MANIPAL INSTITUTE OF TECHNOLOGY
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Department of Electrical & Electronics

Engineering Digital System Design Lab – III

Semester

MINI PROJECT REPORT

TITLE

MEASUREMENT OF TEMPERATURE USING ADT7420 SENSOR ON NEXYS 4 DDR FPGA

Submitted by

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Abstract

This project involves designing a temperature measurement system using the ADT7420 temperature sensor integrated with the Nexys 4 DDR FPGA board. The system is developed in Verilog, focusing on interfacing the sensor with the FPGA through the I2C communication protocol. The temperature data is read, processed, and displayed in real-time on an output medium such as an LCD or seven-segment display. The project aims to demonstrate the use of FPGA for real-time temperature monitoring, with potential applications in embedded systems and IoT.

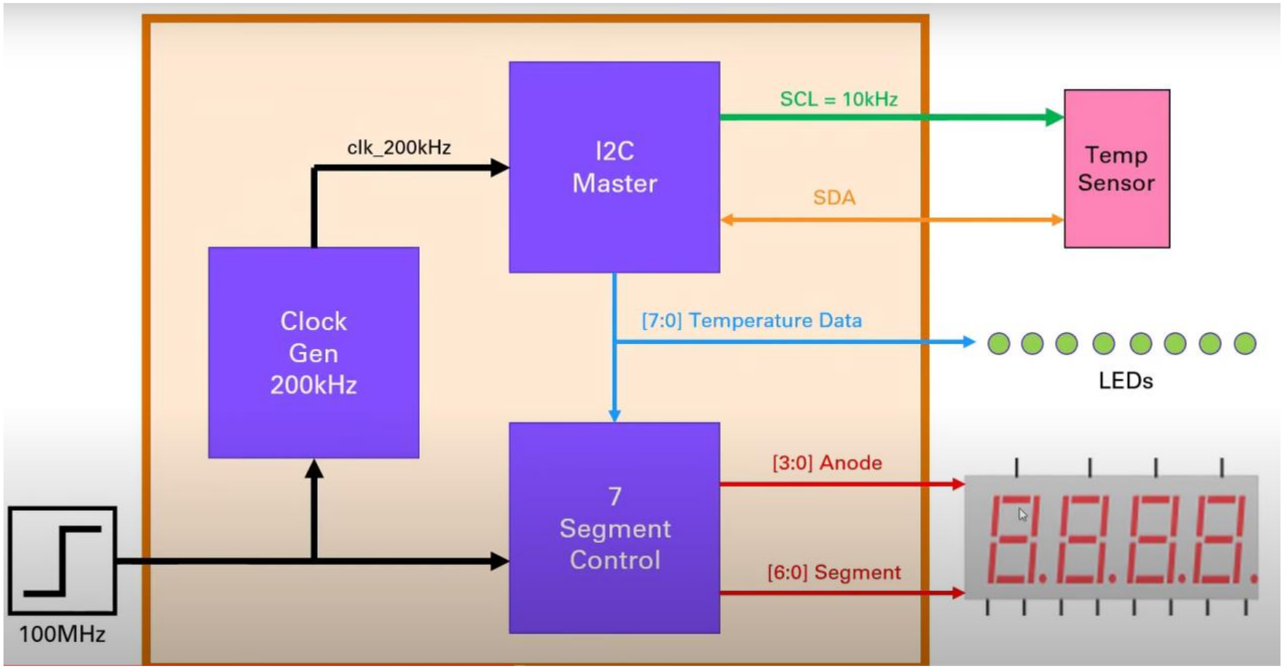
The main objectives of the project include:

- Interfacing the ADT7420 temperature sensor with the FPGA using the I2C protocol.
- Developing the Verilog-based I2C controller.
- Processing and displaying real-time temperature data.

Background theory and details about Nexys 4 DDR FPGA

The Nexys 4 DDR FPGA is a versatile development board featuring the Xilinx Artix-7 FPGA (XC7A100T-1CSG324C), offering 15,850 logic slices, 4,860 Kbits of fast block RAM, and 240 DSP slices. It includes 16MB of Micron DDR2 memory for advanced data processing tasks. The board supports a 100MHz clock for the FPGA and provides an additional programmable clock source. It comes with abundant I/O, including 16 switches, 16 LEDs, seven-segment displays, and Pmod connectors for external peripherals. The Nexys 4 DDR is ideal for applications in digital signal processing, embedded systems, and hardware prototyping

Methodology with Block Diagram



1. Clock Generation: The system operates using a 100MHz clock input from the FPGA, which is divided down to 200kHz by the Clock Generator module. This 200kHz clock is used to drive the I2C Master module for proper communication timing with the temperature sensor.

