

ECE385 Final Project Report

Frogger in System Verilog

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I. INTRODUCTION

For this project, we recreated the classic game called Frogger. The basic premise of Frogger is to navigate three frogs through obstacles from the bottom to the top of the screen. Frogger must first pass through four lanes of traffic and a river full of lily pads in order to successfully make it to the other side of the map. A frog may die by either colliding with a moving car or falling in the water. There are a total of three frogs that the user must navigate to the other end of the map, and once all three frogs move to their particular ending location, the user wins. If a user dies three times, then the game is over.

This system was developed in System Verilog in Quartus-II on an Altera-DE2-115 FPGA Board, and used software drivers developed in C to communicate with a USB keyboard (to be used as the controller).

II. LIST OF FEATURES

- User controlled frog sprite moves according to grid set on VGA display
 - Up, down, left, or right depending on keyboard input
 - Frog position restricted to on-screen
 - Frog direction held after keyboard direction inputed
 - Frog contains collision algorithms for obstacles
 - A total of three frogs placed into game at three different starting points
 - * three endpoints for frogs to get to
 - * frog can finish at any endpoint but only one frog can finish per endpoint
- Generation of moving obstacles
 - Four lanes of at most four cars in them
- * Each row moves at specific speed, direction
- * Cars wrap around screen
- * Frogger dies upon impact with car ending the game
- Four lanes of at most four lily pads in them
- * Each row moves at specific speed, direction
- * Lily pads wrap around screen
- * Frogger lives by stepping onto the lily pad, drowns by falling into the water
- * If the lily pad moves off the screen with Frogger on it, Frogger will fall into the water
- Working game clock at the top of the screen.
 - 60 seconds to complete the level.
 - Clock resets at the start of the game
 - Game ends when the game clock runs out of time
- Color/VGA Monitor Output
 - Detailed sprites give look and feel in graphical user interface
 - Colors allow user to clearly differentiate between obstacle, user controlled frog, and the map background
- Game reset button established that can reset the game at any point.

III. BLOCK DIAGRAM

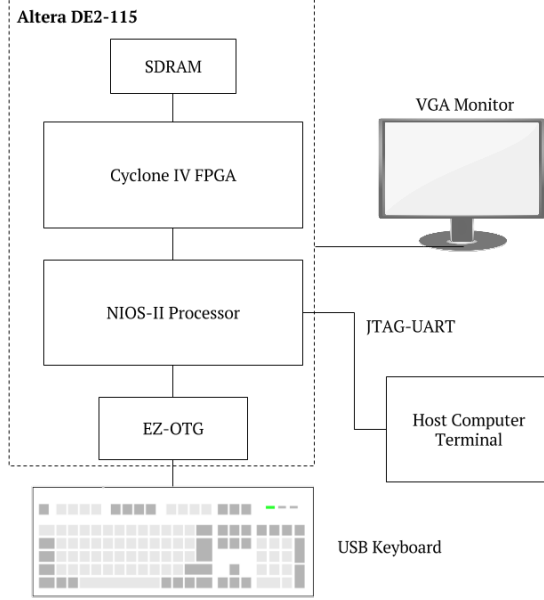


Fig. 1: Top Block Diagram

IV. PURPOSE OF MODULES

A. *final_frogger_top*

This is the top level module that both initializes all modules to use in the game and initializes their parameters. Three frogs are initialized and depending on the button the user presses (either 1, 2, or 3 on the numpad) either one is active at a single instant. Both cars and lilypads are initialized using parameter constant arrays, as shown in Figure 2 and Figure 3.

```

/***** Car Parameters *****/
parameter bit [2:0] Number_Cars_Row [0:3] = '{3'd4,
                                           3'd4,
                                           3'd4,
                                           3'd4};

parameter bit [7:0] Gap_Size_Cars_Row [0:3] = '{8'd80,
                                                8'd80,
                                                8'd80,
                                                8'd80};

parameter bit [5:0] Speed_Cars_Row [0:3] = '{5'd20,
                                             5'd15,
                                             5'd10,
                                             5'd5};

parameter bit Direction_Cars_Row [0:3] = '{1'b1,
                                           1'b0,
                                           1'b1,
                                           1'b0};

parameter bit [10:0] Start_Y_Cars_Row [0:3] = '{11'd400,
                                                11'd360,
                                                11'd320,
                                                11'd280};

