



2048

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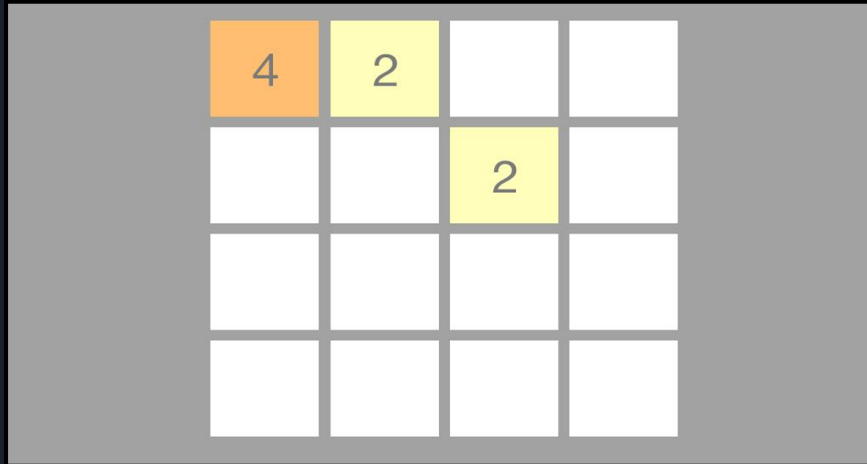


How it works

- Receiver to accept input from a computer, serially at 9600 baud, across a USB
- PuTTY is used to transfer this data
- Accepts only the characters w, a, s, and d, and only lowercase
- Output of receiver is a 3 bit encoded direction, with MSB being a pulse when a correct character is output, and the last two being the direction
- This is sent to a control circuit, and read by an FSM
- FSM generates 2 or 4 randomly and puts it on the grid
- FSM adds matching values when shifting in direction dictated by receiver, and also checks to see if any of the values equal 2048 (victory condition)
- It is possible to lose the game if all the tiles are full and cannot be added together
- Grid is constantly outputted to a file that makes it compatible for a VGA, then sent to a VGA

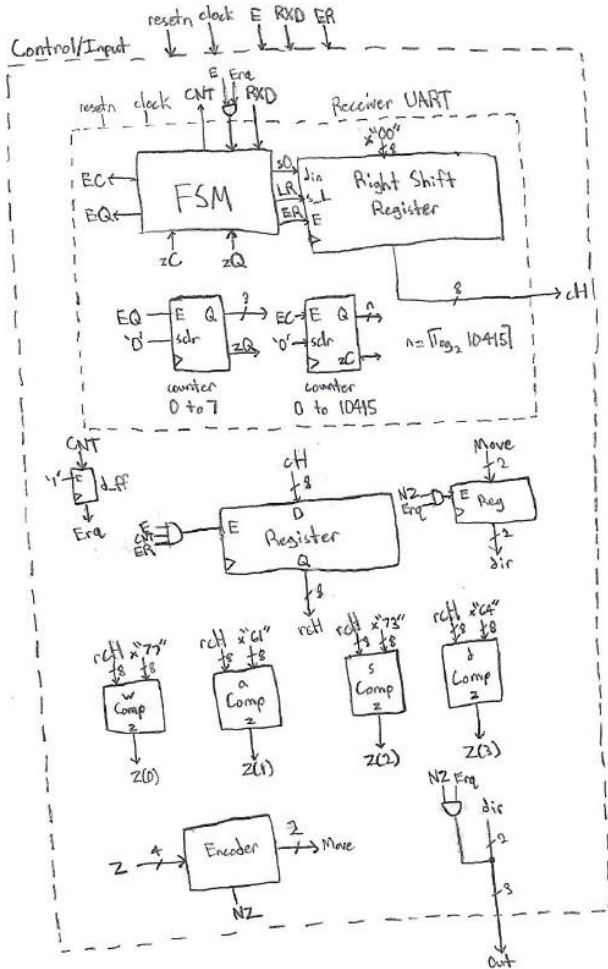


The Game



- 2048 is a game where the user slides tiles in a direction, and matching tiles add up.
- Random numbers spawn with each slide
- If the table fills, they lose, if they reach 2048, they win
- The game was created in 2014 by Gabrielle Cirulli as a web game
- Was based on “Threes”, which was a much slower paced game released the same year