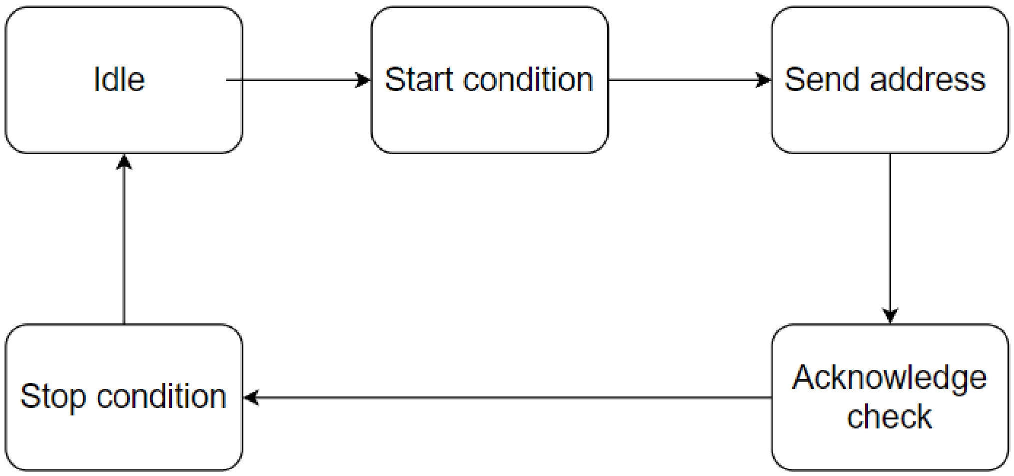
2. I2C Communication: The I2C Master module communicates with the temperature sensor via the I2C protocol, using a 10kHz clock for the serial clock line (SCL) and the serial data line (SDA) to transmit and receive temperature data from the sensor.

3. Temperature Data Handling: The temperature sensor sends 8-bit temperature data to the FPGA through the I2C interface. This temperature data is then transmitted to the 7 Segment Control and LEDs.

4. Display on LED's: The lower 8 bits of temperature data are displayed on the LEDs, providing a binary representation of the current temperature.

5. Display on 7 Segment: The 7 Segment Control module takes the temperature data and drives the 7-segment display by controlling both the Anode (for digit selection) and the Segment pins (to display the digit), allowing the real-time temperature to be displayed in a human-readable format

State Diagram:



1. Idle:

- Initial state where the I2C bus is idle, and no communication is happening.

2. Start Condition:

- Transition occurs when the master initiates communication by generating the start condition (SCL high, SDA from high to low).

3. Send Address:

- The master sends the 7-bit slave address (for the ADT7420 sensor), followed by the R/W bit to indicate whether it wants to read or write.

4. Wait for ACK:

- After sending the address, the master waits for an acknowledgment (ACK) from the slave (ADT7420). If ACK is received, it proceeds to the next step.

5. Data Transmission:

- Depending on whether it's a read or write operation:
  For Read: The master reads the temperature data from the sensor.
  For Write: The master sends configuration or command data to the sensor.

6. Stop Condition:

- The master generates a stop condition (SCL high, SDA transitioning from low to high), signalling the end of the communication.

7. Return to Idle:

- After the stop condition, the master returns to the idle state, ready for the next communication cycle.

Simulation Results:

