ECE385 Final Project Report

Frogger in System Verilog

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I. INTRODUCTION

For this ECE 385 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 lilypads 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
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 1 and Figure 2.

```
/*===== 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. 1: 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. 2: 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 means the logic for what the frog does when detecting it is colliding with a car, a lilypad, water , or the end position. The frog state diagram is explained below in the "Finite State Machines" section.

D. car

The car module contains the logic for the moving cars in the bottom half of the screen. This module detects if there is a collision between its location and the location of frogger. This logic is shown in Figure **??**.

E. car_row

F. lilypad

G. lilypad_row

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, clk, 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

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 7, 8, and 9.

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 pallette 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

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. 3: 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. 4: Lilypad Collision Logic

```verilog
//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. 5: Car Row Generation

```verilog
//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;
```

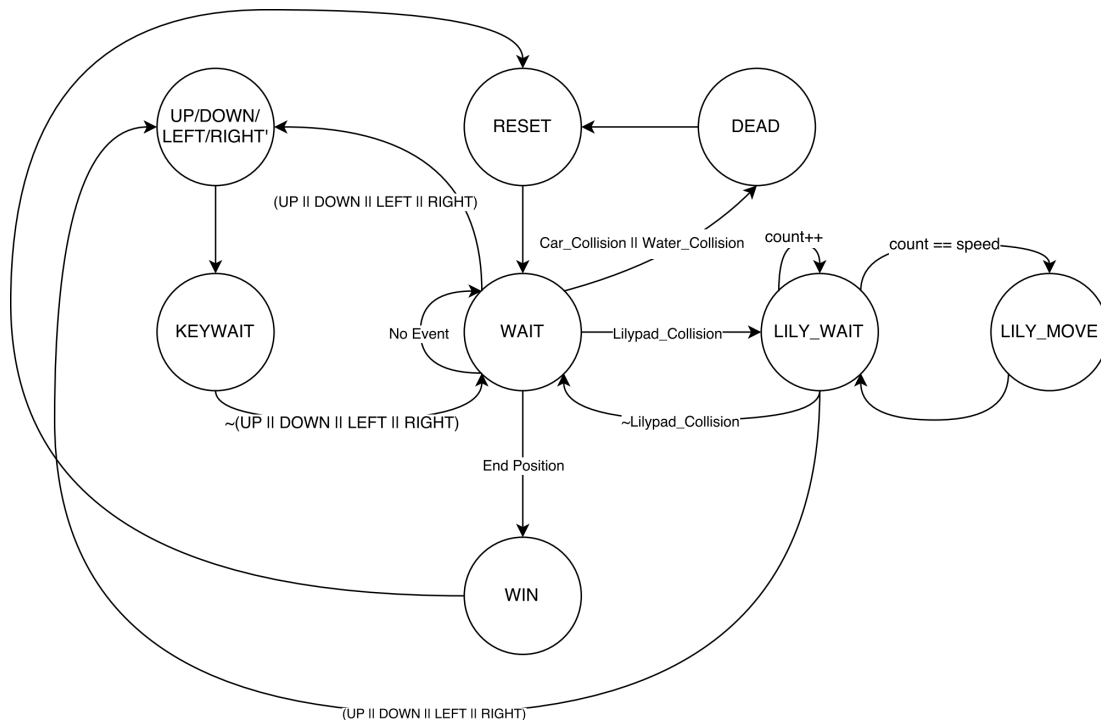Fig. 6: Lilypad Row Generation

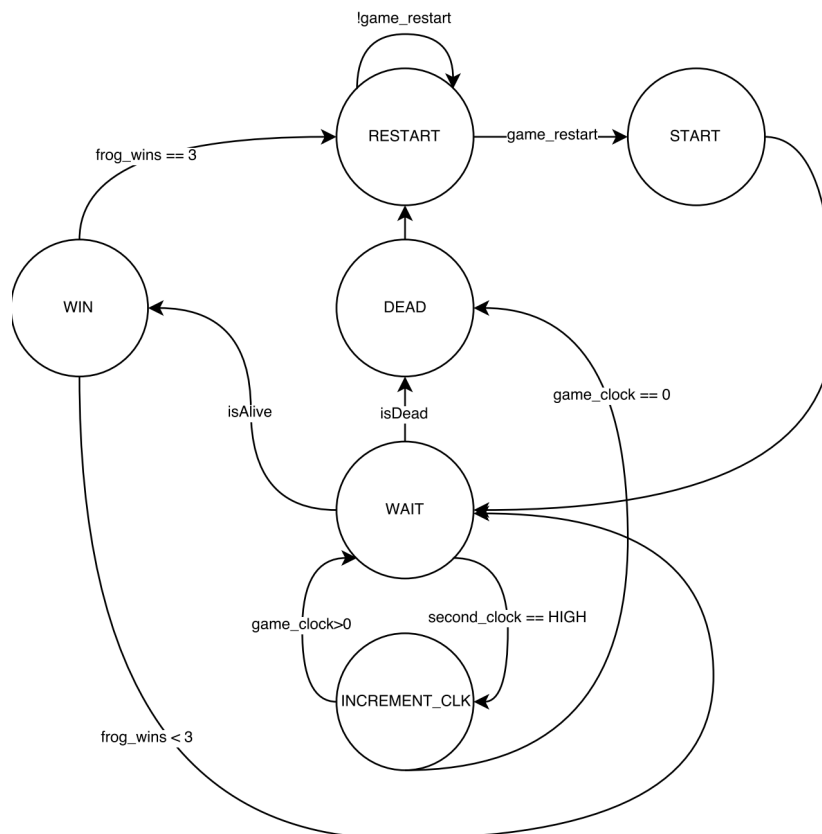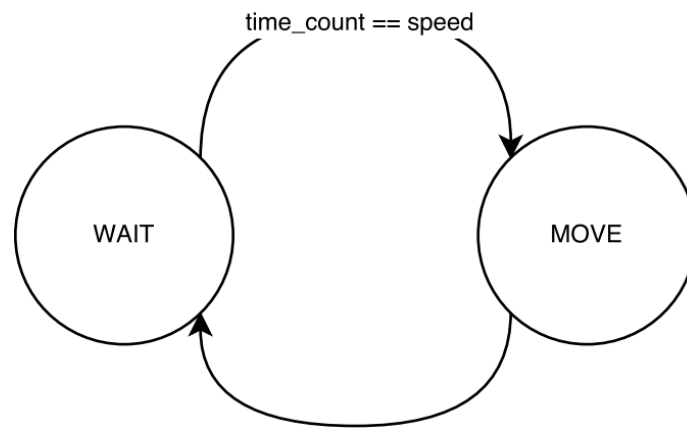Fig. 7: Frogger State Diagram

Fig. 8: Game Logic State Diagram

Fig. 9: Moving Obstacles State Diagram

APPENDIX