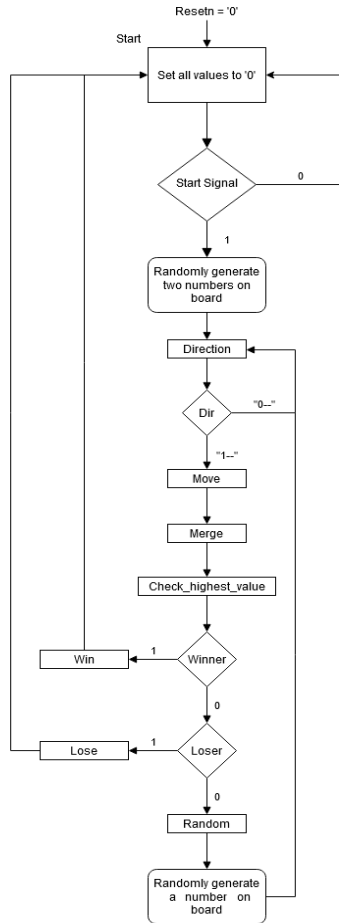
Receiver Datapath



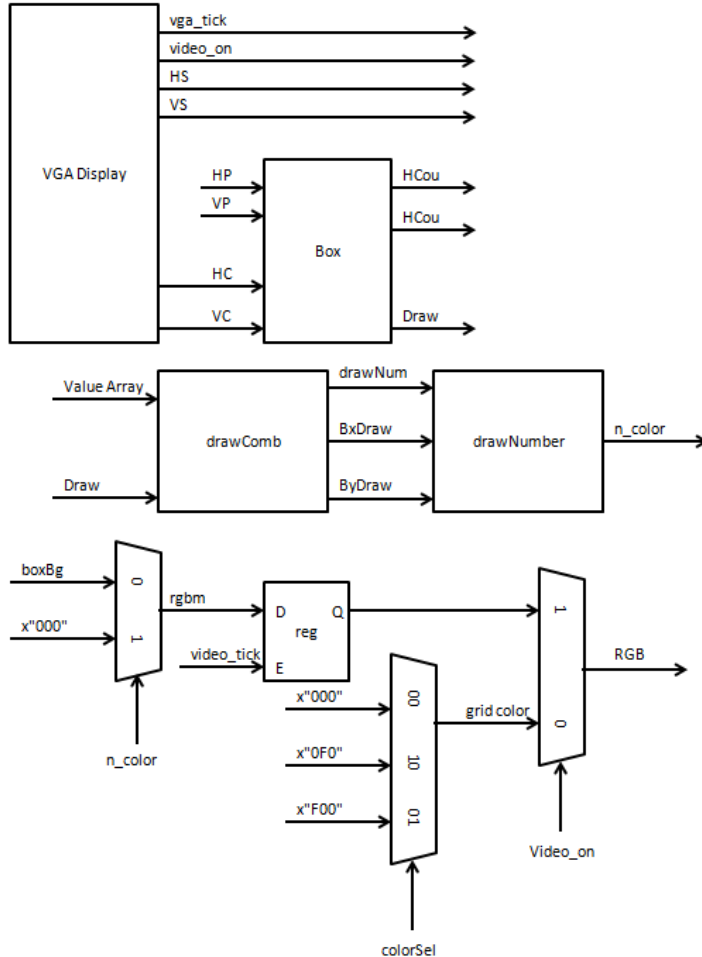
- Composed of UART, comparators, an encoder, registers, and logic gates
- Output earlier described can be seen
- The characters w, a, s, and d that are compared to are stored similarly to an LUT

FSM

- Main controller of the game
- Determines number movement and merging
- Stores values into an array



