Four-Way Traffic Light Controller

Nick Legato, Emanuel Shabo, Caleb Iott

Electrical and Computer Engineering Department

School of Engineering and Computer Science

Oakland University, Rochester, MI

nlegato@oakland.edu, eshabo@oakland.edu, calebiott@oakland.edu

Abstract - For the four-way traffic light controller, we are going to use the Nexys A7-100T board to simulate a traffic light at an intersection. More specifically, the traffic light at a standard intersection, will be simulating north/south and east/west with two sets of LEDs all in green, yellow, and red. Two sets of three LEDs was implemented rather than four sets of three LEDs to provide a simpler design. Throughout this project, it will be done with VHDL on Vivado. Inside the code, making each color combination a "state" made the project go a lot smoother. In addition, the changes between colors or states were uniform to make it easier to simulate. The main goal of the project is to simulate how traffic lights work when assigned to a four-way intersection.

Introduction - Our choice of simulation for this project is a four-way traffic light controller. The goal of the project is to make the lights change in a manner that is meant to control traffic. It is important to make the LEDs change in that manner because cars will have to have time to slow down from green to red. In addition, the motivation is to implement synchronous circuits to analyze a real world problem involving traffic flow. To simulate the cars, as they operate in reality, there will be two inputs to act as each polar direction. For example, north and south are in one set of LEDs and in the other set are east and west. Therefore, the green, yellow and red LEDs are the outputs to the circuit. Again, it is important to make the lights transition in a controlled manner. Lastly, the LED outputs will be displayed on a breadboard, wired to the Nexys A7-100T. Within the report, a better understanding of the thought process, design, and data recorded will be given so that a crucial understanding of the designers intent is understood.

Methodology & Setup - In any finished project, there will be problems that will arise in their makings. In this project particularly, there were several notable problems that arose.

A. Complications - Starting with the most significant issue, the implementation of a night time feature into the circuit and overall project created a few complications. Firstly, a major goal of the controller was to implement another feature to the light sets that would simulate flashing yellow lights for north-south directions and flashing red lights for east-west directions. To remedy this, a button or a switch could be inputted high or low. Due to an absence of a group member, the process of coding became more difficult and time consuming. Which caused group deadlines to suffer as a result. Once the code for the daytime feature was complete, the night time code was endeavored. At the beginning, the new lines of code were put into FSM.vhd and underneath each daytime state. Thus, a new state was created first, following with the addition of a new output assigned "night". After this, the "night" output was to be implemented into the process below the daytime process, but at that point, the work imbalanced and unexpectedly prevented the features completion. Ultimately, it was decided to leave the feature entirely: along with its corresponding code.

Another major issue was ascertaining how the states in each LED combination should be configured. In the beginning of the project, the wiring was virtually complete for the traffic light system, but getting the states to properly function proved to be a challenge. At the start, four sets of lights were designated to be implemented, but as deadlines mounted, it was decided that simply using two sets of LEDs was a better tradeoff due to the ease of coding. Although not as aesthetically pleasing and perhaps not as functional, since two sets appeared to be able convey the necessary information about the traffic lights, it was decided to implement two sets so that a functional circuit could be provided. It is of note that the two sets of the labeled LEDs still function as both sides of the poles in the proper directions: just merged into two separate entities.

B. Design & Components - Now that the main issues were dealt with, the next topics addressed is the inner workings of the circuit and the hardware components of the controller. This includes the Nexys A7-100T board, VHDL code for Vivado, the breadboard and each part of the physical circuit on the breadboard. It is crucial that the basics of the circuit be understood at this stage. A block diagram will be utilized to aid in comprehension

