Cellular Automata on FPGA

James

Jeff

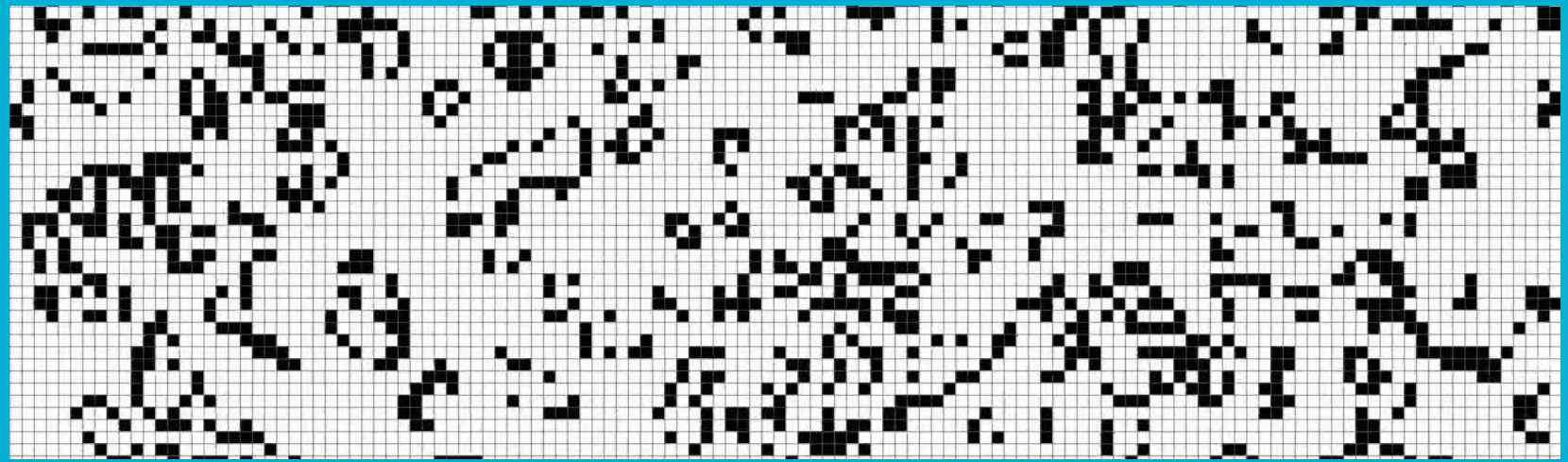
Priscilla

Robert

Serena

The Dream

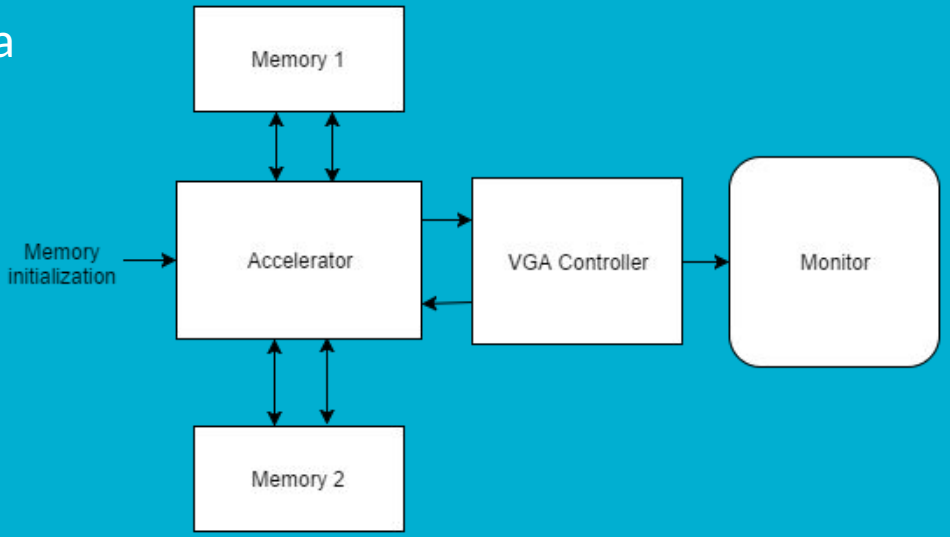
- Simulate Conway's Game of Life!
- Display at 1280x1024 @ 60Hz
- Compute sufficiently fast to refresh grid at 60 Hz