VGA Display



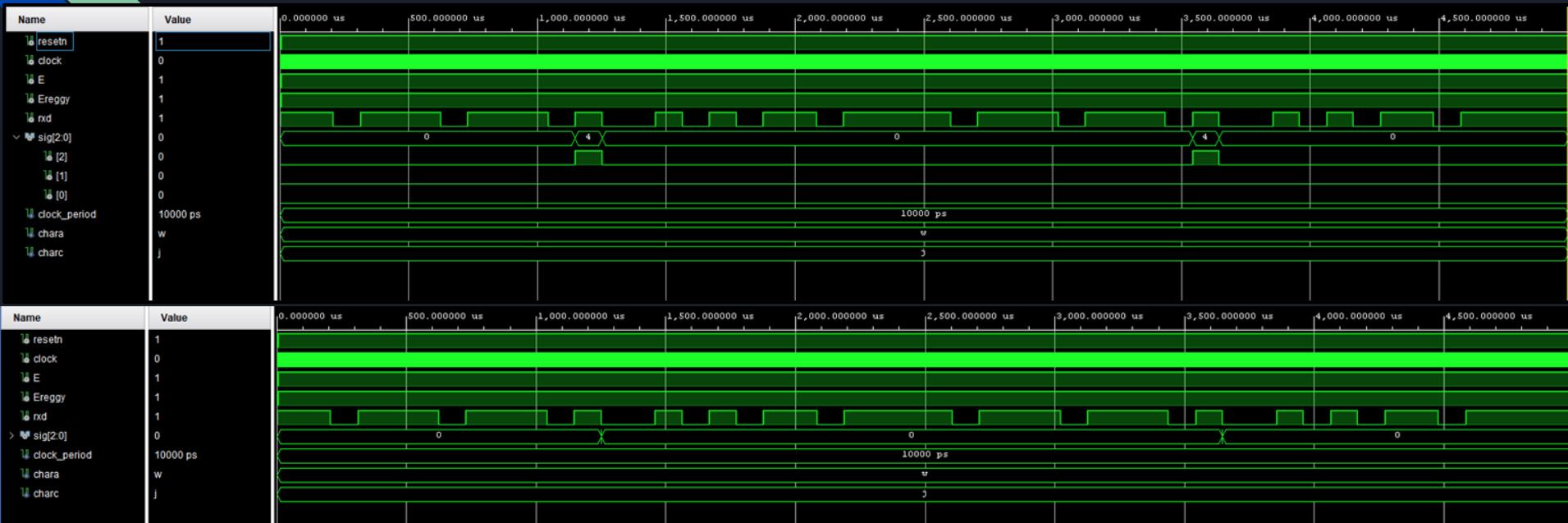
- Uses a VGA connection to output to a monitor
- Objects are drawn on the screen depending on the Horizontal and Vertical count.
- Kept in sync by HS and VS to keep images from moving.
- Screen is thought of as a graph and is told to color a certain area when a signal is high.

FSM Simulation

value[0:3,0:3]	(0,16,32,1	(4,0,0,0),(0,□	(4,0,2,0),(0,0,0,0),(0,0,0,0),□	(4,0,2,0),(0,0,0,0)□	(4,2,0,0),(0,0,0,0),(0,0,0,0),□	(4,2,0,0),(0,0,0,4)□	(0,0,4,2□	(0,0,4,2),(0,0,0,4)□	(4,0,4,2)□			
> [3,3:0]	2,4,16,2	0,2,0,0	0,0,0,0	2,0,4,0	0,0,2,4	2,0,2,4	2,2,4,0	8,0,0,0				
> [2,3:0]	16,128,2,4				0,0,0,0							
> [1,3:0]	4,16,64,8		0,0,0,0					4,0,0,0				
> [0,3:0]	16,32,16,0	0,0,0,4	0,2,0,4		0,0,2,4		2,4,0,0	2,4,0,4				
y	lose	st□	direction	move	merge	check hi□	random	direction	move	merge	check hi□	random
btn_direction[2:0]	5		5		4		6		7			
value[0:3,0:3]	(0,16,32,1	(0,□	(4,0,4,2),(0,0,0,4)□	(0,0,0,0),(0,0,0,2),(0,0,0,4),□	(0,4,0,2),(0,0,0,2)□	(4,4,4,2□	(4,4,4,16),(0,0,0,0□	(4,4,4,16),(0,0,0,0□	(4,4,4,1□	(8,4,16,0),(0,0,0,0□		
> [3,3:0]	2,4,16,2		8,0,0,0	8,4,0,4	8,0,0,0	0,0,0,0	2,0,4,0	0,0,2,4				
> [2,3:0]	16,128,2,4		0,0,0,0	4,0,0,0			0,0,0,0					
> [1,3:0]	4,16,64,8		4,0,0,0	2,0,0,0			0,0,0,0					
> [0,3:0]	16,32,16,0	2,4□	2,4,0,4	0,0,0,0	2,0,4,0	2,4,4,4	16,4,4,4	0,16,4,8				
y	lose	che□	random	direction	move	merge	check hi□	random	direction	move	merge	check hi□
btn_direction[2:0]	5		6		7		5		4			

Btn_direction: 4 is right, 5 is down, 6 is left, 7 is right

Receiver Simulation



- Sig is the output, w and j are input by the simulation
- Emits a pulse with each input matching the internal LUT
- Ignores inputs that don't match the internal LUT
- Problem: Matching wrong clock pulse
- Resolved by moving S5 'done' output of UART to S1



References

- <https://2048game.info/the-history-of-2048/>
- <https://www.ibtimes.com/what-2048-convoluted-origin-threes-1024-game-clone-topping-app-store-charts-1568533>