The Simon State Machine

(Part 1)

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Executive Summary

This lab focused on leveraging and adapting the knowledge and designs acquired throughout previous labs in the semester. The core objective was to modify the Random Number Generator developed earlier. The team achieved this by replacing the existing Sound Decoder with a VHDL block called TEST_Controller.

The initial steps involved gathering the necessary equipment, including a computer, USB cable, DE2 board, Simon Game box, and a speaker. After launching Quartus Prime, the team accessed their previously designed Random Counter. The Seven-Segment block, used in a prior lab, was removed, and a counter megafunction block was integrated into the schematic. The team meticulously renamed pins before successfully updating the symbol file and proceeding further.

Following this, the team replaced the Sound Decoder block with the TEST_Controller block within the schematic. Connections within the schematic were then optimized, and the project was recompiled alongside the Random Number Generator. After successful compilation, the team verified the DE2 board connections. Upon successful verification, the team observed the speaker connected to the DE2 board produce random sequences of LEDs lighting up at various octaves corresponding to their colors. This confirmed the successful completion of Lab 7.

The subsequent sections of this report delve into the background and objectives of the lab, the experimental procedures and methodologies employed, and the relevant schematics. The report then explores the lab results and their significance. A concise discussion of various lab-related aspects follows, leading to a concluding summary that highlights the report's purpose and its impact on the team's understanding. The report concludes with acknowledgments and a list of references utilized for both the lab and the report itself.

Introduction

This lab's focus is on integrating various components developed throughout the course to create a functional state machine. The ultimate objective is to build a working "game" where lights illuminate in a sequence and change upon pressing a specific button on the Simon Game Box or Key[0].

The core component of this lab is the development of a random counter. Its purpose is to generate a sequence that dictates the order in which the lights appear. Random counters are useful for producing unpredictable sequences of numbers and determining the order of outcomes when interacting with circuits or the Simon Game Box. In Lab 7, our team leveraged a random counter to create the sequence of flashing lights on the Simon Game Box, triggered by an initial random button illumination. To win the Simon Game, players must correctly press the randomly chosen button and then replicate the subsequent random sequence of lights.

This component is subsequently integrated with an audio block and a control block. The control block manages the behavior and audio frequency associated with each button. Pressing a button on the Simon Game Box generates a unique frequency, programmed within a VHDL file. While the frequency remains constant for each button throughout the Simon Game, the sequence of illuminated lights changes with each new game.

Similar to Lab 6, this lab provided an opportunity to refine problem-solving skills and apply VHDL coding knowledge acquired in previous labs. This expertise was used to develop a new VHDL design for implementing the test controller. The methodology and results of this lab are detailed in the following sections.

Experimental Methodology

In this lab, Group 18 embarked on the task of integrating various components developed throughout the course to create a functional state machine. To achieve this, the team utilized a DE2 Board, Simon Game Box, speaker, and reference materials including the "Simon State Machine" video and "TEST_Controller.zip" files.

Following the established procedure, Group 18 commenced the lab by reviewing the "Simon State Machine" video. Next, they opened the latest iteration of the SimonGame project for schematic design continuation. Within this project framework, an additional schematic file was included, meticulously replicating the provided 32-bit Sine Wave Synthesizer design and designated "Audio." The essential file "sin_16bit.mif" retrieved from the lab website was seamlessly integrated into the project folder.

With the schematic established, Group 18 undertook the crucial step of calculating the P-value required for generating a 200 Hz sine wave. This calculated parameter was then strategically substituted for the predefined constant value within the schematic. Subsequently, a symbol file for the Sine Wave Synthesizer was generated and named "Audio." This symbol was strategically positioned adjacent to the CODEC and linked to the Audio block's AUD_DACLRCK clock input. The output bus was designated as sound[15..0], with subsequent bit shifting to the AUD_outL/R inputs, adhering to the guidance provided in the video and schematics.

To verify functionality, the 200 Hz Sine Wave was observed using Signal Tap. The project compilation prioritized CODEC as the top-level entity. SignalTap Logic Analyzer was activated via the Tools menu, configuring the Hardware to USB-Blaster and setting Signal Tap: pre-synthesis as Filter. The AUD_DACLRCK was selected from the designated list, with a Sample Depth of 8k established. Further customization entailed the addition of the sound output to the nodes list and the configuration of the Display Format to a Signed Line Chart. Compilation and reprogramming ensued, culminating in the analysis initiation, facilitating observation of the sine wave output. The subsequent phase involved modifications to the Audio schematic to accommodate five distinct constant values, rectifying inaccuracies in the originally provided values. The updated symbol file for "Audio" was generated, replacing the existing symbol at the top level. A dedicated block was created to facilitate input from the debounce block, with sound output selection contingent upon the activated input. GPIO and LED connections were established accordingly. Leveraging the provided "SevenSegment.vhd" file, Group 18 formulated a new VHDL block, ensuring compatibility with the "STD_Logic" data type to accommodate single-bit inputs. The VHDL code for the "SoundDecoder" was meticulously crafted, followed by the creation of a symbol file and its integration into the CODEC schematic. Subsequent compilation, programming, and verification were conducted to ascertain the complete functionality of the project.

