Final Project: ES4 Spring 2021

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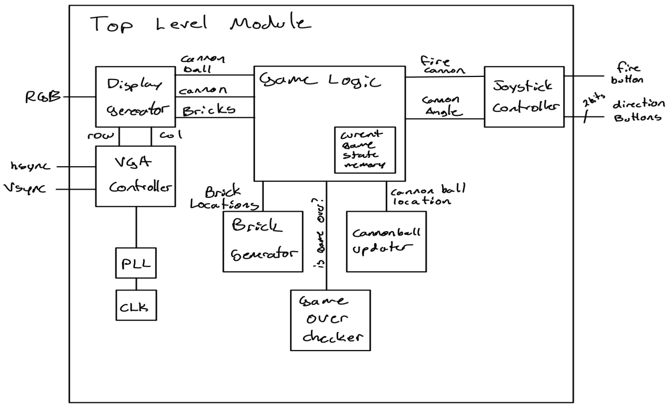
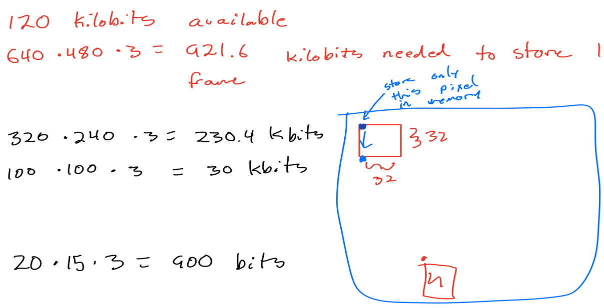
1 Overview





This game is a variation of the game Brick-Breaker where the player fires a cannonball out of a cannon and works to destroy the bricks that are displayed on the screen. There are three main parts to this project: displays, controls, and game logic. 'Displays' were done using a VGA, 'controls' were done by using an NES gamepad, and 'game logic' done in the 'top' module of our project. VGA sends the current row and column to display on the screen. The NES gamepad takes data in the form of buttons pressed and stores it in a shift-register. A clock is driven for 8 cycles (the number of buttons is 8) and the data signal is synchronized with the clock. When a button is pressed the corresponding bit of the output of the register is set to low. The top module controls the general logic of the game such as drawing the bricks and the cannon. Top also controls the memory usage of the game. Overall, objects are drawn in the top module, displayed via the display module, and those objects are then controlled via the cannon module (which is connected to the gamepad).

2 Technical Description and Design

2.1 Top Module

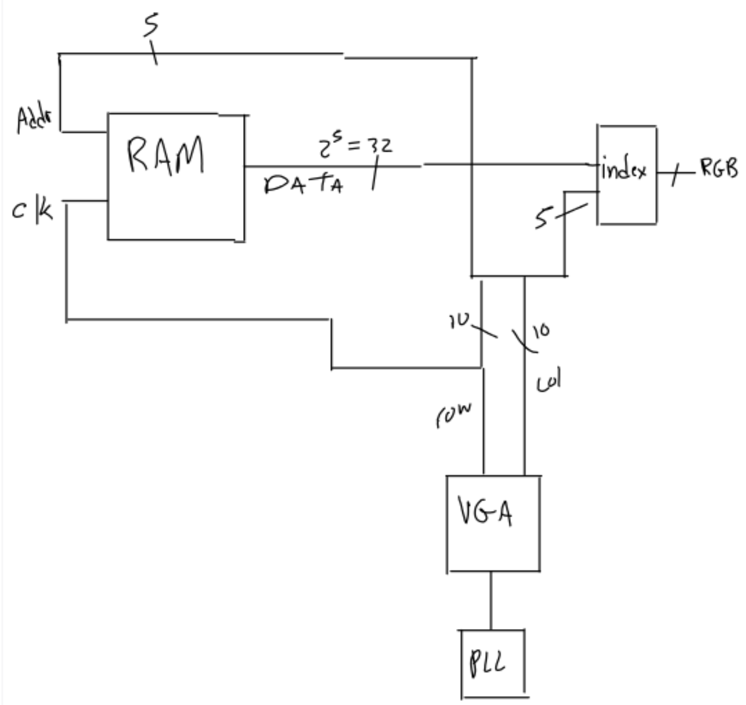
The top module is where the main game logic is handled. It's inputs are the 12MHz clock of the FPGA and the data from the controller. It outputs the necessary signals for the controller and the VGA to work. It's components are the pll, vga, display, and cannon. The main function of top is to draw the game objects. This the code to draw the bricks:

```vhdl
TYPE ram_brick IS ARRAY(0 TO 2 ** 5 - 1) OF std_logic_vector(32 - 1 DOWNTO 0);
    SIGNAL ram_block : ram_brick := (0 =>  "00000000000011111100111100111111",
                                     1 =>  "00000000000011111111111111111111",
                                     2 =>  "00000000000011111110000001111111",
                                     3 =>  "00000000000011111001111110011111",
                                     4 =>  "00000000000011110011111111001111",
                                     others => (others => '0'));
```

