Lab 6: Theme Park Monorail

Submission Due Dates:
Source Code: 2020/11/24 18:30
Report: 2020/11/29 23:59

Objective

1 Getting familiar with modeling finite state machines with Verilog.
2 Getting familiar with the control of keyboard and other I/Os on the FPGA board.

Description

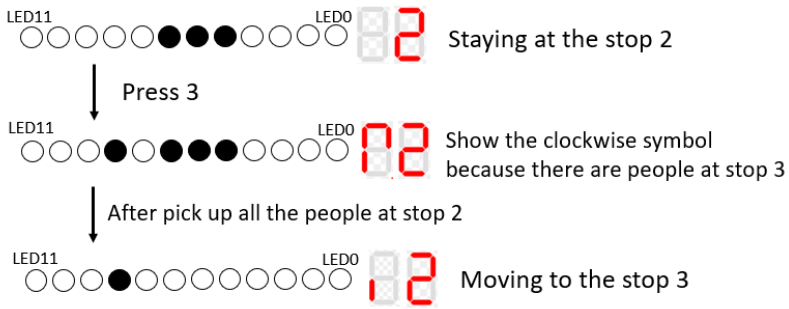
Tisneyland is one of the most famous theme parks in the world for all ages. There are many exciting facilities for visitors. But walking around the park can be exhausting after a long day. Therefore, your company proposed to provide a pick-up service for visitors, of course, by using the FPGA board with I/Os (keyboard, buttons, LEDs, and seven-segment display). Your company recently invented the teleport machine with quantum technology to transport customers to any facility they want! However, the teleport machine has to keep moving all the time to maintain its functionality. Therefore, your mission is to design a monorail, which equips the teleport machine, driving either clockwise or counterclockwise to pick up visitors.

- The monorail route includes three stops: *Galaxy Roller Coaster* (Stop 1), *Seven-Sea Ferris Wheel* (Stop 2), and *Viking Pirate Ship* (Stop 3). After being reset, the monorail starts from the Roller Coaster. Assume no visitor waits at each facility.
- Use the keyboard to increase the number of people at a specific facility. The number "1" represents the Roller Coaster (Stop 1), "2" for Ferris Wheel (Stop 2), and "3" for Pirate Ship (Stop 3). For example, press "2" to increase the number of people waiting at the Ferris Wheel by one. You only need to support the *numeric keypad* on the keyboard's right-hand side (as shown as follows).

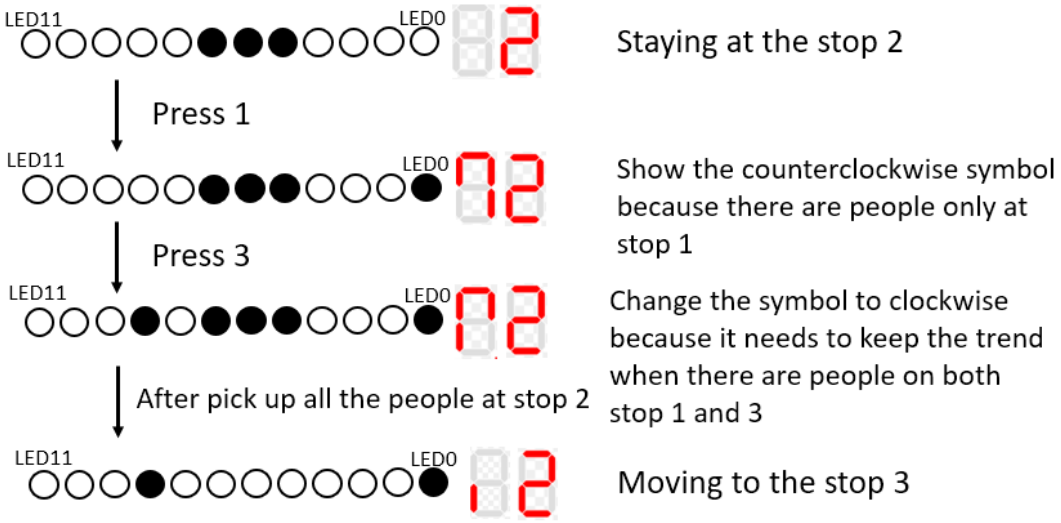
- We use 12 LEDs to represent the number of people waiting at each facility. From right to left, LEDs 0~3 indicate the number of people waiting at Roller Coaster (Stop 1); LEDs 4~7 at Ferris Wheel (Stop 2); LEDs 8~11 at Pirate Ship (Stop 3). There can be zero to four

people at each stop, using one LED for one person from right to left. The following figure shows an example with two persons at Stop 1, one at Stop 2 and nobody at Stop 3.