```

Fig. 2: Car Parameters

```

/***** Lilypad Parameters *****/
parameter bit [2:0] Number_LPad_Row [0:3] = '{3'd4,
                                           3'd4,
                                           3'd4,
                                           3'd4};

parameter bit [7:0] Gap_Size_LPad_Row [0:3] = '{8'd80,
                                                8'd80,
                                                8'd80,
                                                8'd80};

parameter bit [5:0] Speed_LPad_Row [0:3] = '{5'd15,
                                             5'd17,
                                             5'd20,
                                             5'd25};

parameter bit Direction_LPad_Row [0:3] = '{1'b1,
                                           1'b0,
                                           1'b1,
                                           1'b0};

parameter bit [10:0] Start_Y_LPad_Row [0:3] = '{11'd80,
                                                11'd120,
                                                11'd160,
                                                11'd200};

```

Fig. 3: Lilypad Parameters

B. *Color_Mapper*

- 1) *Displays Frogger, Cars, and Lilypads :*
- 2) *Sets orientation of Frog Direction:*

C. *frog*

The frog module contains the logic for the moving component controlled by the user (the “frog”). This entails the logic for what the frog does when detecting it is colliding with a car, a lilypad, water, or the end position. The frog is implemented as a state machine that depending on the actions of the user, will move to the cooresponding state. The frog state diagram is explained below in the “Finite State Machines” section.

This module takes inputs as the desired start position of the frog, the controller keys (up, down, left, right), lilypad collision signals, car collision signals, lilypad parameters (so it can sync up with the movements of the lilypad when colliding), and the win/lose signal. The module outputs the frog x and y position to display on the screen. Depending on the state of these win/lose signals the frog stops responding to input.

D. *car*

The car module contains the logic for the moving cars in the bottom half of the screen. This module also detects if there is a collision between its location and the location of the frog. It takes input of the desired speed/direction and updates/outputs the position of the car to display on the screen. It also takes inputs of the frog x and y position so it can determine if the car is collided with the frog. If it is, then it outputs a collision

signal.

The logic for the collision detection is shown in Figure 4.

E. car_row

The car_row module uses a generate block to create four car modules and depending on the number of cars used, it updates the collision signal. It takes inputs as the number of cars, speed/direction of cars, and the gap size in between each car. This is shown in Figure 6

F. lilypad

The lilypad module is similar to the functionality of the car module. This module contains the logic for the moving lilypads in the top half of the screen. It takes inputs of the desired direction/speed along with the frog x and y position and outputs the new location of the lilypad to draw to the screen. The frog x and y position are used to determine if a collision is occurring between the frog and the lilypad. This will output a collision signal if so.

Lilypads differ from cars in that they “carry” the frog once the two objects collide. This means that there must be a method to “sync” up the movements of both the lilypad and the frog once they collide. For this reason, the lilypad module also must output its remaining count on its state machine cycle for its speed. This is so that if the frog lands on the lilypad midway through its “move” cycle, then the frog can essentially take over the count of the lilypad and be synced up and move accordingly.

G. lilypad_row

The lilypad_row module is similar to that of the car_row module. Th

H. game_logic

Module game_logic.sv controls the overall finite state machine of the Frogger game. This module monitors number of frogs to successfully get to the other side of the screen. It then sends the game into a win or death state depending on the outcome of the game. This module also controls the value of the game clock. If the game clock runs out of time before the three frogs reach the other side, the game ends and the player loses.

