SAGa

Sprite Animated Game

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I. Introduction

SAGa is an adaptation of the popular *Worms*[1] turn-based PC game from the 1990's. The core of the game includes an expansive gameboard with randomly-generated terrain, animated worms and weaponry, destructive environments, and multi-player functionality via either single-system "hot-seating" or two ethernet-connected systems. Synchronization of the gameboard and worm location across a networked game is accomplished manually by pressing the synchronization key on the "master" system and sending the appropriate location data to the "slave" system. In addition to these general features, a version of SAGa is provided that allows the user to manipulate a character using an attached video camera as well as play an audible tone when firing the the bazooka weapon.

Both teams in the game begin with 2 worms per side, each with full health. Above each worm's head resides an arrow specifying not only which player is active but also the current health of said player as measured by the height of the arrow above the worm. When a worm experiences damage caused either by an explosive projectile or contact with a swinging baseball bat, it suffers a loss of health. When a worm's health is fully depleted, the worm is "dead" and disappears until a new game begins.

I.1 A Typical SAGa Game

A typical SAGa game begins with two players either playing "hotseat" on a single computer or connected via ethernet on separate systems. The first player then moves his/her worm around the gameboard via the keyboard's left/right keys, increasing or decreasing the angle of her weapon via the up/down arrow buttons and the strength of her attack with the PageUp/PageDown buttons. The player can also select between the far-range bazooka and the close-range baseball bat by pressing the END key. When he/she is ready to attack, the player simply presses the spacebar on the keyboard, which either swings the baseball bat or fires the bazooka, depending on the selected weapon, at the angle and with the power specified by the user. Damage to the opposing worm is then calculated and control shifts to the other user.

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[1] Wikipedia contributors, "Worms (series)," *Wikipedia, The Free Encyclopedia*, http://en.wikipedia.org/wiki/Worms_(series) (accessed May 13, 2011).

Once a worm has sustained a sufficient amount of damage, he “dies” and is unavailable until the next game.

II. General Layout of SAGa

SAGa is a combination of modules designed from both hardware and software components, oftentimes in concert with external devices. The following block diagram outlines the key components of SAGa and how they are connected.

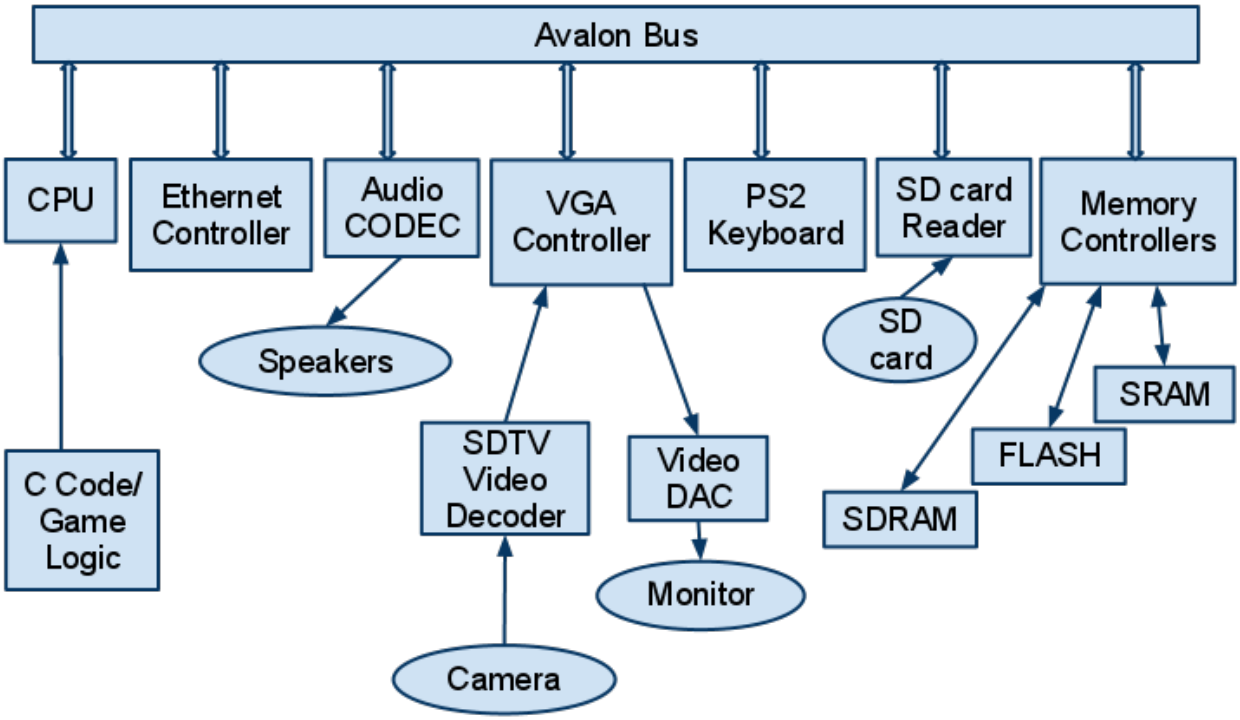

Figure 1.1 – Block Diagram for SAGa

III. VGA controller

The VGA controller is the hardware module which generates all the graphics for the game. The block diagram for this module is the following:

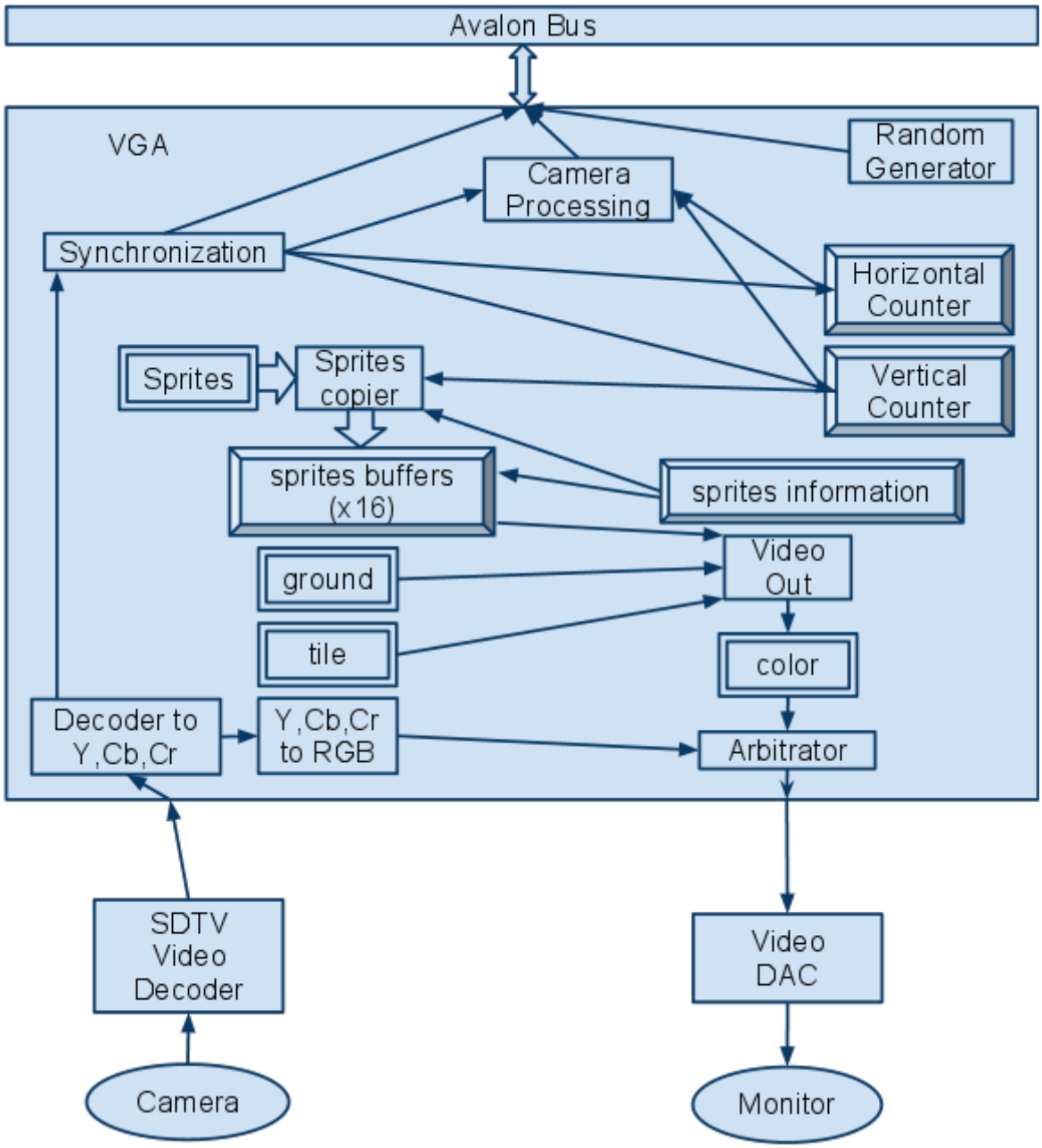

Figure III.1 – VGA Controller Block Diagram

This module contains the following data structures:

- ***Sprites***: it contains the information for each pixel from every sprite (there are 32 different sprites). Each sprite is 32 by 32 pixels, using 1 byte for each pixel. 'Sprites' is synthesized as a (32x32x32x8bits/32bits =) 8192 by 32 bits ROM memory.
- ***Tile***: it contains information for each pixel from the tile which is used to draw the ground. 'Tile' is synthesized as a (60x64x8bits/32bits =) 3840 by 32 bits ROM memory.

- ***Color**:* this is the color table which has the color equivalences between the 8 bits representation, used in 'Tile' and 'Sprites', to the 30 bit representation, used in the Video DAC. 'Color' is synthesized as a 255 by 10 bits ROM memory.
- ***Ground***: it contains the ground height description array. 'Ground' is synthesized as a 1024 by 10 bits dual-port RAM memory.
- ***Sprites information***: it contains a copy of the information transmitted from the software about the position, image, and flip state for each sprite on the game-board. 'Sprites information' is synthesized as 32 by 27 bits dual-port dual-clock RAM memory.
- ***Sprite buffers***: this is an array of 16 buffers. Each buffer will contain the information from the appropriate row from each sprite shown on the screen at the current screen row. 'Sprite buffers' is synthesized as a (16*8 =)128 by 32 bits register bank. it is implemented as a registers bank because each buffer will act as a shift register.

This hardware module can perform the following functions:

- Display on the screen the different game elements: sprites, ground, and background.
- If there is a camera connected, it takes the input from the camera as background. It also samples the color at two different positions in the image received from the camera.

The software can use this module to:

- Display up to 16 sprites simultaneously with overlapping between them.
- Specify the terrain height, up to 1024 points. The actual game-board is 1024x1024 points, being bigger than the screen resolution, which is 640x480.
- Select the portion of the game-board that is displayed.
- Ask for random generated numbers, used to generate the ground height and starting positions of worms.
- If there is a camera connected, it can set two different locations on the background/camera image to be sampled at each refresh cycle. Then it can ask for the color at those locations.

The software can situate the "sampled locations" at both sides of the active worm (this is the "active sprite"), and using the color information, move the worm to the left or to the right depending on the side it detects a certain color (we choose a dark red). So now If a red card is "placed" close to the active worm (the image from the camera is displayed as background), it

will move the worm to the opposite direction. So it looks like you are “pushing” the worm in one direction.

The horizontal and the vertical counters represent which pixel from the screen we are going to generate and send to the video DAC.
At the beginning of each row on the screen the following procedure is performed:

- ***Cycle 0***: Determine which sprites we want to display on the screen using the information contained in the ‘Sprites Information’ RAM.
- ***Cycle 1-128***: Copy the row from the sprite that is going to be shown at this row from each sprite selected at the cycle 0.

Five cycles prior to display a pixel on the screen we start the process to decide which RGB components send to the Video DAC for that location.

- ***Cycle N-5***: compute at which locations we want to read from the Sprite Buffers and Tile ROM.
- ***Cycle N-4***: read the Tile information from that location.
- ***Cycle N-3***: compare every element which are at that pixel from the buffers, if none of the buffers has an element at that location, or all of them are transparent, check the ground height; if it there is no ground, then select the background to be shown.
- ***Cycle N-2***: get the RGB color representation from the Color ROM using the information from the cycle N-3. And also shift the registers which have been compared during the cycle N-3.
- ***Cycle N-1***: the Arbitrator sub-module selects if it has to show the color information from the camera as background, a black background or the RGB color components obtained the previous cycle.
- ***Cycle N***: The Video DAC displays that RGB components at pixel N on the screen.

Without the camera, the synchronization signals are generated locally using the 27 MHz clock. If the camera is connected, the synchronization signals are generated using the 27 MHz clock in sync with the signals from the camera and the camera local clock.

Note that inside the sub-module “YCbCr to RGB” there are 3 dual-clock, dual-port RAM’s of 1024 bytes each. These RAM’s are used to buffer the signal from the camera that has a higher data rate than the Video DAC.

IV. Keyboard and Networking

IV.1 Keyboard

SAGa utilizes the PS2 keyboard interface provided in Lab 2 for the user interface portion of the design. The keyboard acts on an interrupt system like the ethernet adapter, with the main program periodically checking the keyboard module to see if the key value stored by the keyboard has changed (signifying a key press event by the user). All key translation occurs in software, and is communicated to the non-active player when appropriate via the network messaging protocol outlined below.

IV.2 Networking

The multi-player functionality of SAGa is provided by interfacing with the network adapter on the DE2 (the DM9000A Fast Ethernet controller) and utilizing a simple communication protocol at the software level of synchronizing the gameplay between the two systems.

IV.1 DM9000A Fast Ethernet controller

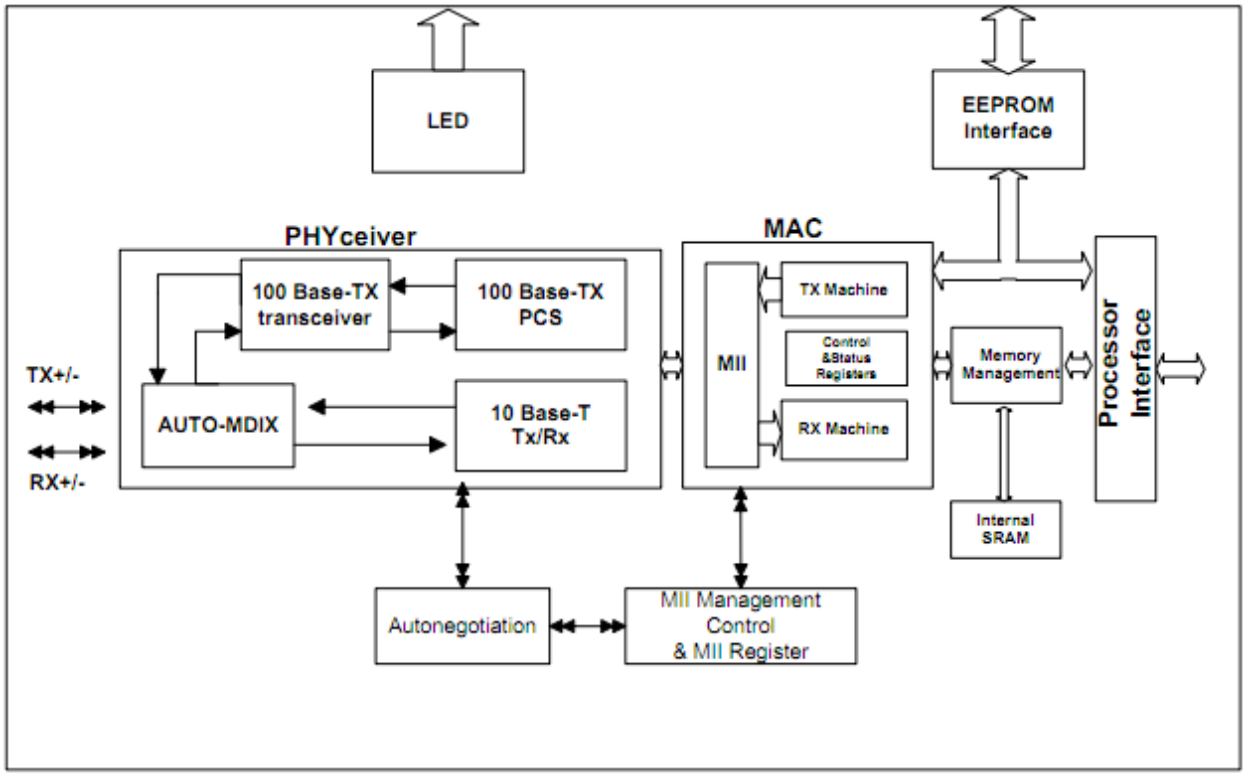

Figure IV.1 – DM9000A block diagram[2]

The decision was made to utilize the DM9000A component used in Lab 2 for SAGa because it could be easily ported to our initial design and provided the level of functionality needed for the project. Communication between the component and the rest of the system occurs along a 16-bit data bus, with interruptions being used to notify the system when a packet is received by the device. Data are thus sent and received by the device in 4-byte packets, with the hardware capable of buffering up to 13K of incoming data and 3K of outgoing data at any given point, limits that were never approached by our implementation.

IV.2 Network Software

Communication between the two systems typically occurred in one of two instances:

1. Synchronizing of the game state at the beginning of a new session, and
2. Updating the non-active player of the current player's actions during gameplay.

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[2] Davicom DM9000A Fast Ethernet controller, pg. 6, *Davicom Semiconductor, Inc.,* http://www.cs.columbia.edu/~sedwards/classes/2011/4840/Davicom-DM9000A-Ethernet-controller.pdf (accessed May 13, 2011).

The same basic framework was employed for both communication circumstances, though with unique protocols for creating and interpreting data sent between the two units.

IV.2(a) General Communication Framework

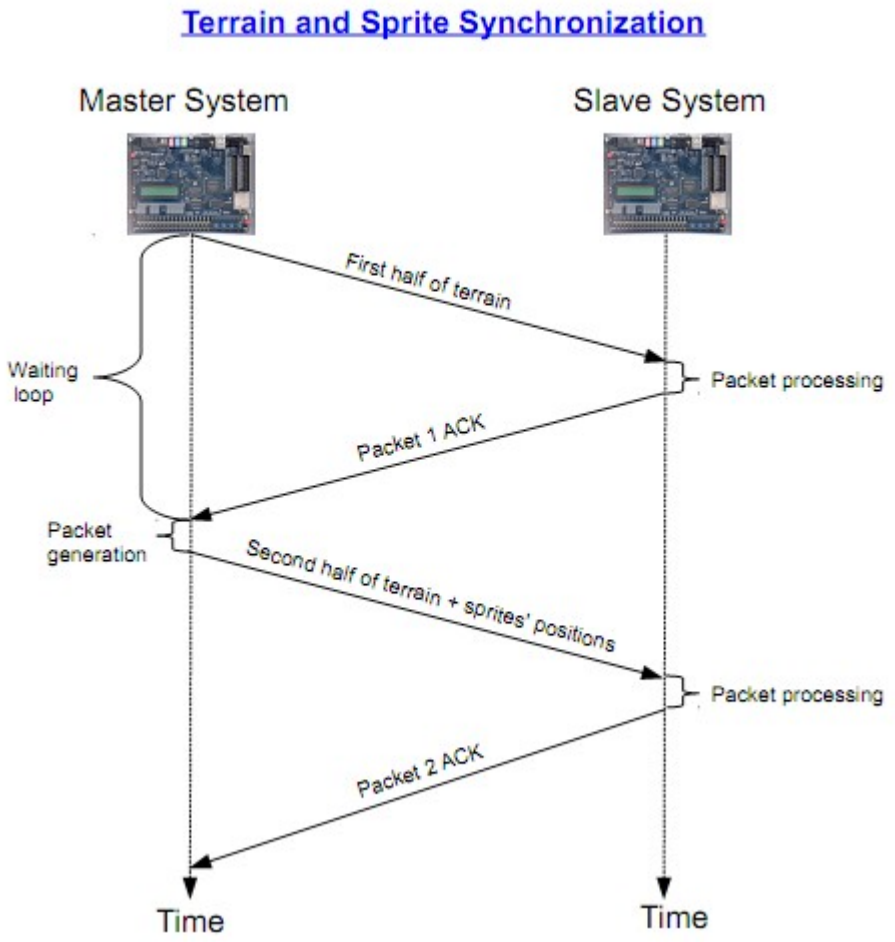
SAGa utilizes the general communication framework employed in Lab 2, sending UDP packets with the appropriate header information along with a single data payload in byte increments. This byte-based payload organization initially posed a problem since the integer values being sent in said packet oftentimes exceeded the 0-255 range that could be represented by a byte (e.g. terrain values exceeded 300 at certain instances). To correct for this limitation, data were converted to 2-byte representations prior to transmission and converted back to a single integer representation upon receipt. This decision resulted in a doubling of the payload size per transmission and necessitated the move to multiple transmissions for specific transactions, but was necessary to maintain numerical fidelity and did not cause a degradation in gameplay or system stability.

The other general design decision made was to not implement procedures for dealing with lost or damaged packets. This is due to a number of factors, chief amongst them the notion that the game would typically be played between two systems either directly linked together or connected via a router with little to no outside traffic, and thus packet loss or degradation was unlikely. Furthermore, adding error correction procedures such as timers introduced the possibility of further complications and unexpected behavior during gameplay, and was an unnecessary given the turn-based nature of the game. In the unlikely event that data was lost, the user has the option to manually resend the data by pressing the corresponding input key again or “re-syncing” the terrain and sprites according to the procedures outlined below.

IV.2(b) Synchronization of Initial Game State

Since the terrain and sprite location for SAGa is randomly generated on each system, it was necessary to create a mechanism for synchronizing these factors across both games during a two-player game. After some early trials with delayed initialization on launch, it was determined that the most efficient method would be for one system to act as the “master” and the other as the “slave” and synchronize the gamestate according to the master's gameboard. To this end, the master initiates the synchronization process by pressing the DEL key on his/her keyboard.

Below is a graphical representation of the synchronization process when it is initiated by the master user.



Since the gameboard is 1024 pixels in width and the maximum size of a single datagram over ethernet is 1500 bytes, the terrain data is evenly divided and sent in two packets for synchronization. As mentioned in section 2(a), each terrain value is first converted to a 2-byte representation and then inserted into the datagram payload, resulting in a terrain payload of 1024 bytes that, combined with the 42 bytes necessary for IP and UDP headers, equates to a base packet size of 1066 bytes. Each packet also includes a code identifying the nature of the packet (i.e. first/second half of the terrain) that replaces the checksum value in the UDP header.

After the master sends the first terrain packet, it enters into a waiting loop until it receives an acknowledgment from the slave that this first packet was received and processed. This acknowledgment from the slave system comes in the form of a 2-byte code that updates the

wait condition for the master system and initiates the transfer of the second half of the terrain. The second half of the terrain is then inserted into another datagram, and the initial positions of the four worms are also included after the terrain data. This packet is then sent to the slave, which processes the data and sends a confirmation packet back to the master.[3]

IV.2(c) Updating the Non-Active Player During Gameplay

During gameplay, the non-active user needs to be informed of the action(s) being performed by the active user so that the game states are maintained. To this end, when the active player performs an action such as moving the current worm or aiming a weapon, this information is encoded into a UDP packet and sent to the remote user in much the same manner as the synchronization procedure outlined in 2(b), but with two caveats. Since the data being sent is a single keypress, a single packet is all that is required. When the active player presses the SPACEBAR, control of the game is symbolically transferred to the other user when that keypress is transmitted, and the current player's turn officially ends.

V. Audio controller

At first point we created an audio controller which was able to play high quality sound (16 bits per sample, at 44000 K samples per second), reading it directly from the SD card.
Basically, the hardware has a buffer of 512 bytes, each time we wanted to play sound from the SD card the software started reading from it (using a hardware SD card reader controller),. Then the software checked if that buffer was about to be emptied, if it is, the software read 512 bytes from the SD card at the appropriate memory location and sent the next 512 bytes to the hardware. This process continued until the sound was completely played (~0.5 seconds for a simple comment from the worm).

When we tried to include the sound, with the camera and the network it resulted that we run out of memory (M4K blocks). Because of that, we decided to include low quality sound instead, because, as we thought, better low quality that no sound. at all.

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[3] Note that while it should not be necessary to synchronize the gameboard more than once per game, the active user may initiate the synchronization process at any time by pressing the DEL key.

So the the audio controller implemented in the project is based on the audio controller developed for the lab 3. Basically, inside this module there is a small ROM that contains one cycle of the sine function. Reading this ROM at different rates it possible to generate a fm modulated sound signal with the expression:

$$x(t) = sin(Wc*t + I*sin(t*Wm))$$

Where the timbre of the signal is largely determined by the ratio Wc/Wm, in this case this ratio has been set to 3. To generate different sounds we just have to change I, the modulation index.