It's a Hardware Project

Basic Design

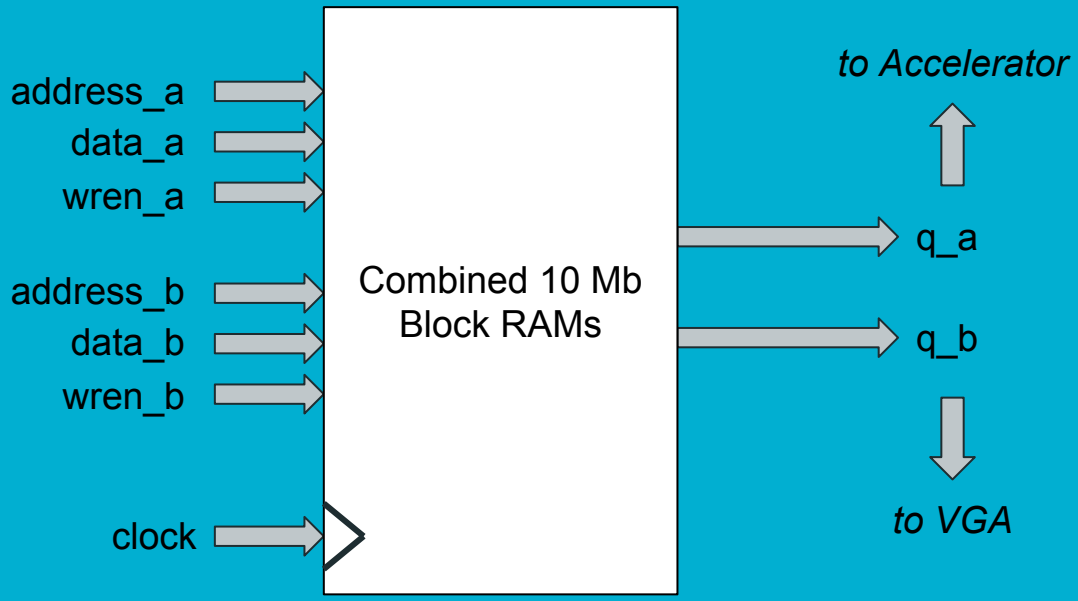
- Store two states at a time in memory: a current state and the next state.
- Use the data in current state to simultaneously
  - Draw to screen
  - Calculate and overwrite the next state
- Toggle the direction between the memories to indicate current and next states



No way, Conway!

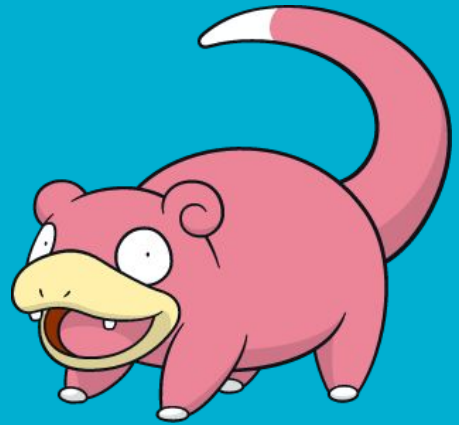
- A 1280 x 1024 grid of cells requires a lot of memory! (1280 x 1024 = 1310720 bits)
- Use on-chip 10 Mb block RAMs to store the state
- 20 bit words gave us a clean 64 words per row (total of 65536 words)
- Megawizard:
  - Creates the RAM using the on-chip M10K memory blocks
  - Instantiates the module twice