I. hpi_io_intf

This method takes HPI output values from the NIOS II as input, checks for a call to reset, and if no reset, assigns these values to the proper values to be outputted by the top-level module to the CY7C67200 chip. Inputs and outputs used are shown below.

```
input [1:0] from_sw_address,
output [15:0] from_sw_data_in,
input [15:0] from_sw_data_out,
input from_sw_r, from_sw_w, from_sw_cs,
inout [15:0] OTG_DATA,
output [1:0] OTG_ADDR,
output OTG_RD_N, OTG_WR_N, OTG_CS_N, OTG_RST_N,
input OTG_INT, c1k, Reset);
```

J. VGA_controller

The VGA_controller manages output to the monitor. Inputs include clock and reset. Outputs include several sync signals, a pixel clock specified for 25 MHz and 10 bit horizontal and vertical coordinate signals as shown below.

V. CIRCUIT SCHEMATICS

ERIC SECTION - easy, just when done take screen-shots of the circuit, 5 min

VI. FINITE STATE MACHINES

There were a total of 3 FSMs implemented in Frogger. One for the user-controlled component (the frog), another for the moving components (cars and lilypads), and the last for the game logic.

The frog module state diagram controls what happens to frogger when a particular action occurs. For example, if frogger collides with a car or water, it must die. However, if frogger collides with a lilypad, it must move at the same rate as the lilypad. These state machines are shown in Figures 8, 9, and 10.

VII. COLOR & SPRITE GENERATION

A Java file was used to generate all sprite files for the game. First the sprite was developed on Piskel (a free online sprite editor) and optimized for the minimal amount of color use. A palette was then generated based on all sprites in the project. For example...

VIII. DIFFICULTY

Producing the Frogger game in less than five weeks was no simple task. The team came across a number of issues on a range of the features that were implemented into the game. Most of the problems encountered came about from dealing with the System Verilog software. What would be a simple function in a high-level programming language became rather tedious in System Verilog and required some thought in order to successfully implement.

One of the most difficult tasks in making the game was collision control for the Frogger sprite with obstacles, particularly with the lily pads. The algorithm for collision control turned into a long AND/OR statement for the cars. Collision for the frog with the cars was easy once that long statement was put into place and modified for precision. It was easy because a simple contact between the frog sprite and car sprite killed the frog and ended the game. Creating collision control with the lily pads was far more difficult to implement. The frog should land on the lily pad and live, floating across the screen holding its position fixed to the lily pad until another direction key is pressed. Clock issues came into play when trying to match up the speeds of the two colliding sprites, especially when the two sprites have different frame clocks.

Another issue was generating the high level graphics for the sprites and background. The on-chip memory alone was not enough to hold the amount of colors and pixels of all graphics desired for the project. SDRAM had to be implemented to store the memory for all 640 x 480 pixels on the screen.

A LOT MORE COULD BE ADDED HERE

IX. CONCLUSION

Resource	Value
LUT	9239
DSP	0
Memory (BRAM)	82,944
Flip-Flop	656
Frequency	73.32 MHz
Static Power	102.66 mW
Dynamic Power	50.68 mW
Total Power	249.76 mW