During the game play, any time the player press the space bar key (which means “shoot”), the software asks the hardware to generate several consecutive sounds with ascendant modulation index. With this procedure we got the sound similar to the “charging weapon” sound from the original Worms video game.

VI. Gameplay and Game Logic

VI.1 Sprite Conversion and Storage

Sprite animations for SAGa came in an animated GIF format in a size of 60x60. The first attempt to do the conversion was to decode the GIF file format, but initial attempts to read the binary file and decode all the header information (some 60 lines worth) proved untenable. GIF headers include a lot of information, like colormaps, sub-image data, sub-image color maps, etc, and much of this information is unnecessary for simple pixel conversion. After some investigation, though, we were able to access the compressed image data itself.

Unfortunately, because the files were compressed using LZW compression, each file included a running “dictionary” of common strings to compress data, which provided yet another time-consuming hurdle. After looking further into it, a simpler method for obtaining the data was found by using Microsoft paint to convert the GIF files to BMPs, which have much simpler formatting. After some trial and error, we decided that our sprite files would be 32x32 pixels, the smallest size that still allowed for the sprites to be visible. This sprite size meant that we could

store 32 sprites in memory, which allowed for unique animations and diversity in sprites (e.g. worm breathing, swinging a bat, pointing a bazooka at various angles, etc.)

VI.2 Terrain Design

The key software components of SAGa included terrain generation, animations, placement of worms, controlling the game scrolling, the projectile dynamics, and all the game stats (worm health, power and angle for each worm, etc.) For conciseness, this section will focus on just terrain generation and the animation algorithm, which is the basic game structure. Initially, the design for the terrain was to have 32x32 size tiles, like many sprite-based games. Unfortunately, this would have produced blocky terrain and made simulating the dynamic terrain damage clunky. Instead, we organized the hardware to have one of two values: “terrain” or “sky.” If the pixel height was less than a software-selectable value in an array, it would display a tile. The terrain is organized as an array of 1024 values, each value being the height of the terrain from 0-1024.

There are two main terrain functions: one function initializes the terrain, and the second function updates the terrain with a damage radius. To initialize the terrain, the software queries the hardware for a set of random numbers (0-255). Each random number is scaled and used as the curvature for a pre-defined length of terrain. In order to produce well-behaved terrains, two boundary conditions were imposed: the lower bound of 10 pixels, and an upper bound of 400. If the randomly generated curvatures hit one of those bounds, the slope of the terrain is reversed. This algorithm produces nice, fun terrain that has curves, peaks, and valleys. To draw the damage, the horizontal distance from every pixel to the damage location was calculated, and if it is less than a constant value DAMAGE_RADIUS, the height of the circle is subtracted from that location. This produces perfectly semi-circular damage on flat terrain, and somewhat uneven damage on sloped terrain. Thus, due to the random terrain, a static algorithm produced random-looking damage.

VI.3 Game Logic

The purpose of the game logic is to display the appropriate sprites at the appropriate times based on the keyboard input and internal game states. The program is structured in two loops.

The outer loop goes indefinitely, so the game play will never end. It initializes the game variables, generates the terrain, and places the worms randomly on the screen. The inner loop cycles once per frame while the variable *nextGame* is false.

Within this inner loop, there is first a switch statement which maps the key pressed to a game state. This updates a variable, *state*, which controls the main game state. The key selected could be either local or foreign (sent via ethernet). Prior to the second switch statement, a few functions are called that are updated every frame regardless of the state, such as the breathing animation.

The specific keyboard inputs and a short description of their effect are provided in the following table:

Key	Effect
	Move the worm to the left
	Move the worm to the right
	Move the worm's aim/reticule up
	Move the worm's aim/reticule down
PGUP	Increases the power of the projectile
PGDOWN	Decrease the power of the projectile
END	Switch the selected weapon between the bazooka and the baseball bat
SPACEBAR	Fires the chosen weapon and switches control to the other team
DEL	Used to synchronize the terrain and sprite locations during two-player games

Table VI.1 – Keyboard Inputs

Each game state does one of two things: it either updates a game variable, or updates an animation. Game variables include the projectile angle, power, and weapon type (bat or bazooka).[4] Animations include swinging the bat, walking left, walking right, projectile motion of the bazooka shell, projectile motion of a worm after being batted, the worm breathing, and the arrow bouncing. One problem encountered was how to run each animation at rate independent of the others. To resolve this, the animation is broken up into two pieces: a master variable (*animCount*) that updates once per frame (approximately 60 Hz), and a “local” animation

[4] As a side note, Tony did not know that that sin, cos, pow, and sqrt functions were included in the standard library, so he originally wrote all of these functions himself, later replacing them with the standard library implementations. Both sin and cos are included in the math.h file.

variable (eg., *walking*). Each animation function only updates the local animation variable, and the animation speed is set by a condition in the main program which divides the *animCount* down by the appropriate value.

VI.4 Gameplay

In addition to the overview of the game provided above, a few additional nuances to the game are included here:

- The “health” of a worm is conveyed to the player based on the height of the identifying arrow above the worm's head. The closer the arrow is to the character, the less health that remains.
- Projectiles that reach either the left or right bounds of the gameboard will ricochet back into the game, as will any worms that travel to those bounds.
- Worms can be damaged based on their proximity to an explosion in addition to an actual contact with a projectile.
- In a remote game, the non-active player will be unable to interact with the game via the keyboard even though his/her worms will be animated.

VII. Lessons Learned

1. **Start Coding Early**. Our group did extensive planning very early in the game, even generating a spreadsheet with tasks, times, and who was responsible for which jobs. However much of that planning was rendered irrelevant when we got down writing the code and realized that our initial design needed to be adjusted. Much of the work we imagined we would have to do was different the work we actually had to do to build the project. Of course we didn't know this until we started building not planning. So I would advise groups to build while they plan and and to anchor the plans in the concrete requirements of each module. Don't just plan to build a vga controller and a video input decoder but take note of how much memory each module requires and what clock requirements each module has and if there any conflicts between the modules.
2. **Integration is Everything**. Each module in our project was fairly easy to build on its own. Very early on we had a video controller running, and a simple ethernet program to draw circles on the vga and move them over the network. The tough work was getting every element to play nicely together. In some cases we found that the demands of one module were in conflict with another and things needed to be rewritten or scrapped.
3. **The DM9000A Controller will break (your heart).** The ethernet controller proved to be the most finicky of the modules we implemented. The code from lab 2 is not so portable. So simplest way we found to integrate networking in our project required us to port our code into the lab2 project.

VIII. Roles

While everyone in the group was involved in all aspects of the program to varying extents, the principal duties performed by each member are:

Carlos

- Principal Designer of the VGA module as well as the camera and sound.

Tony

- Principal designer of the game logic and sprite generation.

Sam

- Co-Principal designer of the network and keyboard components.

Matt

- Co-Principal designer of the network and keyboard components and resident documentation hound.

IX. SAGa-specific Code:

Hardware:

- de2_sram_controller.vhd
- de2_vga_raster.vhd
- main.vhd
- de2_ps2.vhd
- DM9000A_IF.v
- YcbCr2RGB.v – created by Altera but found by SAGa team
- ram2.v – created by Altera but found by SAGa team
- MAC_3.v – created by Altera but found by SAGa team
- itu_r656_decoder.v – created by Altera but found by SAGa team
- dul_port_c1024.v – created by Altera but found by SAGa team
- de2_wm8731_audio.vhd – created by Altera but found by SAGa team

de2_sram_controller.vhd

```
library ieee;
use ieee.std_logic_1164.all;

entity de2_sram_controller is

  port (
    signal chipselect : in std_logic;
    signal write, read : in std_logic;
    signal address  :  in std_logic_vector(17 downto 0);
    signal readdata : out std_logic_vector(15 downto 0);
    signal writedata : in std_logic_vector(15 downto 0);
    signal byteenable : in std_logic_vector(1 downto 0);

    signal SRAM_DQ   : inout std_logic_vector(15 downto 0);
    signal SRAM_ADDR : out std_logic_vector(17 downto 0);
    signal SRAM_UB_N, SRAM_LB_N : out std_logic;
    signal SRAM_WE_N, SRAM_CE_N : out std_logic;
    signal SRAM_OE_N            : out std_logic
    );
```

```
end de2_sram_controller;

architecture dp of de2_sram_controller is
begin

  SRAM_DQ <= writedata when write = '1' else (others => 'Z');
  readdata <= SRAM_DQ;
  SRAM_ADDR <= address;
  SRAM_UB_N <= not byteenable(1);
  SRAM_LB_N <= not byteenable(0);
  SRAM_WE_N <= not write;
  SRAM_CE_N <= not chipselect;
  SRAM_OE_N <= not read;

end dp;
```

de2_vga_raster.vhd

```
library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;

entity de2_vga_raster is

  port (
    reset                :in std_logic;
    clk                  :in std_logic; -- Should be 25.125 MHz for the VGA so I am gonna convert
it
          read           :in std_logic;
          write          :in std_logic;
          chipselect     :in std_logic;
          address    : in  unsigned(2 downto 0);
    writedata  : in  unsigned(31 downto 0);
          readdata   : out unsigned(31 downto 0);

    VGA_CLK,                                    -- Clock
    VGA_HS,                                     -- H_SYNC
    VGA_VS,                                     -- V_SYNC
    VGA_BLANK,                                          -- BLANK
    VGA_SYNC   : out std_logic;                         -- SYNC
    VGA_R,                                      -- Red[9:0]
    VGA_G,                                      -- Green[9:0]
    VGA_B          : out std_logic_vector(9 downto 0);-- Blue[9:0]
```

```
        LEDR : out std_logic_vector(17 downto 0);   -- Red LEDs (for debugging)

        TD_DATA : in std_logic_vector(7 downto 0);  -- Data bus 8 bits
    TD_HS,                                  -- H_SYNC
    TD_VS : in std_logic                    -- V_SYNC
    );

end de2_vga_raster;

architecture rtl of de2_vga_raster is

  -- Video parameters

  constant HTOTAL       : integer := 800;
  constant HSYNC        : integer := 96;
  constant HBACK_PORCH  : integer := 48;
  constant HACTIVE      : integer := 640;
  constant HFRONT_PORCH : integer := 16;
  constant HREAL                : integer := 1024;

  constant VTOTAL       : integer := 525;
  constant VSYNC        : integer := 2;
  constant VBACK_PORCH  : integer := 33;
  constant VACTIVE      : integer := 480;
  constant VFRONT_PORCH : integer := 10;
  constant VREAL                : integer := 1024;

  --sprites&tiles parameters
  constant HSPRITE              : integer := 32;
  constant VSPRITE              : integer := 32;
  constant HTILE                : integer := 120;
  constant VTILE                : integer := 128;

-- Data structures (ROMS, RAM, Sprite position vectors, etc)
  type rom_type1 is array (0 to 8191)           of unsigned (31 downto 0);     --memory,       All the
sprites (32x32x31spritesx8bits/32bits = 7936). Each sprite has 256 positions (8192 bits). Each
row of one sprite has 8 positions (256 bits)
  type rom_type2 is array (0 to 255)   of std_logic_vector (31 downto 0);     --memory,       Color
table
  type rom_type3 is array (0 to 3839) of unsigned (7 downto 0);       --memory,    Tile
  type ram_type  is array (0 to 1023)           of unsigned (9 downto 0);       --memory,
Transparency layer (from top to bottom, reversed from Tony's)
  type sp_map           is array (0 to 31)              of unsigned (26 downto 0);     --
registers,Sprite positioning information [shown(1)|H(10)|V(10)|sprite#(5)|spriteFlip(1)]
```

type buf   is array (0 to 127)   of unsigned (31 downto 0);   --registers,Buffer for all the sprites in this row. (16 sprites*8 positions=128). 8 positions per sprite.

-- Sprites definition
signal sprites : rom_type1 := (
----Sprite File for baseball08 (0)
"11111011111110111111101111111011","11111011111110111111101111111011","11111011
111110111111101111111011","11111011111110111111101111111011","1111101111111011
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0100011",
"10011011","10011011","10100011","10011011","10011011","10011011","01011010","0101101
1","01011010","01010011","00001010","01001010","01010010","10100100","10101011","10100
100","10100011","01011011","10100011","01011010","01010010","00001010","01010010","010
11010","10100011","10100011","10100100","01100011","10011011","01010011","01011011","0
1011010",
"01011010","01010011","01001001","00001010","01001001","00010001","00001010","0100101
0","00001010","00001010","00001010","01010010","01010001","01001010","01010001","01001
010","00001010","01001010","01001001","00001010","01010010","10101100","10101100","101
01100","10101100","10101100","10100011","10101100","10101100","10101100","10100100","0
1011011");

  -- Signals for the video controller
  signal Hcount : unsigned (9 downto 0); -- TOTAL Horizontal position
  signal Vcount : unsigned (9 downto 0); -- TOTAL Vertical position
  signal HcountR: integer; -- Real Horizontal position (0-800)
  signal VcountR: integer; -- Real Vertical position (0-524)
  signal EndOfLine, EndOfField : std_logic;