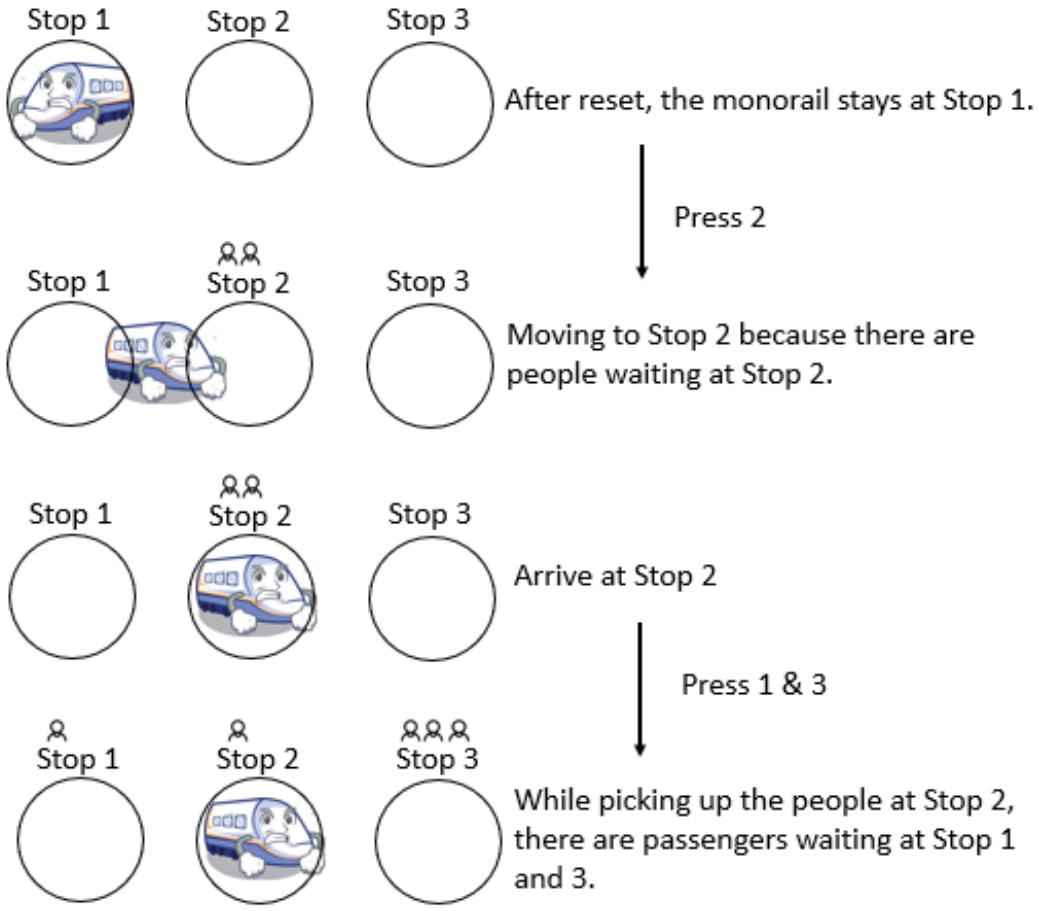
- The controller has three states: STAY, CLOCKWISE and COUNTERCLOCKWISE:
  1. In the STAY state, the monorail stays at the same facility. If someone is at the same facility as the monorail. The monorail will carry them one by one (with frequency of clk/(2^26)).
  2. In the CLOCKWISE/COUNTERCLOCKWISE state, the monorail moves clockwise/counterclockwise. It will take four clock cycle time (each with frequency of clk/(2^26)) to go to the next stop. All the visitors have to wait when the monorail is moving.
  3. If no visitor is waiting, the monorail stops at the last facility.
- The number of people at each stop should be able to increase anytime (even when the monorail is picking up the people at the same stop).
- The monorail operates in two directions: clockwise and counterclockwise:
  1. In the clockwise direction, the monorail follows the clockwise order repeatedly: Stop 1 → Stop 2 → Stop 3
  2. Otherwise, the counterclockwise order: Stop 1 → Stop 3 → Stop 2
- Press ***mode*** can switch the between the modes of the monorail.
  1. The monorail has two modes: auto and fixed. After reset, the monorail will be in the auto mode.
  2. In the auto mode, the direction of the monorail depends on which stop has visitors waiting.
     a. If the monorail is at Stop 2 and there are only visitors at Stop 3, the monorail will go to Stop 3 to pick up the visitors.

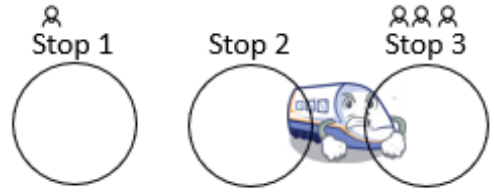


b. If there are visitors at both Stop 1 and Stop 3 when the monorail is at Stop 2, the monorail keeps its direction. For example, if, before at Stop 2, the monorail was at Stop 1, it will go to Stop 3 first. If, for any reason, the monorail stays still and does not have any direction to follow, you may decide to go either clockwise or counterclockwise.