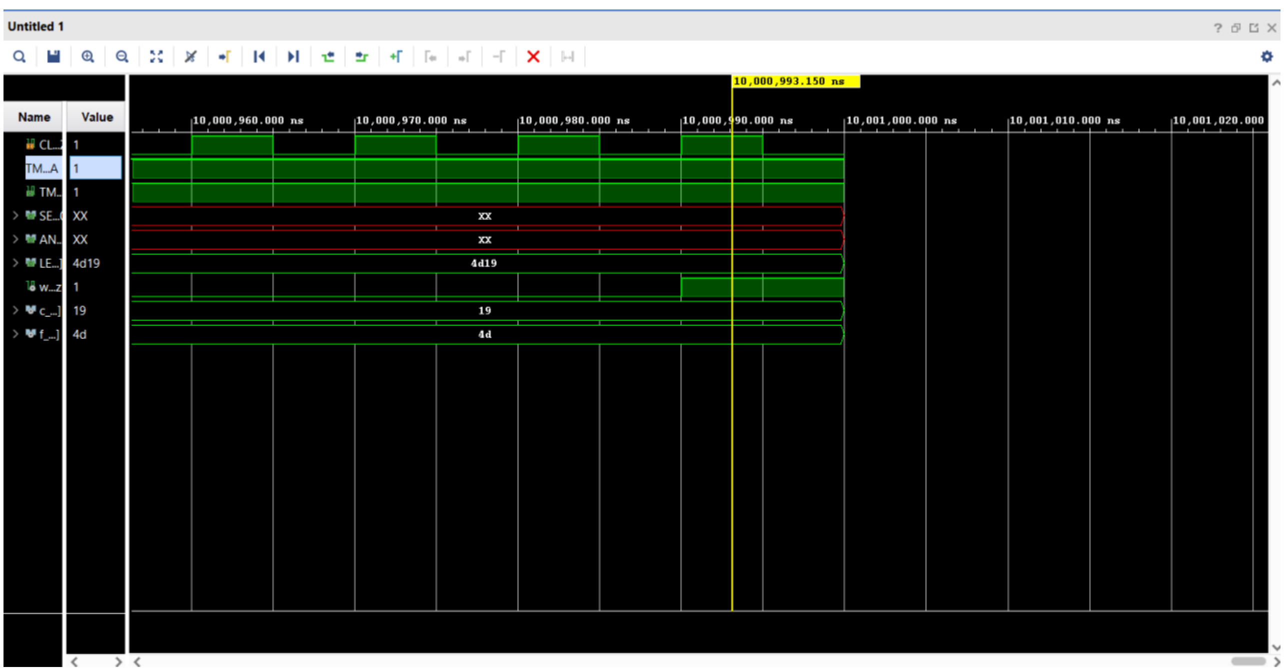


Figure 1: Temperature 25°C (19 in hex) and 77°F (4D in hex) showed by the LED's

Result Analysis:

The project was tested under various temperature conditions to verify the ADT7420 sensor's accuracy and the FPGA's data handling capabilities. The Nexys 4 DDR FPGA correctly displayed temperature readings in both Fahrenheit and Celsius on the seven-segment display.

1. Higher Temperature Simulation:

- To simulate a warmer environment, a hair dryer was used to increase the ambient temperature around the ADT7420 sensor. The display readings, as shown in the photograph, indicated a high temperature in both Fahrenheit and Celsius, reflecting the system's response to temperature rise.

2. Lower Temperature Simulation:

- To test the sensor's response to cooler conditions, the setup was placed near an air conditioner. The temperature readings decreased as expected, with the display showing lower values for both Fahrenheit and Celsius, validating the sensor's sensitivity and accuracy in detecting cooler temperatures.

Observations

- The FPGA was able to interpret and display both high and low temperatures accurately, demonstrating effective real-time monitoring.

- The stable readings in different environments suggest that the I2C communication between the FPGA and ADT7420 sensor is reliable.

- Also, the first 4 of the present 8 seven segment displays are used to display the temperature on °F and the next 4 are used to display the temperature in °C. The 16 LEDs are divided into 2 (0-7) which is used for displaying the °C temperatures in binary format and the (8-15) is used for displaying the °F temperatures in binary format
- The communication between the Artix-7 and the ADT7420 temperature sensor from Analog Devices utilizes the I2C on-chip protocol. Since both integrated circuits (ICs) are located on the same die, I2C is employed for this interaction. In this setup, the Artix-7 acts as the master, while the ADT7420 functions as the slave. Bus arbitration is not a concern in this scenario, as there is only one master present.