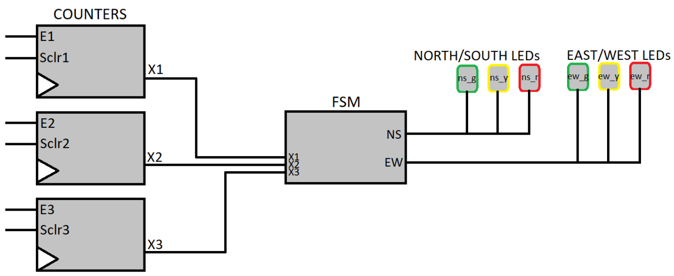

Figure 1: Block Diagram

In *Figure 1*, the block diagram illustrates what the traffic light circuit will look like. There are three counters, each with an enable switch, clear switch, clock and sets of outputs. These are wired to one Finite State Machine (FSM). Off the FSM are the pair of LED sets. Each set includes green, yellow, and red LEDs.

In regards to the design and physical appearance of the circuit, it was noted previously why the use of a pair of sets featuring three LEDs was implemented into the design. However, considering the rest of the circuit, it can be observed that there are a few other components. For example, resistors and wires were implemented. The resistors were placed in a series with each LED light, each 220Ω. As one may understand, these were used to prevent the LEDs from burning out. Thankfully, this did not become an issue.

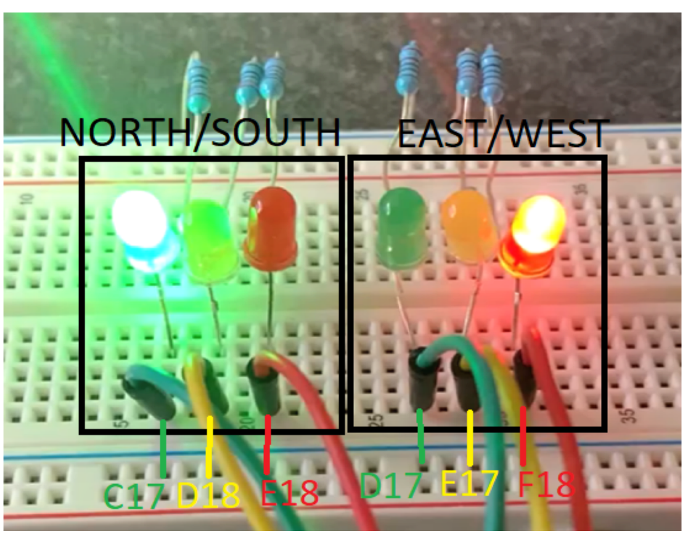

Figure 2: Two sets of LEDs representing north/south and east/west.

In *Figure 2*, it is observed that on the left side of the breadboard which consists of a green, yellow, and red LED, is labeled “NORTH/SOUTH”. On the right, the same LED set is wired similarly but with the difference that the pins are given the label “EAST/WEST”. The labeled pins will be explained further on in the report, but it should be noted that hey are connected to the Nexys A7-100T board. It should also be noted that a breadboard must be added to the circuit to hold the LEDs, wires, and resistors properly.

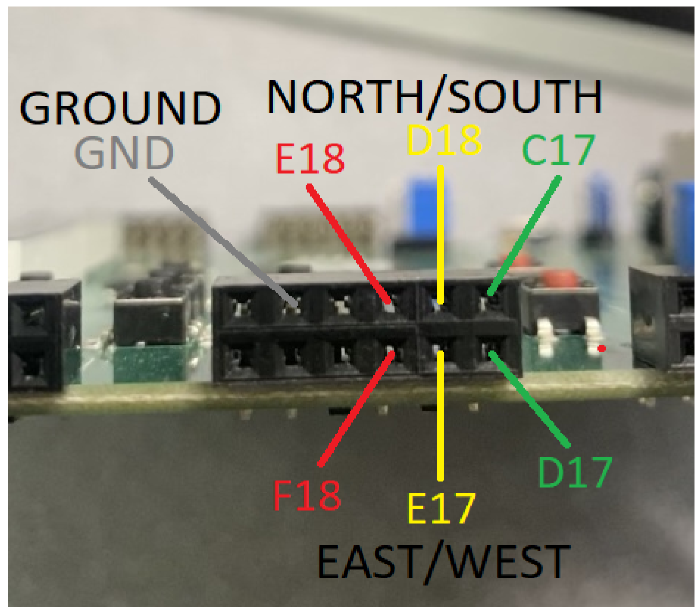

Figure 3: “JA” Ports for pin inputs into the Artix-7 board from the breadboard.