TABLE I: Design Statistics

X. FIGURES

```

/* 4 Scenarios for Collision with Car:
 * UPPER LEFT
 * UPPER RIGHT
 * BOTTOM LEFT
 * BOTTOM RIGHT
 * Change Frog_X and Frog_Y values to change tolerance to sprite collisions (in future)
 */
if (
  ((Frog_X+X_TOLERANCE) >= Car_X_Position && (Frog_X+X_TOLERANCE) <= (Car_X_Position + Car_Width) /*TOP LEFT*/
  && (Frog_Y+Y_TOLERANCE) >= Car_Y_Position && (Frog_Y+Y_TOLERANCE) <= (Car_Y_Position + Car_Height))
  ||
  ((Frog_X+X_TOLERANCE) >= Car_X_Position && (Frog_X+X_TOLERANCE) <= (Car_X_Position + Car_Width) /*BOTTOM LEFT*/
  && ((Frog_Y-Y_TOLERANCE) + Frog_Side) >= Car_Y_Position && ((Frog_Y-Y_TOLERANCE) + Frog_Side) <= (Car_Y_Position + Car_Height))
  ||
  (((Frog_X-X_TOLERANCE) + Frog_Side) >= Car_X_Position && ((Frog_X-X_TOLERANCE) + Frog_Side) <= (Car_X_Position + Car_Width) /*TOP RIGHT*/
  && (Frog_Y+Y_TOLERANCE) >= Car_Y_Position && (Frog_Y+Y_TOLERANCE) <= (Car_Y_Position+Car_Height))
  ||
  (((Frog_X-X_TOLERANCE) + Frog_Side) >= Car_X_Position && ((Frog_X-X_TOLERANCE) + Frog_Side) <= (Car_X_Position + Car_Width) /*BOTTOM RIGHT*/
  && ((Frog_Y-Y_TOLERANCE) + Frog_Side) >= Car_Y_Position && ((Frog_Y-Y_TOLERANCE) + Frog_Side) <= (Car_Y_Position + Car_Height))
)
  Car_Collision = 1'b1;
else
  Car_Collision = 1'b0;
end

```

Fig. 4: Car Collision Logic

```

/*
 * 4 Scenarios for Collision with LPad:
 * UPPER LEFT
 * UPPER RIGHT
 * BOTTOM LEFT
 * BOTTOM RIGHT
 * Change Frog_X and Frog_Y values to change tolerance to sprite collisions (in future)
 */
if (
  ((Frog_X+X_TOLERANCE) >= LPad_X_Position && (Frog_X+X_TOLERANCE) <= (LPad_X_Position + LPad_Width) /*TOP LEFT*/
  && (Frog_Y+Y_TOLERANCE) >= LPad_Y_Position && (Frog_Y+Y_TOLERANCE) <= (LPad_Y_Position + LPad_Height))
  ||
  ((Frog_X+X_TOLERANCE) >= LPad_X_Position && (Frog_X+X_TOLERANCE) <= (LPad_X_Position + LPad_Width) /*BOTTOM LEFT*/
  && ((Frog_Y-Y_TOLERANCE) + Frog_Side) >= LPad_Y_Position && ((Frog_Y-Y_TOLERANCE) + Frog_Side) <= (LPad_Y_Position + LPad_Height))
  ||
  (((Frog_X-X_TOLERANCE) + Frog_Side) >= LPad_X_Position && ((Frog_X-X_TOLERANCE) + Frog_Side) <= (LPad_X_Position + LPad_Width) /*TOP RIGHT*/
  && (Frog_Y+Y_TOLERANCE) >= LPad_Y_Position && (Frog_Y+Y_TOLERANCE) <= (LPad_Y_Position+LPad_Height))
  ||
  (((Frog_X-X_TOLERANCE) + Frog_Side) >= LPad_X_Position && ((Frog_X-X_TOLERANCE) + Frog_Side) <= (LPad_X_Position + LPad_Width) /*BOTTOM RIGHT*/
  && ((Frog_Y-Y_TOLERANCE) + Frog_Side) >= LPad_Y_Position && ((Frog_Y-Y_TOLERANCE) + Frog_Side) <= (LPad_Y_Position + LPad_Height))
)
  LPad_Collision = 1'b1;
else
  LPad_Collision = 1'b0;
end

```

Fig. 5: Lilypad Collision Logic

```

//This will generate a total of 4 Car Modules every time
//Color Mapper will determine which ones must be on and which ones must be off
generate
    genvar i;
    for (i = 0; i <= 2'd3; i = i + 1)
    begin: car_i
        car car_instance(.Reset,
            .frame_clk,
            .CarX(Car_X[i]),
            .CarY(Car_Y[i]),
            .Car_Start_X(Car_Start_X + Gap_Size*i + i*11'd80),
            .Car_Start_Y,
            .Direction,
            .Speed,
            .Frog_X,
            .Frog_Y,
            .Car_Collision(car_collision_intermediate[i])
        );
    end
endgenerate

assign Car_Collision = ((car_collision_intermediate [0] && Number_Cars >= 1) ||
    (car_collision_intermediate [1] && Number_Cars >= 2) ||
    (car_collision_intermediate [2] && Number_Cars >= 3) ||
    (car_collision_intermediate [3] && Number_Cars == 4)) ? 1 : 0;