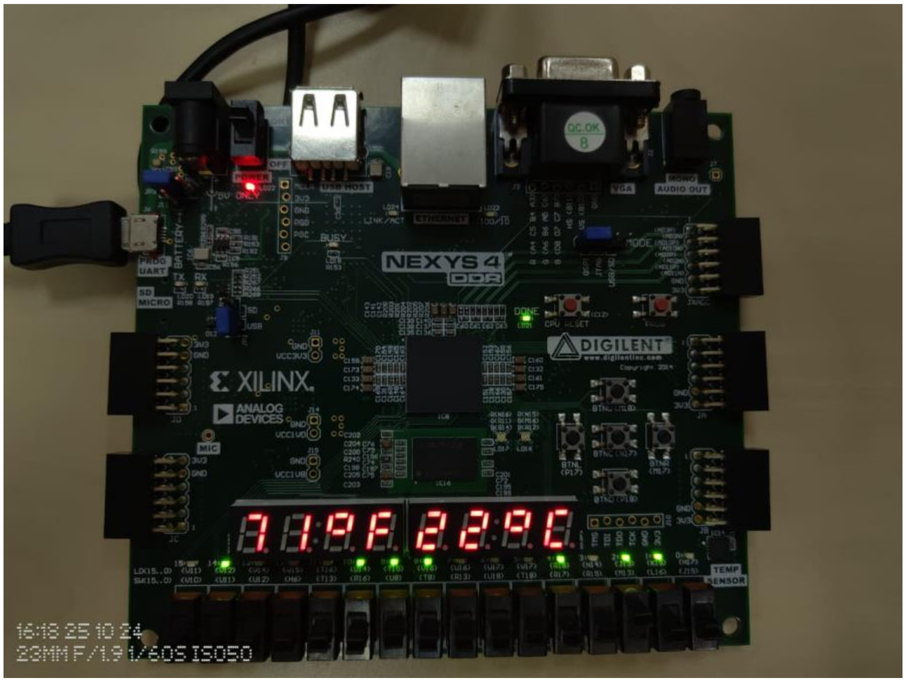


Figure 2: Measuring Cold environment (22°C,71°F)

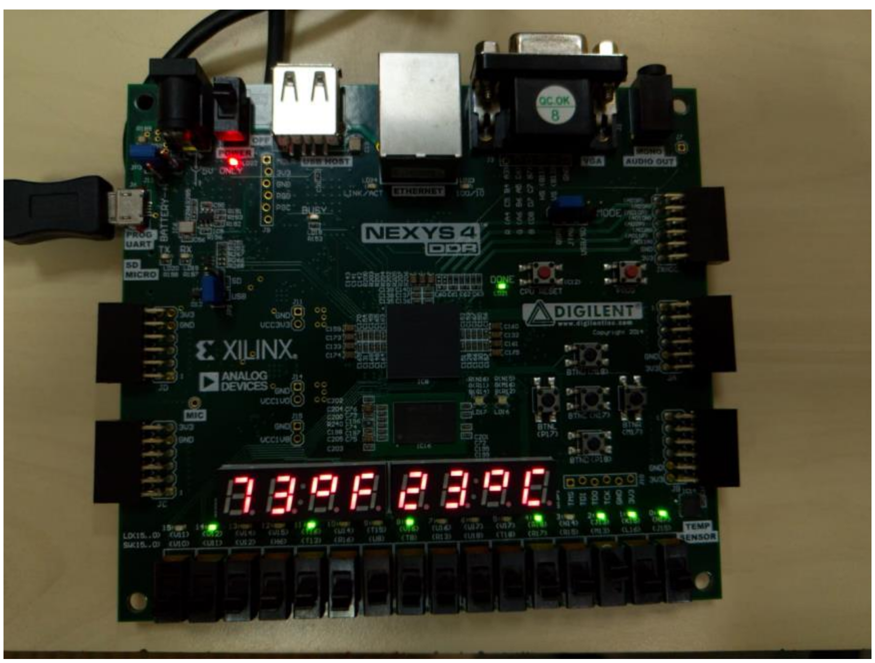


Figure 3: Measuring Cold environment (23°C,73°F)

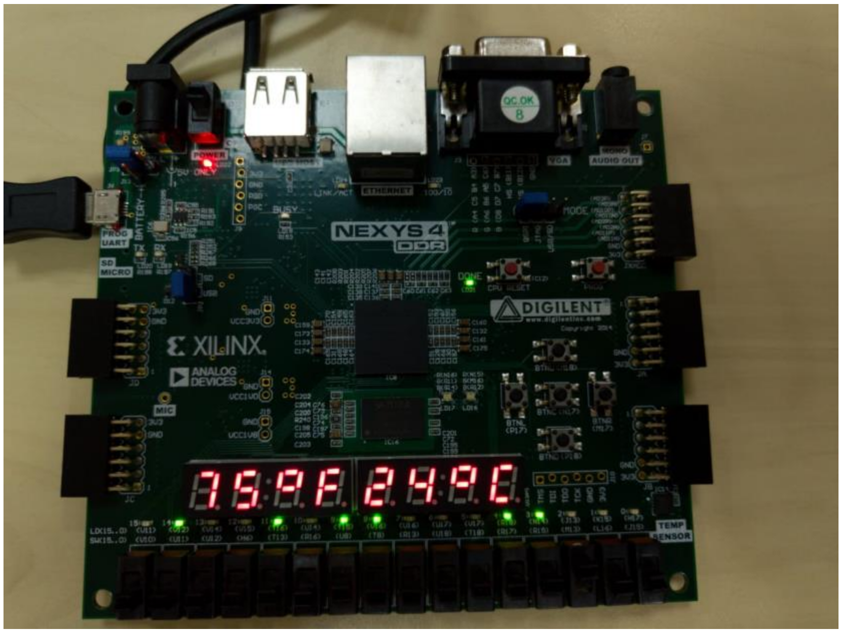


Figure 4: Measuring cold environment (24°C,75°F)