  signal vga_hblank, vga_hsync, vga_vblank, vga_vsync : std_logic; -- Sync. signals

```
  signal Hextra: integer := 0;
  signal Vextra: integer := 0;

  -- Internmediate signals
  signal sprite_map              : sp_map;
  signal sprite_buffer   : buf;
  signal show_spriteTile: std_logic                              := '0' ;
  signal show_something : std_logic                              := '0' ;
  signal sprite_pointer : unsigned (2  downto 0):= TO_UNSIGNED(0,3);
  signal sprites_2_show         : unsigned (15 downto 0):= TO_UNSIGNED(0,16);--
  signal sprites_copied : unsigned (15 downto 0):= TO_UNSIGNED(0,16);--
  signal sp_pointer     : unsigned (12 downto 0):= TO_UNSIGNED(0,13);
  signal buffer_pointer : unsigned (6  downto 0):= TO_UNSIGNED(0,7);
  signal en_sprite               : std_logic                                     := '0';
  signal en_sprite1      : std_logic                             := '0';
  signal buffer_pointer1: unsigned (6  downto 0):= TO_UNSIGNED(0,7);
  signal cop_sprite              : unsigned (31 downto 0):= TO_UNSIGNED(0,32);

  signal tile_pixel_h   : unsigned (6 downto 0) := TO_UNSIGNED(0,7);
  signal tile_pixel_v   : unsigned (6 downto 0) := TO_UNSIGNED(0,7);
  signal tile_pixel              : unsigned (7 downto 0) := TO_UNSIGNED(0,8);
  signal tl_pointer     : integer;

  signal transparency   : ram_type;
  signal tranCounter    : unsigned (9 downto 0):=TO_UNSIGNED(0,10);
  signal old_transparency:unsigned (9 downto 0);--no default needed


  signal color_2_show   : unsigned (7 downto 0):=TO_UNSIGNED(0,8);
  signal colorInternal  : std_logic_vector (31 downto
0):=std_logic_vector(TO_UNSIGNED(0,32));

  signal random                         : unsigned (31 downto 0):= TO_UNSIGNED(0,32);

  signal clk25                  : std_logic := '0';          -- 25 MHz clock

  signal VGA_R_IN               : std_logic_vector(9 downto 0);-- Red[9:0]
  signal VGA_G_IN               : std_logic_vector(9 downto 0);-- Green[9:0]
  signal VGA_B_IN         : std_logic_vector(9 downto 0);-- Blue[9:0]

  signal Y                              : std_logic_vector(7 downto 0);
  signal Cb                             : std_logic_vector(7 downto 0);
  signal Cr                             : std_logic_vector(7 downto 0);
```

```
  component itu_r656_decoder
  port(   CLOCK,TD_HS,TD_VS         : in std_logic;
                    TD_D : in std_logic_vector(7 downto 0);
                    Y,Cb,Cr          : out std_logic_vector(7 downto 0);
                    R,G,B  : out std_logic_vector(9 downto 0));
  end component;

  component YCbCr2RGB
  port( iY,iCb,iCr : in std_logic_vector(7 downto 0);
                    iRESET,iCLK : in std_logic;
                    Red,Green,Blue         : out std_logic_vector(9 downto 0));
  end component;

begin
  --to avoid warnings
  LEDR <= (others => '0');

  -- CLK conversion
  ClkConver : process (clk)     --create a PLL with a megafunction
  begin
    if rising_edge(clk) then
      clk25 <= not clk25;
    end if;
  end process ClkConver;
--
--  PLL to create a 25 MHz clock
--  ClkPLL : entity work.pll
--                      port map(inclk0=>clk, c0=>clk25);
  --Color table
--  Color : entity work.colors_rom
--                      port
map(address=>std_logic_vector(color_2_show),clock=>clk25,q=>colorInternal);

  --Decoder : itu_r656_decoder port map(CLOCK=>clk25, TD_D=>TD_DATA,
TD_HS=>TD_HS, TD_VS=>TD_VS, Y=>Y, Cb=>Cb, Cr=>Cr, R=>VGA_R_IN, G=>VGA_G_IN,
B=>VGA_B_IN);

  --Conver : YCbCr2RGB port map(Red=>VGA_R_IN, Green=>VGA_G_IN, Blue=>VGA_B_IN,
iY=>Y, iCb=>Cb, iCr=>Cr, iRESET =>'0', iCLK=>clk25);

  --random numbers generator
  RandomGenerator : process (clk)
  begin
          if rising_edge(clk)then
```

```
            if random = TO_UNSIGNED(255,32) then
              random <= (others => '0');
            else
                    random <= random + 1;
            end if;
           end if;
  end process RandomGenerator;

  -- Horizontal and vertical counters
  HCounter : process (clk25)
  begin
    if rising_edge(clk25) then
      if reset = '1' then
        Hcount  <= (others => '0');
                    HcountR <= -1;
      elsif EndOfLine = '1' then
        Hcount  <= (others => '0');
                    HcountR <= -1;
      else
        Hcount <= Hcount + 1;
                    if Hcount >= HSYNC + HBACK_PORCH - 2 then --change to 0 two cycles before
than vga_hblank => '0'
                      HcountR <= HcountR + 1;
                    end if;
      end if;
    end if;
  end process HCounter;

  EndOfLine <= '1' when Hcount = HTOTAL - 1 else '0';

  VCounter: process (clk25)
  begin
    if rising_edge(clk25) then
      if reset = '1' then
        Vcount <= (others => '0');
                    VcountR <= -1;
      elsif EndOfLine = '1' then
        if EndOfField = '1' then
          Vcount  <= (others => '0');
                      VcountR <= -1;
        else
          Vcount <= Vcount + 1;
                      if Vcount >= VSYNC + VBACK_PORCH - 1 then    --same cycle than
vga_vblank => '0'
```

```
                        VcountR <= VcountR + 1;
                    end if;
      end if;
    end if;
  end if;
end process VCounter;

EndOfField <= '1' when Vcount = VTOTAL - 1 else '0';

-- State machines to generate HSYNC, VSYNC, HBLANK, and VBLANK
HSyncGen : process (clk25)
begin
  if rising_edge(clk25) then
    if reset = '1' or EndOfLine = '1' then
      vga_hsync <= '1';
    elsif Hcount = HSYNC - 1 then
      vga_hsync <= '0';
    end if;
  end if;
end process HSyncGen;

HBlankGen : process (clk25)
begin
  if rising_edge(clk25) then
    if reset = '1' then
      vga_hblank <= '1';
    elsif Hcount = HSYNC + HBACK_PORCH then
      vga_hblank <= '0';          --executed in the cycle 144, visible in the 145
    elsif Hcount = HSYNC + HBACK_PORCH + HACTIVE then
      vga_hblank <= '1';
    end if;
  end if;
end process HBlankGen;

VSyncGen : process (clk25)
begin
  if rising_edge(clk25) then
    if reset = '1' then
      vga_vsync <= '1';
    elsif EndOfLine ='1' then
      if EndOfField = '1' then
        vga_vsync <= '1';
      elsif Vcount = VSYNC - 1 then
        vga_vsync <= '0';
```

```
      end if;
    end if;
  end if;
end process VSyncGen;

VBlankGen : process (clk25)
begin
  if rising_edge(clk25) then
    if reset = '1' then
      vga_vblank <= '1';
    elsif EndOfLine = '1' then
      if Vcount = VSYNC + VBACK_PORCH - 1 then
        vga_vblank <= '0';
      elsif Vcount = VSYNC + VBACK_PORCH + VACTIVE
- 1 then
        vga_vblank <= '1';
      end if;
    end if;
  end if;
end process VBlankGen;

                                                    --          [31        27|   26          |25 16|15  6|
5       1|     0       ]
  --sprites from the SW, format: [SpriteID(5)|shown(1)|H(10)|V(10)|sprite#(5)|spriteFlip(1)]

  SpriteGen : process (clk25)
  begin
          if rising_edge(clk25) then
            L0: for c in 0 to 15 loop
                  if sprite_map(c)(26)='1' and VcountR>=(TO_INTEGER(sprite_map(c)(15 downto
6))-Vextra) and VcountR<(TO_INTEGER(sprite_map(c)(15 downto 6))+VSPRITE-Vextra)then
                    sprites_2_show(c) <= '1';
                  else
                    sprites_2_show(c) <= '0';
                  end if;
            end loop L0;

            if VcountR>=0 and VcountR<VACTIVE  and Hcount=TO_UNSIGNED(0,10) then
          --Cycle 0
                  sprites_copied  <= (others => '0');
                  sprite_pointer  <= "000";
            end if;

            if VcountR>=0 and VcountR<VACTIVE  and Hcount>TO_UNSIGNED(0,10) and
Hcount<TO_UNSIGNED(129,10) then          --Cycle 1-128: copy the row of the sprites thaat are
```

```
shown to buffers
                if sprites_2_show(0)='1' and sprites_copied(0)='0' then

                  buffer_pointer        <= TO_UNSIGNED(8*0,7) + sprite_pointer;
                  sp_pointer            <= TO_UNSIGNED(256*TO_INTEGER(sprite_map(0)(5
downto 1)),13) + TO_UNSIGNED(8*(VcountR-TO_INTEGER(sprite_map(0)(15 downto 6))
+Vextra),13) + sprite_pointer;
                  en_sprite             <= '1';

                  if sprite_pointer = "111" then --review
                        sprite_pointer <= "000";
                        sprites_copied(0) <= '1';
                  else
                        sprite_pointer <= sprite_pointer+1;
                  end if;
                elsif sprites_2_show(1)='1' and sprites_copied(1)='0' then
                  buffer_pointer        <= TO_UNSIGNED(8*1,7) + sprite_pointer;
                  sp_pointer            <= TO_UNSIGNED(256*TO_INTEGER(sprite_map(1)(5
downto 1)),13) + TO_UNSIGNED(8*(VcountR-TO_INTEGER(sprite_map(1)(15 downto 6))
+Vextra),13) + sprite_pointer;
                  en_sprite             <= '1';

                  if sprite_pointer = "111" then --review
                        sprite_pointer <= "000";
                        sprites_copied(1) <= '1';
                  else
                        sprite_pointer <= sprite_pointer+1;
                  end if;
                elsif sprites_2_show(2)='1' and sprites_copied(2)='0' then
                  buffer_pointer        <= TO_UNSIGNED(8*2,7) + sprite_pointer;
                  sp_pointer            <= TO_UNSIGNED(256*TO_INTEGER(sprite_map(2)(5
downto 1)),13) + TO_UNSIGNED(8*(VcountR-TO_INTEGER(sprite_map(2)(15 downto 6))
+Vextra),13) + sprite_pointer;
                  en_sprite             <= '1';

                  if sprite_pointer = "111" then --review
                        sprite_pointer <= "000";
                        sprites_copied(2) <= '1';
                  else
                        sprite_pointer <= sprite_pointer+1;
                  end if;
                elsif sprites_2_show(3)='1' and sprites_copied(3)='0' then
                  buffer_pointer        <= TO_UNSIGNED(8*3,7) + sprite_pointer;
                  sp_pointer            <= TO_UNSIGNED(256*TO_INTEGER(sprite_map(3)(5
downto 1)),13) + TO_UNSIGNED(8*(VcountR-TO_INTEGER(sprite_map(3)(15 downto 6))
```

```
+Vextra),13) + sprite_pointer;
                    en_sprite               <= '1';

                    if sprite_pointer = "111" then --review
                            sprite_pointer <= "000";
                            sprites_copied(3) <= '1';
                    else
                            sprite_pointer <= sprite_pointer+1;
                    end if;
                   elsif sprites_2_show(4)='1' and sprites_copied(4)='0' then
                    buffer_pointer          <= TO_UNSIGNED(8*4,7) + sprite_pointer;
                    sp_pointer              <= TO_UNSIGNED(256*TO_INTEGER(sprite_map(4)(5
downto 1)),13) + TO_UNSIGNED(8*(VcountR-TO_INTEGER(sprite_map(4)(15 downto 6))
+Vextra),13) + sprite_pointer;
                    en_sprite               <= '1';

                    if sprite_pointer = "111" then --review
                            sprite_pointer <= "000";
                            sprites_copied(4) <= '1';
                    else
                            sprite_pointer <= sprite_pointer+1;
                    end if;
                   elsif sprites_2_show(5)='1' and sprites_copied(5)='0' then
                    buffer_pointer          <= TO_UNSIGNED(8*5,7) + sprite_pointer;
                    sp_pointer              <= TO_UNSIGNED(256*TO_INTEGER(sprite_map(5)(5
downto 1)),13) + TO_UNSIGNED(8*(VcountR-TO_INTEGER(sprite_map(5)(15 downto 6))
+Vextra),13) + sprite_pointer;
                    en_sprite               <= '1';

                    if sprite_pointer = "111" then --review
                            sprite_pointer <= "000";
                            sprites_copied(5) <= '1';
                    else
                            sprite_pointer <= sprite_pointer+1;
                    end if;
                   elsif sprites_2_show(6)='1' and sprites_copied(6)='0' then
                    buffer_pointer          <= TO_UNSIGNED(8*6,7) + sprite_pointer;
                    sp_pointer              <= TO_UNSIGNED(256*TO_INTEGER(sprite_map(6)(5
downto 1)),13) + TO_UNSIGNED(8*(VcountR-TO_INTEGER(sprite_map(6)(15 downto 6))
+Vextra),13) + sprite_pointer;
                    en_sprite               <= '1';

                    if sprite_pointer = "111" then --review
                            sprite_pointer <= "000";
                            sprites_copied(6) <= '1';
```

```
                    else
                        sprite_pointer <= sprite_pointer+1;
                    end if;
                  elsif sprites_2_show(7)='1' and sprites_copied(7)='0' then
                    buffer_pointer      <= TO_UNSIGNED(8*7,7) + sprite_pointer;
                    sp_pointer          <= TO_UNSIGNED(256*TO_INTEGER(sprite_map(7)(5
downto 1)),13) + TO_UNSIGNED(8*(VcountR-TO_INTEGER(sprite_map(7)(15 downto 6))
+Vextra),13) + sprite_pointer;
                    en_sprite           <= '1';

                    if sprite_pointer = "111" then --review
                        sprite_pointer <= "000";
                        sprites_copied(7) <= '1';
                    else
                        sprite_pointer <= sprite_pointer+1;
                    end if;
                  elsif sprites_2_show(8)='1' and sprites_copied(8)='0' then
                    buffer_pointer      <= TO_UNSIGNED(8*8,7) + sprite_pointer;
                    sp_pointer          <= TO_UNSIGNED(256*TO_INTEGER(sprite_map(8)(5
downto 1)),13) + TO_UNSIGNED(8*(VcountR-TO_INTEGER(sprite_map(8)(15 downto 6))
+Vextra),13) + sprite_pointer;
                    en_sprite           <= '1';

                    if sprite_pointer = "111" then --review
                        sprite_pointer <= "000";
                        sprites_copied(8) <= '1';
                    else
                        sprite_pointer <= sprite_pointer+1;
                    end if;
                  elsif sprites_2_show(9)='1' and sprites_copied(9)='0' then
                    buffer_pointer      <= TO_UNSIGNED(8*9,7) + sprite_pointer;
                    sp_pointer          <= TO_UNSIGNED(256*TO_INTEGER(sprite_map(9)(5
downto 1)),13) + TO_UNSIGNED(8*(VcountR-TO_INTEGER(sprite_map(9)(15 downto 6))
+Vextra),13) + sprite_pointer;
                    en_sprite           <= '1';

                    if sprite_pointer = "111" then --review
                        sprite_pointer <= "000";
                        sprites_copied(9) <= '1';
                    else
                        sprite_pointer <= sprite_pointer+1;
                    end if;
                  elsif sprites_2_show(10)='1' and sprites_copied(10)='0' then
                    buffer_pointer      <= TO_UNSIGNED(8*10,7) + sprite_pointer;
                    sp_pointer          <= TO_UNSIGNED(256*TO_INTEGER(sprite_map(10)(5
```

```
downto 1)),13) + TO_UNSIGNED(8*(VcountR-TO_INTEGER(sprite_map(10)(15 downto 6))
+Vextra),13) + sprite_pointer;
                    en_sprite               <= '1';

                    if sprite_pointer = "111" then --review
                            sprite_pointer <= "000";
                            sprites_copied(10) <= '1';
                    else
                            sprite_pointer <= sprite_pointer+1;
                    end if;
                   elsif sprites_2_show(11)='1' and sprites_copied(11)='0' then
                    buffer_pointer          <= TO_UNSIGNED(8*11,7) + sprite_pointer;
                    sp_pointer              <= TO_UNSIGNED(256*TO_INTEGER(sprite_map(11)(5
downto 1)),13) + TO_UNSIGNED(8*(VcountR-TO_INTEGER(sprite_map(11)(15 downto 6))
+Vextra),13) + sprite_pointer;
                    en_sprite               <= '1';

                    if sprite_pointer = "111" then --review
                            sprite_pointer <= "000";
                            sprites_copied(11) <= '1';
                    else
                            sprite_pointer <= sprite_pointer+1;
                    end if;
                   elsif sprites_2_show(12)='1' and sprites_copied(12)='0' then
                    buffer_pointer          <= TO_UNSIGNED(8*12,7) + sprite_pointer;
                    sp_pointer              <= TO_UNSIGNED(256*TO_INTEGER(sprite_map(12)(5
downto 1)),13) + TO_UNSIGNED(8*(VcountR-TO_INTEGER(sprite_map(12)(15 downto 6))
+Vextra),13) + sprite_pointer;
                    en_sprite               <= '1';

                    if sprite_pointer = "111" then --review
                            sprite_pointer <= "000";
                            sprites_copied(12) <= '1';
                    else
                            sprite_pointer <= sprite_pointer+1;
                    end if;
                   elsif sprites_2_show(13)='1' and sprites_copied(13)='0' then
                    buffer_pointer          <= TO_UNSIGNED(8*13,7) + sprite_pointer;
                    sp_pointer              <= TO_UNSIGNED(256*TO_INTEGER(sprite_map(13)(5
downto 1)),13) + TO_UNSIGNED(8*(VcountR-TO_INTEGER(sprite_map(13)(15 downto 6))
+Vextra),13) + sprite_pointer;
                    en_sprite               <= '1';

                    if sprite_pointer = "111" then --review
                            sprite_pointer <= "000";
```

```
                        sprites_copied(13) <= '1';
                    else
                        sprite_pointer <= sprite_pointer+1;
                    end if;
                elsif sprites_2_show(14)='1' and sprites_copied(14)='0' then
                    buffer_pointer      <= TO_UNSIGNED(8*14,7) + sprite_pointer;
                    sp_pointer          <= TO_UNSIGNED(256*TO_INTEGER(sprite_map(14)(5
downto 1)),13) + TO_UNSIGNED(8*(VcountR-TO_INTEGER(sprite_map(14)(15 downto 6))
+Vextra),13) + sprite_pointer;
                    en_sprite           <= '1';

                    if sprite_pointer = "111" then --review
                        sprite_pointer <= "000";
                        sprites_copied(14) <= '1';
                    else
                        sprite_pointer <= sprite_pointer+1;
                    end if;
                elsif sprites_2_show(15)='1' and sprites_copied(15)='0' then
                    buffer_pointer      <= TO_UNSIGNED(8*15,7) + sprite_pointer;
                    sp_pointer          <= TO_UNSIGNED(256*TO_INTEGER(sprite_map(15)(5
downto 1)),13) + TO_UNSIGNED(8*(VcountR-TO_INTEGER(sprite_map(15)(15 downto 6))
+Vextra),13) + sprite_pointer;
                    en_sprite           <= '1';

                    if sprite_pointer = "111" then --review
                        sprite_pointer <= "000";
                        sprites_copied(15) <= '1';
                    else
                        sprite_pointer <= sprite_pointer+1;
                    end if;
                end if;
            end if;

            if Hcount=TO_UNSIGNED(129,10) then
                en_sprite <= '0';
            end if;

            if en_sprite='1' then
                en_sprite1 <= '1';
            else
                en_sprite1 <= '0';
            end if;

            if en_sprite='1' then
                cop_sprite<= sprites(TO_INTEGER(sp_pointer));
```

```
                buffer_pointer1 <= buffer_pointer;
        end if;

        if en_sprite1='1' then
                sprite_buffer(TO_INTEGER(buffer_pointer1)) <= cop_sprite;
        else
                L1: for d in 0 to 15 loop
                  if sprites_2_show(d)='1' and HcountR>=(TO_INTEGER(sprite_map(d)(25
downto 16))-Hextra) and HcountR<(TO_INTEGER(sprite_map(d)(25 downto 16))-
Hextra+HSPRITE) then
                        if sprite_map(d)(0)='0' then
                          L2: for c in 0 to 6 loop
                                sprite_buffer(8*d+c)(31 downto 8)  <= sprite_buffer(8*d+c)(23
downto 0);
                                sprite_buffer(8*d+c)(7 downto 0)   <= sprite_buffer(8*d+c+1)(31
downto 24);
                          end loop L2;

                          sprite_buffer(8*d+7)(31 downto 8) <= sprite_buffer(8*d+7)(23 downto 0);
                          sprite_buffer(8*d+7)(7 downto 0)  <= (others => '0');
                        else
                          sprite_buffer(8*d+0)(31 downto 24)
 <= sprite_buffer(8*d+7)(7 downto 0);
                          sprite_buffer(8*d+0)(23 downto 0)  <= sprite_buffer(8*d+0)(31 downto
8);

                          L3: for c in 1 to 7 loop
                                sprite_buffer(8*d+c)(31 downto 24) <= sprite_buffer(8*d+c-1)(7
downto 0);
                                sprite_buffer(8*d+c)(23 downto 0)  <= sprite_buffer(8*d+c)(31
downto 8);
                          end loop L3;
                        end if;
                  end if;
                end loop L1;
        end if;

        if VcountR>=0 and VcountR<VACTIVE and
Hcount>=TO_UNSIGNED(HSYNC+HBACK_PORCH-3,10) and
Hcount<TO_UNSIGNED(HSYNC+HBACK_PORCH+HACTIVE-3,10) then --Cycle 141
                if tile_pixel_h = TO_UNSIGNED(63,7) then --updating counters for the tile
                  tile_pixel_h <= (others => '0');
                else
                  tile_pixel_h <= tile_pixel_h + 1;
```

```
            end if;
        end if;

        if VcountR>=0 and VcountR<VACTIVE and
Hcount=TO_UNSIGNED(HSYNC+HBACK_PORCH+HACTIVE-3,10) then          --cycle 141
            if Hextra < 64 then
              tile_pixel_h <= TO_UNSIGNED(Hextra,7);
            elsif     Hextra < 128 then
              tile_pixel_h <= TO_UNSIGNED(Hextra-64,7);
            elsif     Hextra < 192 then
              tile_pixel_h <= TO_UNSIGNED(Hextra-128,7);
            elsif     Hextra < 256 then
              tile_pixel_h <= TO_UNSIGNED(Hextra-192,7);
            elsif     Hextra < 320 then
              tile_pixel_h <= TO_UNSIGNED(Hextra-256,7);
            elsif     Hextra < 384 then
              tile_pixel_h <= TO_UNSIGNED(Hextra-320,7);
            end if;

            if tile_pixel_v = TO_UNSIGNED(59,7) then
              tile_pixel_v <= (others => '0');
            else
              tile_pixel_v <= tile_pixel_v + 1;
            end if;
        end if;

        if Vcount = TO_UNSIGNED(0,10) then --before: if VcountR = VACTIVE then
            if Vextra < 60 then
              tile_pixel_v <= TO_UNSIGNED(Vextra,7);
            elsif     Vextra < 120 then
              tile_pixel_v <= TO_UNSIGNED(Vextra-60,7);
            elsif     Vextra < 180 then
              tile_pixel_v <= TO_UNSIGNED(Vextra-120,7);
            elsif     Vextra < 240 then
              tile_pixel_v <= TO_UNSIGNED(Vextra-180,7);
            elsif     Vextra < 300 then
              tile_pixel_v <= TO_UNSIGNED(Vextra-240,7);
            elsif     Vextra < 360 then
              tile_pixel_v <= TO_UNSIGNED(Vextra-300,7);
            elsif     Vextra < 420 then
              tile_pixel_v <= TO_UNSIGNED(Vextra-360,7);
            elsif     Vextra < 480 then
              tile_pixel_v <= TO_UNSIGNED(Vextra-420,7);
            elsif     Vextra < 540 then
```

```
                tile_pixel_v <= TO_UNSIGNED(Vextra-480,7);
              elsif     Vextra < 600 then
                tile_pixel_v <= TO_UNSIGNED(Vextra-540,7);
              end if;

              tile_pixel_h <= (others => '0');
        end if;

        if VcountR>=0 and VcountR<VACTIVE and
Hcount>=TO_UNSIGNED(HSYNC+HBACK_PORCH-2,10) and
Hcount<TO_UNSIGNED(HSYNC+HBACK_PORCH+HACTIVE-2,10) then          --Cycle 142
              tile_pixel <= tile(TO_INTEGER(tile_pixel_v*TO_UNSIGNED(64,8)+tile_pixel_h));
        end if;

        if VcountR>=0 and VcountR<VACTIVE and HcountR>=0 and HcountR<HACTIVE then
--Cycle 143: 1 cycle before we arrive to the screen (we arrive at cycle 144, Hcount >= 144)
              if sprites_2_show(0)='1' and HcountR>=TO_INTEGER(sprite_map(0)(25 downto
16)-Hextra) and HcountR<(TO_INTEGER(sprite_map(0)(25 downto 16))+HSPRITE-Hextra) and
sprite_buffer(8*0)(31 downto 24)/=TO_UNSIGNED(251,8) then--sprite_buffer(8*0)(31 downto
24)/=TO_UNSIGNED(3,8) and sprite_buffer(8*0)(31 downto 24)/=TO_UNSIGNED(10,8) and
sprite_buffer(8*0)(31 downto 24)/=TO_UNSIGNED(27,8) and sprite_buffer(8*0)(31 downto
24)/=TO_UNSIGNED(36,8) and sprite_buffer(8*0)(31 downto 24)/=TO_UNSIGNED(45,8) and
sprite_buffer(8*0)(31 downto 24)/=TO_UNSIGNED(54,8) and sprite_buffer(8*0)(31 downto
24)/=TO_UNSIGNED(63,8) and sprite_buffer(8*0)(31 downto 24)/=TO_UNSIGNED(73,8) and
sprite_buffer(8*0)(31 downto 24)/=TO_UNSIGNED(82,8) and sprite_buffer(8*0)(31 downto
24)/=TO_UNSIGNED(91,8) and sprite_buffer(8*0)(31 downto 24)/=TO_UNSIGNED(100,8) and
sprite_buffer(8*0)(31 downto 24)/=TO_UNSIGNED(109,8) and sprite_buffer(8*0)(31 downto
24)/=TO_UNSIGNED(118,8) and sprite_buffer(8*0)(31 downto 24)/=TO_UNSIGNED(127,8) and
sprite_buffer(8*0)(31 downto 24)/=TO_UNSIGNED(251,8) then
                color_2_show <= sprite_buffer(8*0)(31 downto 24);
                show_spriteTile <= '1';
              elsif sprites_2_show(1)='1' and HcountR>=TO_INTEGER(sprite_map(1)(25
downto 16)-Hextra) and HcountR<(TO_INTEGER(sprite_map(1)(25 downto 16))+HSPRITE-
Hextra) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(251,8) then--sprite_buffer(8*1)
(31 downto 24)/=TO_UNSIGNED(3,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(10,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(27,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(36,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(45,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(54,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(63,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(73,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(82,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(91,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(100,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(109,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(118,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(127,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(251,8)
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then
                    color_2_show <= sprite_buffer(8*1)(31 downto 24);
                    show_spriteTile <= '1';
                  elsif sprites_2_show(2)='1' and HcountR>=TO_INTEGER(sprite_map(2)(25
downto 16)-Hextra) and HcountR<(TO_INTEGER(sprite_map(2)(25 downto 16))+HSPRITE-
Hextra) and sprite_buffer(8*2)(31 downto 24)/=TO_UNSIGNED(251,8) then--sprite_buffer(8*1)
(31 downto 24)/=TO_UNSIGNED(3,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(10,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(27,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(36,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(45,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(54,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(63,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(73,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(82,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(91,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(100,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(109,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(118,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(127,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(251,8)
then
                    color_2_show <= sprite_buffer(8*2)(31 downto 24);
                    show_spriteTile <= '1';
                  elsif sprites_2_show(3)='1' and HcountR>=TO_INTEGER(sprite_map(3)(25
downto 16)-Hextra) and HcountR<(TO_INTEGER(sprite_map(3)(25 downto 16))+HSPRITE-
Hextra) and sprite_buffer(8*3)(31 downto 24)/=TO_UNSIGNED(251,8) then--sprite_buffer(8*1)
(31 downto 24)/=TO_UNSIGNED(3,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(10,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(27,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(36,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(45,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(54,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(63,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(73,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(82,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(91,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(100,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(109,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(118,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(127,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(251,8)
then
                    color_2_show <= sprite_buffer(8*3)(31 downto 24);
                    show_spriteTile <= '1';
                  elsif sprites_2_show(4)='1' and HcountR>=TO_INTEGER(sprite_map(4)(25
downto 16)-Hextra) and HcountR<(TO_INTEGER(sprite_map(4)(25 downto 16))+HSPRITE-
Hextra) and sprite_buffer(8*4)(31 downto 24)/=TO_UNSIGNED(251,8) then--sprite_buffer(8*1)
(31 downto 24)/=TO_UNSIGNED(3,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(10,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(27,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(36,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(45,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(54,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(63,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(73,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(82,8) and
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sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(91,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(100,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(109,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(118,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(127,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(251,8)
then
                    color_2_show <= sprite_buffer(8*4)(31 downto 24);
                    show_spriteTile <= '1';
                  elsif sprites_2_show(5)='1' and HcountR>=TO_INTEGER(sprite_map(5)(25
downto 16)-Hextra) and HcountR<(TO_INTEGER(sprite_map(5)(25 downto 16))+HSPRITE-
Hextra) and sprite_buffer(8*5)(31 downto 24)/=TO_UNSIGNED(251,8) then--sprite_buffer(8*1)
(31 downto 24)/=TO_UNSIGNED(3,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(10,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(27,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(36,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(45,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(54,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(63,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(73,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(82,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(91,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(100,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(109,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(118,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(127,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(251,8)
then
                    color_2_show <= sprite_buffer(8*5)(31 downto 24);
                    show_spriteTile <= '1';
                  elsif sprites_2_show(6)='1' and HcountR>=TO_INTEGER(sprite_map(6)(25
downto 16)-Hextra) and HcountR<(TO_INTEGER(sprite_map(6)(25 downto 16))+HSPRITE-
Hextra) and sprite_buffer(8*6)(31 downto 24)/=TO_UNSIGNED(251,8) then--sprite_buffer(8*1)
(31 downto 24)/=TO_UNSIGNED(3,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(10,8)
 and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(27,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(36,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(45,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(54,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(63,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(73,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(82,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(91,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(100,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(109,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(118,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(127,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(251,8) then
                    color_2_show <= sprite_buffer(8*6)(31 downto 24);
                    show_spriteTile <= '1';
                  elsif sprites_2_show(7)='1' and HcountR>=TO_INTEGER(sprite_map(7)(25
downto 16)-Hextra) and HcountR<(TO_INTEGER(sprite_map(7)(25 downto 16))+HSPRITE-
Hextra) and sprite_buffer(8*7)(31 downto 24)/=TO_UNSIGNED(251,8) then--sprite_buffer(8*1)
(31 downto 24)/=TO_UNSIGNED(3,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(10,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(27,8) and
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sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(36,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(45,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(54,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(63,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(73,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(82,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(91,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(100,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(109,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(118,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(127,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(251,8)
then
                    color_2_show <= sprite_buffer(8*7)(31 downto 24);
                    show_spriteTile <= '1';
                  elsif sprites_2_show(8)='1' and HcountR>=TO_INTEGER(sprite_map(8)(25
downto 16)-Hextra) and HcountR<(TO_INTEGER(sprite_map(8)(25 downto 16))+HSPRITE-
Hextra) and sprite_buffer(8*8)(31 downto 24)/=TO_UNSIGNED(251,8) then--sprite_buffer(8*1)
(31 downto 24)/=TO_UNSIGNED(3,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(10,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(27,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(36,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(45,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(54,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(63,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(73,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(82,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(91,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(100,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(109,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(118,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(127,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(251,8)
then
                    color_2_show <= sprite_buffer(8*8)(31 downto 24);
                    show_spriteTile <= '1';
                  elsif sprites_2_show(9)='1' and HcountR>=TO_INTEGER(sprite_map(9)(25
downto 16)-Hextra) and HcountR<(TO_INTEGER(sprite_map(9)(25 downto 16))+HSPRITE-
Hextra) and sprite_buffer(8*9)(31 downto 24)/=TO_UNSIGNED(251,8) then--sprite_buffer(8*1)
(31 downto 24)/=TO_UNSIGNED(3,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(10,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(27,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(36,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(45,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(54,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(63,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(73,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(82,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(91,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(100,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(109,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(118,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(127,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(251,8)
then
                    color_2_show <= sprite_buffer(8*9)(31 downto 24);
                    show_spriteTile <= '1';
                  elsif sprites_2_show(10)='1' and HcountR>=TO_INTEGER(sprite_map(10)(25
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downto 16)-Hextra) and HcountR<(TO_INTEGER(sprite_map(10)(25 downto 16))+HSPRITE-
Hextra) and sprite_buffer(8*10)(31 downto 24)/=TO_UNSIGNED(251,8) then--sprite_buffer(8*1)
(31 downto 24)/=TO_UNSIGNED(3,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(10,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(27,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(36,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(45,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(54,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(63,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(73,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(82,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(91,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(100,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(109,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(118,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(127,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(251,8)
then
                    color_2_show <= sprite_buffer(8*10)(31 downto 24);
                    show_spriteTile <= '1';
                  elsif sprites_2_show(11)='1' and HcountR>=TO_INTEGER(sprite_map(11)(25
downto 16)-Hextra) and HcountR<(TO_INTEGER(sprite_map(11)(25 downto 16))+HSPRITE-
Hextra) and sprite_buffer(8*11)(31 downto 24)/=TO_UNSIGNED(251,8) then--sprite_buffer(8*1)
(31 downto 24)/=TO_UNSIGNED(3,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(10,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(27,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(36,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(45,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(54,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(63,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(73,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(82,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(91,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(100,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(109,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(118,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(127,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(251,8)
then
                    color_2_show <= sprite_buffer(8*11)(31 downto 24);
                    show_spriteTile <= '1';
                  elsif sprites_2_show(12)='1' and HcountR>=TO_INTEGER(sprite_map(12)(25
downto 16)-Hextra) and HcountR<(TO_INTEGER(sprite_map(12)(25 downto 16))+HSPRITE-
Hextra) and sprite_buffer(8*12)(31 downto 24)/=TO_UNSIGNED(251,8) then--sprite_buffer(8*1)
(31 downto 24)/=TO_UNSIGNED(3,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(10,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(27,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(36,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(45,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(54,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(63,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(73,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(82,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(91,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(100,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(109,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(118,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(127,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(251,8)
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then
                    color_2_show <= sprite_buffer(8*12)(31 downto 24);
                    show_spriteTile <= '1';
                  elsif sprites_2_show(13)='1' and HcountR>=TO_INTEGER(sprite_map(13)(25
downto 16)-Hextra) and HcountR<(TO_INTEGER(sprite_map(13)(25 downto 16))+HSPRITE-
Hextra) and sprite_buffer(8*13)(31 downto 24)/=TO_UNSIGNED(251,8) then--sprite_buffer(8*1)
(31 downto 24)/=TO_UNSIGNED(3,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(10,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(27,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(36,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(45,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(54,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(63,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(73,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(82,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(91,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(100,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(109,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(118,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(127,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(251,8)
then
                    color_2_show <= sprite_buffer(8*13)(31 downto 24);
                    show_spriteTile <= '1';
                  elsif sprites_2_show(14)='1' and HcountR>=TO_INTEGER(sprite_map(14)(25
downto 16)-Hextra) and HcountR<(TO_INTEGER(sprite_map(14)(25 downto 16))+HSPRITE-
Hextra) and sprite_buffer(8*14)(31 downto 24)/=TO_UNSIGNED(251,8) then--sprite_buffer(8*1)
(31 downto 24)/=TO_UNSIGNED(3,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(10,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(27,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(36,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(45,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(54,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(63,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(73,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(82,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(91,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(100,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(109,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(118,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(127,8) and sprite_buffer(8*1)(31
 downto 24)/=TO_UNSIGNED(251,8) then
                    color_2_show <= sprite_buffer(8*14)(31 downto 24);
                    show_spriteTile <= '1';
                  elsif sprites_2_show(15)='1' and HcountR>=TO_INTEGER(sprite_map(15)(25
downto 16)-Hextra) and HcountR<(TO_INTEGER(sprite_map(15)(25 downto 16))+HSPRITE-
Hextra) and sprite_buffer(8*15)(31 downto 24)/=TO_UNSIGNED(251,8) then--sprite_buffer(8*1)
(31 downto 24)/=TO_UNSIGNED(3,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(10,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(27,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(36,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(45,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(54,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(63,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(73,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(82,8) and
```

```
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(91,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(100,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(109,8) and
sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(118,8) and sprite_buffer(8*1)(31 downto
24)/=TO_UNSIGNED(127,8) and sprite_buffer(8*1)(31 downto 24)/=TO_UNSIGNED(251,8)
then
                    color_2_show <= sprite_buffer(8*15)(31 downto 24);
                    show_spriteTile <= '1';
                  elsif VcountR > (TO_INTEGER(old_transparency)-Vextra) then      --show tile

                    color_2_show <= tile_pixel;
                    show_spriteTile <= '1';
                  else
                    color_2_show <= (others => '0');
                    show_spriteTile <= '0';
                  end if;
            end if;

            if show_spriteTile='1' then    --Cycle 144: get color for next pixel, visible in the cycle 145

                  colorInternal <= color(TO_INTEGER(color_2_show));         --show sprite or tile

                  show_something <= '1';
            else
                  show_something <= '0';
            end if;

          end if;
  end process SpriteGen;

  Communication : process(clk)         --Communication from the SW
  begin
          if rising_edge(clk)then
            if chipselect = '1' and write = '1' and address = "001" then
                  transparency(TO_INTEGER(tranCounter)) <=
unsigned(TO_UNSIGNED(1023,10) - unsigned(writedata(9 downto 0)));
            end if;

            if (HcountR+1+Hextra)<1024 then
                  old_transparency <= transparency(HcountR+1+Hextra);
            end if;

            if chipselect = '1' and write = '1' then
                  if address = "000" then
                    tranCounter <= (others => '0');
                  elsif address = "001" then
```

```
                if tranCounter = TO_UNSIGNED(1023,10) then
                        tranCounter <= (others => '0');
                else
                        tranCounter <= tranCounter + 1;
                end if;
               --          [31         27|   26          |25 16|15  6|5        1|     0        ]
               elsif address = "010" then --sprites from the SW, format: [SpriteID(5)|shown(1)|
H(10)|V(10)|sprite#(5)|spriteFlip(1)]
                if writedata(26) = '1' then
                        sprite_map(TO_INTEGER(writedata(31 downto 27))) <= (writedata(26
downto 0));
                else
                        sprite_map(TO_INTEGER(writedata(31 downto 27))) <= (others => '0');
                end if;
               elsif address = "011" then
                sprite_map <= (others => (others => '0'));
                Hextra           <= 0;
                Vextra           <= 0;
               elsif address = "100" then
                Hextra <= TO_INTEGER(writedata(31 downto 22));
                Vextra <= TO_INTEGER(writedata(21 downto 12));
               end if;
          end if;

          if chipselect = '1' and read = '1' then
                if address = "000" then
                        readdata <= random;
                end if;
          end if;
         end if;
 end process Communication;

 VideoOut : process (clk25)   -- Registered video signals going to the video DAC
 begin
        if rising_edge(clk25) then
          if reset = '1' then
                VGA_R <= "0000000000";
                VGA_G <= "0000000000";
                VGA_B <= "0000000000";
          else
                if vga_hblank = '0' and vga_vblank ='0' then            --paint a sprite/tile (cycle
145)
                 if show_something = '1' then
                        VGA_R <= colorInternal(31 downto 22);
```

```
                        VGA_G <= colorInternal(21 downto 12);
                        VGA_B <= colorInternal(11 downto 2);
                    else
                        VGA_R <= "0000000000";    --VGA_R_IN;          --paint background
                        VGA_G <= "0000000000";    --VGA_G_IN;
                        VGA_B <= "0000000000";    --VGA_B_IN;
                    end if;
                else                                                    --out of the visible area
(synchronization signals)
        VGA_R <= "0000000000";
        VGA_G <= "0000000000";
        VGA_B <= "0000000000";
                end if;
            end if;
    end if;
  end process VideoOut;

  VGA_CLK <= clk25;
  VGA_HS <= not vga_hsync;
  VGA_VS <= not vga_vsync;
  VGA_SYNC <= '0';
  VGA_BLANK <= not (vga_hsync or vga_vsync);

end rtl;

--          [31        27|   26          |25 16|15  6|5        1|     0        ]
  --sprites from the SW, format: [SpriteID(5)|shown(1)|H(10)|V(10)|sprite#(5)|spriteFlip(1)]
  --cycles needed to paint a sprite (new): (sprite starts at 144, HSYNC + HBACK_PORCH =
144)
  --cycle 0                  : determine sprites in this row.
  --cycle 1-128 : copy them to the 16 shift registers.
  --cycle 140    : Hcounter >= HSYNC+HBACKPORCH and Vcounter >=
VSYNC+VBACKPORCH-1 then show the first sprite
  --cycle 141    : if in that pixel there is no sprite, show tile, if not show background. If there is one
or more sprites, compare all and show the 1st not transparent, at the same time shift all the
registers in the right/left direction (it depends on the FlipBit)
  --cycle 142    : look for color information in the color table.
  --cycle 143    : show RGB color
```

