River-Raid III (CU Edition)

W4840 Embedded System Design

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Overview

- DE1-SOC board (Cyclone V FPGA + ARM Cortex HPS).
- Resolution: 320 x 240 -> 640 x 480 @60Hz
- RAM
  - Background Tile: Mapping for 20 x 15, plus 1 extra row of hidden tiles (for scrolling)
  - Sprite: 16 total sprites on screen
- ROM
  - 16 x 16 pixel per sprite/tile
  - 6 bit color index for per pixel
  - Both support at most 32 artwork
- # of Colors Support: 4 Color Palette x 64 colors
- Audio
  - Sample Rate: 8 KHz
  - Sample Word: 8 bit
- Original Atari Controller
**Hardware Overview**

- Sprite and Tile artwork stored in Tile and Sprite ROMs
- VGA Counter
- Tile Generator:
  - TileRAM: Tile id, Pal id of tiles to draw
  - [hcount, vcount, Vscroll] -> TileRAM_address
  - [TileRAMData, hcount, vcount, VScroll] -> TileROM_address
  - [TileROMData, Palette] -> TilePixelVal
- Sprite Generator:
  - SpriteRAM: X, Y, Sprite id, Pal id of sprite to draw
  - 16 total sprites.
  - Sprite order Tile, Sprite_0, Sprite_1, Sprite_15
  - Sprite Row Buffer (Double buffering)
- Pixel Selector: Color Pallette return the actual RGB color
- 4x Audio ROMS, 8bit-8Khz Mono, simultaneous playback
Software and Hardware Interface

- **read_status**: reads the joystick status and update frame signal, by *polling*, controlling the aircraft
- **set_vscroll**: Writes the vertical scroll value
- **set_audio**: Selects the audio sample by *audio id* for different events (e.g. Crash, Fire, Fly)
- **set_tileMAP**: Writes the *tile id* and *color palette id* in Tile RAM at given “*slot*”
- **set_spriteMAP**: Writes the information of given sprite into the Sprite RAM
Software (Game Loop)

- **rr_read_hw_stat**: Reads joystick and update_frame flag from the hardware.
- **rr_player_update**: Updates player’s position and fuel level.
- **rr_enemy_update**: Creates new enemy ship (total of 5 enemies can exist at a time). Updates enemy position. Sets enemy attack mode.
- **rr_collision_detect**: Collision if two sprite overlap (16 x 16 boundary)
- **rr_spriteMap_update()**: Collect all the updates and update them at once
- **rr_tile_update()**: Increments Vscroll register and writes Tile MAP RAM via tile map RAM register.
  - tiles are reading from a pre-define txt file

**Question:**
How often do we update sprite/tiles?
**Improvements**

- Explore and incorporate other available on chip and on board peripherals. Eg. SDRAM.
- Graphics - higher resolution (Too conservative on the resource budget).
- Audio - improve quality, length, add effects.
- Make some sprite, tile and audio data loadable from software.
Lessons Learned

- Programming game is a never ending task
- Timing required for games
- Importance of testbench
- Make the process as fun as possible
DEMO

Hope you like our adaptation of the classic Atari River Raid game!!