Space Invaders on FPGA with WII Remote

I. Introduction

Everyone knows the classic arcade game Space Invaders which was released in 1978 and originally played on arcade cabinets. The goal of this project is to implement Space Invaders on a Altera DE1-SOC FPGA, and using a wii remote for the game input. The whole game will be implemented in hardware and for this the Verilog HDL is used.

II. Resources

As mentioned before a wii remote is used for player input, to connect the wii remote to the FPGA we use the GPIO pins located on the board. For visual output a monitor with VGA connection is used. The game uses a total of 6528 Flip-Flops, 1 PLL and 6 on-chip memories:

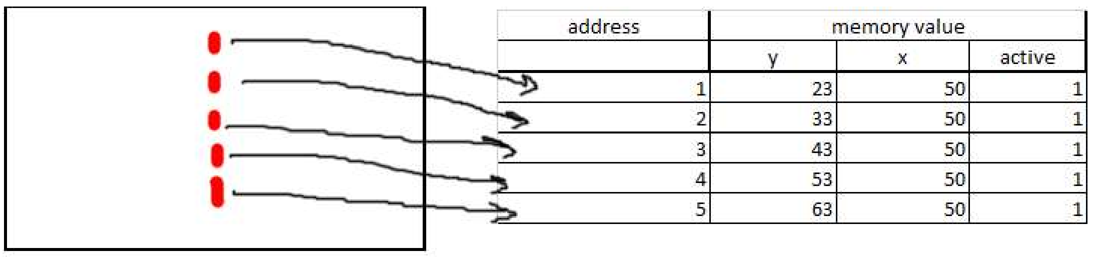
- 1-Port ROM: 4 bit addresses with a length of 24 bits used as colour palette
- 3X 1-Port ROM: 8 bit addresses with a length of 4 bits used for sprite storage for ship, bullets and enemies.
- 2-Port RAM: 6 bit addresses with a length of 24 bits used as storage for the bullets that were shot
- 2-Port RAM: 5 bit addresses with a length of 24 bits used as storage for the active enemies

The most challenging part of this project is to generate “infinite” bullets, and make them all move and disappear independently. This also applies for the enemies, they also have to be generated, moved and disappear independently. We also have to create the illusion that an infinite amount of enemies can spawn. Our solution to this problem is to store all bullets in a RAM memory. For a bullet we need 2 parameters: position, active. The position of the bullet is represented by an x and y value, the active parameters tells if the bullet has been shot. The bullet is thus represented by a 24 bit value:

{y coordinate(11 bit), x coordinate(12 bit), active(1 bit)}

Because a frame is drawn from top to bottom, we want the bullets to be arranged from top to bottom. This means address 0 corresponds to the top most bullet on the screen, address 1 corresponds to the bullet beneath it,…. This way we only need to increment the address to get the next bullet. If a bullet is shot it is inserted into the memory at the first address where the new bullet’s y value is bigger than the y value of the bullet that currently at that address and if the current address does not contain an active bullet. This presents another problem, the next example will clarify this:

Lets say we have shot 5 bullets, the current situation is seen in Figure 1.

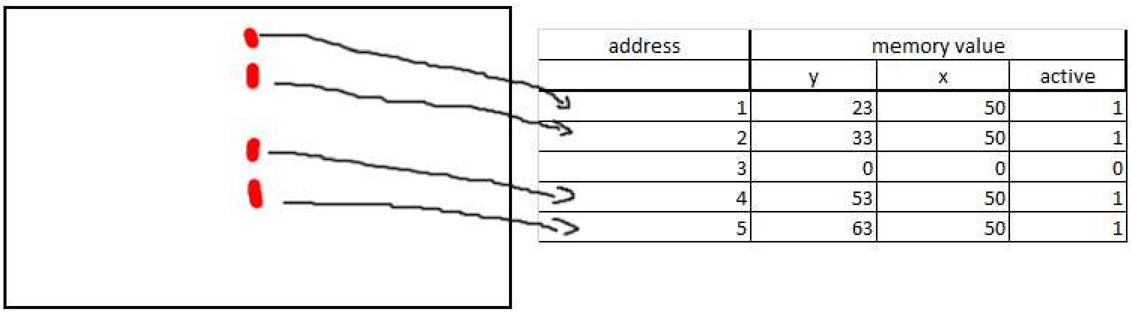


address	memory value		
	y	x	active
1	23	50	1
2	33	50	1
3	43	50	1
4	53	50	1
5	63	50	1

Figuur 1

Pellicciotta Allesio, Vandeweyer Joren

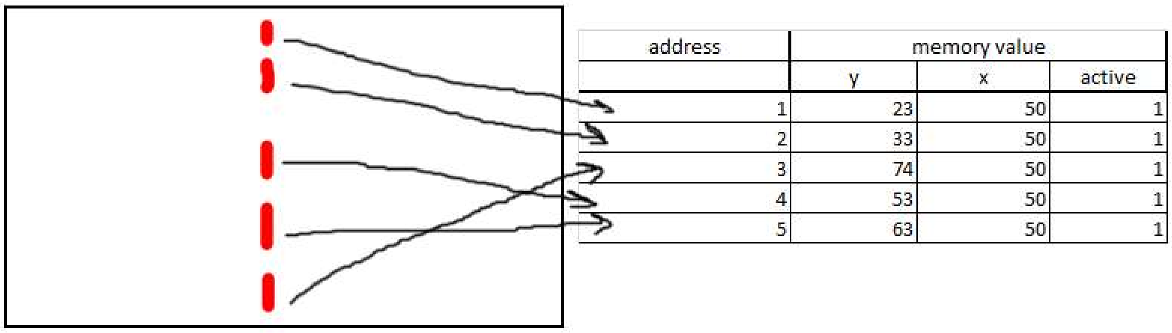
Figure 2 shows what happens when the third bullet hits and enemy.