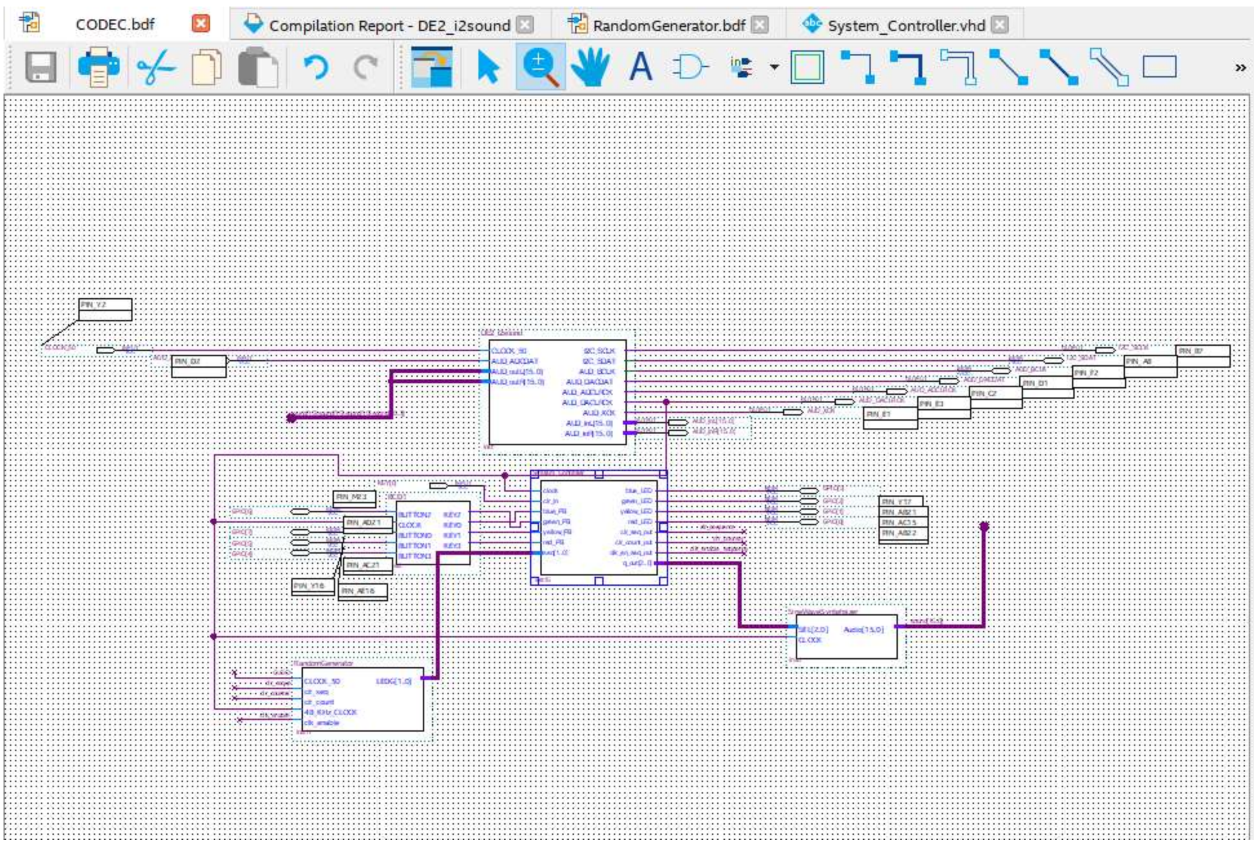

Figure 1 - Top-Level Schematic with TEST_Controller

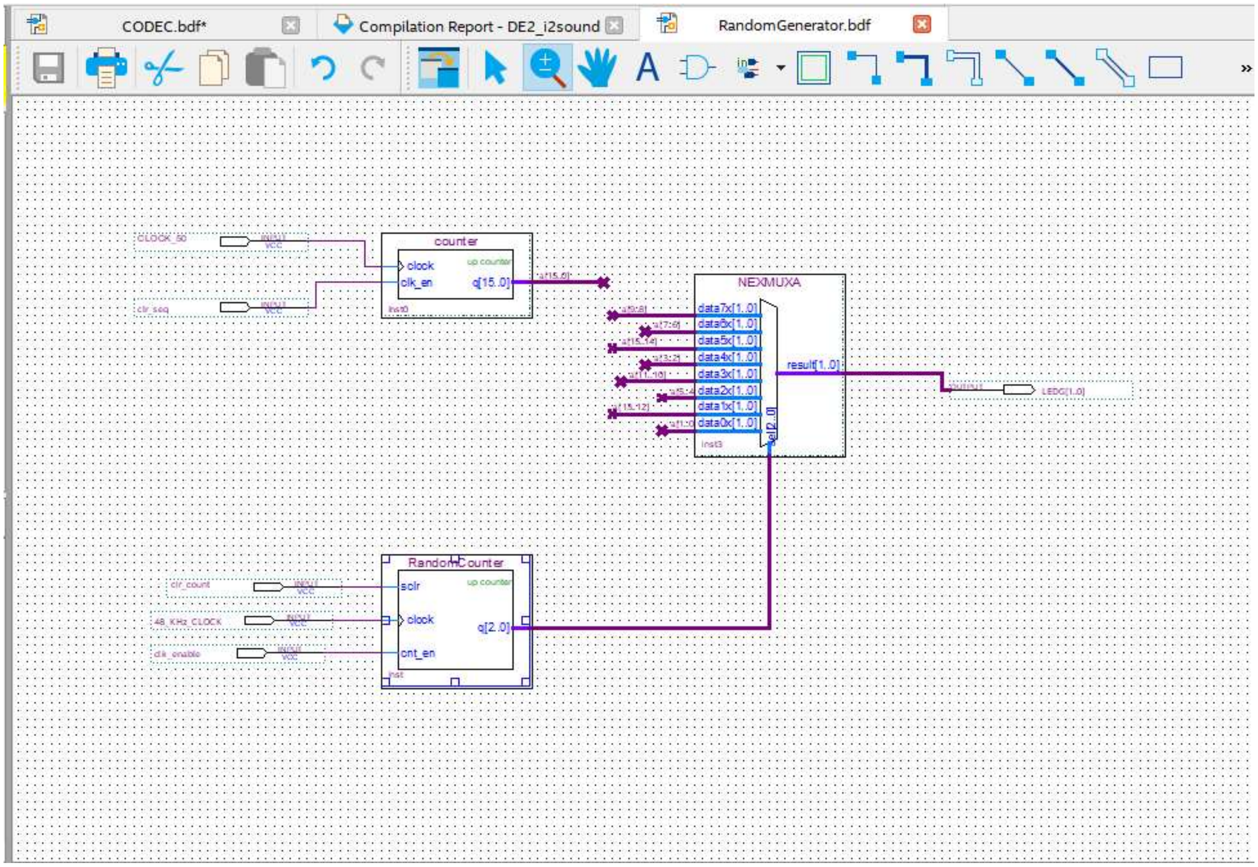

Figure 2 - Modified Random Generator Schematic

Results

Lab 7 focused on enhancing problem-solving skills by modifying the existing Random Number Generator. Additionally, the Sound Decoder was replaced with a custom VHDL block named TEST_Controller. Following the development of the initial schematic, a symbol file for the updated random counter was created, effectively replacing the previous counter component. Subsequently, the Sound Decoder block from the prior lab was successfully replaced by integrating the TEST_Controller. With the symbol file established, the project was compiled for execution.

Using a USB blaster cable connected to the DE2 board, along with the Simon Game box and speaker, the team observed the final functionality. The experiment showcased a fully operational game. Pressing various keys triggered pre-determined LED sequences, transforming the game into a light-based challenge. Simultaneously, the speaker emitted sounds in distinct octaves based on the activated LED. Notably, pressing KEY[0], as instructed, resulted in a successful random sequence of lights and corresponding sounds on the Simon Game.

Discussion

In simpler terms, a pseudo-random number generator employs eight inputs but yields only one output selected at random. This implies that each input has a one-in-eight probability of being chosen. The eight inputs represent various options for the random multiplexer to select from. Since there's just a single output, these eight inputs provide the multiplexer with a pool of choices to pick one at random.
The "RandomCounter" within the random number generator serves the purpose of feeding an input into the multiplexer, enabling it to select one of the eight inputs randomly. The counter alters the multiplexer's functionality whenever it needs to select an input, ensuring a random selection each time.