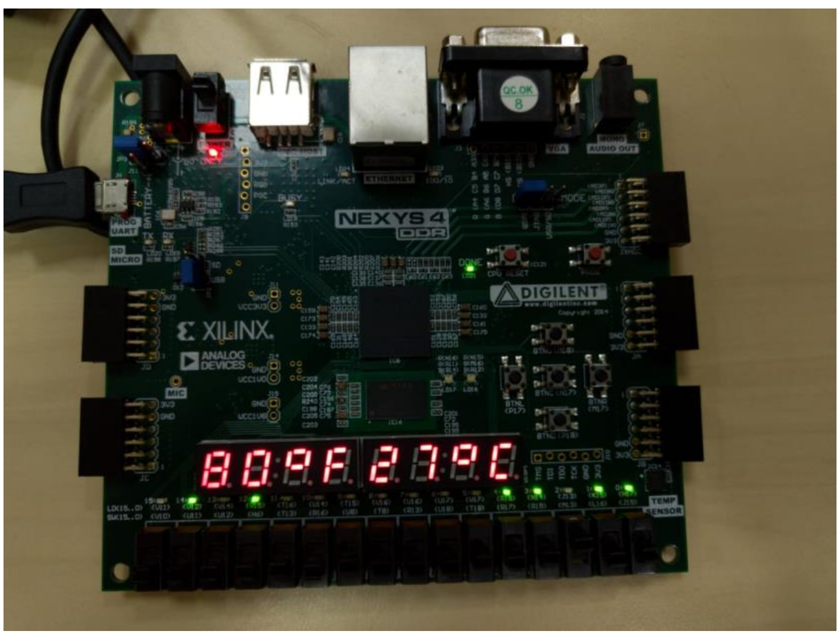


Figure 3: Measuring room temperature (27°C,80°F)

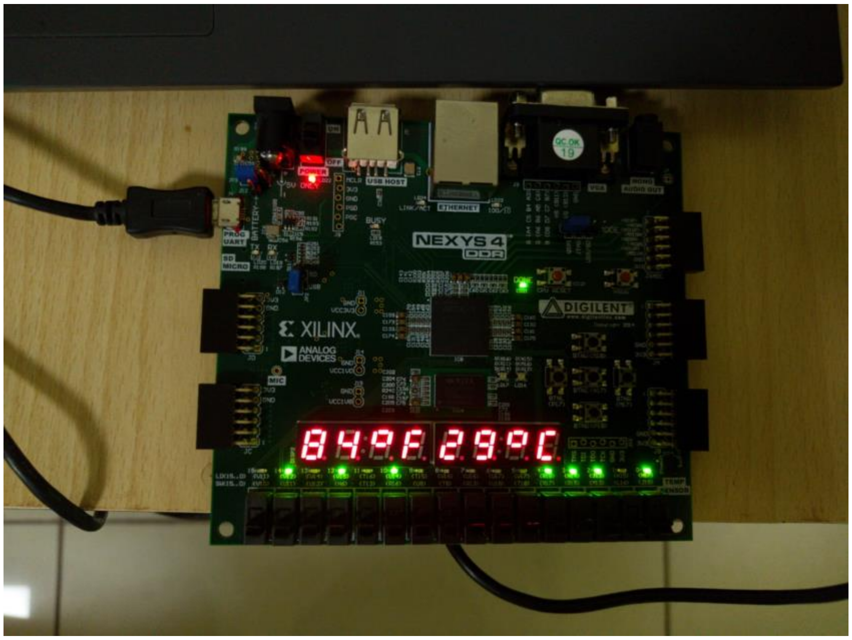


Figure 4: Measuring warm temperature (29°C,84°F)