main.vhd

```
library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;
```

```
entity main is

  port (
    -- Clocks

    CLOCK_27,                           -- 27 MHz
    CLOCK_50,                           -- 50 MHz
    EXT_CLOCK : in std_logic;                   -- External Clock

    -- Buttons and switches

    KEY : in std_logic_vector(3 downto 0);         -- Push buttons
    SW : in std_logic_vector(17 downto 0);         -- DPDT switches

    -- LED displays

    HEX0, HEX1, HEX2, HEX3, HEX4, HEX5, HEX6, HEX7 -- 7-segment displays
      : out std_logic_vector(6 downto 0);
    LEDG : out std_logic_vector(8 downto 0);       -- Green LEDs
    LEDR : out std_logic_vector(17 downto 0);      -- Red LEDs

    -- RS-232 interface

    UART_TXD : out std_logic;                   -- UART transmitter
    UART_RXD : in std_logic;                    -- UART receiver

    -- IRDA interface

--    IRDA_TXD : out std_logic;                   -- IRDA Transmitter
    IRDA_RXD : in std_logic;                    -- IRDA Receiver

    -- SDRAM

    DRAM_DQ : inout std_logic_vector(15 downto 0); -- Data Bus
    DRAM_ADDR : out std_logic_vector(11 downto 0); -- Address Bus
    DRAM_LDQM,                                  -- Low-byte Data Mask
    DRAM_UDQM,                                  -- High-byte Data Mask
    DRAM_WE_N,                                  -- Write Enable
    DRAM_CAS_N,                                 -- Column Address Strobe
    DRAM_RAS_N,                                 -- Row Address Strobe
    DRAM_CS_N,                                  -- Chip Select
    DRAM_BA_0,                                  -- Bank Address 0
    DRAM_BA_1,                                  -- Bank Address 0
```

```
DRAM_CLK,                          -- Clock
DRAM_CKE : out std_logic;              -- Clock Enable

-- FLASH

FL_DQ : inout std_logic_vector(7 downto 0);      -- Data bus
FL_ADDR : out std_logic_vector(21 downto 0);  -- Address bus
FL_WE_N,                           -- Write Enable
FL_RST_N,                          -- Reset
FL_OE_N,                           -- Output Enable
FL_CE_N : out std_logic;               -- Chip Enable

-- SRAM

SRAM_DQ : inout std_logic_vector(15 downto 0); -- Data bus 16 Bits
SRAM_ADDR : out std_logic_vector(17 downto 0); -- Address bus 18 Bits
SRAM_UB_N,                         -- High-byte Data Mask
SRAM_LB_N,                         -- Low-byte Data Mask
SRAM_WE_N,                         -- Write Enable
SRAM_CE_N,                         -- Chip Enable
SRAM_OE_N : out std_logic;             -- Output Enable

-- USB controller

OTG_DATA : inout std_logic_vector(15 downto 0); -- Data bus
OTG_ADDR : out std_logic_vector(1 downto 0);    -- Address
OTG_CS_N,                          -- Chip Select
OTG_RD_N,                          -- Write
OTG_WR_N,                          -- Read
OTG_RST_N,                         -- Reset
OTG_FSPEED,                -- USB Full Speed, 0 = Enable, Z = Disable
OTG_LSPEED : out std_logic;     -- USB Low Speed, 0 = Enable, Z = Disable
OTG_INT0,                          -- Interrupt 0
OTG_INT1,                          -- Interrupt 1
OTG_DREQ0,                         -- DMA Request 0
OTG_DREQ1 : in std_logic;              -- DMA Request 1
OTG_DACK0_N,                       -- DMA Acknowledge 0
OTG_DACK1_N : out std_logic;           -- DMA Acknowledge 1

-- 16 X 2 LCD Module

LCD_ON,                -- Power ON/OFF
LCD_BLON,                -- Back Light ON/OFF
LCD_RW,                -- Read/Write Select, 0 = Write, 1 = Read
```

```
LCD_EN,                 -- Enable
LCD_RS : out std_logic;     -- Command/Data Select, 0 = Command, 1 = Data
LCD_DATA : inout std_logic_vector(7 downto 0); -- Data bus 8 bits

-- SD card interface

SD_DAT,                 -- SD Card Data
SD_DAT3,                -- SD Card Data 3
SD_CMD : inout std_logic;   -- SD Card Command Signal
SD_CLK : out std_logic;     -- SD Card Clock

-- USB JTAG link

TDI,                    -- CPLD -> FPGA (data in)
TCK,                    -- CPLD -> FPGA (clk)
TCS : in std_logic;         -- CPLD -> FPGA (CS)
TDO : out std_logic;        -- FPGA -> CPLD (data out)

-- I2C bus

I2C_SDAT : inout std_logic; -- I2C Data
I2C_SCLK : out std_logic;   -- I2C Clock

-- PS/2 port

PS2_DAT,                -- Data
PS2_CLK : in std_logic;     -- Clock

-- VGA output

VGA_CLK,                    -- Clock
VGA_HS,                     -- H_SYNC
VGA_VS,                     -- V_SYNC
VGA_BLANK,                  -- BLANK
VGA_SYNC : out std_logic;           -- SYNC
VGA_R,                      -- Red[9:0]
VGA_G,                      -- Green[9:0]
VGA_B : out std_logic_vector(9 downto 0);       -- Blue[9:0]

--  Ethernet Interface

ENET_DATA : inout std_logic_vector(15 downto 0);    -- DATA bus 16Bits
ENET_CMD,           -- Command/Data Select, 0 = Command, 1 = Data
ENET_CS_N,                  -- Chip Select
```

```
    ENET_WR_N,                              -- Write
    ENET_RD_N,                             -- Read
    ENET_RST_N,                             -- Reset
    ENET_CLK : out std_logic;                   -- Clock 25 MHz
    ENET_INT : in std_logic;                  -- Interrupt

    -- Audio CODEC

    AUD_ADCLRCK : inout std_logic;                -- ADC LR Clock
    AUD_ADCDAT : in std_logic;                  -- ADC Data
    AUD_DACLRCK : inout std_logic;                -- DAC LR Clock
    AUD_DACDAT : out std_logic;                  -- DAC Data
    AUD_BCLK : inout std_logic;                 -- Bit-Stream Clock
    AUD_XCK : out std_logic;                   -- Chip Clock

    -- Video Decoder

    TD_DATA : in std_logic_vector(7 downto 0);  -- Data bus 8 bits
    TD_HS,                                -- H_SYNC
    TD_VS : in std_logic;                     -- V_SYNC
    TD_RESET : out std_logic;                  -- Reset

    -- General-purpose I/O

    GPIO_0,                                -- GPIO Connection 0
    GPIO_1 : inout std_logic_vector(35 downto 0) -- GPIO Connection 1
    );

end main;

architecture datapath of main is
begin

  nios: entity work.nios_system port map (
    reset_n => '1',
    clk => CLOCK_50,
    VGA_CLK_from_the_vga => VGA_CLK,
    VGA_HS_from_the_vga => VGA_HS,
    VGA_VS_from_the_vga => VGA_VS,
    VGA_BLANK_from_the_vga => VGA_BLANK,
    VGA_SYNC_from_the_vga => VGA_SYNC,
    VGA_R_from_the_vga => VGA_R,
    VGA_G_from_the_vga => VGA_G,
    VGA_B_from_the_vga => VGA_B,
```

```
  TD_DATA_to_the_vga => TD_DATA,
  TD_HS_to_the_vga => TD_HS,
  TD_VS_to_the_vga => TD_VS,
        LEDR_from_the_vga => LEDR,
  PS2_Clk_to_the_keyboard => PS2_CLK,
  PS2_Data_to_the_keyboard => PS2_DAT,
  ENET_DATA_to_and_from_the_DM9000A         => ENET_DATA,
  ENET_CMD_from_the_DM9000A => ENET_CMD,
  ENET_CS_N_from_the_DM9000A          => ENET_CS_N,
  ENET_WR_N_from_the_DM9000A          => ENET_WR_N,
  ENET_RD_N_from_the_DM9000A          => ENET_RD_N,
  ENET_RST_N_from_the_DM9000A         => ENET_RST_N,
  --ENET_CLK_from_the_DM9000A          => ENET_CLK,
  ENET_INT_to_the_DM9000A       => ENET_INT,
  SRAM_ADDR_from_the_sram      => SRAM_ADDR,
  SRAM_CE_N_from_the_sram      => SRAM_CE_N,
  SRAM_DQ_to_and_from_the_sram => SRAM_DQ,
  SRAM_LB_N_from_the_sram      => SRAM_LB_N,
  SRAM_OE_N_from_the_sram      => SRAM_OE_N,
  SRAM_UB_N_from_the_sram      => SRAM_UB_N,
  SRAM_WE_N_from_the_sram      => SRAM_WE_N
);

TD_RESET <= '1';

HEX7    <= "0001001"; -- Leftmost
HEX6    <= "0000110";
HEX5    <= "1000111";
HEX4    <= "1000111";
HEX3    <= "1000000";
HEX2    <= (others => '1');
HEX1    <= (others => '1');
HEX0    <= (others => '1');         -- Rightmost
LEDG    <= (others => '0');
--LEDR    <= (others => '1');
LCD_ON   <= '1';
LCD_BLON <= '1';
LCD_RW <= '1';
LCD_EN <= '0';
LCD_RS <= '0';
SD_DAT3 <= '1';
SD_CMD <= '1';
SD_CLK <= '1';
--SRAM_DQ <= (others => 'Z');
```

```
--SRAM_ADDR <= (others => '0');
--SRAM_UB_N <= '1';
--SRAM_LB_N <= '1';
--SRAM_CE_N <= '1';
--SRAM_WE_N <= '1';
--SRAM_OE_N <= '1';
UART_TXD <= '0';
DRAM_ADDR <= (others => '0');
DRAM_LDQM <= '0';
DRAM_UDQM <= '0';
DRAM_WE_N <= '1';
DRAM_CAS_N <= '1';
DRAM_RAS_N <= '1';
DRAM_CS_N <= '1';
DRAM_BA_0 <= '0';
DRAM_BA_1 <= '0';
DRAM_CLK <= '0';
DRAM_CKE <= '0';
FL_ADDR <= (others => '0');
FL_WE_N <= '1';
FL_RST_N <= '0';
FL_OE_N <= '1';
FL_CE_N <= '1';
OTG_ADDR <= (others => '0');
OTG_CS_N <= '1';
OTG_RD_N <= '1';
OTG_RD_N <= '1';
OTG_WR_N <= '1';
OTG_RST_N <= '1';
OTG_FSPEED <= '1';
OTG_LSPEED <= '1';
OTG_DACK0_N <= '1';
OTG_DACK1_N <= '1';
TDO <= '0';
--ENET_CMD <= '0';
--ENET_CS_N <= '1';
--ENET_WR_N <= '1';
--ENET_RD_N <= '1';
--ENET_RST_N <= '1';
ENET_CLK <= '0';
I2C_SCLK <= '1';
AUD_DACDAT <= '1';
AUD_XCK <= '1';
-- Set all bidirectional ports to tri-state
```

```
  DRAM_DQ     <= (others => 'Z');
  FL_DQ       <= (others => 'Z');
  --SRAM_DQ     <= (others => 'Z');
  OTG_DATA    <=
 (others => 'Z');
  LCD_DATA    <= (others => 'Z');
  SD_DAT      <= 'Z';
  I2C_SDAT    <= 'Z';
  --ENET_DATA   <= (others => 'Z');
  AUD_ADCLRCK <= 'Z';
  AUD_DACLRCK <= 'Z';
  AUD_BCLK    <= 'Z';
  GPIO_0      <= (others => 'Z');
  GPIO_1      <= (others => 'Z');

end datapath;
```

pll.vhd

```
-- megafunction wizard: %ALTPLL%
-- GENERATION: STANDARD
-- VERSION: WM1.0
-- MODULE: altpll

-- ============================================================
-- File Name: pll.vhd
-- Megafunction Name(s):
--                         altpll
--
-- Simulation Library Files(s):
--                         altera_mf
-- ============================================================
-- ************************************************************
-- THIS IS A WIZARD-GENERATED FILE. DO NOT EDIT THIS FILE!
--
-- 7.2 Build 151 09/26/2007 SJ Full Version
-- ************************************************************


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```

```
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--without limitation, that your use is for the sole purpose of
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--Altera or its authorized distributors.  Please refer to the
--applicable agreement for further details.


LIBRARY ieee;
USE ieee.std_logic_1164.all;

LIBRARY altera_mf;
USE altera_mf.all;

ENTITY pll IS
	PORT
	(
		inclk0		: IN STD_LOGIC  := '0';
		c0		: OUT STD_LOGIC
	);
END pll;


ARCHITECTURE SYN OF pll IS

	SIGNAL sub_wire0	: STD_LOGIC_VECTOR (5 DOWNTO 0);
	SIGNAL sub_wire1	: STD_LOGIC ;
	SIGNAL sub_wire2	: STD_LOGIC ;
	SIGNAL sub_wire3	: STD_LOGIC_VECTOR (1 DOWNTO 0);
	SIGNAL sub_wire4_bv	: BIT_VECTOR (0 DOWNTO 0);
	SIGNAL sub_wire4	: STD_LOGIC_VECTOR (0 DOWNTO 0);



	COMPONENT altpll
	GENERIC (
		clk0_divide_by		: NATURAL;
		clk0_duty_cycle		: NATURAL;
		clk0_multiply_by		: NATURAL;
		clk0_phase_shift		: STRING;
		compensate_clock		: STRING;
		inclk0_input_frequency		: NATURAL;
```

```
intended_device_family              : STRING;
lpm_hint            : STRING;
lpm_type            : STRING;
operation_mode              : STRING;
port_activeclock            : STRING;
port_areset         : STRING;
port_clkbad0        : STRING;
port_clkbad1        : STRING;
port_clkloss        : STRING;
port_clkswitch      : STRING;
port_configupdate           : STRING;
port_fbin           : STRING;
port_inclk0         : STRING;
port_inclk1         : STRING;
port_locked         : STRING;
port_pfdena         : STRING;
port_phasecounterselect             : STRING;
port_phasedone              : STRING;
port_phasestep              : STRING;
port_phaseupdown            : STRING;
port_pllena         : STRING;
port_scanaclr       : STRING;
port_scanclk        : STRING;
port_scanclkena             : STRING;
port_scandata       : STRING;
port_scandataout            : STRING;
port_scandone               : STRING;
port_scanread       : STRING;
port_scanwrite      : STRING;
port_clk0           : STRING;
port_clk1           : STRING;
port_clk2           : STRING;
port_clk3           : STRING;
port_clk4           : STRING;
port_clk5           : STRING;
port_clkena0        : STRING;
port_clkena1        : STRING;
port_clkena2        : STRING;
port_clkena3        : STRING;
port_clkena4        : STRING;
port_clkena5        : STRING;
port_extclk0        : STRING;
port_extclk1        : STRING;
port_extclk2        : STRING;
```

```
		port_extclk3		: STRING
	);
	PORT (
			inclk	: IN STD_LOGIC_VECTOR (1 DOWNTO 0);
			clk	: OUT STD_LOGIC_VECTOR (5 DOWNTO 0)
	);
	END COMPONENT;

BEGIN
	sub_wire4_bv(0 DOWNTO 0) <= "0";
	sub_wire4	<= To_stdlogicvector(sub_wire4_bv);
	sub_wire1	<= sub_wire0(0);
	c0	<= sub_wire1;
	sub_wire2	<= inclk0;
	sub_wire3	<= sub_wire4(0 DOWNTO 0) & sub_wire2;

	altpll_component : altpll
	GENERIC MAP (
		clk0_divide_by => 2,
		clk0_duty_cycle => 50,
		clk0_multiply_by => 1,
		clk0_phase_shift => "0",
		compensate_clock => "CLK0",
		inclk0_input_frequency => 20000,
		intended_device_family => "Cyclone II",
		lpm_hint => "CBX_MODULE_PREFIX=pll",
		lpm_type => "altpll",
		operation_mode => "NORMAL",
		port_activeclock => "PORT_UNUSED",
		port_areset => "PORT_UNUSED",
		port_clkbad0 => "PORT_UNUSED",
		port_clkbad1 => "PORT_UNUSED",
		port_clkloss => "PORT_UNUSED",
		port_clkswitch => "PORT_UNUSED",
		port_configupdate => "PORT_UNUSED",
		port_fbin => "PORT_UNUSED",
		port_inclk0 => "PORT_USED",
		port_inclk1 => "PORT_UNUSED",
		port_locked => "PORT_UNUSED",
		port_pfdena => "PORT_UNUSED",
		port_phasecounterselect => "PORT_UNUSED",
		port_phasedone => "PORT_UNUSED",
		port_phasestep => "PORT_UNUSED",
		port_phaseupdown => "PORT_UNUSED",
```

```
		port_pllena => "PORT_UNUSED",
		port_scanaclr => "PORT_UNUSED",
		port_scanclk => "PORT_UNUSED",
		port_scanclkena => "PORT_UNUSED",
		port_scandata => "PORT_UNUSED",
		port_scandataout => "PORT_UNUSED",
		port_scandone => "PORT_UNUSED",
		port_scanread => "PORT_UNUSED",
		port_scanwrite => "PORT_UNUSED",
		port_clk0 => "PORT_USED",
		port_clk1 => "PORT_UNUSED",
		port_clk2 => "PORT_UNUSED",
		port_clk3 => "PORT_UNUSED",
		port_clk4 => "PORT_UNUSED",
		port_clk5 => "PORT_UNUSED",
		port_clkena0 => "PORT_UNUSED",
		port_clkena1 => "PORT_UNUSED",
		port_clkena2 => "PORT_UNUSED",
		port_clkena3 => "PORT_UNUSED",
		port_clkena4 => "PORT_UNUSED",
		port_clkena5 => "PORT_UNUSED",
		port_extclk0 => "PORT_UNUSED",
		port_extclk1 => "PORT_UNUSED",
		port_extclk2 => "PORT_UNUSED",
		port_extclk3 => "PORT_UNUSED"
	)
	PORT MAP (
		inclk => sub_wire3,
		clk => sub_wire0
	);



END SYN;