In *Figure 3*, it can be seen which wires from the board go into what pin, from *Figure 3*. The “NORTH/SOUTH” LEDs are assigned to the top row of ports and the “EAST/WEST” LEDs are assigned to the bottom row of ports. In addition, the ground wire, as is expected, goes into the GND port to prevent a short in the board.

Moving onto the Nexys A7-100T board, a CPU reset button was implemented to allow for the process to reset. As default, the power switch, universal asynchronous receiver-transmitter (UART) and peripheral module interfaces JA (PMOD) were utilized. These components can be seen in the Nexys A7-100T reference manual *[1]*. The power switch causes, as can be expected, turns on the entire board so that the code and hardware work synchronously. The UART connects the Nexys A7 to the host of the code: in this case, a laptop. The PMODs were implemented to connect the Nexys A7 to the breadboard. In the PMOD JA ports, wires from the

LED sets were drawn so that a connections could be established.

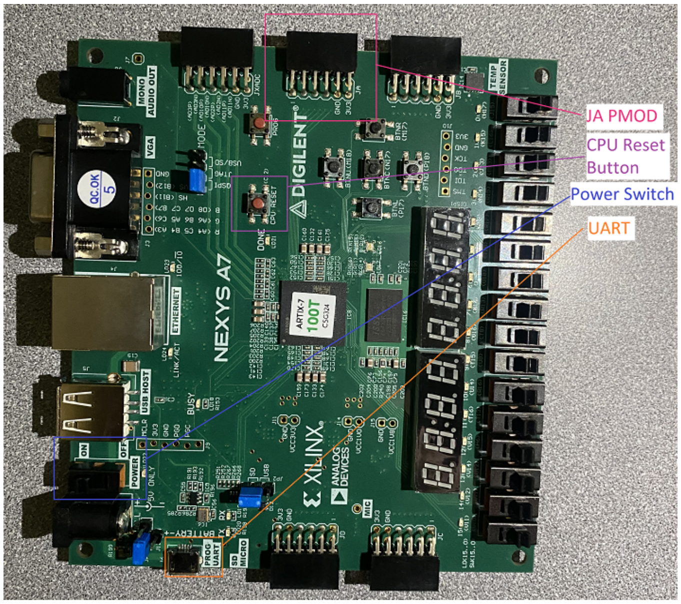

Figure 4: The Nexys A7-100T board's used functions.

Figure 4 provides a good visual of what other components were involved in the project. As mentioned prior, the JA PMOD contains the ports used by the breadboard's pins. It is important to understand that if the night time mode could have been implemented, one of the switches or buttons would have been programmed to switch that mode on or off.

Results - Near the end of the project, a few errors had to be resolved in order for the simulation to function properly. This took first priority in the agenda: without a proper simulation, the board would have not functioned properly. Once the simulation functioned as expected, major errors were still to be found, but, ultimately they were resolved. At the conclusion, the LEDs turned on and off as desired and worked as intended. The set of LEDs on the right turned on and the timing worked as desired. Despite these setbacks throughout the project, it was decided that the project could be slated for presentation.

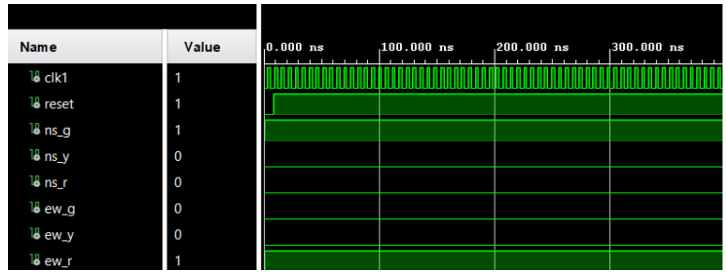

Figure 5: Simulation from Vivado showing the first state in the four-way traffic light controller.