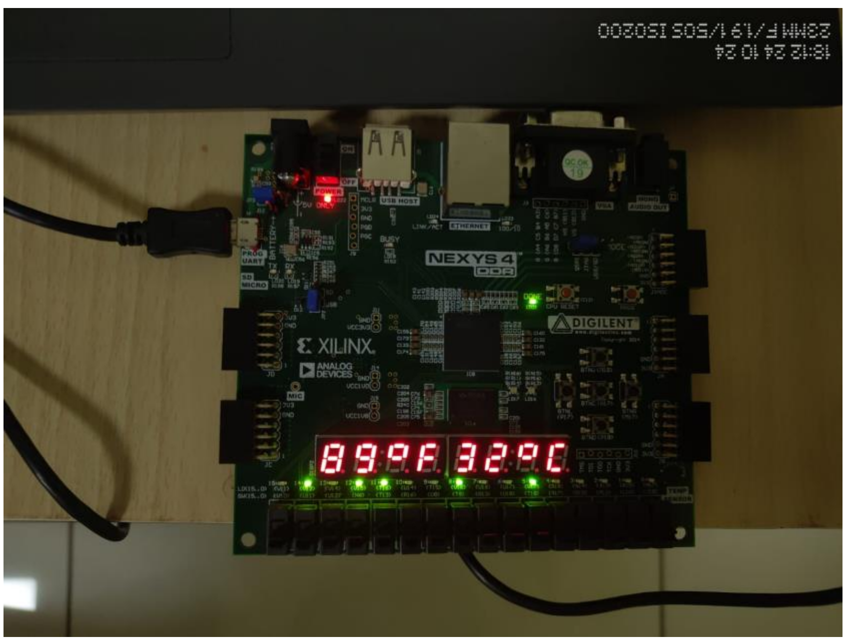


Figure 5: Measuring hot temperature (32°C,89°F)

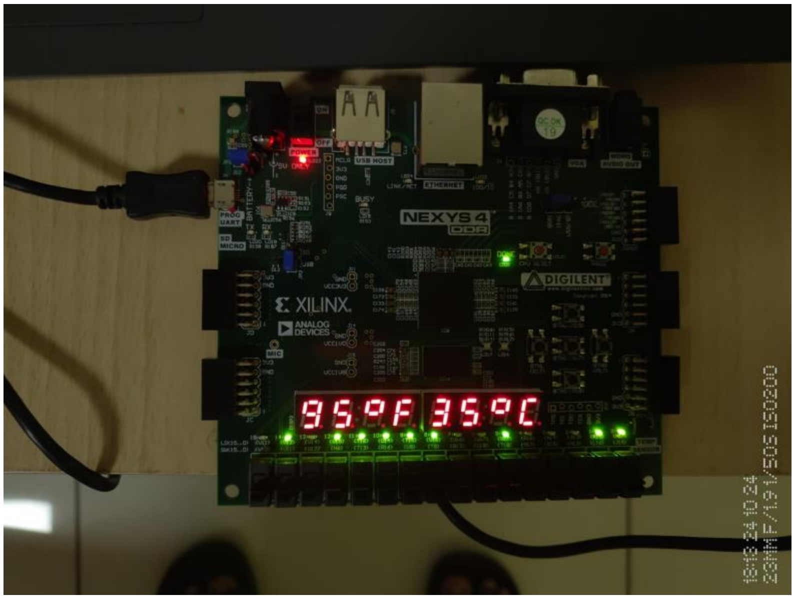


Figure 6: Measuring hot temperature (35°C,95°C)