```

Fig. 6: Car Row Generation

```

//This will generate a total of 4 LPad Modules every time
//Color Mapper will determine which ones must be on and which ones must be off
generate
    genvar i;
    for (i = 0; i <= 2'd3; i = i + 1)
    begin: LPad_i
        lilypad lpad_instance(.Reset,
            .frame_clk,
            .LPadX(LPad_X[i]),
            .LPadY(LPad_Y[i]),
            .LPad_Start_X(LPad_Start_X + Gap_Size*i + i*11'd40),
            .LPad_Start_Y,
            .Direction,
            .Speed,
            .LPad_Remainder_Count(LPad_Remainder_Count_Intermediate[i]),
            .Frog_X,
            .Frog_Y,
            .LPad_Collision(lpad_collision_intermediate[i])
        );
    end
endgenerate

//need to output this to allow LPad_Move State to work
assign LPad_Remainder_Count = LPad_Remainder_Count_Intermediate[0];

assign LPad_Collision = ((lpad_collision_intermediate [0] && Number_LPads >= 1) ||
    (lpad_collision_intermediate [1] && Number_LPads >= 2) ||
    (lpad_collision_intermediate [2] && Number_LPads >= 3) ||
    (lpad_collision_intermediate [3] && Number_LPads == 4)) ? 1 : 0;