Using the RAM



Please be fast enough

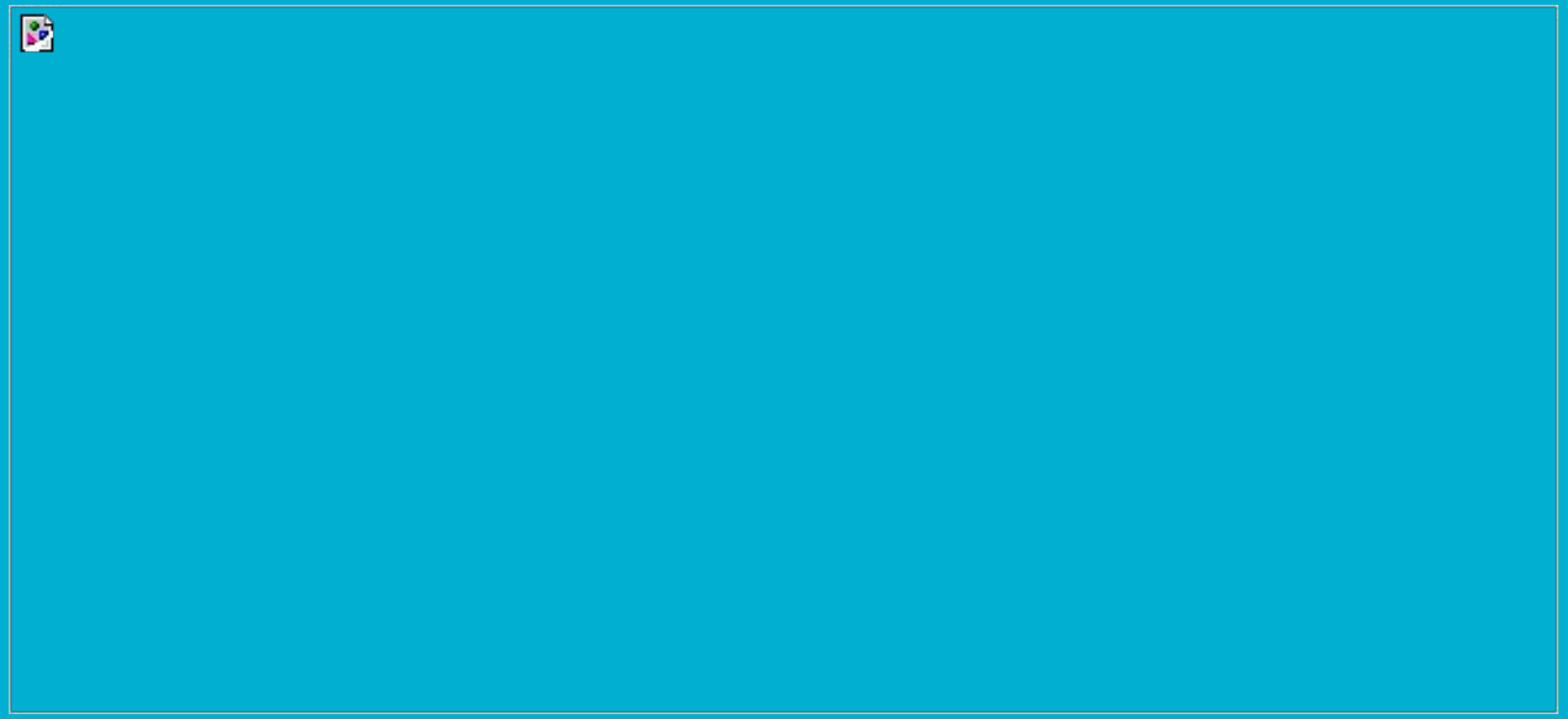
- Computations can be parallelized
- Compute entire words (20 bit) at a time
- Accelerator takes 66 bits to compute 20 bits.



