RetroCore: FPGA GameBoy Emulator

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FPGA GameBoy Emulator

Hardware developers looking for a cycle-accurate reference design, software developers building emulation frameworks, and gaming enthusiasts seeking authentic gameplay all face the same gap: software emulators shortcut real hardware timing, and original GameBoy units are scarce and unreliable. RetroCore fills that gap by running no-MBC / ROM-only GameBoy games directly on an Altera DE2-115 FPGA—reproducing the 4.19 MHz CPU clock, tile-based graphics over VGA, bank-switched memory, and a low-latency controller interface without a PC.

Equipped with the fan-created documentation, Intel documents, an FPGA, and I/O devices (monitor, controller), we recreated the beloved first handheld gaming console in hardware by writing thousands of lines of SystemVerilog and synthesizing it on a board.

System Description



RetroCore aims to match the original hardware specs: 4.19 MHz CPU timing, steady 60 FPS, and full 100% instruction correctness.

System Architecture



System Evaluation

Synthesis results:

- 8% LUT usage

KEY				
Hardware	Memory Mapping	Custom Hardware	Custom Software	
Software	Off The Shelf Part / Tool	Driver / Controller	Test	

This system contains three major units:

- CPU: Multicycle complex instruction set CPU.
- Pixel Processing Unit (PPU): Tile and scanline based graphics engine
- Memory Management Unit (MMU): Memory organization, register mapping, interrupt management.

• 33% Memory BRAM Usage

Metric	Target	Actual
CPU Clock Speed	4.19 MHz	4.19 MHz
60 FPS	100%	100%
Palette Mapping Accuracy	100%	100%
Controller Lag	<30ms	<30ms
Sprite Mapping Accuracy	90%	>80%

Conclusions & Additional Information



We met our base goal of being able to run and play Tetris after many hours of hard work and integration. We learned much about FPGAs, system integration procedures, and systematic debugging approaches.

Features we worked on that did not make demo include audio/color/bank switching, and we would also have liked to play more games-but that requires more debugging. Overall, we are proud of this accomplishment.







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use VGA and GPIO for display and controller respectively.