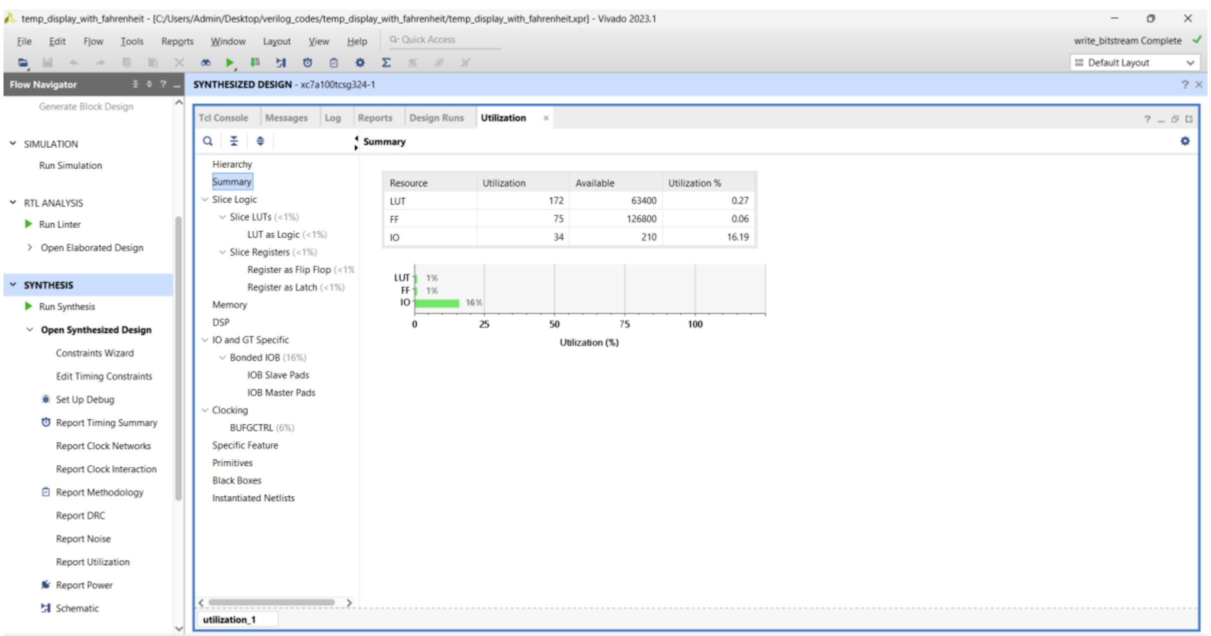


Figure 7: Summary of Power Utilization reports

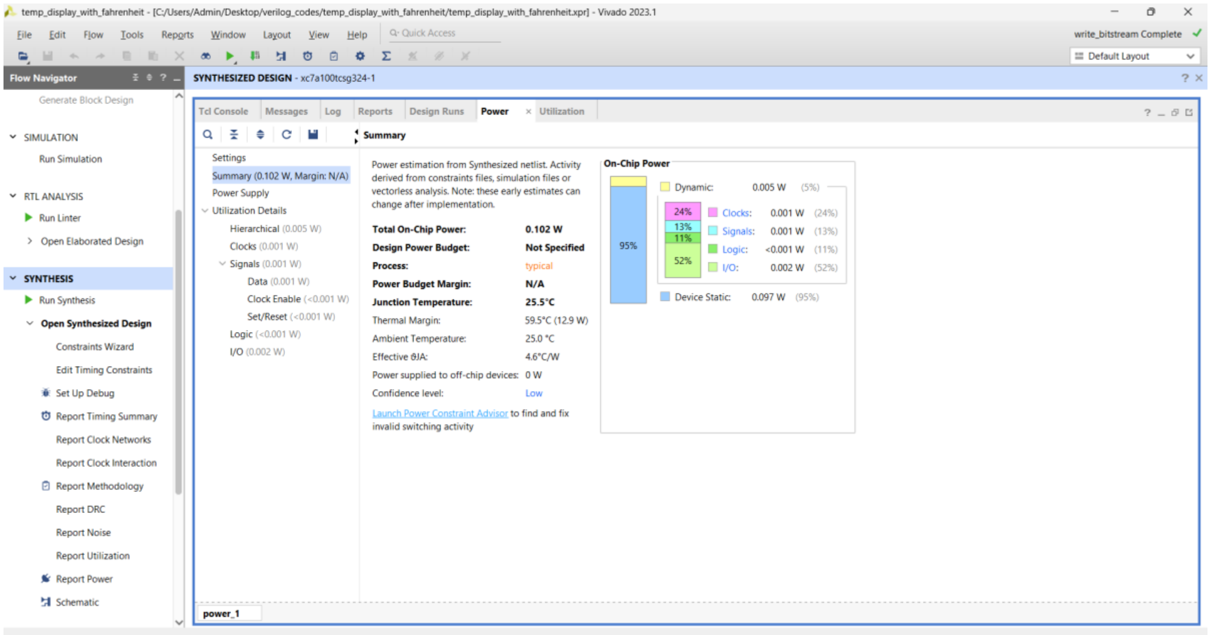


Figure 8: On-Chip Power Utilization for Ambient temperature of 25°C and Junction temperature of 25.5°C

