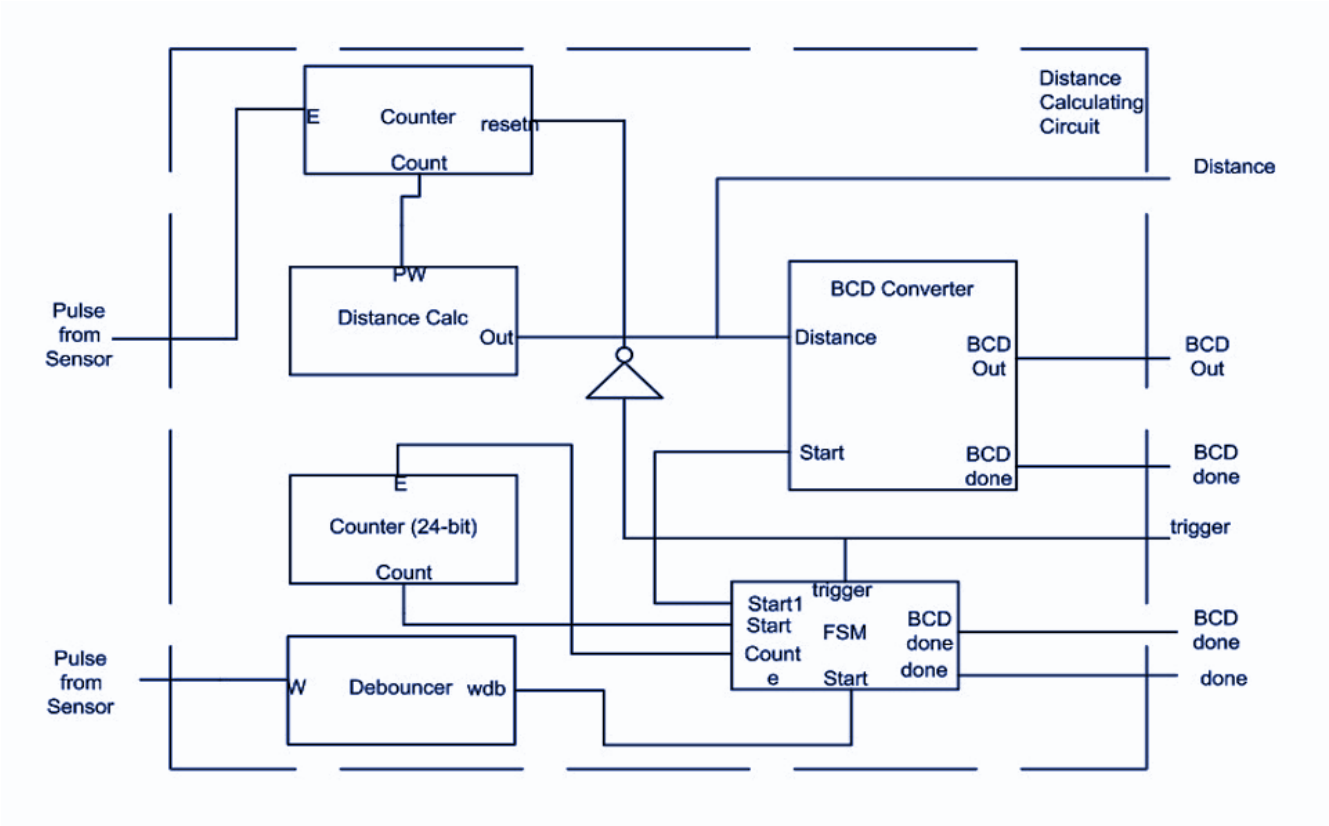
Echo output

Once the Trigger detects a pulse, the Echo pin measures the distance of the object in microseconds.

