Final Project Report

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Abstract
Purpose of this project is to create fahrenheit to celsius converter and celsius to fahrenheit converter. The converter takes in values entered on a keyboard. It supports up to 8 bit binary input that will get converted to either celsius or fahrenheit and output the result on the 7 segment display.

I. Introduction:

Our final project is a fahrenheit to celsius and celsius to fahrenheit converter using a Nexys A7 with a Artix-7 FPGA and keyboard. It converts a 3 digit (8 bit) input from the keyboard in ℃ to ℉ or vice versa. It can switch between fahrenheit and celsius with the help of a switch and multiplexer. This project was created by implementing many different techniques, in VHDL using Vivado, that will be discussed in this paper.

II. Methodology

First, the main control of the circuit will be discussed. The first being the keyboard module that receives a serial data input from a PS/2 keyboard. This was a file that was utilized from Professor Llamocca's Reconfigurable Computing Research Laboratory [2]. Each key press, as well as a key-up code that is sent when a key is released, consists of an 8-bit number. This number is then sent through a decoder which converts said number to BCD by utilizing the scan code which can be found in the Nexys A7 Reference Manual [1]. This BDC number is then sent through to the FSMKEYBOARD module, along with the key-up code labeled done, where it is then utilized for the rest of the project.

The next module is the main control of the system. The FSMKEYBOARD is a state machine consisting of two inputs and three outputs. Seen below in Figure 1. It takes the 8-bit input data and assigns it to the corresponding digits place by running through the different states assigning the values and then simultaneously displays said value on the display. This state change happens every time done = 1. When all three values are imputed the last state sends the concatenated data through for calculation and then shows calculated value on the 7 segment display. See Figure 2 for the ASM diagram.

The final module control is the state machine that acts as the driver for the 7 segment display. Since all of the digits on the 7 segment display are connected to the same input, a state machine is required to drive the display. This state machine is called FSMDISPLAY and has one input and two outputs. The input is an enable that is supplied by a counter that supplies a '1' for 1 clock cycle after is counts 100,000 clock cycles. This gives the 7 segment display a refresh time of 1ms. The first output is used to activate a particular digit of the 7 segment display and turn off the rest. The second output controls the input that is displayed on the activated digit. Each digit has a corresponding input from the multiplexer. These outputs loop through the 3 digits used on the display incrementing every time the input in '1' (every 1ms). This gives the human eye the illusion of a solid display of different numbers at each digit. See Figure 3 for the ASM diagram.