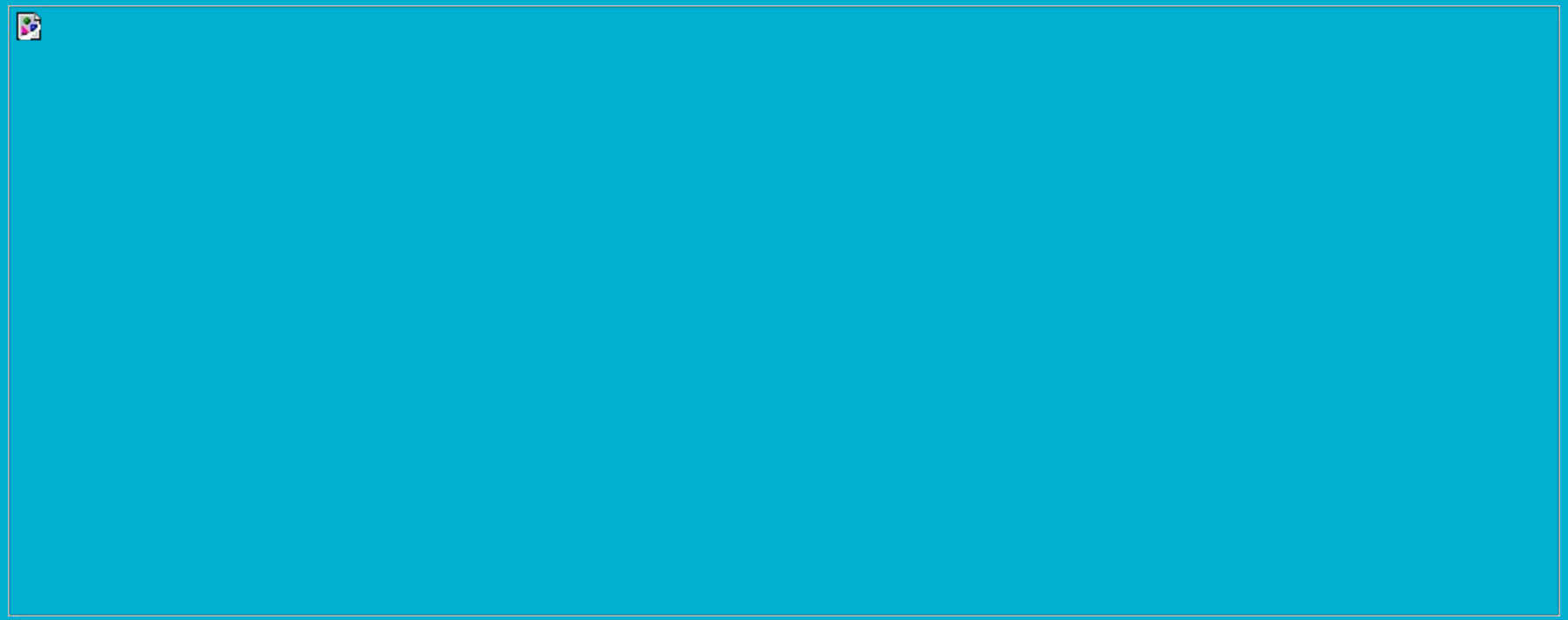
But not too fast!

- Cycles needed for every screen = 200704 cycles
  - 3 clock cycles for each word
  - Four cycles at the end of every row
  - Every row: 3*64+4=196 clock cycles
  - Every screen: 1024*196 = 200704 cycles
- 108MHz: Conway ‘refresh rate’ of ~555Hz. This is much faster than the screen’s 60Hz.
- Once the accelerator finishes updating the memory with the next state, it waits to receive a ready signal which goes high when the screen finishes updating.

Memory Pipeline

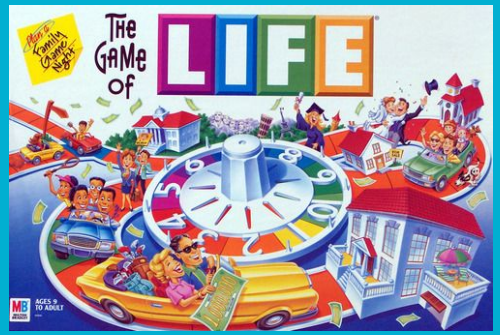


Register that.



