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Abstract

For design project 2, we will create a video game processor using a Video Graphic Adaptor (VGA) on the Xilinx Spartan-3E FPGA. The game that we are tasked with creating is the classic pong game where 2 players control a paddle and play a virtual game of table tennis. Each player will be able to control a paddle with the switches on the board, and the goal is to block the ball from entering your goal, while scoring by putting the ball past your opponent’s goal line. Each time the ball is hit by a paddle, the ball’s speed is flipped, and the result causes the ball to move in the opposing direction, towards the goal of the other player. If a wall is hit, the y-direction is flipped, acting as a ball would it hit a real wall. Each time the ball passes a goal line, it will change colors before returning to its original color, and reappearing in the center of the screen. The program must send RGB, HSYNC and VSYNC values to the display using the VGA.

Introduction

Games are a great way to relax and destress. The entire point is to stop thinking about boring tasks in mundane everyday life and engrossing yourself in a virtual world. One of the earliest and most important video games is Pong. In this project, we investigate how to implement this simple video game processor using a VGA and a spartan-3e board. The VGA will control our display, which uses CRT technology to scan across the screen to display pixels. Students will gain practical insight in designing and implementing real-time signal generators with custom logic programming. As students are creating pong using a VGA, the display will need to be updated constantly in real-time. Because of this fact, we will define a few specifications like the vertical and horizontal parameters of the game, clock cycles for ach parameter and more. Both players will be allowed to control 1 paddle, their own, and move it upwards or downwards to prevent the ball from crossing their goal line. The display must be updated with each input. Basic pong rules apply for this game.

System Specifications

3 main system specifications for the video game processor must be noted.

1. Static video frame: We must see all the elements such as the game borders/walls and the static background image/color of the game, and dynamic components that impact gameplay.
2. Dynamic elements: There are 3 dynamic elements that must be accounted for in the pong game; the ball and 2 paddles. Each element is moving and are required to change locations as the game continues in order to play the game. The paddles can hit the ball which will cause it to move opposite in the horizontal direction, towards the opponent. The paddles themselves can only move vertically to defend their goals. Players will be able to input directions while the game is playing. The program will interpret the input and subsequently move the corresponding player’s paddle up or down.
3. The game’s behaviour: What happens if the ball is either missed or hit by a paddle? When a ball is hit by a paddle, the ball’s trajectory must be changed by 90°, from the ball’s initial trajectory before it was hit. The next scenario occurs when the ball is missed by a paddle and ends up behind it. Once this occurs, the “goal” is entered, causing the ball’s color to change, indicating that a point was scored. Then the ball will reappear in its original color in the middle of the screen.

Device Description/Design

**VGA specification**

The VGA specifications are as follows: The Horizontal and Vertical parameters. The horizontal time periods are specified in multiples of the given VGA pixel clock, noted as 25MHz for a 60Hz refresh rate. The vertical lines are noted in multiples of the VGA lines. The following tables note the respective parameters.

|  |  |
| --- | --- |
| Parameter | Clock Cycles |
| Complete Line | 800 |
| Front Porch | 16 |
| Sync Pulse | 96 |
| Back Porch | 48 |
| Active Area | 640 |

Table 1. VGA Horizontal Parameters

|  |  |
| --- | --- |
| Parameter | Clock Cycles |
| Complete Frame | 525 |
| Front Porch | 10 |
| Sync Pulse | 2 |
| Back Porch | 33 |
| Active Area | 480 |

Table 2. VGA Vertical Parameters

**Symbols and Block Diagrams**

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Figure 1. Symbol of top level entity.

In Figure 1, the components of the pong game are shown. The left side has the inputs, while the right side contains the output signals. Player up and down pins are on the left side, as the game requires these signals, processes them, and changes the display accordingly. They are used to change the paddle locations up or down, depending on the signal. When one direction is set to high, the other direction is set to low, ensuring they do not get locked. When both directions are set low, this means that the paddle is not moving. The CLK pin is set to 25MHz this way the image of the board is displayed correctly without issues as the board cuts off at greater clock speeds.

The output pins HSYNC and VSYNC notify the VGA when new lines or frames must be drawn. The R, G, B output pins are used to select different colors for the board with mixtures of red, green, and blue color combinations. These colors are used to indicate the border walls, the paddles, the ball, as well as the background. The VGA will receive all these output signals every 20ns to draw the game’s interface and to be able to update it to make it playable.

**State/Process Diagrams**

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Figure 2. Process diagram of gameplay

Figure 2 displays the process diagram of the game. The game begins with a yellow ball in the center of the screen. The ball moves towards one of the paddles once the game begins. The ball’s speed is constant, however, once it hits a wall or a player paddle, the direction will be inverted. If the ball hits a wall, the y-direction is flipped, while if it hits a paddle, the x-direction is flipped. If the ball enters a goal, located behind a player paddle, the ball will turn red for a moment, before it is repositioned back in the center and turns the regular yellow color again, starting the game over again.

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Figure 3. Process diagram for updating frame display.

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Figure 4. Color VGA

Figure 3 shows how frames are displayed and updated. Horizontal and vertical cursors are used in the VGA to determine the position of the pixel that must be drawn. These will be controlled by the position counter processes, both initially set to 0. HSYNC and VSYNC are both set to high once the frame-drawing process starts. Within each cycle, which lasts 20ns, the horizontal position counter is increased by 1 so that the next pixel is drawn. When the horizontal counter reaches the maximum value (640 pixels, as per the lab manual specifications), the vertical counter will be incremented, moving the line to be updated down by 1 pixel. The HSYNC will also be returned to low to note that the line has been completed, and the horizontal counter is set back to 0. This process continues until the vertical counter reaches the maximum value (480 pixels, as per lab manual specifications). This means that it will require 307 200 cycles in total to complete. Once both counters are completed, HSYNC and VSYNC are set to 0, as an indicator that the frame is drawn. The counters will be reset to 0, which the sync signals are set to 1, in order to begin drawing the next frame. This process runs the entire time the program is running. And ball or paddle movement will happen once every frame in order to prevent screen tear.

Results

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Figure 4. Timing diagram when sync signals are 1.

Figure 4 is a diagram of the timings when both sync signals are set high, meaning that the frame is being drawn. The RGB signals indicate that the color is white. This means the border is being drawn.

A green and black screen

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Figure 5. Timing diagram when HSYNC is low and VSYNC is high.

Figure 5 indicates that a horizontal line has finished drawing and is incrementing to a new line. The colors indicate that a green pixel is being drawn, indicating the playing area. The vertical position is still within the drawing region.

A green screen with a square and a blue square

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Figure 6. Simulated results of pong game

Conclusions

This project taught the importance of digital systems and their many uses and just how precise they can be. The design choices taken contribute to flow and gameplay. While a pong game may seem simple compared to most modern games, the background information required for even such a simple game is very complicated. The project was a great experience creating a pong game.

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Appendix

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Game pins ucf file

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