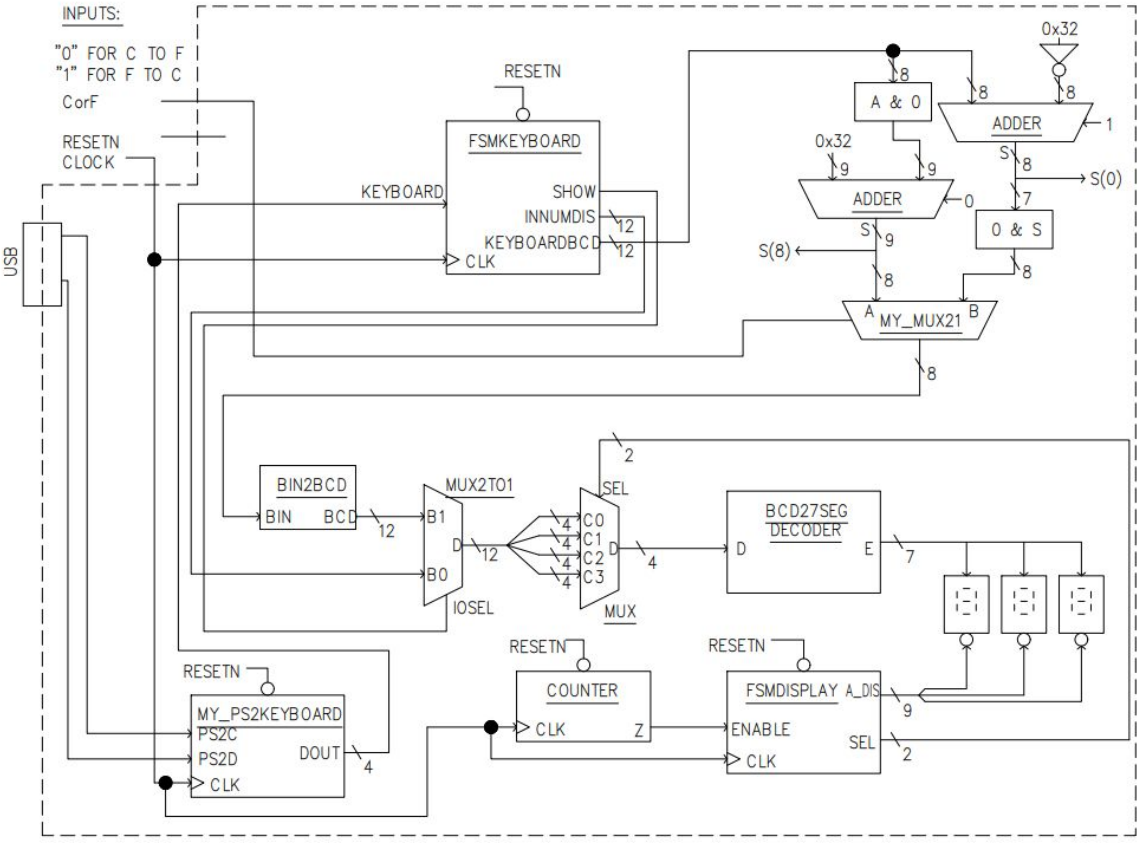

Figure 1: The overall block diagram of temperature converter system.

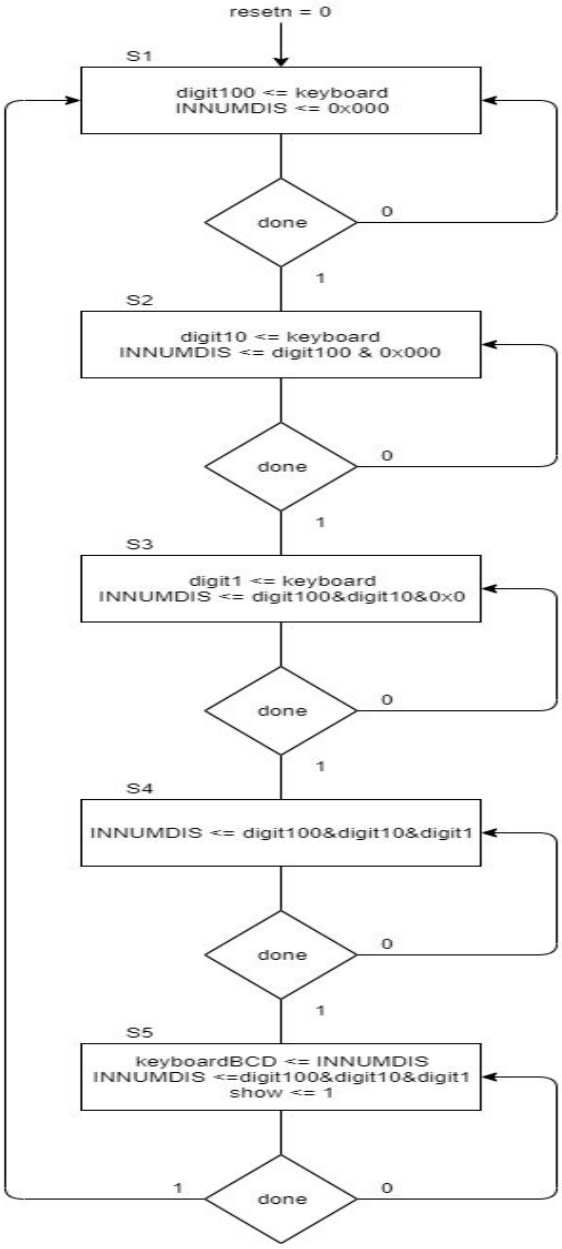

Figure 2: FSMKEYBOARD diagram.