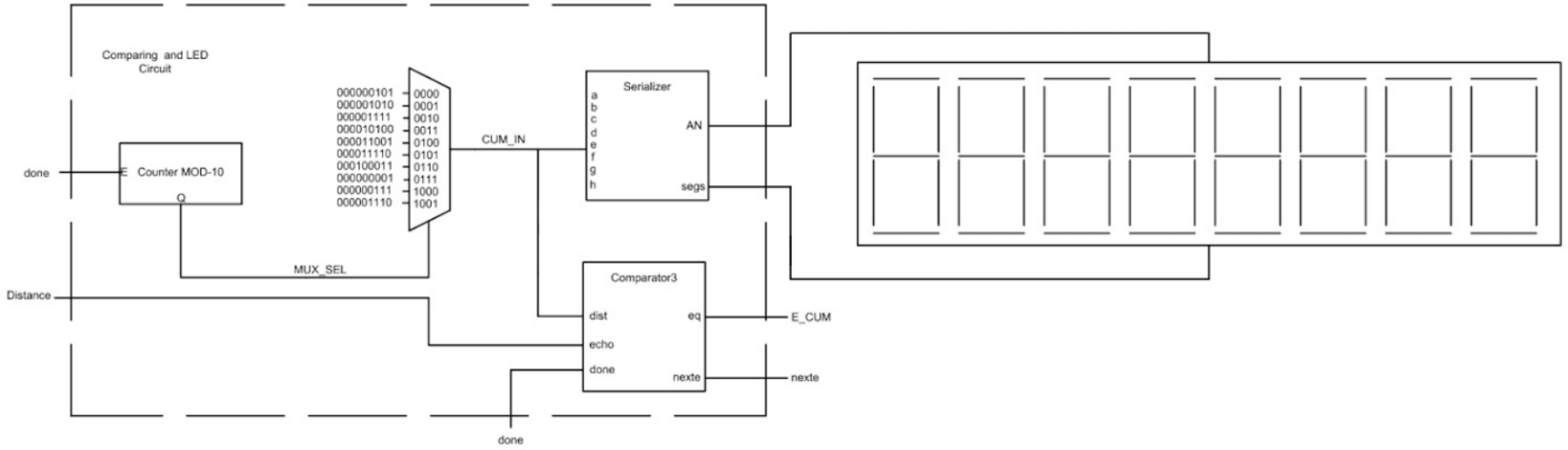
Problem statement

Due to the differing clock speeds, it is required that the clocks of both the Nexys board and the proximity sensor are synchronized in order to gather useful, factual data.