-- ============================================================
-- CNX file retrieval info
-- ============================================================
-- Retrieval info: PRIVATE: ACTIVECLK_CHECK STRING "0"
-- Retrieval info: PRIVATE: BANDWIDTH STRING "1.000"
-- Retrieval info: PRIVATE: BANDWIDTH_FEATURE_ENABLED STRING "0"
-- Retrieval info: PRIVATE: BANDWIDTH_FREQ_UNIT STRING "MHz"
-- Retrieval info: PRIVATE: BANDWIDTH_PRESET STRING "Low"
-- Retrieval info: PRIVATE: BANDWIDTH_USE_AUTO STRING "1"
```

-- Retrieval info: PRIVATE: BANDWIDTH_USE_CUSTOM STRING "0"
-- Retrieval info: PRIVATE: BANDWIDTH_USE_PRESET STRING "0"
-- Retrieval info: PRIVATE: CLKBAD_SWITCHOVER_CHECK STRING "0"
-- Retrieval info: PRIVATE: CLKLOSS_CHECK STRING "0"
-- Retrieval info: PRIVATE: CLKSWITCH_CHECK STRING "1"
-- Retrieval info: PRIVATE: CNX_NO_COMPENSATE_RADIO STRING "0"
-- Retrieval info: PRIVATE: CREATE_CLKBAD_CHECK STRING "0"
-- Retrieval info: PRIVATE: CREATE_INCLK1_CHECK STRING "0"
-- Retrieval info: PRIVATE: CUR_DEDICATED_CLK STRING "c0"
-- Retrieval info: PRIVATE: CUR_FBIN_CLK STRING "e0"
-- Retrieval info: PRIVATE: DEVICE_SPEED_GRADE STRING "6"
-- Retrieval info: PRIVATE: DIV_FACTOR0 NUMERIC "1"
-- Retrieval info: PRIVATE: DUTY_CYCLE0 STRING "50.00000000"
-- Retrieval info: PRIVATE: EXPLICIT_SWITCHOVER_COUNTER STRING "0"
-- Retrieval info: PRIVATE: EXT_FEEDBACK_RADIO STRING "0"
-- Retrieval info: PRIVATE: GLOCKED_COUNTER_EDIT_CHANGED STRING "1"
-- Retrieval info: PRIVATE: GLOCKED_FEATURE_ENABLED STRING "1"
-- Retrieval info: PRIVATE: GLOCKED_MODE_CHECK STRING "0"
-- Retrieval info: PRIVATE: GLOCK_COUNTER_EDIT NUMERIC "1048575"
-- Retrieval info: PRIVATE: HAS_MANUAL_SWITCHOVER STRING "1"
-- Retrieval info: PRIVATE: INCLK0_FREQ_EDIT STRING "50.000"
-- Retrieval info: PRIVATE: INCLK0_FREQ_UNIT_COMBO STRING "MHz"
-- Retrieval info: PRIVATE: INCLK1_FREQ_EDIT STRING "100.000"
-- Retrieval info: PRIVATE: INCLK1_FREQ_EDIT_CHANGED STRING "1"
-- Retrieval info: PRIVATE: INCLK1_FREQ_UNIT_CHANGED STRING "1"
-- Retrieval info: PRIVATE: INCLK1_FREQ_UNIT_COMBO STRING "MHz"
-- Retrieval info: PRIVATE: INTENDED_DEVICE_FAMILY STRING "Cyclone II"
-- Retrieval info: PRIVATE: INT_FEEDBACK__MODE_RADIO STRING "1"
-- Retrieval info: PRIVATE: LOCKED_OUTPUT_CHECK STRING "0"
-- Retrieval info: PRIVATE: LONG_SCAN_RADIO STRING "1"
-- Retrieval info: PRIVATE: LVDS_MODE_DATA_RATE STRING "Not Available"
-- Retrieval info: PRIVATE: LVDS_MODE_DATA_RATE_DIRTY NUMERIC "0"
-- Retrieval info: PRIVATE: LVDS_PHASE_SHIFT_UNIT0 STRING "deg"
-- Retrieval info: PRIVATE: MIRROR_CLK0 STRING "0"
-- Retrieval info: PRIVATE: MULT_FACTOR0 NUMERIC "1"
-- Retrieval info: PRIVATE: NORMAL_MODE_RADIO STRING "1"
-- Retrieval info: PRIVATE: OUTPUT_FREQ0 STRING "25.00000000"
-- Retrieval info: PRIVATE: OUTPUT_FREQ_MODE0 STRING "1"
-- Retrieval info: PRIVATE: OUTPUT_FREQ_UNIT0 STRING "MHz"
-- Retrieval info: PRIVATE: PHASE_RECONFIG_FEATURE_ENABLED STRING "0"
-- Retrieval info: PRIVATE: PHASE_RECONFIG_INPUTS_CHECK STRING "0"
-- Retrieval info: PRIVATE: PHASE_SHIFT0 STRING "0.00000000"
-- Retrieval info: PRIVATE: PHASE_SHIFT_STEP_ENABLED_CHECK STRING "0"
-- Retrieval info: PRIVATE: PHASE_SHIFT_UNIT0 STRING "deg"

-- Retrieval info: PRIVATE: PLL_ADVANCED_PARAM_CHECK STRING "0"
-- Retrieval info: PRIVATE: PLL_ARESET_CHECK STRING "0"
-- Retrieval info: PRIVATE: PLL_AUTOPLL_CHECK NUMERIC "1"
-- Retrieval info: PRIVATE: PLL_ENA_CHECK STRING "0"
-- Retrieval info: PRIVATE: PLL_ENHPLL_CHECK NUMERIC "0"
-- Retrieval info: PRIVATE: PLL_FASTPLL_CHECK NUMERIC "0"
-- Retrieval info: PRIVATE: PLL_FBMIMIC_CHECK STRING "0"
-- Retrieval info: PRIVATE: PLL_LVDS_PLL_CHECK NUMERIC "0"
-- Retrieval info: PRIVATE: PLL_PFDENA_CHECK STRING "0"
-- Retrieval info: PRIVATE: PLL_TARGET_HARCOPY_CHECK NUMERIC "0"
-- Retrieval info: PRIVATE: PRIMARY_CLK_COMBO STRING "inclk0"
-- Retrieval info: PRIVATE: RECONFIG_FILE STRING "pll.mif"
-- Retrieval info: PRIVATE: SACN_INPUTS_CHECK STRING "0"
-- Retrieval info: PRIVATE: SCAN_FEATURE_ENABLED STRING "0"
-- Retrieval info: PRIVATE: SELF_RESET_LOCK_LOSS STRING "0"
-- Retrieval info: PRIVATE: SHORT_SCAN_RADIO STRING "0"
-- Retrieval info: PRIVATE: SPREAD_FEATURE_ENABLED STRING "0"
-- Retrieval info: PRIVATE: SPREAD_FREQ STRING "50.000"
-- Retrieval info: PRIVATE: SPREAD_FREQ_UNIT STRING "KHz"
-- Retrieval info: PRIVATE: SPREAD_PERCENT STRING "0.500"
-- Retrieval info: PRIVATE: SPREAD_USE STRING "0"
-- Retrieval info: PRIVATE: SRC_SYNCH_COMP_RADIO STRING "0"
-- Retrieval info: PRIVATE: STICKY_CLK0 STRING "1"
-- Retrieval info: PRIVATE:
 SWITCHOVER_COUNT_EDIT NUMERIC "1"
-- Retrieval info: PRIVATE: SWITCHOVER_FEATURE_ENABLED STRING "1"
-- Retrieval info: PRIVATE: SYNTH_WRAPPER_GEN_POSTFIX STRING "0"
-- Retrieval info: PRIVATE: USE_CLK0 STRING "1"
-- Retrieval info: PRIVATE: USE_CLKENA0 STRING "0"
-- Retrieval info: PRIVATE: USE_MIL_SPEED_GRADE NUMERIC "0"
-- Retrieval info: PRIVATE: ZERO_DELAY_RADIO STRING "0"
-- Retrieval info: LIBRARY: altera_mf altera_mf.altera_mf_components.all
-- Retrieval info: CONSTANT: CLK0_DIVIDE_BY NUMERIC "2"
-- Retrieval info: CONSTANT: CLK0_DUTY_CYCLE NUMERIC "50"
-- Retrieval info: CONSTANT: CLK0_MULTIPLY_BY NUMERIC "1"
-- Retrieval info: CONSTANT: CLK0_PHASE_SHIFT STRING "0"
-- Retrieval info: CONSTANT: COMPENSATE_CLOCK STRING "CLK0"
-- Retrieval info: CONSTANT: INCLK0_INPUT_FREQUENCY NUMERIC "20000"
-- Retrieval info: CONSTANT: INTENDED_DEVICE_FAMILY STRING "Cyclone II"
-- Retrieval info: CONSTANT: LPM_TYPE STRING "altpll"
-- Retrieval info: CONSTANT: OPERATION_MODE STRING "NORMAL"
-- Retrieval info: CONSTANT: PORT_ACTIVECLOCK STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_ARESET STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_CLKBAD0 STRING "PORT_UNUSED"

-- Retrieval info: CONSTANT: PORT_CLKBAD1 STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_CLKLOSS STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_CLKSWITCH STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_CONFIGUPDATE STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_FBIN STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_INCLK0 STRING "PORT_USED"
-- Retrieval info: CONSTANT: PORT_INCLK1 STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_LOCKED STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_PFDENA STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_PHASECOUNTERSELECT STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_PHASEDONE STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_PHASESTEP STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_PHASEUPDOWN STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_PLLENA STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_SCANACLR STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_SCANCLK STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_SCANCLKENA STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_SCANDATA STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_SCANDATAOUT STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_SCANDONE STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_SCANREAD STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_SCANWRITE STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_clk0 STRING "PORT_USED"
-- Retrieval info: CONSTANT: PORT_clk1 STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_clk2 STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_clk3 STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_clk4 STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_clk5 STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_clkena0 STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_clkena1 STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_clkena2 STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_clkena3 STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_clkena4 STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_clkena5 STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_extclk0 STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_extclk1 STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_extclk2 STRING "PORT_UNUSED"
-- Retrieval info: CONSTANT: PORT_extclk3 STRING "PORT_UNUSED"
-- Retrieval info: USED_PORT: @clk 0 0 6 0 OUTPUT_CLK_EXT VCC "@clk[5..0]"
-- Retrieval info: USED_PORT: @extclk 0 0 4 0 OUTPUT_CLK_EXT VCC "@extclk[3..0]"
-- Retrieval info: USED_PORT: @inclk 0 0 2 0 INPUT_CLK_EXT VCC "@inclk[1..0]"
-- Retrieval info: USED_PORT: c0 0 0 0 0 OUTPUT_CLK_EXT VCC "c0"
-- Retrieval info: USED_PORT: inclk0 0 0 0 0 INPUT_CLK_EXT GND "inclk0"
-- Retrieval info: CONNECT: @inclk 0 0 1 0 inclk0 0 0 0 0

-- Retrieval info: CONNECT: c0 0 0 0 0 @clk 0 0 1 0
-- Retrieval info: CONNECT: @inclk 0 0 1 1 GND 0 0 0 0
-- Retrieval info: GEN_FILE: TYPE_NORMAL pll.vhd TRUE FALSE
-- Retrieval info: GEN_FILE: TYPE_NORMAL pll.ppf TRUE FALSE
-- Retrieval info: GEN_FILE: TYPE_NORMAL pll.inc FALSE FALSE
-- Retrieval info: GEN_FILE: TYPE_NORMAL pll.cmp FALSE FALSE
-- Retrieval info: GEN_FILE: TYPE_NORMAL pll.bsf FALSE FALSE
-- Retrieval info: GEN_FILE: TYPE_NORMAL pll_inst.vhd FALSE FALSE
-- Retrieval info: GEN_FILE: TYPE_NORMAL pll_waveforms.html FALSE FALSE
-- Retrieval info: GEN_FILE: TYPE_NORMAL pll_wave*.jpg FALSE FALSE
-- Retrieval info: LIB_FILE: altera_mf
-- Retrieval info: CBX_MODULE_PREFIX: ON

de2_ps2.vhd

```
--------------------------------------------------------------------
--
-- Simple (receive-only) PS/2 controller for the Altera Avalon bus
--
-- Presents a two-word interface:
--
-- Byte 0: LSB is a status bit: 1 = data received, 0 = no new data
-- Byte 4: least significant byte is received data,
--         reading it clears the input register
--
-- Make sure "Slave addressing" in the interfaces tab of SOPC Builder's
-- "New Component" dialog is set to "Register" mode.
--
--
-- Stephen A. Edwards and Yingjian Gu
-- Columbia University, sedwards@cs.columbia.edu
--
-- From an original by Bert Cuzeau
-- (c) ALSE. http://www.alse-fr.com
--
--------------------------------------------------------------------

-- ----------------------------------------------
--   Simplified PS/2 Controller  (kbd, mouse...)
-- ----------------------------------------------
-- Only the Receive function is implemented !
-- (c) ALSE. http://www.alse-fr.com
-- Author : Bert Cuzeau.
-- Fully synchronous solution, same Filter on PS2_Clk.
```

```
-- Still as compact as "Plain_wrong"...
-- Possible improvement : add TIMEOUT on PS2_Clk while shifting
-- Note: PS2_Data is resynchronized though this should not be
-- necessary (qualified by Fall_Clk and does not change at that time).
-- Note the tricks to correctly interpret 'H' as '1' in RTL simulation.

library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;

entity PS2_Ctrl is
  port(
    Clk       : in  std_logic;  -- System Clock
    Reset     : in  std_logic;  -- System Reset
    PS2_Clk   : in  std_logic;  -- Keyboard Clock Line
    PS2_Data  : in  std_logic;  -- Keyboard Data Line
    DoRead    : in  std_logic;  -- From outside when reading the scan code
    Scan_Err  : out std_logic;  -- To outside : Parity or Overflow error
    Scan_DAV  : out std_logic;  -- To outside when a scan code has arrived
    Scan_Code : out unsigned(7 downto 0) -- Eight bits Data Out
    );
end PS2_Ctrl;

architecture rtl of PS2_Ctrl is

  signal PS2_Datr  : std_logic;

  subtype Filter_t is unsigned(7 downto 0);
  signal Filter    : Filter_t;
  signal Fall_Clk  : std_logic;
  signal Bit_Cnt   : unsigned (3 downto 0);
  signal Parity    : std_logic;
  signal Scan_DAVi : std_logic;

  signal S_Reg     : unsigned(8 downto 0);

  signal PS2_Clk_f : std_logic;

  Type   State_t is (Idle, Shifting);
  signal State : State_t;

begin

  Scan_DAV <= Scan_DAVi;
```

```
-- This filters digitally the raw clock signal coming from the keyboard :
--  * Eight consecutive PS2_Clk=1 makes the filtered_clock go high
--  * Eight consecutive PS2_Clk=0 makes the filtered_clock go low
-- Implies a (FilterSize+1) x Tsys_clock delay on Fall_Clk wrt Data
-- Also in charge of the re-synchronization of PS2_Data

  process (Clk)
  begin
    if rising_edge(Clk) then
      if Reset = '1' then
        PS2_Datr  <= '0';
        PS2_Clk_f <= '0';
        Filter    <= (others => '0');
        Fall_Clk  <= '0';
      else
        PS2_Datr <= PS2_Data and PS2_Data; -- also turns 'H' into '1'
        Fall_Clk <= '0';
        Filter   <= (PS2_Clk and PS2_CLK) & Filter(Filter'high downto 1);
        if Filter = Filter_t'(others=>'1') then
          PS2_Clk_f <= '1';
        elsif Filter = Filter_t'(others=>'0') then
          PS2_Clk_f <= '0';
          if PS2_Clk_f = '1' then
            Fall_Clk <= '1';
          end if;
        end if;
      end if;
    end if;
  end process;

-- This simple State Machine reads in the Serial Data
-- coming from the PS/2 peripheral.

  process(Clk)
  begin
    if rising_edge(Clk) then
      if Reset = '1' then
        State     <= Idle;
        Bit_Cnt   <= (others => '0');
        S_Reg     <= (others => '0');
        Scan_Code <= (others => '0');
        Parity    <= '0';
        Scan_DAVi <= '0';
```

```
    Scan_Err  <= '0';
  else

    if DoRead = '1' then
      Scan_DAVi <= '0'; -- note: this assgnmnt can be overriden
    end if;

    case State is

      when Idle =>
        Parity  <= '0';
        Bit_Cnt <= (others => '0');
        -- note that we do not need to clear the Shift Register
        if Fall_Clk='1' and PS2_Datr='0' then -- Start bit
          Scan_Err <= '0';
          State <= Shifting;
        end if;

      when Shifting =>
        if Bit_Cnt >= 9 then
          if Fall_Clk = '1' then -- Stop Bit
            -- Error is (wrong Parity) or (Stop='0') or Overflow
            Scan_Err  <= (not Parity) or (not PS2_Datr) or Scan_DAVi;
            Scan_Davi <= '1';
            Scan_Code <= S_Reg(7 downto 0);
            State <= Idle;
          end if;
        elsif Fall_Clk = '1' then
          Bit_Cnt <= Bit_Cnt + 1;
          S_Reg <= PS2_Datr & S_Reg (S_Reg'high downto 1); -- Shift right
          Parity <= Parity xor PS2_Datr;
        end if;

      when others => -- never reached
        State <= Idle;

    end case;

    --Scan_Err <= '0'; -- to create a deliberate error

  end if;

end if;
```

```
  end process;

end rtl;

--------------------------------------------------------------------------------

library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;

entity de2_ps2 is

  port (
    avs_s1_clk        : in std_logic;
    avs_s1_reset      : in std_logic;
    avs_s1_address    : in unsigned(0 downto 0);
    avs_s1_read       : in std_logic;
    avs_s1_chipselect : in std_logic;
    avs_s1_readdata   : out unsigned(7 downto 0);

    PS2_Clk           : in std_logic;
    PS2_Data          : in std_logic
    );
end de2_ps2;

architecture rtl of de2_ps2 is

  signal Data          : unsigned(7 downto 0);
  signal DataAvailable : std_logic;
  signal DoRead        : std_logic;

begin

  U1: entity work.PS2_CTRL port map(
    Clk       => avs_s1_clk,
    Reset     => avs_s1_reset,
    DoRead    => DoRead,
    PS2_Clk   => PS2_Clk,
    PS2_Data  => PS2_Data,
    Scan_Code => Data,
    Scan_DAV  => DataAvailable );

  process (avs_s1_clk)
  begin
```

```
  if rising_edge(avs_s1_clk) then
    DoRead <= avs_s1_read and avs_s1_chipselect and avs_s1_address(0);
  end if;
end process;

process (Data, DataAvailable, avs_s1_address, avs_s1_chipselect)
begin
  if avs_s1_chipselect = '1' then
    if avs_s1_address(0) = '1' then
      avs_s1_readdata <= Data;
    else
      avs_s1_readdata <= "0000000" & DataAvailable;
    end if;
  else
    avs_s1_readdata <= "00000000";
  end if;
end process;

end rtl;
```

DM9000A_IF.v

```
module DM9000A_IF(//        HOST Side
                              iDATA,oDATA,iCMD,
                              iRD_N,iWR_N,
                              iCS_N,iRST_N,
                              oINT,
                              //        DM9000A Side
                              ENET_DATA,ENET_CMD,
                              ENET_RD_N,ENET_WR_N,
                              ENET_CS_N,ENET_RST_N,
                              ENET_INT
                              );
//        HOST Side
input   [15:0]  iDATA;
input           iCMD;
input           iRD_N;
input           iWR_N;
input           iCS_N;
input           iRST_N;
output  [15:0]  oDATA;
output          oINT;
//        DM9000A Side
inout   [15:0]  ENET_DATA;
```

```
output          ENET_CMD;
output          ENET_RD_N;
output          ENET_WR_N;
output          ENET_CS_N;
output          ENET_RST_N;
input           ENET_INT;

assign ENET_DATA  =     ENET_WR_N ?     16'hzzzz     :     iDATA ;
assign oDATA      =     ENET_DATA  ;

assign ENET_CMD   =     iCMD;
assign ENET_RD_N  =     iRD_N;
assign ENET_WR_N  =     iWR_N;
assign ENET_CS_N  =     iCS_N;
assign ENET_RST_N=      iRST_N;
assign oINT       =     ENET_INT;

endmodule
```

YcbCr2RGB.v

```
// --------------------------------------------------------------------
// Copyright (c) 2005 by Terasic Technologies Inc.
// --------------------------------------------------------------------
//
// Permission:
//
//   Terasic grants permission to use and modify this code for use
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//
// Disclaimer:
//
//   This VHDL/Verilog or C/C++ source code is intended as a design reference
//   which illustrates how these types of functions can be implemented.
//   It is the user's responsibility to verify their design for
//   consistency and functionality through the use of formal
//   verification methods.  Terasic provides no warranty regarding the use
//   or functionality of this code.
//
// --------------------------------------------------------------------
//
//                     Terasic Technologies Inc
```

```
//                  356 Fu-Shin E. Rd Sec. 1. JhuBei City,
//                  HsinChu County, Taiwan
//                  302
//
//                  web: http://www.terasic.com/
//                  email: support@terasic.com
//
// ---------------------------------------------------------------------
//
// Major Functions:     YCbCr to RGB Color Doamin Converter.
//                                          ( 10 Bits Resolution )
//
// ---------------------------------------------------------------------
//
// Revision History :
// ---------------------------------------------------------------------
//   Ver  :| Author           :| Mod. Date :| Changes Made:
//   V1.0 :| Johnny Chen      :| 05/09/05  :|      Initial Revision
// ---------------------------------------------------------------------

module YCbCr2RGB (          Red,Green,Blue,oDVAL,
                                    iY,iCb,iCr,iDVAL,
                                    iRESET,iCLK);
//        Input
input [7:0] iY,iCb,iCr;
input iDVAL,iRESET,iCLK;
//        Output
output [9:0] Red,Green,Blue;
output reg      oDVAL;
//        Internal Registers/Wires
reg [9:0] oRed,oGreen,oBlue;
reg      [3:0] oDVAL_d;
reg [11:0] X_OUT,Y_OUT,Z_OUT;
wire [27:0] X,Y,Z;

assign Red  = oRed;
assign Green=          oGreen;
assign Blue =  oBlue;

reg [9:0] redram1[0:639];     // 639 memory cells that are 10 bits wide
reg [9:0] redram2[0:639];     // 639 memory cells that are 10 bits wide
reg [9:0] redram3[0:639];     // 639 memory cells that are 10 bits wide
integer count = 0;
```

```
always@(posedge iCLK)
begin
	count <= count + 1;
	if(count > 639) count <= 0;
	if(iRESET)
	begin
		oDVAL<=0;
		oDVAL_d<=0;
		oRed<=0;
		oGreen<=0;
		oBlue<=0;
	end
	else
	begin
		// Red
		if(X_OUT[11])
		oRed<=0;
		else if(X_OUT[10:0]>1023)
		oRed<=1023;
		else
		oRed<=X_OUT[9:0];
		// Green
		if(Y_OUT[11])
		oGreen<=0;
		else if(Y_OUT[10:0]>1023)
		oGreen<=1023;
		else
		oGreen<=Y_OUT[9:0];
		// Blue
		if(Z_OUT[11])
		oBlue<=0;
		else if(Z_OUT[10:0]>1023)
		oBlue<=1023;
		else
		oBlue<= Z_OUT[9:0];
		// Control
		{oDVAL,oDVAL_d}<={oDVAL_d,iDVAL};
	end
end

always@(posedge iCLK)
begin
```

```
        if(iRESET)
        begin
                X_OUT<=0;
                Y_OUT<=0;
                Z_OUT<=0;
        end
        else
        begin
                X_OUT<=( ( X - 105555 ) >>7 ) + 1;
                Y_OUT<=( ( Y + 64218  ) >>7 ) + 1;
                Z_OUT<=( ( Z - 131072 ) >>7 ) + 1;
        end
end

//      Y               551,            0,                      756
MAC_3 u0(     iY,                       iCb,            iCr,
                        18'h00227,      18'h00000,      18'h002F4,
                        X,              iRESET,                 iCLK);
//      Cb              551,            -186,           -385
MAC_3 u1(     iY,                       iCb,            iCr,
                        18'h00227,      18'h3FF46,      18'h3FE7F,
                        Y,              iRESET,                 iCLK);
//      Cr              551,            955,            0
MAC_3 u2(     iY,                       iCb,            iCr,
                        18'h00227,      18'h003BB,      18'h00000,
                        Z,              iRESET,                 iCLK);

endmodule
```

ram2.v

```
// megafunction wizard: %LPM_RAM_DP+%
// GENERATION: STANDARD
// VERSION: WM1.0
// MODULE: altsyncram

// ============================================================
// File Name: RAM2.v
// Megafunction Name(s):
//                      altsyncram
// ============================================================
// ************************************************************
// THIS IS A WIZARD-GENERATED FILE. DO NOT EDIT THIS FILE!
//
```

```
// 5.0 Build 148 04/26/2005 SJ Full Version
// ********************************************************


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// synopsys translate_off
`timescale 1 ps / 1 ps
// synopsys translate_on
module RAM2 (
	data_a,
	wren_a,
	address_a,
	data_b,
	address_b,
	wren_b,
	clock_a,
	clock_b,
	q_a,
	q_b);

	input	[7:0]  data_a;
	input	  wren_a;
	input	[9:0]  address_a;
	input	[7:0]  data_b;
	input	[9:0]  address_b;
	input	  wren_b;
	input	  clock_a;
	input	  clock_b;
	output  [7:0]  q_a;
	output  [7:0]  q_b;
```