Let the Game begin

- Initial state: directly set an initial state in the memory blocks
- A hex or mif file was populated with values and used to set the initial state with the help of the memory initialization Megafunction.
- Python scripts for generating .mif files, updating memory, and programming the board



Putting Conway through the VGA

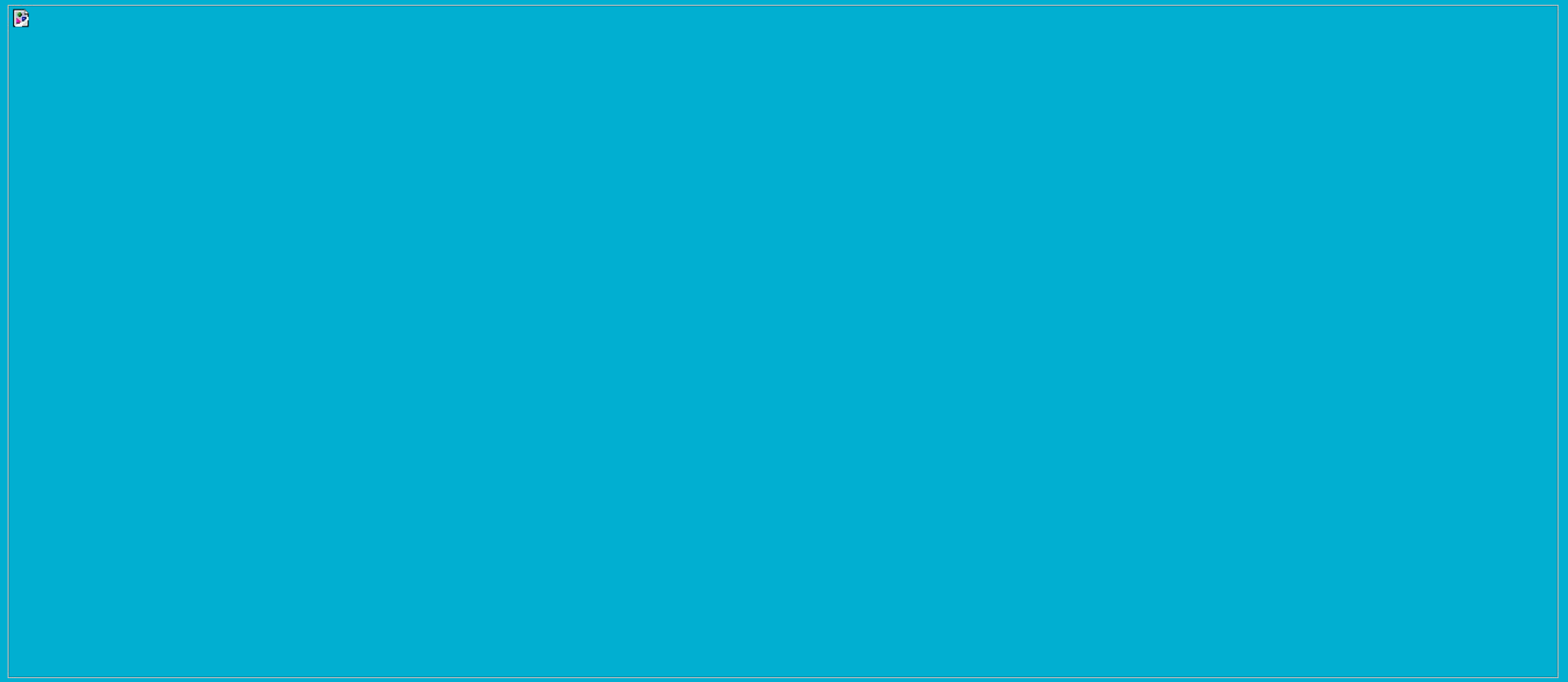
VGA Controller asks for a word at a specific address (*NOTE: VGA controller does not know which memory block it is reading from! How mysterious!)

VGA controller writes the word into a buffer. The elements of this buffer are accessed in order as hcount increments. They tell the corresponding pixel to be alive or dead.

After one word has been completely drawn, the controller immediately requests the replacement.

When the entire screen has been written, VGA Controller sends a ready signal to the Accelerator to begin the next frame's calculations.

Putting Conway through the VGA



Issues and Lessons Learned

The complexity of the project was not fully realized at its conception!

Timing needs to be precise for the project to work at all.

Using ModelSim's simulator was very useful for checking correctness without having to compile.

Having a lot of good ideas doesn't mean you'll have time to implement all of them.