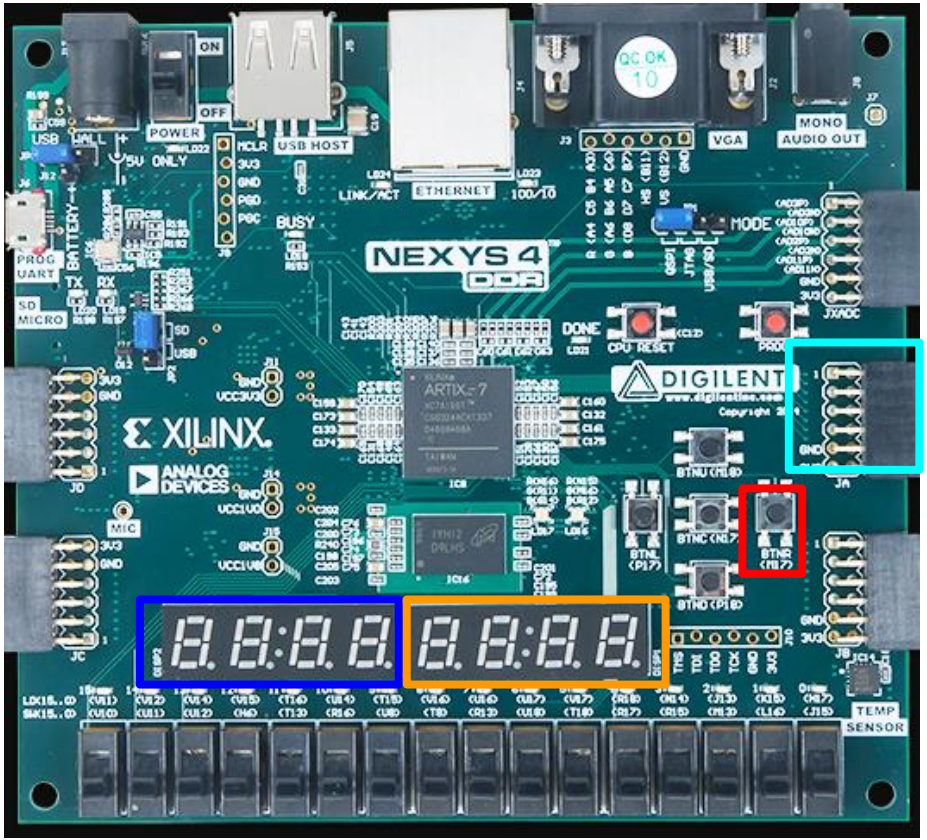
Block Diagram - Distance Circuit



Block Diagram: Capturing the Distance



Hardware Design



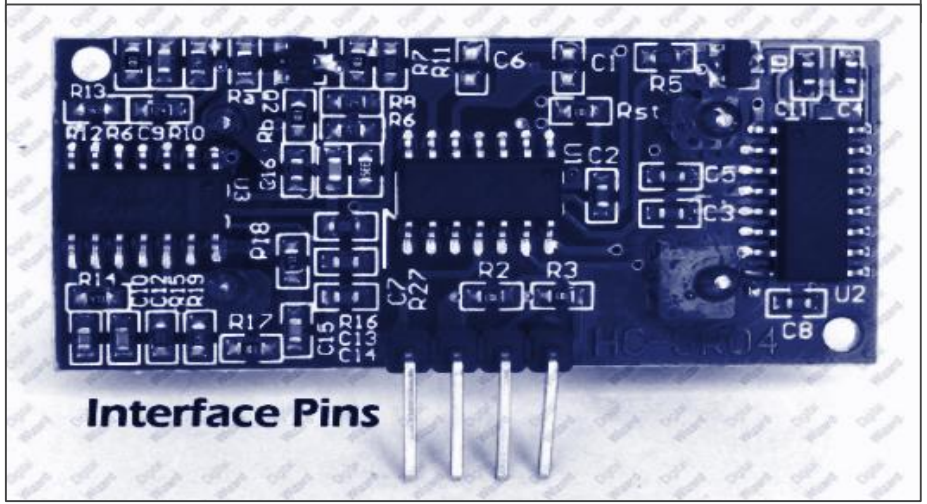
Nexys 4 DDR Artix-7 FPGA

- 4-pin **Pmod (Port JA)** to connect the sensor, 3.3V V_{CC}
- **Button** - when pressed, it sends a pulse to the HC-SR04 'Trigger' pin
- four 7-segment displays for the **target distance** in centimeters
- four displays for the **measured distance**