```
wire [7:0] sub_wire0;
wire [7:0] sub_wire1;
wire [7:0] q_a = sub_wire0[7:0];
wire [7:0] q_b = sub_wire1[7:0];

altsyncram	altsyncram_component (
				.wren_a (wren_a),
				.clock0 (clock_a),
				.wren_b (wren_b),
				.clock1 (clock_b),
				.address_a (address_a),
				.address_b (address_b),
				.data_a (data_a),
				.data_b (data_b),
				.q_a (sub_wire0),
				.q_b (sub_wire1)
				// synopsys translate_off
				,
				.aclr0 (),
				.aclr1 (),
				.addressstall_a (),
				.addressstall_b (),
				.byteena_a (),
				.byteena_b (),
				.clocken0 (),
				.clocken1 (),
				.rden_b ()
				// synopsys translate_on
				);
defparam
	altsyncram_component.intended_device_family = "Cyclone II",
	altsyncram_component.operation_mode = "BIDIR_DUAL_PORT",
	altsyncram_component.width_a = 8,
	altsyncram_component.widthad_a = 10,
	altsyncram_component.numwords_a = 1024,
	altsyncram_component.width_b = 8,
	altsyncram_component.widthad_b = 10,
	altsyncram_component.numwords_b = 1024,
	altsyncram_component.lpm_type = "altsyncram",
	altsyncram_component.width_byteena_a = 1,
	altsyncram_component.width_byteena_b = 1,
	altsyncram_component.outdata_reg_a = "UNREGISTERED",
	altsyncram_component.outdata_aclr_a = "NONE",
```

```
                altsyncram_component.outdata_reg_b = "UNREGISTERED",
                altsyncram_component.indata_reg_b = "CLOCK1",
                altsyncram_component.address_reg_b = "CLOCK1",
                altsyncram_component.wrcontrol_wraddress_reg_b = "CLOCK1",
                altsyncram_component.outdata_aclr_b = "NONE",
                altsyncram_component.clock_enable_input_a = "BYPASS",
                altsyncram_component.clock_enable_output_a = "BYPASS",
                altsyncram_component.clock_enable_input_b = "BYPASS",
                altsyncram_component.clock_enable_output_b = "BYPASS",
                altsyncram_component.power_up_uninitialized = "FALSE";


endmodule

// ============================================================
// CNX file retrieval info
// ============================================================
// Retrieval info: PRIVATE: MEM_IN_BITS NUMERIC "0"
// Retrieval info: PRIVATE: OPERATION_MODE NUMERIC "3"
// Retrieval info: PRIVATE: UseDPRAM NUMERIC "1"
// Retrieval info: PRIVATE: VarWidth NUMERIC "1"
// Retrieval info: PRIVATE: WIDTH_WRITE_A NUMERIC "8"
// Retrieval info: PRIVATE: WIDTH_WRITE_B NUMERIC "8"
// Retrieval info: PRIVATE: WIDTH_READ_A NUMERIC "8"
// Retrieval info: PRIVATE: WIDTH_READ_B NUMERIC "8"
// Retrieval info: PRIVATE: MEMSIZE NUMERIC "8192"
// Retrieval info: PRIVATE: RAM_BLOCK_TYPE NUMERIC "0"
// Retrieval info: PRIVATE: MAXIMUM_DEPTH NUMERIC "0"
// Retrieval info: PRIVATE: IMPLEMENT_IN_LES NUMERIC "0"
// Retrieval info: PRIVATE: Clock NUMERIC "5"
// Retrieval info: PRIVATE: rden NUMERIC "0"
// Retrieval info: PRIVATE: BYTE_ENABLE_A NUMERIC "0"
// Retrieval info: PRIVATE: BYTE_ENABLE_B NUMERIC "0"
// Retrieval info: PRIVATE: BYTE_SIZE NUMERIC "8"
// Retrieval info: PRIVATE: Clock_A NUMERIC "0"
// Retrieval info: PRIVATE: Clock_B NUMERIC "0"
// Retrieval info: PRIVATE: REGdata NUMERIC "1"
// Retrieval info: PRIVATE: REGwraddress NUMERIC "1"
// Retrieval info: PRIVATE: REGwren NUMERIC "1"
// Retrieval info: PRIVATE: REGrdaddress NUMERIC "0"
// Retrieval info: PRIVATE: REGrren NUMERIC "0"
// Retrieval info: PRIVATE: REGq NUMERIC "0"
// Retrieval info: PRIVATE: INDATA_REG_B NUMERIC "1"
// Retrieval info: PRIVATE: WRADDR_REG_B NUMERIC "1"
```

// Retrieval info: PRIVATE: OUTDATA_REG_B NUMERIC "0"
// Retrieval info: PRIVATE: CLRdata NUMERIC "0"
// Retrieval info: PRIVATE: CLRwren NUMERIC "0"
// Retrieval info: PRIVATE: CLRwraddress NUMERIC "0"
// Retrieval info: PRIVATE: CLRrdaddress NUMERIC "0"
// Retrieval info: PRIVATE: CLRrren NUMERIC "0"
// Retrieval info: PRIVATE: CLRq NUMERIC "0"
// Retrieval info: PRIVATE: BYTEENA_ACLR_A NUMERIC "0"
// Retrieval info: PRIVATE: INDATA_ACLR_B NUMERIC "0"
// Retrieval info: PRIVATE: WRCTRL_ACLR_B NUMERIC "0"
// Retrieval info: PRIVATE: WRADDR_ACLR_B NUMERIC "0"
// Retrieval info: PRIVATE: OUTDATA_ACLR_B NUMERIC "0"
// Retrieval info: PRIVATE: BYTEENA_ACLR_B NUMERIC "0"
// Retrieval info: PRIVATE: enable NUMERIC "0"
// Retrieval info: PRIVATE: CLOCK_ENABLE_INPUT_A NUMERIC "0"
// Retrieval info: PRIVATE: CLOCK_ENABLE_OUTPUT_A NUMERIC "0"
// Retrieval info: PRIVATE: CLOCK_ENABLE_INPUT_B NUMERIC "0"
// Retrieval info: PRIVATE: CLOCK_ENABLE_OUTPUT_B NUMERIC "0"
// Retrieval info: PRIVATE: ADDRESSSTALL_A NUMERIC "0"
// Retrieval info: PRIVATE: ADDRESSSTALL_B NUMERIC "0"
// Retrieval info: PRIVATE: READ_DURING_WRITE_MODE_MIXED_PORTS NUMERIC "2"
// Retrieval info: PRIVATE: INIT_TO_SIM_X NUMERIC "0"
// Retrieval info: PRIVATE: BlankMemory NUMERIC "1"
// Retrieval info: PRIVATE: MIFfilename STRING ""
// Retrieval info: PRIVATE: INIT_FILE_LAYOUT STRING "PORT_A"
// Retrieval info: PRIVATE: JTAG_ENABLED NUMERIC "0"
// Retrieval info: PRIVATE: JTAG_ID STRING "NONE"
// Retrieval info: PRIVATE: INTENDED_DEVICE_FAMILY STRING "Cyclone II"
// Retrieval info: CONSTANT: INTENDED_DEVICE_FAMILY STRING "Cyclone II"
// Retrieval info: CONSTANT: OPERATION_MODE STRING "BIDIR_DUAL_PORT"
// Retrieval info: CONSTANT: WIDTH_A NUMERIC "8"
// Retrieval info: CONSTANT: WIDTHAD_A NUMERIC "10"
// Retrieval info: CONSTANT: NUMWORDS_A NUMERIC "1024"
// Retrieval info: CONSTANT: WIDTH_B NUMERIC "8"
// Retrieval info: CONSTANT: WIDTHAD_B NUMERIC "10"
// Retrieval info: CONSTANT: NUMWORDS_B NUMERIC "1024"
// Retrieval info: CONSTANT: LPM_TYPE STRING "altsyncram"
// Retrieval info: CONSTANT: WIDTH_BYTEENA_A NUMERIC "1"
// Retrieval info: CONSTANT: WIDTH_BYTEENA_B NUMERIC "1"
// Retrieval info: CONSTANT: OUTDATA_REG_A STRING "UNREGISTERED"
// Retrieval info: CONSTANT: OUTDATA_ACLR_A STRING "NONE"
// Retrieval info: CONSTANT: OUTDATA_REG_B STRING "UNREGISTERED"
// Retrieval info: CONSTANT: INDATA_REG_B STRING "CLOCK1"
// Retrieval info: CONSTANT: ADDRESS_REG_B STRING "CLOCK1"

```
// Retrieval info: CONSTANT: WRCONTROL_WRADDRESS_REG_B STRING "CLOCK1"
// Retrieval info: CONSTANT: OUTDATA_ACLR_B STRING "NONE"
// Retrieval info: CONSTANT: CLOCK_ENABLE_INPUT_A STRING "BYPASS"
// Retrieval info: CONSTANT: CLOCK_ENABLE_OUTPUT_A STRING "BYPASS"
// Retrieval info: CONSTANT: CLOCK_ENABLE_INPUT_B STRING "BYPASS"
// Retrieval info: CONSTANT: CLOCK_ENABLE_OUTPUT_B STRING "BYPASS"
// Retrieval info: CONSTANT: POWER_UP_UNINITIALIZED STRING "FALSE"
// Retrieval info: USED_PORT: data_a 0 0 8 0 INPUT NODEFVAL data_a[7..0]
// Retrieval info: USED_PORT: wren_a 0 0 0 0 INPUT VCC wren_a
// Retrieval info: USED_PORT: q_a 0 0 8 0 OUTPUT NODEFVAL q_a[7..0]
// Retrieval info: USED_PORT: q_b 0 0 8 0 OUTPUT NODEFVAL q_b[7..0]
// Retrieval info: USED_PORT: address_a 0 0 10 0 INPUT NODEFVAL address_a[9..0]
// Retrieval info: USED_PORT: data_b 0 0 8 0 INPUT NODEFVAL data_b[7..0]
// Retrieval info: USED_PORT: address_b 0 0 10 0 INPUT NODEFVAL address_b[9..0]
// Retrieval info: USED_PORT: wren_b 0 0 0 0 INPUT VCC wren_b
// Retrieval info: USED_PORT: clock_a 0 0 0 0 INPUT NODEFVAL clock_a
// Retrieval info: USED_PORT: clock_b 0 0 0 0 INPUT NODEFVAL clock_b
// Retrieval info: CONNECT: @data_a 0 0 8 0 data_a 0 0 8 0
// Retrieval info: CONNECT: @wren_a 0 0 0 0 wren_a 0 0 0 0
// Retrieval info: CONNECT: q_a 0 0 8 0 @q_a 0 0 8 0
// Retrieval info: CONNECT: q_b 0 0 8 0 @q_b 0 0 8 0
// Retrieval info: CONNECT: @address_a 0 0 10 0 address_a 0 0 10 0
// Retrieval info: CONNECT: @data_b 0 0 8 0 data_b 0 0 8 0
// Retrieval info: CONNECT: @address_b 0 0 10 0 address_b 0 0 10 0
// Retrieval info: CONNECT: @wren_b 0 0 0 0 wren_b 0 0 0 0
// Retrieval info: CONNECT: @clock0 0 0 0 0 clock_a 0 0 0 0
// Retrieval info: CONNECT: @clock1 0 0 0 0 clock_b 0 0 0 0
// Retrieval info: LIBRARY: altera_mf altera_mf.altera_mf_components.all
// Retrieval info: GEN_FILE: TYPE_NORMAL RAM2.v TRUE
// Retrieval info: GEN_FILE: TYPE_NORMAL RAM2.inc TRUE
// Retrieval info: GEN_FILE: TYPE_NORMAL RAM2.cmp TRUE
// Retrieval info: GEN_FILE: TYPE_NORMAL RAM2.bsf TRUE
// Retrieval info: GEN_FILE: TYPE_NORMAL RAM2_inst.v TRUE
// Retrieval info: GEN_FILE: TYPE_NORMAL RAM2_bb.v TRUE
```

MAC_3.v

```
module MAC_3 (      iDA_0,iDA_1,iDA_2,
                        iPA_0,iPA_1,iPA_2,
                        oDATA,iRESET,iCLK);

        input   [7:0] iDA_0,iDA_1,iDA_2;
        input   [17:0] iPA_2,iPA_1,iPA_0;
```

```
output  [27:0] oDATA;
input   iRESET,iCLK;

altmult_add     ALTMULT_ADD_component (
                        .dataa ({iDA_2,iDA_1,iDA_0}),
                        .datab ({iPA_2,iPA_1,iPA_0}),
                        .clock0 (iCLK),
                        .aclr3 (iRESET),
                        .result (oDATA)
                        );
defparam
        ALTMULT_ADD_component.input_register_b2 = "CLOCK0",
        ALTMULT_ADD_component.input_register_a1 = "CLOCK0",
        ALTMULT_ADD_component.multiplier_register0 = "CLOCK0",
        ALTMULT_ADD_component.signed_pipeline_aclr_b = "ACLR3",
        ALTMULT_ADD_component.input_register_a2 = "CLOCK0",
        ALTMULT_ADD_component.multiplier_register1 = "CLOCK0",
        ALTMULT_ADD_component.addnsub_multiplier_pipeline_aclr1 = "ACLR3",
        ALTMULT_ADD_component.multiplier_register2 = "CLOCK0",
        ALTMULT_ADD_component.signed_register_a = "UNREGISTERED",
        ALTMULT_ADD_component.number_of_multipliers = 3,
        ALTMULT_ADD_component.multiplier_aclr0 = "ACLR3",
        ALTMULT_ADD_component.signed_register_b = "UNREGISTERED",
        ALTMULT_ADD_component.lpm_type = "altmult_add",
        ALTMULT_ADD_component.multiplier_aclr1 = "ACLR3",
        ALTMULT_ADD_component.input_aclr_b0 = "ACLR3",
        ALTMULT_ADD_component.output_register = "CLOCK0",
        ALTMULT_ADD_component.width_result = 28,
        ALTMULT_ADD_component.representation_a = "UNSIGNED",
        ALTMULT_ADD_component.signed_pipeline_register_a = "CLOCK0",
        ALTMULT_ADD_component.input_source_b0 = "DATAB",
        ALTMULT_ADD_component.multiplier_aclr2 = "ACLR3",
        ALTMULT_ADD_component.input_aclr_b1 = "ACLR3",
        ALTMULT_ADD_component.input_aclr_a0 = "ACLR3",
        ALTMULT_ADD_component.addnsub_multiplier_register1 = "UNREGISTERED",
        ALTMULT_ADD_component.representation_b = "SIGNED",
        ALTMULT_ADD_component.signed_pipeline_register_b = "CLOCK0",
        ALTMULT_ADD_component.input_source_b1 = "DATAB",
        ALTMULT_ADD_component.input_source_a0 = "DATAA",
        ALTMULT_ADD_component.input_aclr_b2 = "ACLR3",
        ALTMULT_ADD_component.input_aclr_a1 = "ACLR3",
//      ALTMULT_ADD_component.dedicated_multiplier_circuitry = "AUTO",
        ALTMULT_ADD_component.dedicated_multiplier_circuitry = "NO",
        ALTMULT_ADD_component.input_source_b2 = "DATAB",
```

```
                ALTMULT_ADD_component.input_source_a1 = "DATAA",
                ALTMULT_ADD_component.input_aclr_a2 = "ACLR3",
                ALTMULT_ADD_component.output_aclr = "ACLR3",
                ALTMULT_ADD_component.input_source_a2 = "DATAA",
                ALTMULT_ADD_component.intended_device_family = "Stratix II",
                ALTMULT_ADD_component.addnsub_multiplier_pipeline_register1 = "CLOCK0",
                ALTMULT_ADD_component.width_a = 8,
                ALTMULT_ADD_component.input_register_b0 = "CLOCK0",
                ALTMULT_ADD_component.width_b = 18,
                ALTMULT_ADD_component.input_register_b1 = "CLOCK0",
                ALTMULT_ADD_component.input_register_a0 = "CLOCK0",
                ALTMULT_ADD_component.multiplier1_direction = "ADD",
                ALTMULT_ADD_component.signed_pipeline_aclr_a = "ACLR3";

endmodule
```

itu_r656_decoder.v

```
        //*********************************************************************************************
   //*  COMPANY    :  TERASIC.  www.terasic.com  (c) 2005 all rights reserved.              *
   //*  NAME       :  ITU-R BT.656 YCrCb 4:2:2 DECODER
*
   //*  Created    :  7/5/2005                                                              *
   //*  Author     :  Joe Yang                                                              *
   //*********************************************************************************************

`define sync 8'd101
module itu_r656_decoder
(
        CLOCK,   //system clock
        TD_D,    //4:2:2 video data stream
        TD_HS,   //Decoder_hs
        TD_VS,   //Decoder_vs

        Y,       //4:4:4 Y
        Cb,      //4:4:4 Cb
        Cr,      //4:4:4 Cr

        Ypix_clock, //Y pixel clock
   HSx2,
        VSx1,
        Y_check,
        START,
        COUNTER,
```

```
        R,G,B,
        h_tr,
        SW0,SW1,
        blank
);
        input CLOCK;
        input [7:0]TD_D;
        input TD_HS;
        input TD_VS;
    input SW0;
    input SW1;

        output [7:0]Y;
        output [7:0]Cb;
        output [7:0]Cr;

    output HSx2;
        output VSx1;
        output Ypix_clock;


//test
        output Y_check;
        output START;
        output [1:0]COUNTER;


        output [9:0]R;
        output [9:0]G;
        output [9:0]B;
    output h_tr;
    output blank;

        reg [7:0]YY;
        reg [7:0]CCb,Cbb;
        reg [7:0]CCr,Crr;

    reg  HSx2 ;//TD_HS;
        wire VSx1=TD_VS;

        reg[7:0]R1,R2,R3;
        reg[7:0]RR1,RR2,RR3;

        wire [7:0]cr={2'b0,Cr[6:1]};
```

```
        wire [7:0]cb={3'b0,Cb[6:2]};

        wire [7:0]Rr=(Y-16)-{1'b0,Cr[7:0]};
        wire [7:0]Gg= 8'b00000000;  //(Y-16)-cr -cb;
        wire [7:0]Bb=(Y-16)-{1'b0,Cb[7:0]};

    wire [9:0]R={Rr,2'b00};
    wire [9:0]G={Gg,2'b00};
    wire [9:0]B={Bb,2'b00};

//
        wire  Y_check=( (R3==8'hff) && (R2==8'h00) && (R1==8'h00) )?1:0;
        always @(posedge CLOCK) begin
          RR1=TD_D;
          RR2=R1;
          RR3=R2;
        end

        always @(negedge CLOCK) begin
           R1=RR1;
           R2=RR2;
           R3=RR3;
        end

        reg START,Field;
        always @(posedge CLOCK) begin
        if (Y_check==1)
        begin
           START=~TD_D[4];
                Field= TD_D[6];
        end
        end

        reg [1:0]COUNTER;
        always @(posedge CLOCK) begin
                if (!START)
                  COUNTER=0;
                        else COUNTER=COUNTER+1;
    end

    reg Ypix_clock;
        always @(posedge CLOCK) begin
                case (COUNTER)
                        0:begin Cbb=TD_D;               Ypix_clock =0;end
```

```
                        1:begin YY  =TD_D;CCr=Crr;CCb=Cbb; Ypix_clock =1;end
                        2:begin Crr=TD_D;                  Ypix_clock =0;end
                        3:begin YY  =TD_D;CCr=Crr;CCb=Cbb; Ypix_clock =1;end
      endcase
   end



reg [10:0]H_COUNTER;
reg [10:0]RH_COUNTER;
        always @(posedge CLOCK) begin
                if (TD_HS) H_COUNTER=0;
                        else H_COUNTER=H_COUNTER+1;
   end

        always @(posedge TD_HS) begin
                RH_COUNTER=H_COUNTER;
   end

   always @(posedge CLOCK) begin
                if (
                        ((H_COUNTER >= 0) && (H_COUNTER < `sync)) ||
                   ((H_COUNTER >= RH_COUNTER[10:1]) && (H_COUNTER <
(RH_COUNTER[10:1]+`sync+1)))
                        )
                HSx2=0;
                else
                HSx2=1;
   end

        reg [10:0]h;
        reg h_tr;
        reg h_tr_h;

 always @(posedge CLOCK) begin
   if(!HSx2) h=0;
                else
                h=h+1;
   end

  always @(posedge CLOCK) begin
    if ((h< 51) || (h > 771))
                h_tr=0;
                else
```

```
                h_tr=1;
  end
  always @(posedge CLOCK) begin
   if ((h< 41) || (h > 781))
                h_tr_h=0;
                else
                h_tr_h=1;
  end


wire  [7:0]Yw,YYw;
wire  [7:0]Cwr,CCwr;
wire  [7:0]Cwb,CCwb;

reg [10:0]pcounter_h;
reg [10:0]pcounter_v;

always @(posedge CLOCK) begin
if (!h_tr) pcounter_h=0;
else pcounter_h=pcounter_h+1;
end

always @(posedge h_tr) begin
if (!TD_VS) pcounter_v=0;
else pcounter_v=pcounter_v+1;
end

wire t=(
//              ((pcounter_h >=0) && (pcounter_h < 45)  && (pcounter_v[9:5]==5'b00000)) ||
                ((pcounter_h >=0) && (pcounter_h < 90)  && (pcounter_v[9:5]==5'b00001)) ||
                ((pcounter_h >=0) && (pcounter_h < 135) && (pcounter_v[9:5]==5'b00010)) ||
                ((pcounter_h >=0) && (pcounter_h < 180) && (pcounter_v[9:5]==5'b00011)) ||
                ((pcounter_h >=0) && (pcounter_h < 225) && (pcounter_v[9:5]==5'b00100)) ||
                ((pcounter_h >=0) && (pcounter_h < 270) && (pcounter_v[9:5]==5'b00101)) ||
                ((pcounter_h >=0) && (pcounter_h < 315) && (pcounter_v[9:5]==5'b00110)) ||
                //((pcounter_h >=0) && (pcounter_h < 360) && (pcounter_v[9:5]==5'b00111)) ||
                ((pcounter_h >=0) && (pcounter_h < 405) && (pcounter_v[9:5]==5'b01000)) ||
                ((pcounter_h >=0) && (pcounter_h < 450) && (pcounter_v[9:5]==5'b01001)) ||
                ((pcounter_h >=0) && (pcounter_h < 495) && (pcounter_v[9:5]==5'b01010)) ||
                ((pcounter_h >=0) && (pcounter_h < 540) && (pcounter_v[9:5]==5'b01011)) ||
                ((pcounter_h >=0) && (pcounter_h < 585) && (pcounter_v[9:5]==5'b01100)) ||
//              ((pcounter_h >=0) && (pcounter_h < 630) && (pcounter_v[9:5]==5'b01101)) ||
                ((pcounter_h >=0) && (pcounter_h < 675) && (pcounter_v[9:5]==5'b01110)) ||
```

```
                ((pcounter_h >=0) && (pcounter_h < 720) && (pcounter_v[9:5]==5'b01111))

                )?1:0;
wire [7:0]ym= t? 8'hff:8'h80;
wire [7:0]crm=t? 8'h80:8'h80;
wire [7:0]cbm=t? 8'h80:8'h80;

assign YYw  =((h_tr==1) && (VSx1==1))?Yw : 8'h10;//current set
assign CCwr =((h_tr==1) && (VSx1==1))?Cwr: 8'h80;
assign CCwb =((h_tr==1) && (VSx1==1))?Cwb: 8'h80;

wire  [7:0]Ymm  =SW1? ym :Yw ;
wire  [7:0]Crmm =SW1? crm:Cwr;
wire  [7:0]Cbmm =SW1? cbm:Cwb;

reg[10:0]Hde_counter;
reg[10:0]Vde_counter;

always @(posedge CLOCK)begin
        if(HSx2==0)
          Hde_counter=0;
                else
          Hde_counter=Hde_counter+1;
end

always@(posedge  HSx2)begin
if (TD_VS==0)
          Vde_counter=0;
                else
          Vde_counter=Vde_counter+1;
end

wire hde=((Hde_counter > 51) && (Hde_counter < 691)) ? 1:0;//720
wire vde=((Vde_counter > 31) && (Vde_counter < 511)) ? 1:0;//480
wire blank_h  = h_tr   & vde;
wire blank  =   h_tr_h & vde;

wire  [7:0]Y  = (blank_h)?Ymm   :8'h10;
wire  [7:0]Cr = (blank_h)?Crmm  :8'h80;
wire  [7:0]Cb = (blank_h)?Cbmm  :8'h80;

dul_port_c1024 YYYR(
        .iDATA(YY[7:0]),
        .iHSYNC(TD_HS),
```

```
//          .iHSYNCx2(HSx2),
            .iHSYNCx2(blank),
            .Y_CLOCK(Ypix_clock),
            .Y_CLOCKx2(CLOCK),
            .oDATA(Yw[7:0]),
            .field(Field),
            .VS(TD_VS)
);


dul_port_c1024 CBB(
            .iDATA(CCb[7:0]),
            .iHSYNC(TD_HS),
//          .iHSYNCx2(HSx2),
            .iHSYNCx2(blank),
            .Y_CLOCK(Ypix_clock),
            .Y_CLOCKx2(CLOCK),
            .oDATA(Cwb[7:0]),
            .field(Field),
            .VS(TD_VS)
);

dul_port_c1024 CRR(
            .iDATA(CCr[7:0]),
            .iHSYNC(TD_HS),
//          .iHSYNCx2(HSx2),
            .iHSYNCx2(blank),
            .Y_CLOCK(Ypix_clock),
            .Y_CLOCKx2(CLOCK),
            .oDATA(Cwr[7:0]),
            .field(Field),
            .VS(TD_VS)
);

endmodule
```

dul_port_c1024.v

```
//*********************************************************************************************
   //*  COMPANY    :  TERASIC.  www.terasic.com  (c) 2005 all rights reserved.              *
   //*  NAME       :  dual port RAM control
   //*  Created    :  7/5/2005                                                              *
   //*  Author     :  Joe Yang                                                              *
   //*********************************************************************************************
```