address	memory value		
	y	x	active
1	23	50	1
2	33	50	1
3	0	0	0
4	53	50	1
5	63	50	1

Figuur 2

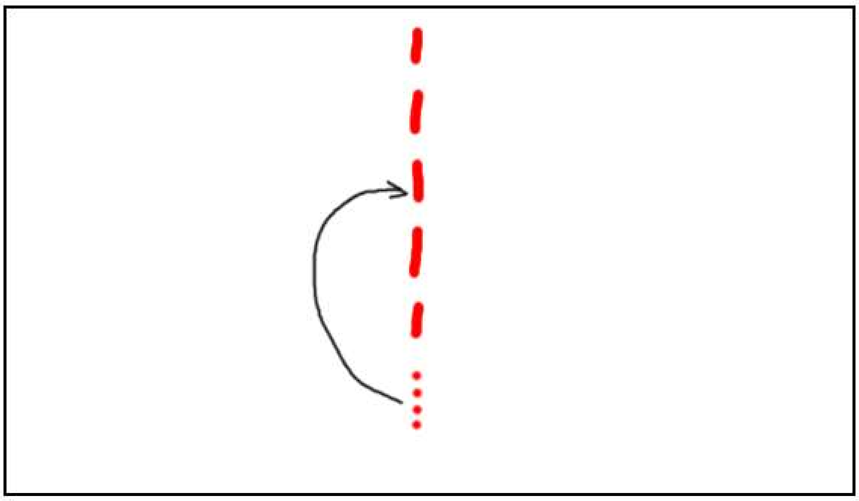
If we shoot another bullet, the game will now place the bullet at address 3, because it is the first bullet that is not active, and the new bullet's y value is bigger than 0. Figure 3 shows the current situation.



address	memory value		
	y	x	active
1	23	50	1
2	33	50	1
3	74	50	1
4	53	50	1
5	63	50	1

Figuur 3

In the next frame the game will try and draw the bullet at address = 3, this will result in the bullet being drawn at the wrong location (Figure 4).

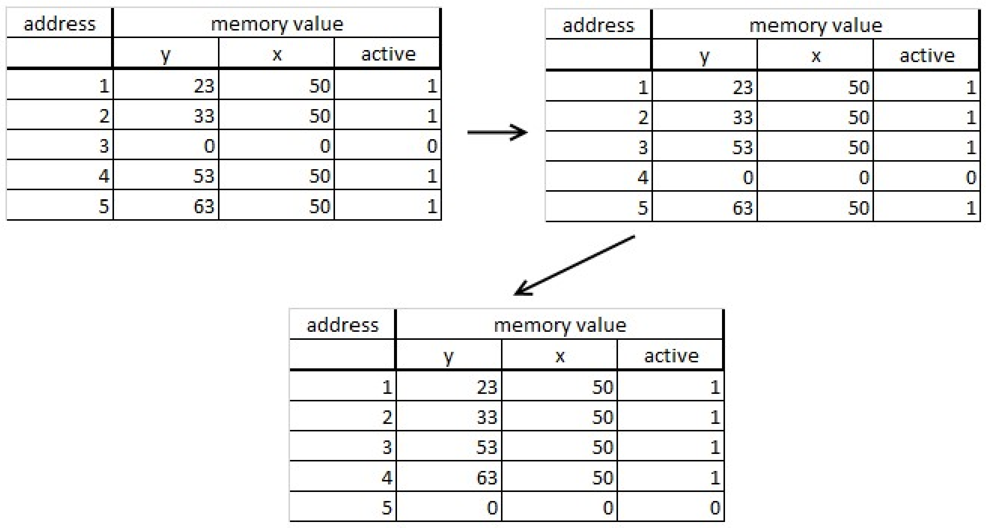


Figuur 4

For this reason we have created the following state machine:

- Clean:

  In this step the game will make sure that all active bullets neighbour each other in the memory. Figure 5 demonstrates this algorithm.



address	memory value		
	y	x	active
1	23	50	1
2	33	50	1
3	0	0	0
4	53	50	1
5	63	50	1

address	memory value		
	y	x	active
1	23	50	1
2	33	50	1
3	53	50	1
4	0	0	0
5	63	50	1

address	memory value		
	y	x	active
1	23	50	1
2	33	50	1
3	53	50	1
4	63	50	1
5	0	0	0

- Insert:

  If the player has shot a bullet, a new active bullet will be created. Else this step does nothing
- Move:

  Loops over the whole memory and moves the bullets up if they are active.
- Idle

This same method is used for the enemies.

III. Demonstration

In the demonstration, the player will be able to move around the playfield using the wii remote. There are also three enemies located on the screen, the player will be able to shoot them. A background with stars is also made, this background will give the illusion that the player and enemies are actually flying.

To make the player move, the left analog joystick on the wii remote is used. To shoot off a bullet, the "A" button on the wii remote is pressed.