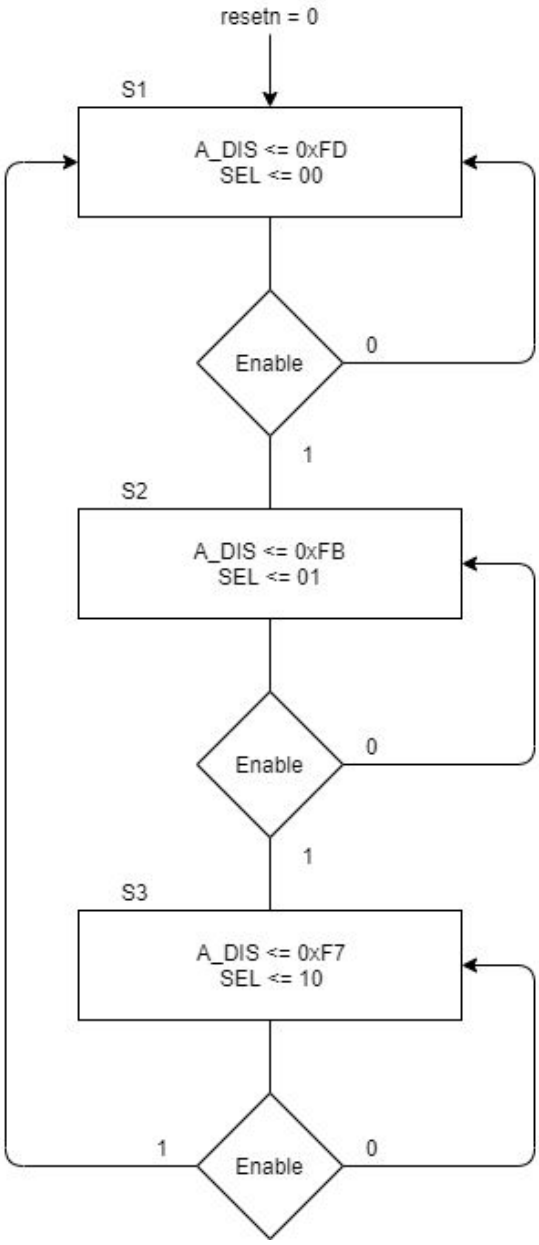

Figure 3: FSMDISPLAY diagram.

The main data path of this system is the conversion arithmetic and manipulation to be displayed on the 7 segment display. To simplify the implementation of this design we used the following formula for ℃:

$$C = (F - 32)/2$$

By rounding 5/9 to 1/2 the division can be done by simply dropping the LSB. In a similar way, the equation for ℉ is obtained:

$$F = C(2) + 32$$

In this case '0' is simply shifted in as the LSB from the number input as C. This rounding does however create a certain amount of error in the final calculation. This

can be up to 10% within the limitation of the system. This error percentage is not linear and increases as the magnitude of the input increases.

The two full adders are used to take the input from FSMKEYBOARD and complete the conversion arithmetic. Based upon the specific operation, the LSB is manipulated either before of after the full adder. In the case of a ℉ to ℃ conversion, the full adder is given a carry in of '1' and paired with a not gate to act as a subtraction operator. MY_MUX21 is a multiplexer where the required conversion is specified based on a switch from the user. A value of '0' indicates a ℃ to ℉ conversion and '1' indicates a ℃ to ℉ conversion. This value will provide the selection into the multiplexer that will feed the correct conversion into the display datapath.

At this point the data is an 8 bit binary number. This number must be displayed in the decimal system on the 7 segment display to be easily read by the user. Each digit must be separately displayed on the first 3 digits of the 7 segment display. In order to do this, the data is converted to 12 bit binary coded decimal (BCD). This is done by the BIN2BCD block.

Next, the multiplexer is used to select which number should be input to the display. It will either select the number being input by the user in the first phase, or it will select the conversion result in the second phase. This selection is controlled by the FSMKEYBOARD keyboard.

Next, another multiplexer is used. This multiplexer takes the 4 bits that make up one digit of the BCD. The data has 12 bits, so 3 inputs are provided. These 3 inputs correspond to the hundreds, tens, and ones place. The selector of the multiplexer is controlled by the FSMDisplay state machine and selects the correct input based on the state it is in. It will cycle through these values during its state changes to stimulate the 7 segment display. Before it is input to the display it is fed to a decoder that translates the decimal value into its corresponding 7 segment display pattern.

III. Experimental Setup

In order to display how each component plays a role in the project, a block diagram of the project was designed. Smaller components like the adders that convert the input into celsius and fahrenheit and later moved on to the more difficult components like those required to obtain data from the keyboard in a way that could be used by the system. Combining all the components together to work properly always presents unique challenges.

IV. Results

Our goal in this project was to read user inputs from the keyboard and then convert the numbers from celsius to fahrenheit or vice versa. We successfully achieved that goal. Through the completion of this project we were able to learn a lot about a variety of topics such as state machines, uses of multiplexers, uses of counters, and the seven segment display. After some issues we were able to finally achieve the desired result of reading inputs from the keyboard performing the conversion and the

displaying the converted value onto the seven segment display. Getting to our end goal was not an easy nor was it a short process. We encountered issues in nearly all parts of the project. One of the first problems we encountered was converting the inputs from the keyboard into readable numbers for the rest of the circuit. We also encountered a couple of problems in displaying on the seven segment display. The first of these problems was in that sometimes the numbers would not display in the right places. While trying to solve this problem we discovered a latch in the code for the seven segment display. We solved this latch by changing the states where variables were not assigned new values in the same state that required them as an output.

V. Conclusion

Temperature converter has been constructed and coded to make it easier for the user to use. It is made easy by switch 15 on the Nexys A7 board that gives the user and option to choose which conversion they want to display. We ran into some issues while designing this converter, but were able to quickly fix those issues. All the issues were resolved and the converter works efficiently and displays the correct conversations on the seven segment display.

VI. References

[1] https://reference.digilentinc.com/reference/programmable-logic/nexys-a7/reference-manual

[2] Llamocca, Daniel. "WHDL Coding for FPGA'S." Reconfigurable Computing Research Laboratory. N.p., n.d. Web. 6 Nov 2019.