```
module dul_port_c1024(
        iDATA,
        iHSYNC,
        iHSYNCx2,
        Y_CLOCK,
        Y_CLOCKx2,
        VS,
        oDATA,
        field
        //test
/*
        counter,
        I,
        COUNTER_a,
   COUNTER_b,
   CLOCK_a,
   CLOCK_b,
        I_a,
        I_b
*/
);

input  [7:0]iDATA;
input  iHSYNC;
input  iHSYNCx2;
input  Y_CLOCK;
input  Y_CLOCKx2;
input  field;
input  VS;
output [7:0]oDATA;
/*
output [9:0]counter;
output I;
output [9:0]COUNTER_a;
output [9:0]COUNTER_b;
output CLOCK_a;
output CLOCK_b;
output I_a;
output I_b;
*/
reg I;
always@(negedge iHSYNC)begin
        if (VS)
```

```
                l=field;
        else
                l=~l;
end

reg  [9:0]counter;
always@(posedge iHSYNC or posedge Y_CLOCK)begin
if (iHSYNC)
         counter=0;
else counter=counter+1;
end

reg  [9:0]counterx2;
always@(negedge iHSYNCx2 or posedge Y_CLOCKx2)begin
if (!iHSYNCx2)
         counterx2=0;
else counterx2=counterx2+1;
end

wire [7:0]DATA_a,DATA_b;
wire I_a= l;
wire I_b=~l;
wire [9:0]COUNTER_a=(l==1)?counter:counterx2;
wire [9:0]COUNTER_b=(l==0)?counter:counterx2;
wire CLOCK_a=(l==1)?~Y_CLOCK:~Y_CLOCKx2;
wire CLOCK_b=(l==0)?~Y_CLOCK:~Y_CLOCKx2;
wire [7:0]oDATA=(l==0)?DATA_a:DATA_b;


RAM2 u(
        .data_a(iDATA[7:0]),
        .wren_a(I_a),
        .address_a(COUNTER_a[9:0]),
        .clock_a(CLOCK_a),
        .q_a(DATA_a[7:0]),

        .data_b(iDATA[7:0]),
        .wren_b(I_b),
        .address_b(COUNTER_b[9:0]),
        .clock_b(CLOCK_b),
        .q_b(DATA_b[7:0])
        );

endmodule
```

de2_wm8731_audio.vhd

```
library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;

entity de2_wm8731_audio is
port (
   signal clk                    : in  std_logic;
   signal reset_n                : in  std_logic;
         signal read             : in  std_logic;
         signal write            : in  std_logic;
         signal chipselect       : in  std_logic;
   signal address       : in  unsigned(1 downto 0);
   signal readdata      : out unsigned(15 downto 0);
   signal writedata     : in  unsigned(15 downto 0);

   -- Audio interface signals
   signal AUD_ADCLRCK  : out  std_logic;   --    Audio CODEC ADC LR Clock
   signal AUD_ADCDAT   : in   std_logic;   --    Audio CODEC ADC Data
   signal AUD_DACLRCK  : out  std_logic;   --    Audio CODEC DAC LR Clock
   signal AUD_DACDAT   : out  std_logic;   --    Audio CODEC DAC Data
   signal AUD_BCLK     : inout std_logic;  --    Audio CODEC Bit-Stream Clock
         signal AUD_XCK        : out std_logic;    -- Chip Clock

         signal I2C_SDAT       : inout std_logic; -- I2C Data
   signal I2C_SCLK     : out std_logic   -- I2C Clock

         --ps/2
         --PS2_DAT,                 -- Data
   --PS2_CLK : in std_logic;     -- Clock
);
end  de2_wm8731_audio;

architecture rtl of de2_wm8731_audio is

         --new
         component de2_i2c_av_config is
         port (
                  iCLK : in std_logic;
                  iRST_N : in std_logic;
                  I2C_SCLK : out std_logic;
                  I2C_SDAT : inout std_logic
```

```
        );
        end component;

        signal audio_request: std_logic;

        --/other
        signal audio_clock      : std_logic;      --unsigned(2 downto 0)
    signal counter_basic: unsigned(5 downto 0) := "000000";
    signal counter              : unsigned(5 downto 0) := "000000";
    signal my_data              : unsigned(15 downto 0);
    signal prescaler      : unsigned(7 downto 0) := X"00";
    signal mid_value      : unsigned(7 downto 0) := X"00";
    signal note                 : unsigned(3 downto 0) := X"C";
    signal phase                : unsigned(15 downto 0):= X"0000";
    signal norm_phase : signed(5 downto 0)   := "000000";
    signal signed_phase         : signed(5 downto 0)   := "000000";
    signal mod_counter          : unsigned(5 downto 0) := "000000";
    signal mod_depth   : unsigned(1 downto 0) := "01";
    signal extra_counter: unsigned(1 downto 0) := "00";
    signal silent           : std_logic                         := '1';           --CHECK: depende de la
repeticion de las teclas
        --new

    signal lrck : std_logic;
    signal bclk : std_logic;
    signal xck  : std_logic;

    signal lrck_divider : unsigned(7 downto 0);
    signal bclk_divider : unsigned(3 downto 0);

    signal set_bclk : std_logic;
    signal set_lrck : std_logic;
    signal clr_bclk : std_logic;
    signal lrck_lat : std_logic;

    signal shift_out : unsigned(15 downto 0);

        --new lookup tables
        type table is array (0 to 47) of unsigned(15 downto 0);
        constant my_table      : table := (0 => X"0000",1 => X"10b4",2 => X"2120",3 => X"30fb",4
=> X"3fff",5 => X"4deb",6 => X"5a81",7 => X"658b",
        8 => X"6ed9",9 => X"7640",10 => X"7ba2",11 => X"7ee6",12 => X"7fff",13 =>
X"7ee6",14 => X"7ba2",15 => X"7640",16 => X"6ed9",17 => X"658b",
        18 => X"5a81",19 => X"4deb",20 => X"3fff",21 => X"30fb",22 => X"2120",23 =>
X"10b4",24 => X"0000",25 => X"ef4b",26 => X"dee0",27 => X"cf05",
```

```
	28 => X"c001",29 => X"b215",30 => X"a57e",31 => X"9a74",32 => X"9127",33 =>
X"89bf",34 => X"845d",35 => X"8119",36 => X"8000",37 => X"8119",
	38 => X"845d",39 => X"89bf",40 => X"9127",41 => X"9a74",42 => X"a57e",43 =>
X"b215",44 => X"c000",45 => X"cf05",46 => X"dee0",47 => X"ef4b");
	type table2 is array (0 to 12) of integer range 0 to 255;
	constant freq_table : table2 := (0=>18, 1=>20, 2=>21, 3=>22, 4=>23, 5=>24, 6=>26,
7=>28, 8=>29, 9=>30, 10=>32, 11=>34, 12=>36);
	constant mid_table : table2 := (0=>9, 1=>10, 2=>10, 3=>11, 4=>11, 5=>12, 6=>13,
7=>14, 8=>14, 9=>15, 10=>16, 11=>17, 12=>18);

begin

 --new
 process (clk)
 begin
	if rising_edge (clk) then
		if prescaler = X"00" then
			prescaler <= TO_UNSIGNED(freq_table(TO_INTEGER(note)),8);
			mid_value <= TO_UNSIGNED(mid_table(TO_INTEGER(note)),8);
			audio_clock <= '0';
		else
			prescaler <= prescaler - 1;
			if prescaler = mid_value then
				audio_clock <= '1';
			end if;
		end if;
	end if;
 end process;

 process (clk)
 begin
	if rising_edge (clk) then
	  if chipselect = '1' then
		if write = '1' then
		  if address = "00" then
			silent <= '1';
		  elsif address = "01" then
			note <= writedata(3 downto 0);
			silent <= '0';
		  elsif address = "10" then
			mod_depth <= writedata(1 downto 0);
			silent <= '0';
		  end if;
		end if;
```

```
            end if;
        end if;
    end process;

    process(audio_clock)
    begin
        if rising_edge (audio_clock) then
            if audio_request = '1' then
                --computing phase
                if extra_counter = "00" then
                    if mod_counter = "101111" or reset_n = '0' then
                        mod_counter <= "000000";
                    else
                        mod_counter <= mod_counter + 1;
                    end if;

                    phase <= my_table(TO_INTEGER(mod_counter));

                    norm_phase <= phase(15) & "00" & phase(14) & phase(13) &
phase(12);--normalizing the phase

                    signed_phase <=
TO_SIGNED(TO_INTEGER(norm_phase)*TO_INTEGER(mod_depth),6);--scalling the phase

                    extra_counter <= "10";          -- because Wc = 3Wm
                else
                    extra_counter <= extra_counter - 1;
                end if;

                --computing period
                if counter_basic >= "101111" or reset_n = '0' then    --less than 47
                    counter_basic <= "000000";
                else
                    counter_basic <= counter_basic + 1;

                end if;

                --adding phase(phase) to period(counter_basic)
                counter <= counter_basic + TO_INTEGER(signed_phase);          --in
theory if the real_phase>counter_basic it should reset itself

                --generating sinusoidal
                if silent = '1' then
                    my_data <= X"0000";
                else
```

```
                                my_data <= my_table(TO_INTEGER(counter));
                            end if;
                        end if;
                end if;
end process;

--new

process (audio_clock)
begin
  if rising_edge(audio_clock) then
    if reset_n = '0' then
      lrck_divider <= (others => '0');
    elsif lrck_divider = X"1F"  then        -- X"BF"
      lrck_divider <= X"00";
    else
      lrck_divider <= lrck_divider + 1;
    end if;
  end if;
end process;

process (audio_clock)
begin
  if rising_edge(audio_clock) then
    if reset_n = '0' then
      bclk_divider <= (others => '0');
    elsif bclk_divider = X"1" or set_lrck = '1'  then  --X"B"
      bclk_divider <= X"0";
    else
      bclk_divider <= bclk_divider + 1;
    end if;
  end if;
end process;

set_lrck <= '1' when lrck_divider = X"1F" else '0';    --X"BF"

process (audio_clock)
begin
  if rising_edge(audio_clock) then
    if reset_n = '0' then
      lrck <= '0';
    elsif set_lrck = '1' then
      lrck <= not lrck;
    end if;
```

```
  end if;
end process;

-- BCLK divider
set_bclk <= '1' when bclk_divider(3 downto 0) = X"0" else '0';       --"0101"
clr_bclk <= '1' when bclk_divider(3 downto 0) = X"1" else '0';       --"1011"

process (audio_clock)
begin
  if rising_edge(audio_clock) then
    if reset_n = '0' then
      bclk <= '0';
    elsif set_lrck = '1' or clr_bclk = '1' then
      bclk <= '0';
    elsif set_bclk = '1' then
      bclk <= '1';
    end if;
  end if;
end process;

-- Audio data shift output
process (audio_clock)
begin
  if rising_edge(audio_clock) then
    if reset_n = '0' then
      shift_out <= (others => '0');
    elsif set_lrck = '1' then
        shift_out <= my_data;
    elsif clr_bclk = '1' then
      shift_out <= shift_out (14 downto 0) & '0';
    end if;
  end if;
end process;

  -- Audio outputs

  AUD_ADCLRCK  <= lrck;
  AUD_DACLRCK  <= lrck;
  AUD_DACDAT   <= shift_out(15);
  AUD_BCLK     <= bclk;
         AUD_XCK <= audio_clock;

  process(audio_clock)
  begin
```

```
    if rising_edge(audio_clock) then
      lrck_lat <= lrck;
    end if;
  end process;

  process (audio_clock)
  begin
    if rising_edge(audio_clock) then
      if lrck_lat = '1' and lrck = '0' then
        audio_request <= '1';
      else
        audio_request <= '0';
      end if;
    end if;
  end process;


 i2c : de2_i2c_av_config port map (
  iCLK     => clk,
  iRST_n   => '1',
  I2C_SCLK => I2C_SCLK,
  I2C_SDAT => I2C_SDAT
 );

end architecture;
```

Software

- gameLogic.h
- math.h
- network.h
- rxInterrupt.h
- sprites.h
- terrain.h
- main.c

gameLogic.h

```
#ifndef GAMELOGIC_H_
#define GAMELOGIC_H_
#define ANGLE_INC 5
#define BAT_RADIUS 20
#define MAX_STEPS 10
```

```
int selectNextWorm(int *wormsTurn, int *wormHealth)
{
   int nextGame;

   if(((*(wormHealth + 0) > 0)||(*(wormHealth + 2) > 0)) && ((*(wormHealth + 1) > 0)||
(*(wormHealth + 3) > 0))) {nextGame = 0;}
   else nextGame = 1;

   if(nextGame == 0)
   {
   if((*wormsTurn) == 0)      {if((*(wormHealth + 1) > 0)) {*wormsTurn = 1;} else {*wormsTurn =
3;}}
   else if((*wormsTurn) == 1) {if((*(wormHealth + 2) > 0)) {*wormsTurn = 2;} else {*wormsTurn =
0;}}
   else if((*wormsTurn) == 2) {if((*(wormHealth + 3) > 0)) {*wormsTurn = 3;} else {*wormsTurn =
1;}}
   else if((*wormsTurn) == 3) {if((*(wormHealth + 0) > 0)) {*wormsTurn = 0;} else {*wormsTurn =
2;}}
   }

   return nextGame;
}

int findHitWorm(struct spriteStruct *s, int wormsTurn)
{
int i;
int distance;
int hitWorm = wormsTurn;
for(i = 0; i < 4; i++)
 {
   if(i != wormsTurn)
   {
      distance = (*(s + wormsTurn)).h - (*(s + i)).h;
      if(distance < 0) distance = -distance;

      if(distance < BAT_RADIUS) {hitWorm = i;}
   }
 }
return hitWorm;
}

#endif /*GAMELOGIC_H_*/
```

math.h

```
#ifndef MATH_
#define MATH_
#define IORD_VGA_DATA(base,offset) IORD_32DIRECT(base,offset*4)

float getRandom()
{
   int rawResult = IORD_VGA_DATA (VGA_BASE,0);
   int pause = rawResult*500;
   while(pause){pause--;}
   return ((float)rawResult)/255;
}


float sin(float angle)
{
   float x = angle*(6.28318/360);
   float result = x - pow(x,3)/6 + pow(x,5)/120 - pow(x,7)/5040;
   return result;
}

float cos(float angle)
{
   float x = angle*(6.28318/360);
   float result = 1 - pow(x,2)/2 + pow(x,4)/24 - pow(x,6)/720;
   return result;
}


#endif /*MATH_*/
```

network.h

```
#ifndef NETWORK_H_
#define NETWORK_H_

#include "sprites.h"

#define UDP_PACKET_PAYLOAD_OFFSET 42
#define UDP_PACKET_LENGTH_OFFSET 38

#define UDP_PACKET_PAYLOAD (transmit_buffer + UDP_PACKET_PAYLOAD_OFFSET)

#define MAX_MSG_LENGTH 128
```

```
#define TERRAIN_REDRAW_1 33
#define TERRAIN_REDRAW_2 34
#define TERRAIN_REDRAW_RECEIVE_1 35
#define TERRAIN_REDRAW_RECEIVE_2 36
#define SPRITE_SEND 37
#define SPRITE_SEND_RECEIVE 38

#define MAX_MSG_LENGTH 1500// Max size for our payload - more than necessary



unsigned char transmit_buffer[MAX_MSG_LENGTH] = {
  // Ethernet MAC header
  0xFF, 0xFF, 0xFF, 0xFF, 0xFF, 0xFF, // Destination MAC address
  0x01, 0x60, 0x6E, 0x11, 0x02, 0xCF, // Source MAC address
  0x08, 0x00,                         // Packet Type: 0x800 = IP

  // IP Header
  0x45,              // version (IPv4), header length = 20 bytes
  0x00,              // differentiated services field
  0x00,0x9C,           // total length: 20 bytes for IP header +
                   // 8 bytes for UDP header + 128 bytes for payload
  0x3d, 0x35,          // packet ID
  0x00,              // flags
  0x00,              // fragment offset
  0x80,              // time-to-live
  0x11,              // protocol: 11 = UDP
  0xa3,0x43,           // header checksum: incorrect
  0xc0,0xa8,0x01,0x01, // source IP address
  0xc0,0xa8,0x01,0xff, // destination IP address

  // UDP Header
  0x67,0xd9, // source port port (26585: garbage)
  0x27,0x2b, // destination port (10027: garbage)
  0x00,0x88, // length (136: 8 for UDP header + 128 for data)
  0x00,0x00, // checksum: 0 = none

  // UDP payload
  0x74, 0x65, 0x73, 0x74, 0x20, 0x6d, 0x73, 0x67,
  0x74, 0x65, 0x73, 0x74, 0x20, 0x6d, 0x73, 0x67,
  0x74, 0x65, 0x73, 0x74, 0x20, 0x6d, 0x73, 0x67,
  0x74, 0x65, 0x73, 0x74, 0x20, 0x6d, 0x73, 0x67,
```

```
  0x74, 0x65, 0x73, 0x74, 0x20, 0x6d, 0x73, 0x67,
  0x74, 0x65, 0x73, 0x74, 0x20, 0x6d, 0x73, 0x67,
  0x74, 0x65, 0x73, 0x74, 0x20, 0x6d, 0x73, 0x67,
  0x74, 0x65, 0x73, 0x74, 0x20, 0x6d, 0x73, 0x67,
  0x74, 0x65, 0x73, 0x74, 0x20, 0x6d, 0x73, 0x67,
  0x74, 0x65, 0x73, 0x74, 0x20, 0x6d, 0x73, 0x67,
  0x74, 0x65, 0x73, 0x74, 0x20, 0x6d, 0x73, 0x67,
  0x74, 0x65, 0x73, 0x74, 0x20, 0x6d, 0x73, 0x67,
  0x74, 0x65, 0x73, 0x74, 0x20, 0x6d, 0x73, 0x67,
  0x74, 0x65, 0x73, 0x74, 0x20, 0x6d, 0x73, 0x67,
  0x74, 0x65, 0x73, 0x74, 0x20, 0x6d, 0x73, 0x67,
  0x74, 0x65, 0x73, 0x74, 0x20, 0x6d, 0x73, 0x67
};
// Ethernet MAC address.  Choose the last three bytes yourself
unsigned char mac_address[6] = { 0x01, 0x60, 0x6E, 0x11, 0x02, 0xCF };

unsigned int interrupt_number;

float terrain[GAMEBOARD_LENGTH+1];
struct spriteStruct s[16];

int terrain_packet_num = 0;

short net_master = 0;

// Splits an integer into a two-byte char
void splitInt(unsigned char* c, int x, int index){
   c[index+1] = x;
   c[index] = x >> 8;
}

// Merges said two-byte char into a single integer
float mergeChars(unsigned char* c, int index){
   int x, y;
   x = 256*(int)c[index];
   y = (int)c[index+1];
   return (float)(x + y);
}

// Checks the packet's integrity and extends/changes when necessary
int Check_Packet(unsigned char *data_ptr, int tx_len){
   int i;
   unsigned int temp_carry = 0x00; // Stores the carry-over used for 1's complement.
   unsigned int checksum = 0x00;
```

```
int header = 0x00;
unsigned int temp_len = 0;
unsigned int packet_ID = 0; // The current packet's ID



data_ptr[24] = 0x00;
data_ptr[25] = 0x00;

packet_ID = data_ptr[18]<<8 | (data_ptr[19]);
packet_ID++;

// Update the IP packet counter
data_ptr[18] = packet_ID>>8;
data_ptr[19] = packet_ID & 0xFF;

// Computing the checksum by summing the header info, then taking the 1's complement
for ( i=14; i<33; i +=2){
   header += ((data_ptr[i]<<8)|data_ptr[i+1]);
   //printf("%d = %x\n%d = %x\n", i, data_ptr[i], i+1, data_ptr[i+1]);
}
temp_carry = header >> 16;
checksum = 0xFFFF & ~(header + temp_carry); // Compute the checksum

// Update the IP packet with the proper checksum
data_ptr[24] = checksum>>8;
data_ptr[25] = checksum & 0xFF;

// Stuff the packet with additional data if not the minimal size.
if (64-tx_len > 0){

   for (i=tx_len; i < 64; i++){
      data_ptr[i] = 0;
   }
   temp_len = i;
}

data_ptr[38] = 0x00;
data_ptr[39] = 0x00;
data_ptr[40] = 0x00;
data_ptr[41] = 0x00;

// Update the packet with the proper length
data_ptr[38] = tx_len >> 8;
```

```
    data_ptr[39] = tx_len & 0xFF;

    // Update the UDP packet checksum
    // Computing the checksum by summing the header info, then taking the 1's complement
    header = 0;
    //printf("%d\n", tx_len + 8);
    for (i=34; i<39; i +=2)
        header += ((data_ptr[i]<<8)|data_ptr[i+1]);
    temp_carry = header >> 16;
    checksum = 0xFFFF & ~(header + temp_carry); // Compute the checksum

    // Update the UDP packet with the proper checksum
    data_ptr[40] = checksum>>8;
    data_ptr[41] = checksum & 0xFF;

    //for (i=0; i<tx_len; i++)
    //    printf("%d = %x\n", i, data_ptr[i]);

    return temp_len;
}


// Reads in the terrain data from the network
void read_terrain(float *terrainT, struct spriteStruct *worms, unsigned char* data, int size, int
terrain_code){
    int i=0;
    size = size - (UDP_PACKET_PAYLOAD_OFFSET+2);
    size = size/2;
    for(i=0; i<size; i++){
        int index = UDP_PACKET_PAYLOAD_OFFSET+2+(i*2);
        terrainT[i] = mergeChars(data, index);
    }

    if (terrain_code == TERRAIN_REDRAW_1){
        //drawTerrain(terrain, size, 0);
        for (i=0; i<GAMEBOARD_LENGTH/2; i++){
            terrain[i] = terrainT[i];
        }
    }
    else if (terrain_code == TERRAIN_REDRAW_2){
        for(i=0; i<GAMEBOARD_LENGTH/2; i++){
            terrain[(GAMEBOARD_LENGTH/2)+i] = terrainT[i];
        }
        for ( i = GAMEBOARD_LENGTH/2; i < (GAMEBOARD_LENGTH/2) + 4; i++){
```

```
            int index = UDP_PACKET_PAYLOAD_OFFSET+2+(i*2);
            worms[i- (GAMEBOARD_LENGTH/2)].h = mergeChars(data, index);
        }
        drawTerrain(terrain, GAMEBOARD_LENGTH, 0);
    // Sprite synchronization received
    } else if (terrain_code == SPRITE_SEND){
        for(i=0; i<4; i++){

        }
    }


    if (terrain_code == TERRAIN_REDRAW_1)
        transmit_buffer[UDP_PACKET_PAYLOAD_OFFSET] =
TERRAIN_REDRAW_RECEIVE_1;
    else if (terrain_code == TERRAIN_REDRAW_2)
        transmit_buffer[UDP_PACKET_PAYLOAD_OFFSET] =
TERRAIN_REDRAW_RECEIVE_2;

    transmit_buffer[UDP_PACKET_PAYLOAD_OFFSET+1] = 0;
    TransmitPacket(transmit_buffer, UDP_PACKET_PAYLOAD_OFFSET+2);

    net_master = 0;