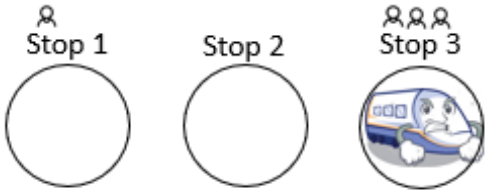


c. The following figure demonstrates an example of the auto mode:

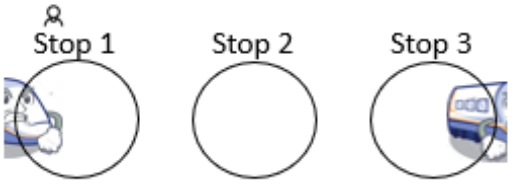




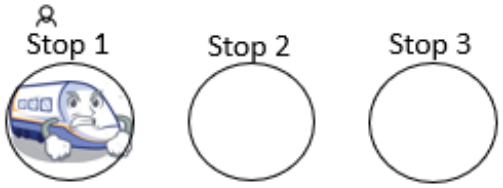
Because the monorail comes from Stop 1, it will move to Stop 3 since it needs to keep its trend.



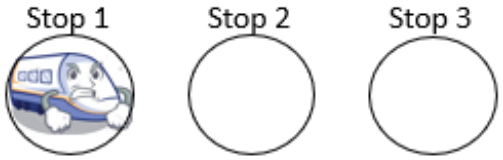
Arrive at Stop 3 and Pick up the waiting people.



Moving to Stop 1 because there are people waiting at Stop 1.



Pick up the waiting people.



Since there are no passengers waiting, the monorail will stop at the last stop(Stop 1) ☺☺

3 If the monorail is in the fixed mode, the monorail simply follows the present direction. You may assume that the monorail has its present direction. Before any visitors waiting at any stops after reset, the mode button is disabled. Pressing the button has no effect, i.e., the monorail can't switch to the fixed mode before its first move.

4 LED[15] will turn on when the monorail is in the fixed mode, and turn off in the auto mode.

- Use two 7-segment digits to indicate the status of the monorail. The right digit indicates the monorail's location (1: Stop 1, 2: Stop 2, 3: Stop 3) while the left digit indicates its movement. In the STAY state, the left digit shows the specific symbol to indicate the monorail's direction (either clockwise or counterclockwise). In the CLOCKWISE/COUNTERCLOCKWISE state, the digit shows the animation to represent the moving.

	Counterclockwise	Clockwise
Symbol:		
Animation:		

- Please refer to the demo video:
  https://www.youtube.com/watch?v=OrAbTwWQxK8
  0:00-0:08 the ***mode*** is disabled & the number of people can increase at anytime.
  0:09-0:30 the monorail in auto mode: 1→2→3→1→2 (notice the symbol and it keeps its direction from 3→1)
  0:31-0:48 the monorail in fixed mode: 1→3→2→1 (because of the fixed mode, the monorail needs to move counterclockwise from 3 to 1)
  0:49-1:20 simple example combined with auto/fixed mode.

I/O signal specification

- ***clk***: clock signal with the frequency of 100MHz (connected to pin W5)
- ***rst***: asynchronous active-high reset (connected to BTNC). The location of the monorail should be reset to Stop 1 and all LEDs are off.
- ***mode***: (connected to BTNL). Switch between the auto and fixed modes.
- DISPLAY[6:0]: signals to show the digits on the 7-segment displays.
- DIGIT[3:0]: signals to enable one of the 7-segment displays.
- LED[15:0]: LED[11:0] indicating the number of people at each stop; LED[15] indication the direction; others are off.

Note

1 The operating frequency of the monorail is clk/(2^26).
2 For the keyboard control, you may refer to KeyboardController and KeyboardDecoder discussed in class.
3 PS2_CLK and PS2_DATA are `inout` signals, that is, bidirectional signals. Don't change them to input or output.
4 LEDs 12~14 are no use in this lab. Make sure to turn them off all the time.

Hint

1 You must design at least one finite state machine (FSM).
2 Use the following template for your design:

```
module lab06(clk, rst, mode, LED, DISPLAY, DIGIT, PS2_CLK,
PS2_DATA);
    input rst;
    input clk;
    input mode;
    inout PS2_DATA;
    inout PS2_CLK;
    output [6:0] DISPLAY;
    output [3:0] DIGIT;
    output [15:0] LED;
    // add you design here
    //
endmodule
```

3 Highly recommend that you should design your block diagram first before coding.

Attention

- ✓ The XDC constraints file is ready to use without any modification.
- ✓ You should hand in one single file, i.e., lab6.v. If you have several modules for your design, merge them into lab6.v. (You don't need to put KeyboardDecoder, Onepulse, Debounce into lab6.v)
- ✓ You should also hand in your report as lab6_report_StudentID.pdf (i.e., lab6_report_108080001.pdf).
- ✓ You should be able to answer questions of this lab from TA during the demo.
- ✓ You need to generate the bitstream before the demo.