Lastly, the TEST_CONTROLLER introduced in this lab serves as a replacement for the previous sound decoder. It accomplishes a new functionality that leads to the creation of the Simon Game Box. The TEST_CONTROLLER takes separate inputs for the clock and button colors and then outputs them to their corresponding colors and sequences. This functionality deviates from the prior sound decoder implemented in the CODEC file.

Conclusion

In essence, this lab provided Group 18 with a valuable platform to solidify their understanding of Audio Synthesizer implementation using SignalTap and Quartus Prime. The lab involved simulating a Sine wave in SignalTap, analyzing its characteristics like shape and frequency. This simulated Sine wave then became the foundation for constructing a Sound Decoder within Quartus Prime, along with the corresponding Audio schematic and a clock input. Building upon this schematic, Group 18 successfully designed a four-input circuit. This circuit assigned a unique audio frequency to each colored button, resulting in both sound emission and button illumination upon pressing. Overall, the lab offered an exceptional opportunity for hands-on practice by applying theoretical concepts learned in class to a software platform capable of accurately simulating circuit behavior.

Acknowledgments

All members of Group 18 contributed equally and participated in all lab activities. In terms of the lab report, Siwei wrote the discussion and conclusion sections. Ansh described the executive summary, and introduction, and edited the document. Rushi wrote the experimental methodology and results sections.

References

- Lab report template - [Lab-Report-Submission-Instructions]
- Lab 7 document - [The-Simon-State-Game]