Where there is a '1' bit is where a brick is drawn. The other details are more complicated but in general $'1' =$ brick drawn $'0' =$ brick not drawn. $0 - 4$ represent the

row being drawn. One of the major challenges encountered here was figuring out how to destroy a brick when it is hit by a cannon. This means where there is a $'1'$ bit, meaning a block is drawn at that position, we have to invert the bit when it is hit by the ball. The display module now knows not to draw that brick. This was solved by using bit-masking to change the bit.
eg) consider the row of bricks: 00000000000011111100111100111111 suppose the block at index 31 needs to be destroyed then the XOR logical operation works well for this.
$00000000000011111100111100111111 \oplus 00000000000000000000000000000010 =$
$00000000000011111100111100111101$

We create a new bit word of the same size as the ram block with the corresponding bit we want destroyed to be '1' and the other bits to '0'. Then $1 \oplus 1 = 0$ so this will invert the bit we want inverted. The other bits are unchanged as $1 \oplus 0 = 1$ and $0 \oplus 0 = 0$. A schematic of our top module is shown below:



2.2 Display Module

The VGA module is responsible for sending the current row and column that we are writing to the display. It outputs the HSYNC and VSYNC as well as the 10-bit unsigned for the row and column number.

The display module is responsible for setting the rgb value of pixels on the screen. This module takes in the row and column we are writing to from the VGA, as well as the position of the cannon, cannonball, and bricks. Using a process block, we color pixels whose row and column match the positions of the cannon, cannonball, or bricks. Since the bricks are only represented as a single bit in RAM, our condition for coloring the pixels colors a 32 x 32 pixel area based on the single bit provided by the RAM.

2.3 Cannon Control Module

This is where the NES gamepad is used to control our game objects: the cannon and the cannon ball. Cannon sends it's data signal (which is also in the top module) to the NES controller and outputs the ball and cannon position based on the which button is pressed. Instead of using all 8 bits of the output of the NES only three were used the left and right button to move the cannon horizontally and the "A" button to fire the cannon ball. The rest of the bits were sent to 0.

The logic for moving the cannon was relatively simple: if the button is pressed (the signal is low) change the cannon's position by 1 to the left or right (which is later used in the top and display modules in order to actually display the change). If the fire button is pressed: change the row the ball is displayed (move the ball up) else set the column of the ball to the cannon's column and it's row to the cannon's row as well.

The biggest challenge we had was figuring out how to smoothly fire the cannon ball. The firing was happening too rapidly, pressing the button jumped the ball too far up the screen. The solution we came up with was to have the ball continuously be where the cannon is and if the user presses the fire button the ball goes up and stops once the user stops pressing the button. The ball shot 4-24 times based on how long the button was held.

3 Results and Testing

Overall, we were able to create a functioning game that is able to be controlled using the vga controller. It is able to move left and right and shoot the bricks and delete or destroy them in the process if the position of the cannonball is the same as the bricks. There were a few parts of our project we were not able to implement. We were not able to make the bricks different colors and change the angle of shooting. We were also not able store "levels" so randomly generated bricks to be added in every few seconds to make the game harder. Moreover we were missing a game over functionality. If we had more time, we would like to add all of these things.

This is the initial state of the game:

After firing some cannon balls some of the bricks were destroyed and this is the result:

The game did have some bugs at the end however:

1. The cannonball does not move smoothly and can only move if the fire button is held. It also doe not go through each row and skips rows so it might not destroy all the blocks at once.

2. Sometimes the connection is not tight or fully connected so it would randomly move or shoot.

3. The firing is not exactly very smooth and might skip some bricks that were supposed to be deleted.

4 Reflection

This project overall was fairly difficult and a lot of issues occurred. I think next time we should have planned the modules, especially the brick diagram more closely and specifically so it would be easier to implement the VHDL. In addition if we can add anything it would add complexity so there would be different levels with different patterns of bricks. Also, we would add it so the cannonball and cannon can change angles and also bounce to destroy the bricks. Finally, we would make it harder so the bricks would move down every 3 seconds like Tetris. What went well was the fact that we were able to combine what other team members into the top level effortlessly without any issues. It was a nice surprise. There were so many errors from other parts of the project that that was our best moment. Aside from the VGA and NES which was done by people that did the labs, we all live coded using VSCode for the rest of the parts of the projects. We all worked on fixing issues in every VHDL file and merging everything to the top level to create this game. So all the work was distributed equally.

5 Work Divison

Willy Lin - vga.vhdl, pll.vhdl, display.vhd, top.vhdl, VGA hardware James Eidson - cannon.vhdl, top.vhdl, nes.vhdl Zach Osman - cannon.vhdl, top.vhd, display.vhd, VGA hardware Ibrahima Barry - Nes.vhdl, cannon.vhdl, counter.vhdl, top.vhd, NESgamepad hardware

6 Debug Log

See debug.txt file for information

7 source code

https://github.com/barrycoder123/getBricked