**CSCE230102: Digital Design 1**

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**Project 2 (Pong Game)**

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1. **Introduction**

The project involves designing and integrating several modules to handle paddle and ball movement, collision detection, score display, and VGA output. The following report outlines the design approach, the key modules utilized, and challenges faced during the implementation process.

1. **Design Approach**

The design consists of modular components, each serving a specific purpose. This modularity allows for easier debugging, understanding, and expansion of the project. The major modules implemented are:

1. Display and Timing Control:

Ensures that the game's visual output aligns with the VGA monitor's timing requirements. A 60Hz refresh rate is maintained for smooth gameplay.

2. Paddle Control:

* Implements independent movement for Player 1 and Player 2 paddles.
* Paddle movement is regulated using debounced inputs to eliminate erratic signals caused by mechanical switches.

3. Ball Movement:

* The ball's position is updated at every refresh cycle.
* Collisions with paddles, walls, or boundaries trigger a reversal in velocity to simulate a bounce.

4. Game Text and Graphics:

* Displays static and dynamic text, such as "SCORE:" and the rule
* Uses ROM-based lookup tables to map ASCII characters to pixel data.

1. **Modules and Their Functions**

#### Top Module

The top module is the central hub that instantiates and connects all other modules. It handles the coordination between the VGA controller, game logic, input processing, and text rendering. It also integrates the clocking system and ensures proper synchronization of all subsystems. Key tasks include:

* Managing the VGA signals (hsync, vsync) and enabling pixel rendering.
* Instantiating and connecting the game\_display, text, and debouncer modules.
* Generating clock pulses for consistent game timing.

#### 2. Game\_Display Module

This module is responsible for rendering the game objects, including paddles, the ball, and the background, onto the VGA display. Key features include:

* Paddle Control: Implements movement logic for Player 1 and Player 2 based on button inputs (up\_1, down\_1, up\_2, down\_2).
* Ball Movement: Manages the ball's position, velocity, and direction. Handles collisions with walls and paddles.
* Color Assignment: Assigns unique colors to paddles, the ball, walls, and background pixels.

#### 3. Text Module

The text module displays static and dynamic text elements, such as scores, game rules, and endgame messages. Its components include:

* ASCII ROM: Stores character bitmaps for rendering text on the screen.
* Dynamic Addressing: Updates character addresses to reflect game states, such as score changes or game-over conditions.
* Display Logic: Ensures text elements appear in predefined regions on the VGA display, such as the top for scores.

#### 4. Debouncer Module

The debouncer module stabilizes button inputs by filtering out spurious signals caused by mechanical bounce. This ensures smooth paddle movement and reliable game interactions.

#### 5. VGA Controller

Although integrated indirectly, the VGA controller plays a critical role in generating synchronization signals (hsync and vsync) for the monitor. It divides the clock signal to achieve a 60 Hz refresh rate and calculates pixel coordinates (x, y) used by other modules.

#### 6. Ball ROM Module

This module stores the 8x8 bitmap for rendering the ball. It uses a simple lookup system to determine which pixels of the ball are active, ensuring a visually appealing circular shape.

1. **Challenges Faced**

During the development of our Pong arcade game, we encountered several challenges. One persistent issue was the "You Win" text appearing randomly. Synchronizing the clock for the ball shadow was also an issue we faced, as the timing modules were not correctly synchronized. Additionally, problems with text colors and pixel display required debugging our VGA output module to ensure proper rendering. Aligning the display elements also posed a challenge, which we resolved through systematic adjustments and testing. Initially, the ball would bounce off the center of the paddle instead of its surface, so we refined our collision detection logic to account for paddle boundaries accurately. Time constraints limited our ability to implement extra features we had envisioned, pushing us to prioritize core functionality. Collision detection, for instance, was particularly complex as it involved designing accurate and efficient interactions between the moving ball and paddles. Significant adjustments were necessary to ensure smooth ball deflection upon hitting paddles or walls. Another challenge was the VGA timing, which required precise tuning of horizontal and vertical counters to achieve compatibility with the 640x480 resolution standard. This required us to deeply understand the VGA protocol. Additionally, button debouncing was an issue due to the noise generated by physical switches, which required us to create a debouncer module to stabilize inputs and integrate it seamlessly with the paddle control logic. These challenges collectively enhanced our problem solving skills and teamwork.