```

Fig. 7: Lilypad Row Generation

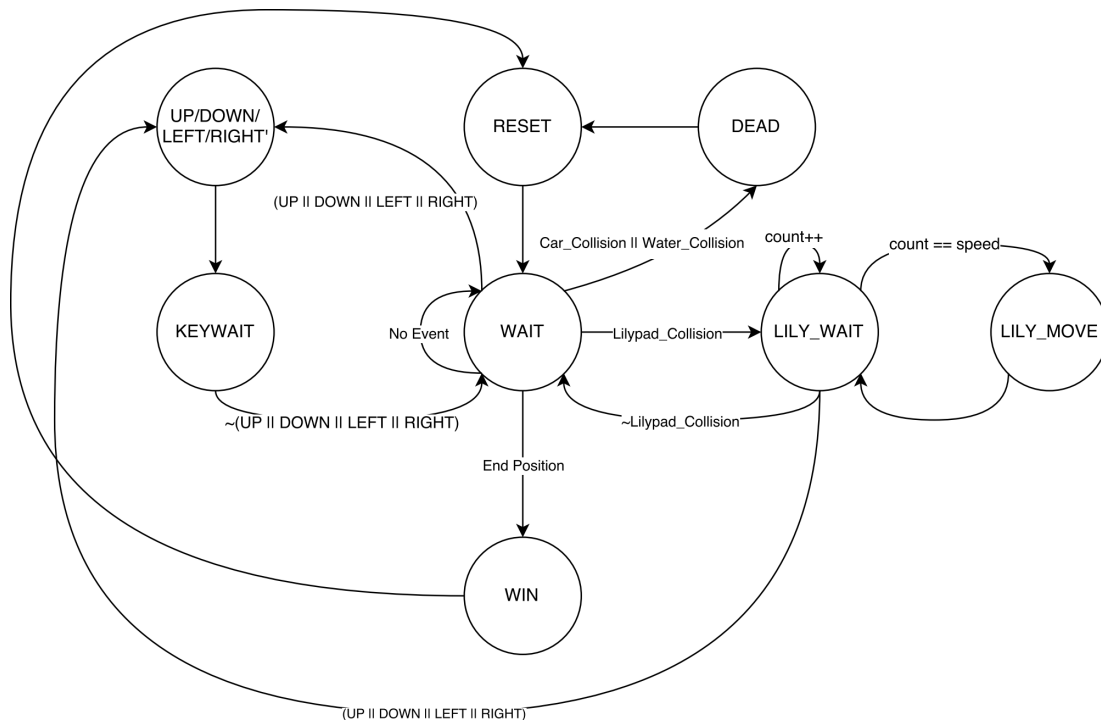


Fig. 8: Frogger State Diagram

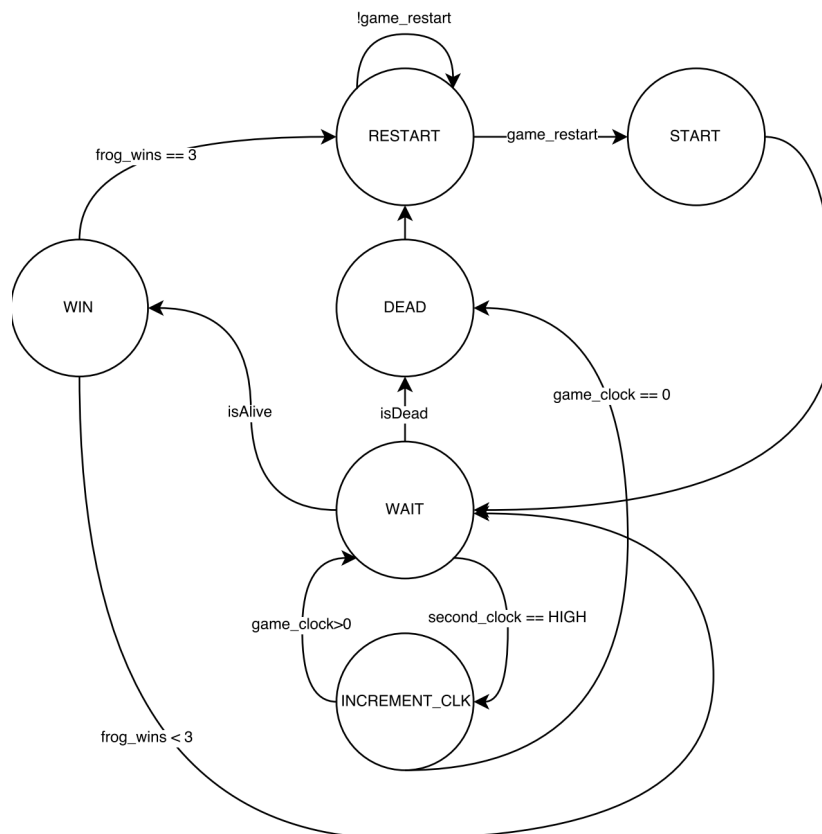


Fig. 9: Game Logic State Diagram

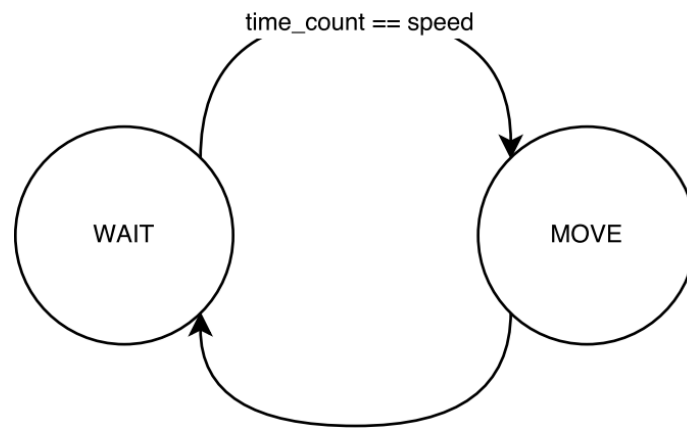


Fig. 10: Moving Obstacles State Diagram

APPENDIX