Hardware Design

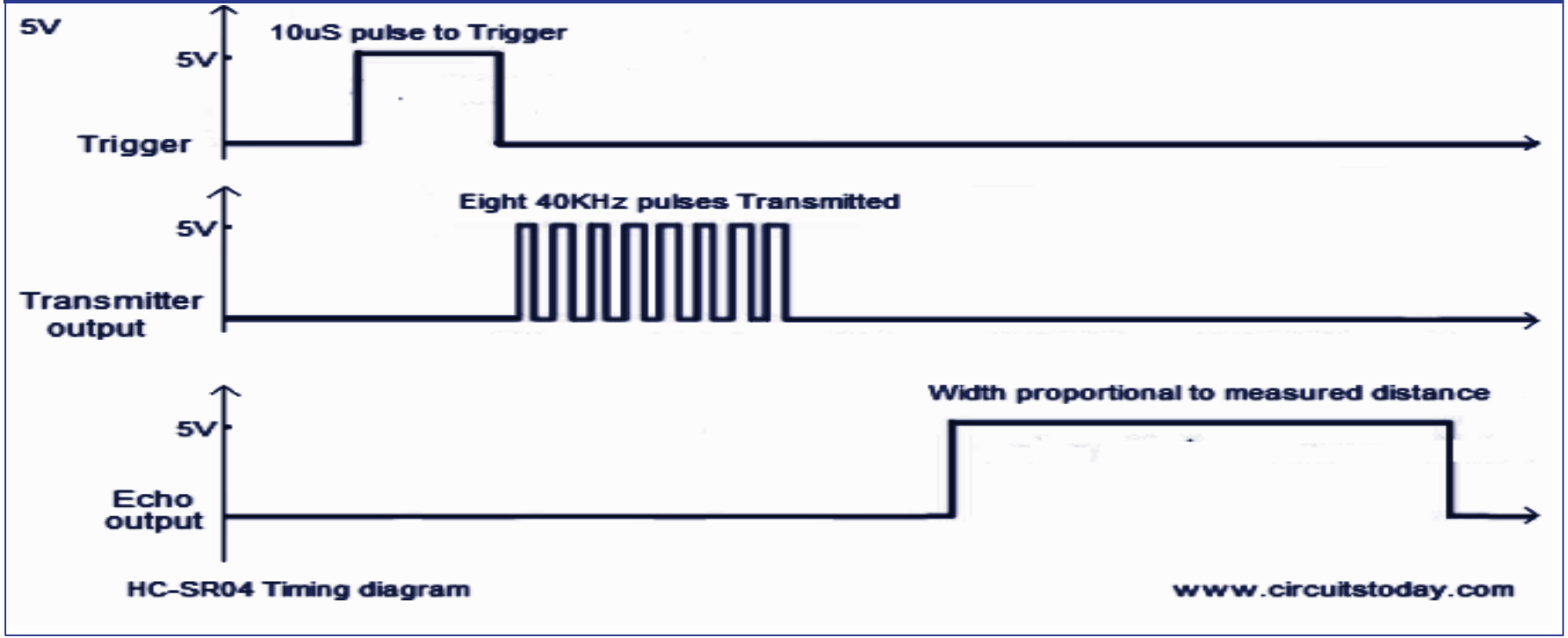
Proximity Sensor: HC-SR04

- ★ Trigger
  Transmitter
  - Sends minimum of 10us pulse to Echo pin
  - As soon as pulse is received, 8 cycles @ 40 kHz is sent out
- ★ Echo
  Receiver
  - Calculates the distance to the obstacle by measuring the time taken for the 40 kHz pulse to return



Proximity Sensor HC-SR04

How it works:



Proximity Sensor HC-SR04

Calculating the Distance

Recall,

$$\text{Distance} = \text{speed} \times \text{time} \quad \& \quad \text{Distance to Obstacle} = \frac{\text{speed} \times \text{time}}{2}$$

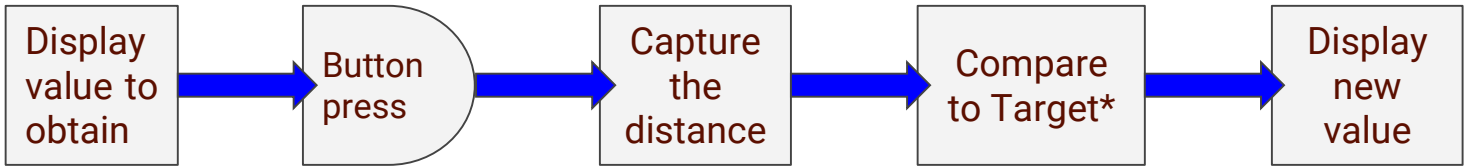
*where the speed of sound in air is 0.03436cm/us

Thus,

$$\text{Distance to Obstacle} = 0.01718 \times \text{time}$$

The range is calculated based on the time interval between sending the trigger pulse and receiving the echo signal.

Software Design: Basic Overview



***The target value is only incremented once the user places the object within a specific range of the target distance, otherwise the user can try again until the object within proper distance**

Challenges

Performance

For optimized performance, the sensor should be on a steady, smooth plane as to not affect the measuring results.

Electrical Connections

HC-SR04 module should not connect directly to a power supply. Otherwise, the performance of the device is affected. Also, voltage output on the Nexys board is 3.3V but the sensor V_{CC} is 5V.

Interfacing

Since the working frequency of the HC-SR04 and the clock frequency of the Nexys Board greatly differ, the board and the sensor had to be systematized such that their clock speeds were synchronous.

Solutions

- Ensured that the sensor was placed on a steady surface
- Connected the sensor to a breadboard that was powered by the Arduino Uno
- Synchronized the pulses from the Trigger & Echo pins to a counter which relied on the pulses from the master clock

Implementation