Figure 5 shows a proper simulation of the first state of the LEDs: this was assigned the to be "s0", for state 0. In this state, north-south green (ns_g) and east-west red (ew_r) are high. This indicates that the set of LEDs in the north-south directions are green. Translated into the real world, this permits the cars within those directions to pass through the intersection, while keeping the cars in the east-west directions immobile. Once this state ends, the program will then proceed to the subsequent state, in which ns_g will become low and north-south yellow (ns_y) will become high, while ew_r will remain high. Theoretically, the cars coming from north-south directions will be required to slow down and come to a complete stop. Therefore, ns_y will become low and north-south red (ns_r) will become high, while ew_r remains high. Eventually, this same process will repeat but the east-west LEDs will go from green to yellow, then to red, and then it will complete a full rotation of states.

State	N/S LED Color	E/W LED Color
0	Green	Red
1	Yellow	Red
2	Red	Red
3	Red	Green
4	Red	Yellow
5	Red	Red

Table 1: Table of each state.

Table 1 shows what each state is composed of and backs up *Figure 5*. As seen in *Figure* 5, a screenshot of the actual simulation of one of the states, *Table 1* continues said simulation, but in a more simplistic manner: these states will go in order. Once they reach state 5, the system will go back to state 0.

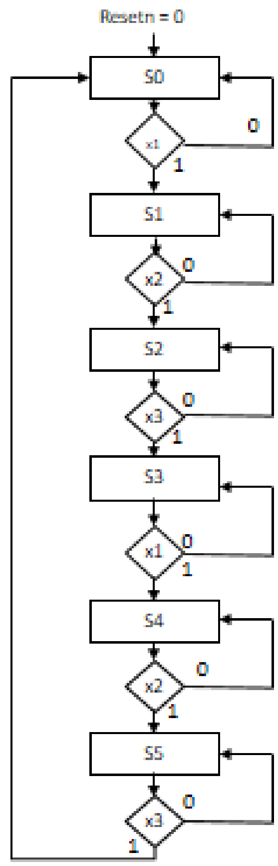

Figure 6: State Diagram.

Referencing *Figure 6*, this state diagram provides an understanding of what each state's potential should be. For instance, each state can only goto, if the requirements are met, either the next state, or, if the requirements are not met, will go back to the beginning of the state in which they were originally in. For a state to proceed, the variable "x" must be 1. In essence, the diagram backs up the thought process the group came to make the LEDs change to the proper colors.

In order to digitally demonstrate what the finalized traffic light looks like, a video was made. In the youtube video *[2],* it shows the entire process the LEDs go through. It is clear that each LED turns on in the correct order, and the timing is correctly inputted. One can, in fact, see that there are two sets of LEDs instead of four sets, like it was discussed earlier.

Conclusion - The simulation of the circuit and all of the LEDs on the breadboard illuminated in their proper order. With the resolution of many of the mistakes and errors, a lot of important information was gained. Arguably, the penultimate lesson learned from the process was the VHDL coding and developing the proper logic to achieve a functional implementation of the circuit. Within the code, many new designs not previously practiced, though alluded to, had to be written. Another learning curve was how to properly put together the enable and clear switches inside of the counters: while tying those components to the FSM. Although the coding process proved quite difficult at times, the hardware components and wiring was fairly straightforward: because common experience with such things. By this stage, the project appeared to be in sufficiently operational condition: despite circumstances outside of the technical development. Unfortunately, due to time constraints and other factors, the night time feature could not be incorporated into the final design. This mode was in development, but the time table for implementation required it to be withheld from the final product. Furthermore, within the presentation to explain and demonstrate the design and implementation of the circuit, it was discovered that a state diagram was missing as well. One crucial improvement that could have been made is the implementation of all four sets of LEDs, rather than just a pair. As mentioned earlier, this was partially due to an intergroup dilemma and also because it was a more simplistic design. In the end, a lot of experience was garnered about the development of, and implementation of, digital logic design to a real world application.