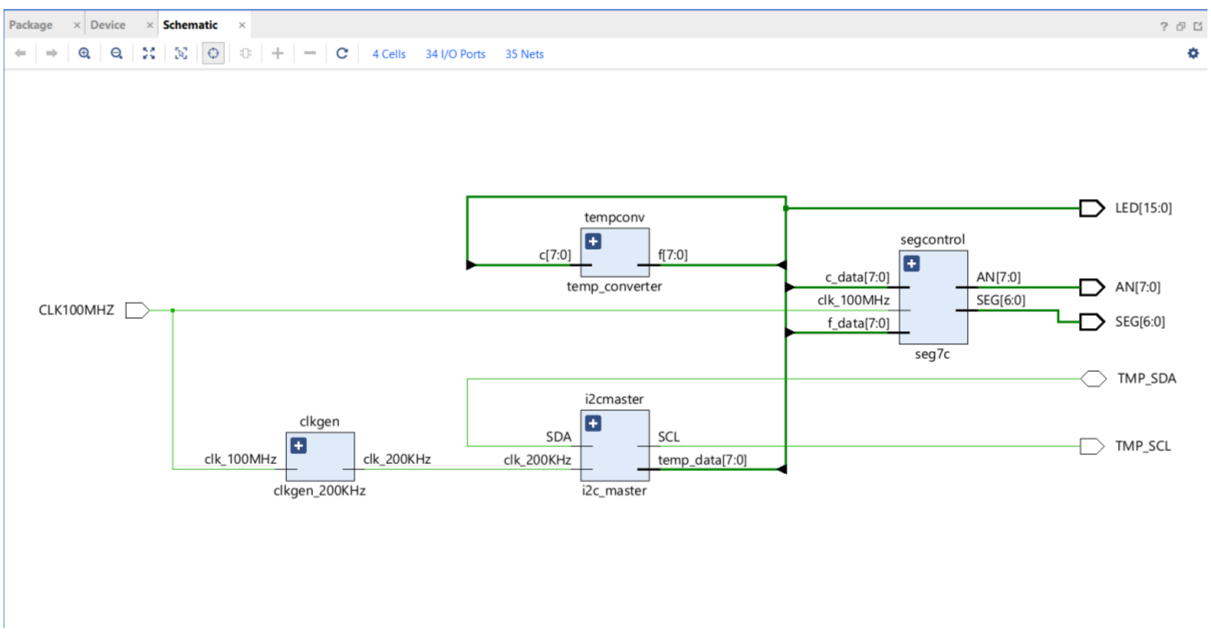


Figure 9: RTL Schematic

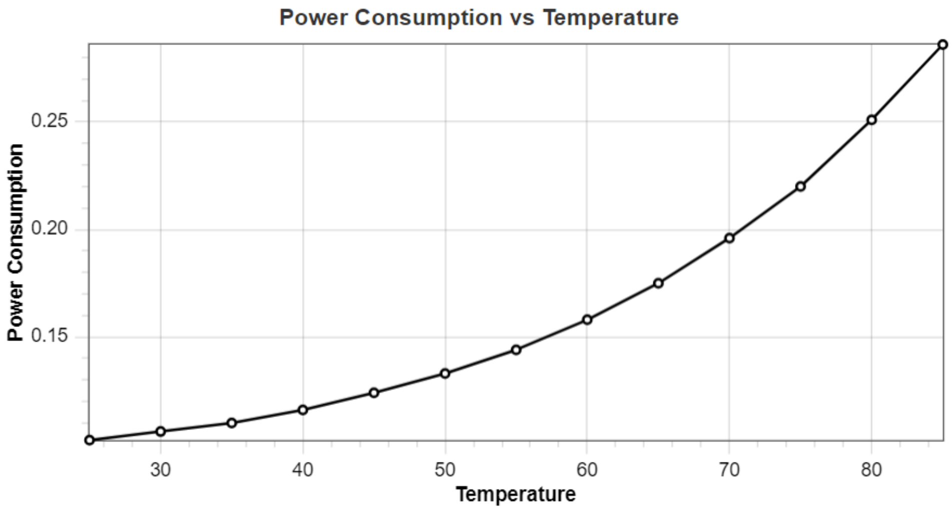


Figure 10: Graph between Power Consumption vs Temperature

Individual Contributions:

1. Venkata Krishna Tej:

- Abstract: Write the abstract summarizing the project.
- Result Analysis: Handle the analysis of the simulation results, including observations from higher and lower temperature simulations.
- Report Documentation: Documented the report and included the Power vs Temperature graph

3. Shubham Mahajan:

- Methodology: Detail the methodology section, explaining how the system is implemented.
- State Diagram: Create and describe the state diagram, including transitions and conditions.
- Block Diagram: Create the block diagram illustrating the system architecture.

4. Utkarsh Choudary:

- I2C Communication: Elaborate on the I2C communication protocol, explaining how it is implemented in the project.
- Temperature Data Handling: Discuss how the temperature data is processed and how it flows through the system.

- Display on LED’s: Explain the method used to display temperature data on LEDs.

5. Raghav Bandral:

- Background Theory: Write the background theory about the Nexys 4 DDR FPGA, its features, and relevance to the project.
- Display on 7 Segment: Detail how the seven-segment display is controlled to show temperature data.
- Simulation Results: Summarize the simulation results, including images and their significance in demonstrating the project’s effectiveness.

References:

1. https://digilent.com/reference/programmable-logic/nexys-4-ddr/reference-manual

2. https://www.analog.com/media/en/technical-documentation/data-sheets/ADT7420.pdf

3. https://www.ti.com/lit/an/slva704/slva704.pdf?ts=1729916487416&ref_url=https%253A%252F%252Fwww.google.com%252F