References -

[1] Brown, A. (n.d.). *Nexys A7 Reference Manual*. Nexys A7 Reference Manual - Digilent Reference. Retrieved April 21, 2023, from https://digilent.com/reference/programmable-logic/nexys-a7/reference-manual

[2] "Traffic Light Video." Youtube, nlegato, 19 April 2023, https://youtu.be/uNnRW8VPhPs

Abstract—Succinct summary description of your project: purpose, major findings, conclusions, and main recommendations. DO NOT USE SPECIAL CHARACTERS, SYMBOLS, OR MATH IN YOUR TITLE OR ABSTRACT.

I. Introduction

Indicate the scope of the project (i.e., what the report will cover), setting the scene for the remainder of the report. Make a case for your project. For example: what is the motivation? What are the implications of your project? What topics that you learnt in the class does your project cover? What topics did you learn on your own? What are the applications of your project? Think of the rest of the report as an expansion of some of the points in the introduction.

II. Methodology

This is the body of your report. Here you explain how you designed your project.

A. First Section

The main body of the report may be divided into multiple sections as the case may be. You may have different sections which delve into different aspects of the problem. The organization of the report here is problem specific. You may also have a separate section for statement of design methodology, or experimental methodology.

B. Second Section

The report should be easy to read and professional in its presentation. The use of figures is strongly encouraged.

III. Experimental Setup

Indicate the setup you used to verify the functioning of your project. What software/hardware tools did you use? What was the specific configuration of those tools? What are the expected results?

IV. Results

List all results you obtained, For example: audiovisual results, results in an oscilloscope, etc. You can include pictures and/or links to video of your project functioning.

Include some discussion of your findings and relate them to the topic learnt in class. Were the results what you expected? In what cases are the results explainable, and in what cases unexplainable (if any)?

Conclusions

State the main take-away points from your work. List further work as well as what you learnt. What issues remain to be solved? What improvements can be made?

References

List and number all bibliographical references in 9-point Times, single-spaced, at the end of your paper. When referenced in the text, enclose the citation number in square brackets, for example [1]. Where appropriate, include the name(s) of editors of referenced books. The template will number citations consecutively within brackets [1]. The sentence punctuation follows the bracket [2]. Refer simply to the reference number, as in [3]—do not use "Ref. [3]" or "reference [3]" except at the beginning of a sentence: "Reference [3] was the first . . ."

[1] G. Eason, B. Noble, and I. N. Sneddon, "On certain integrals of Lipschitz-Hankel type involving products of Bessel functions," Phil. Trans. Roy. Soc. London, vol. A247, pp. 529–551, April 1955. *(references)*

[2] J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[3] I. S. Jacobs and C. P. Bean, "Fine particles, thin films and exchange anisotropy," in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.

[4] R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.

[5] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].

[6] M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science, 1989.

[7] Electronic Publication: Digital Object Identifiers (DOIs):

Article in a journal:

[8] D. Kornack and P. Rakic, "Cell Proliferation without Neurogenesis in Adult Primate Neocortex," Science, vol. 294, Dec. 2001, pp. 2127-2130, doi:10.1126/science.1065467.

Article in a conference proceedings:

[9] H. Goto, Y. Hasegawa, and M. Tanaka, "Efficient Scheduling Focusing on the Duality of MPL Representatives," Proc. IEEE Symp. Computational Intelligence in Scheduling (SCIS 07), IEEE Press, Dec. 2007, pp. 57-64, doi:10.1109/SCIS.2007.357670.