}

void send_message( alt_u8 msg){
      printf("Msg to Send: ");
      UDP_PACKET_PAYLOAD[1] = 0xAB;
      UDP_PACKET_PAYLOAD[1] = msg;
      UDP_PACKET_PAYLOAD[2] = 0; // Terminate the string
      unsigned int packet_length = UDP_PACKET_PAYLOAD_OFFSET + 2;

      transmit_buffer[UDP_PACKET_LENGTH_OFFSET] = packet_length >> 8;
      transmit_buffer[UDP_PACKET_LENGTH_OFFSET+4 ] = packet_length & 0xff;
      if (TransmitPacket(transmit_buffer, UDP_PACKET_PAYLOAD_OFFSET +
3)==DMFE_SUCCESS) {
        printf("\nMessage sent successfully\n");
      } else {
        printf("\nMessage sending failed\n");
      }
      // reset data
        int curMsgChar;
        for (curMsgChar=MAX_MSG_LENGTH-1; curMsgChar>0; curMsgChar--) {
```

```
            UDP_PACKET_PAYLOAD[curMsgChar] = 0;
        }
      // }
       printf("Msg to Send: ");

}

void send_terrain(int *msg, struct spriteStruct * worms, int start, int end, int terrain_code){
    int i=0;
    transmit_buffer[UDP_PACKET_PAYLOAD_OFFSET] = terrain_code;
    transmit_buffer[UDP_PACKET_PAYLOAD_OFFSET+1] = 0;
    int index;
    for(i=start; i<end; i++){
        //transmit_buffer[UDP_PACKET_PAYLOAD_OFFSET+i] = msg[i];
        index = UDP_PACKET_PAYLOAD_OFFSET+2+(2*i);
        splitInt(transmit_buffer, msg[i], index);
    }
    if ( worms != NULL){
        for (i = end; i < end+4 ; i++){
          index   = UDP_PACKET_PAYLOAD_OFFSET+2+(2*i);
          splitInt(transmit_buffer, worms[i-end].h, index);

        }

    }
    transmit_buffer[index+2] = 0;

    unsigned int packet_length = Check_Packet(transmit_buffer,
UDP_PACKET_PAYLOAD_OFFSET+2*i);

    transmit_buffer[UDP_PACKET_LENGTH_OFFSET] = packet_length >> 8;
    transmit_buffer[UDP_PACKET_LENGTH_OFFSET + 1] = packet_length & 0xff;


     if (TransmitPacket(transmit_buffer, index+2)==DMFE_SUCCESS) {
              printf("\nMessage sent successfully\n");
              net_master = 1;

     } else {
              printf("\nMessage sending failed\n");
           }
}

short getMaster(){
```

```
    return net_master;
}



#endif /*NETWORK_H_*/
```

rxInterrupt.h

```
#ifndef RXINTERRUPT_H_
#define RXINTERRUPT_H_

#include "network.h"

#define MAX_MSG_LENGTH 128
//Key definitions
#define LEFT_ARROW 0x6B
#define RIGHT_ARROW 0x74
#define UP_ARROW 0x75
#define DOWN_ARROW 0x72
#define SPACEBAR 0x29
#define ENTER 0x5A
#define LEFT_ARROW_NET 0xB6
#define SPACEBAR_NET 0xC2
#define RIGHT_ARROW_NET 0x47
#define UP_ARROW_NET 0x57
#define DOWN_ARROW_NET 0x27
#define PAGE_UP_NET 0xd7
#define PAGE_DOWN_NET 0xa7
#define END_NET 0x96
#define PLUS_SIGN 0x3d
#define PAGE_UP 0x7d
#define PAGE_DOWN 0x7a
#define END 0x69
#define HOME 0x6c
#define DEL 0x71

#define PLAYER_NUMBER 1

unsigned int receive_buffer_length;
unsigned char receive_buffer[1600];
short second_packet_ready = 0;
short terrainReceived = 0;
alt_u8 remoteKey = 0;
```

```
static void ethernet_interrupt_handler() {
  unsigned int receive_status;
  int i;

  receive_status = ReceivePacket(receive_buffer, &receive_buffer_length);

  if (receive_status == DMFE_SUCCESS) {
    printf("\n\nReceive Packet Length = %d\n", receive_buffer_length);

    // Gets the terrain-redraw code from the packet creator.
    unsigned int code = receive_buffer[UDP_PACKET_PAYLOAD_OFFSET];


    // Redraw first half of the terrain
    if (code == TERRAIN_REDRAW_1){
       float terrainT[641];
       read_terrain(terrainT, s, receive_buffer, receive_buffer_length, code);
       printf("\n\nTerrain 1 Packet Length = %d\n", receive_buffer_length);
    }
    // Redraw the second half of the terrain
    else if (code == TERRAIN_REDRAW_2){
       float terrainT[641];
       read_terrain(terrainT,s, receive_buffer, receive_buffer_length, code);
       printf("\n\nTerrain 2 Packet Length = %d\n", receive_buffer_length);
    }
    // Means first half of the terrain has been processed
    else if (code == TERRAIN_REDRAW_RECEIVE_1){
       second_packet_ready = 1;
    }
    else if (code == TERRAIN_REDRAW_RECEIVE_2){
       second_packet_ready = 0;
       terrainReceived = 1;
    }
    else{
       remoteKey = receive_buffer[UDP_PACKET_PAYLOAD_OFFSET+1];
       printf("%x\n", remoteKey);

       switch(remoteKey){

        case LEFT_ARROW:
          printf("Left Arrow\n");
        break;
```

```
        case RIGHT_ARROW:
          printf("Right Arrow\n");
        break;
       }
    }


    printf("Packet received correctly\n");
  } else {
    printf("Error receiving packet\n");
  }

  usleep(STD_DELAY);
  dm9000a_iow(ISR, 0x3F);

  /* Re-enable DM9000A interrupts */
  dm9000a_iow(IMR, INTR_set);
}

short getTerrainSent(){
    return terrainReceived;
}

alt_u8 getRemoteKey(){
    alt_u8 tempKey = remoteKey;
    remoteKey = 0x00;
    return tempKey;
}

void initializeEthernet()
{
  DM9000_init(mac_address);
  alt_irq_register(DM9000A_IRQ, NULL, (void*)ethernet_interrupt_handler);
}
#endif /*RXINTERRUPT_H_*/
```

sprites.h

```
#ifndef SPRITES_
#define SPRITES_
#define IOWR_VGA_DATA(base,offset,data) IOWR_32DIRECT(base,offset*4,data)
#define BLUE_ARROW 11
#define RED_ARROW 21
#define BLUE_RETICLE 12
```

```
#define RED_RETICLE 22
#define PROJECTILE 20
#define ARROW_OFFSET 30
#define LEFT 0
#define RIGHT 1
#define WALK_DISTANCE 2
#define G .8
#define BAZOOKA 0
#define BAT 1
#define RETICLE_OFFSET 30

struct spriteStruct{
   int shown;
   int h;
   int v;
   int spriteNumber;
   int flip;
};

void updateSprites(struct spriteStruct *s)
{
int i;
int spriteID = 0;
int shown = 0;
int h = 0;
int v = 0;
int spriteNumber = 0;
int spriteFlip = 0;

unsigned int c;

for(i = 0; i < 16; i++)
{

        spriteID = i;
        shown = (*(s + i)).shown;
        h = (*(s + i)).h;
        v = (*(s + i)).v;
        spriteNumber = (*(s + i)).spriteNumber;
        spriteFlip = (*(s + i)).flip;

        spriteID <<= 27;
        shown <<= 26;
        h <<= 16;
```

```
        v <<= 6;
        spriteNumber <<= 1; // between 0 and 30

        c = (spriteID|shown|h|v|spriteNumber|spriteFlip);

        IOWR_VGA_DATA(VGA_BASE,2,c);
}
}

void initializeWorms(struct spriteStruct *s, float *terrain)
{

IOWR_VGA_DATA(VGA_BASE,3,0);

int i;

for(i = 0; i < 4; i++)
{
  (*(s + i)).shown = 1;
  (*(s + i)).flip = LEFT;
  (*(s + i)).h = 20 + (int)((GAMEBOARD_LENGTH - 40)*getRandom());
  (*(s + i)).v = (int)(GAMEBOARD_HEIGHT-*(terrain + (*(s + i)).h + 16) - 23);
}

}

void sitWorms(struct spriteStruct *s, float *terrain)
{
int i;

for(i = 0; i < 4; i++)
{
  (*(s + i)).v = (int)(GAMEBOARD_HEIGHT-*(terrain + (*(s + i)).h + 16) - 23);
}
}

void placeReticle(struct spriteStruct *s, int wormsTurn, float angle, float pow)
{
  (*(s + 8)).shown = 1;
  (*(s + 8)).flip = 0;
  if(wormsTurn == 0 || wormsTurn == 2) {(*(s + 8)).spriteNumber = BLUE_RETICLE;}
  if(wormsTurn == 1 || wormsTurn == 3) {(*(s + 8)).spriteNumber = RED_RETICLE;}

  (*(s + 8)).v = (*(s + wormsTurn)).v + (int)((pow)*sin(angle));
```

```
  if((*(s + wormsTurn)).flip) {(*(s + 8)).h = (*(s + wormsTurn)).h + (int)((pow)*cos(angle));}
  else {(*(s + 8)).h = (*(s + wormsTurn)).h - (int)((pow)*cos(angle));}
}

void placeArrows(struct spriteStruct *s, int wormsTurn, int *wormHealth, int *arrowBounce)
{
//Update Animation
 *arrowBounce -= 2;
 if(*arrowBounce == 0) {*arrowBounce = 30;}

int i = 0;
for(i = 0; i < 4; i++)
{
 if(*(wormHealth + i) > 0){(*(s + i + 4)).shown = 1;}
 else {(*(s + i + 4)).shown = 0;}
 (*(s + i + 4)).flip = 0;
}

  (*(s + 4)).spriteNumber = BLUE_ARROW;
  (*(s + 5)).spriteNumber = RED_ARROW;
  (*(s + 6)).spriteNumber = BLUE_ARROW;
  (*(s + 7)).spriteNumber = RED_ARROW;

  (*(s + 4)).h = (*(s + 0)).h;
  (*(s + 5)).h = (*(s + 1)).h;
  (*(s + 6)).h = (*(s + 2)).h;
  (*(s + 7)).h = (*(s + 3)).h;

  (*(s + 4)).v = (*(s + 0)).v - *(wormHealth + 0)/2;
  (*(s + 5)).v = (*(s + 1)).v - *(wormHealth + 1)/2;
  (*(s + 6)).v = (*(s + 2)).v - *(wormHealth + 2)/2;
  (*(s + 7)).v = (*(s + 3)).v - *(wormHealth + 3)/2;

  (*(s + wormsTurn + 4)).v = (*(s + wormsTurn)).v - *(wormHealth + wormsTurn)/2 -
*arrowBounce;
}

void animBreath(struct spriteStruct *s, int *breath)
{
int i = 0;

for(i = 0; i < 4; i++)
```

```
{
   (*(breath + i))++;
   if (*(breath + i) == 20) {*(breath + i) = 13;}
   (*(s + i)).spriteNumber = *(breath + i);
}
}

void animSwing(struct spriteStruct *s, int wormsTurn, int *swing)
{
(*(swing))++;
(*(s + wormsTurn)).spriteNumber = *swing;
}

void animWalk(struct spriteStruct *s, float *terrain, int wormsTurn, int *walk)
{
   // Update animation variable for walking
   (*walk)++;

   // Update sprite
   (*(s + wormsTurn)).spriteNumber = 23 + *walk;

   // Update horizontal position
   if((*(s + wormsTurn)).flip == RIGHT)
   {
      if((*(s + wormsTurn)).h < GAMEBOARD_LENGTH - 60)
         {
            (*(s + wormsTurn)).h = (*(s + wormsTurn)).h + WALK_DISTANCE;
            (*(s + wormsTurn)).v = (int)(GAMEBOARD_HEIGHT-*(terrain + (*(s + wormsTurn)).h
+ 16) - 23);
         }
   }
   else
   {
      if((*(s + wormsTurn)).h > 10)
      {
         (*(s + wormsTurn)).h = (*(s + wormsTurn)).h - WALK_DISTANCE;
         (*(s + wormsTurn)).v = (int)(GAMEBOARD_HEIGHT-*(terrain + (*(s + wormsTurn)).h +
16) - 23);
      }
   }
}

int animProjectile(struct spriteStruct *s, float *terrain, int wormsTurn, int *projAnim, float angle,
float power, float *vx, float *vy)
```

```
{
(*(s + 9)).spriteNumber = PROJECTILE;
(*(s + 9)).shown = 1;
(*(s + 9)).flip = 0;

if(*projAnim == 0)
{
   (*(s + 9)).h = (int)(*(s + wormsTurn)).h;
   (*(s + 9)).v = (int)(*(s + wormsTurn)).v;

   if((*(s+wormsTurn)).flip == RIGHT) {*vx = power*cos(angle);}
   if((*(s+wormsTurn)).flip == LEFT) {*vx = -power*cos(angle);}
   *vy = power*sin(angle);
}
else
{
   *vy = *vy + G;
   if(((*(s + 9)).h < 1) ||((*(s + 9)).h > 1008)) {*vx = -(*vx);}
   (*(s + 9)).h = (*(s + 9)).h + (int)(*vx);
   (*(s + 9)).v = (*(s + 9)).v + (int)(*vy);
}

// Increment the animation variable
(*projAnim)++;

// Return the collision coordinate
if((*(s + 9)).v < (GAMEBOARD_HEIGHT-*(terrain + (*(s + 9)).h + 16) - 16)) {return -1;}
else {return (*(s + 9)).h + 16;}
}

//Similar to the animProjectile, but it uses the hitWorm as the sprite
int animFlyingWorm(struct spriteStruct *s, float *terrain, int hitWorm, int wormsTurn, int
*projAnim, float angle, float power, float *vx, float *vy)
{
if(*projAnim == 0)
{
   if((*(s+wormsTurn)).flip == RIGHT) {*vx = power*cos(angle);}
   if((*(s+wormsTurn)).flip == LEFT) {*vx = -power*cos(angle);}
   *vy = power*sin(angle);
}
else
{
   *vy = *vy + G;
   if(((*(s + hitWorm)).h < 1) ||((*(s + hitWorm)).h > 1008)) {*vx = -(*vx);}
```

```
    (*(s + hitWorm)).h = (*(s + hitWorm)).h + (int)(*vx);
    (*(s + hitWorm)).v = (*(s + hitWorm)).v + (int)(*vy);
    // Flip the worm back and forth during flight
    if((*(s + hitWorm)).flip == LEFT) { (*(s + hitWorm)).flip = RIGHT;}
    else if ((*(s + hitWorm)).flip == RIGHT) { (*(s + hitWorm)).flip = LEFT;}
}

// Increment the animation variable
(*projAnim)++;

// Return the collision coordinate
if((*(s + hitWorm)).v < (GAMEBOARD_HEIGHT-*(terrain + (*(s + hitWorm)).h + 16)-22)) {return
-1;}
else {return (*(s + hitWorm)).h + 16;}
}

void drawWeapon(struct spriteStruct *s, int wormsTurn, float angle, int weapon)
{
if(weapon == BAZOOKA)
{
if(angle < -60)                    {(*(s + wormsTurn)).spriteNumber = 10;}
if((angle >= -60) && (angle < -30))  {(*(s + wormsTurn)).spriteNumber = 9;}
if((angle >= -30) && (angle < 30))   {(*(s + wormsTurn)).spriteNumber = 8;}
if((angle >= 30) && (angle < 60))    {(*(s + wormsTurn)).spriteNumber = 7;}
if(angle >= 60)                     {(*(s + wormsTurn)).spriteNumber = 6;}
}

if(weapon == BAT) {(*(s + wormsTurn)).spriteNumber = 0;}

}


#endif /*SPRITES_*/
```

terrain.h

```
#ifndef TERRAIN_H_
#define TERRAIN_H_
#define IOWR_VGA_DATA(base,offset,data) IOWR_32DIRECT(base,offset*4,data)
#define START_TERRAIN 200
#define TERRAIN_MIN 10
#define TERRAIN_MAX 300
#define DAMAGE_RADIUS 25
#define BULLSEYE 5
```

```
#define GAMEBOARD_LENGTH 1024
#define GAMEBOARD_HEIGHT 1024

// Start and end are used for determining which portion of the gameboard to draw
void drawTerrain(float *terrain, int size, int offset)
{
    unsigned int a = 0;
    int i;
     IOWR_VGA_DATA(VGA_BASE,0,a);

   for(i=0;i<size;i++)
   {
     IOWR_VGA_DATA(VGA_BASE,1,(int)*(terrain+i));
   }
}

void genTerrain(float *terrain)
{
float slope = 0;
float curvature = 0;
int i,j,n;

*(terrain + 0) = START_TERRAIN;
n = 1;

for(i = 0; i < 16; i++)
{
  curvature = 0.02*(getRandom()-.5);
  for(j = 0; j < 64; j++)
  {
     slope += curvature;
     *(terrain + n) = *(terrain + n -1) + slope;
     if(*(terrain + n) > TERRAIN_MAX) {slope = -slope;}
     if(*(terrain + n) < TERRAIN_MIN) {slope = -slope;}
     n++;
   }
}
}

void drawDamage(float *terrain, int damageCenter)
{
int i;
float D = 0;
float R = (float)DAMAGE_RADIUS;
```

```
float dy = 0;
for(i = 0; i < GAMEBOARD_LENGTH; i++)
{
  D = (float)(i - damageCenter);
  if(D < 0) {D = -D;}

  if(D < R)
  {
   dy = sqrt(pow(R,2) - pow(D,2));
   *(terrain + i) = *(terrain + i) - dy;
  }

  if(*(terrain + i) < TERRAIN_MIN) {*(terrain + i) = TERRAIN_MIN;}
}
}

void smoothTerrain(float *terrain, int n)
{
int i, j;
for(i = 0; i < n; i++)
{
for(j = 1; j < GAMEBOARD_LENGTH-1; j++)
{
  *(terrain + j) = (*(terrain + j - 1) + *(terrain + j) + *(terrain + j + 1)) / 3;
}
}
}

void centerScreen(int h, int v)
{

h = h - 320;
if(h < 0) h = 0;
if(h > 383) h = 383;

//v = GAMEBOARD_HEIGHT - v;
v = v - 240;
if(v < 0) v = 0;
if(v > 543) v = 543;

unsigned int HVInit;

h <<= 22;
v <<= 12;
```

```
HVInit =  (h|v);
IOWR_VGA_DATA(VGA_BASE,4,HVInit);
}

#endif /*TERRAIN_H_*/
```

main.c

```
#include "basic_io.h"
#include "DM9000A.h"
#include <alt_types.h>
#include "alt_up_ps2_port.h"
#include "ps2_keyboard.h"
#include "math.h"
#include "terrain.h"
#include "sprites.h"
#include "gameLogic.h"
#include "network.h"
#include "keyboard.h"
#include "rxInterrupt.h"


//the HW has only 4 addresses to write to
//#define IOWR_VGA_DATA(base,offset,data) IOWR_32DIRECT(base,offset*4,data)
//#define IORD_VGA_DATA(base,offset) IORD_32DIRECT(base,offset*4)
//#define BLUE_ARROW 11
//#define RED_ARROW 21
//#define BLUE_RETICLE 12
//#define RED_RETICLE 22

unsigned int receive_buffer_length;
unsigned char receive_buffer[1600];
//float terrain[GAMEBOARD_LENGTH+1];


 // Syncs the terrain between master and slave systems.


void syncTerrain(int *terrainNet, struct spriteStruct * worms ){
	int terrainCounter = GAMEBOARD_LENGTH/2;
	int i;
	for (i=0; i<terrainCounter; i++){
	    terrainNet[i] = (int)terrain[i];
	}
```

```
        send_terrain(terrainNet, NULL, 0, terrainCounter, TERRAIN_REDRAW_1);

        while(second_packet_ready == 0){
        }
        for (i=0; i<terrainCounter; i++){
            terrainNet[i] = (int)terrain[terrainCounter+1+i];
        }
        send_terrain(terrainNet, worms, 0, terrainCounter, TERRAIN_REDRAW_2);

}

int main(){

int i;
int terrainNet[GAMEBOARD_LENGTH+1];


alt_u8 key = 0;

// Initalize the DM9000 and the Ethernet interrupt handler
initializeEthernet();

intitialize_keyboard();
printf("Ready to send messages\n");


// Animation (frame) constants
int animCount = 0;
int breath[4] = {13, 15, 17, 19};
int arrowBounce = 30;
int walk = 0;
int swing = 0;
int projAnim = 0;

// Game State Constants
int nextGame = 0;
int wormHealth[4] = {100, 100, 100, 100};
int wormsTurn = 0;        // Indicates which worms turn it is (0-3)
int distance = 0;
int walkCount = MAX_STEPS;
int hitWorm = 0;
float angle[4] = {0, 0, 0, 0};
float power[4] = {0, 0, 0, 0};
float vx = 0;
```

```
float vy = 0;
int collisionPos = 0;
int weapon[4] = {0,0,0,0};

enum GAMESTATE
{
   STANDING,
   WALKING_LEFT,
   WALKING_RIGHT,
   ANGLE_UP,
   ANGLE_DOWN,
   POWER_UP,
   POWER_DOWN,
   CHANGE_WEAPON,
   BAZOOKA_PROJECTILE,
   SWING_BAT,
   BAT_PROJECTILE,
};
enum GAMESTATE state;

while(1)
{
// Initialize the terrain
genTerrain(terrain);
drawTerrain(terrain, GAMEBOARD_LENGTH, 0);
initializeWorms(s, terrain);


// Initialize the game variables
nextGame = 0;
wormsTurn = 0;
state = STANDING;
for(i = 0; i < 4; i++) {wormHealth[i] = 100; angle[i] = 0;}


while((nextGame == 0))
{
    if ((animCount % 50) == 0){
       placeArrows(s, wormsTurn, wormHealth, &arrowBounce);
       if (wormsTurn % 2 == getMaster() ) {
          key = getKey();
          switch(key)
          {
          case LEFT_ARROW:
```

```
    state = WALKING_LEFT;
    walk = 0;
     send_message(LEFT_ARROW_NET);
break;

case RIGHT_ARROW:
    state = WALKING_RIGHT;
    walk = 0;
    send_message(RIGHT_ARROW_NET);
break;

case UP_ARROW:
    state = ANGLE_UP;
    send_message(UP_ARROW_NET);
break;

case DOWN_ARROW:
    state = ANGLE_DOWN;
    send_message(DOWN_ARROW_NET);
break;

case PAGE_UP:
    state = POWER_UP;
    send_message(PAGE_UP_NET);
break;

case PAGE_DOWN:
    state = POWER_DOWN;
    send_message(PAGE_DOWN_NET);
break;

case END:
    state = CHANGE_WEAPON;
    send_message(END_NET);
break;

case SPACEBAR:
    if(weapon[wormsTurn] == BAZOOKA) {state = BAZOOKA_PROJECTILE;}
    else if(weapon[wormsTurn] == BAT) {swing = 0; state = SWING_BAT;}
    send_message(SPACEBAR_NET);
break;

case DEL:
   syncTerrain(terrainNet, s);
```

```
        break;
    }
} else {
    key = getRemoteKey();
     switch(key)
    {
        case LEFT_ARROW_NET:
            state = WALKING_LEFT;
            walk = 0;
        break;

        case RIGHT_ARROW_NET:
            state = WALKING_RIGHT;
            walk = 0;
        break;

        case UP_ARROW_NET:
            state = ANGLE_UP;
        break;

        case DOWN_ARROW_NET:
            state = ANGLE_DOWN;
        break;

        case END_NET:
            state = CHANGE_WEAPON;
        break;

        case PAGE_UP_NET:
            state = POWER_UP;
        break;

        case PAGE_DOWN_NET:
            state = POWER_DOWN;
        break;
         case SPACEBAR_NET:
            if(weapon[wormsTurn] == BAZOOKA) {state = BAZOOKA_PROJECTILE;}
            else if(weapon[wormsTurn] == BAT) {swing = 0; state = SWING_BAT;}
        break;
    }
}

key = 0x00;
```

```
    }

   switch(state)
   {
      case STANDING:
         if((animCount % 50) == 0){
            s[9].shown = 0; // do not show the projectile
            placeReticle(s, wormsTurn, angle[wormsTurn], 5*power[wormsTurn] +
RETICLE_OFFSET);
            animBreath(s, breath);
            sitWorms(s, terrain);
            drawWeapon(s, wormsTurn, angle[wormsTurn], weapon[wormsTurn]);
            centerScreen(s[wormsTurn].h, s[wormsTurn].v);
         }
      break;

   case WALKING_LEFT:
      if((animCount % 40) == 0){
         s[9].shown = 0; // do not show the projectile
         s[8].shown = 0; // do not display reticle

         if(s[wormsTurn].flip == LEFT)
         {
            if(walkCount > 0)
            {
               if(walk == 7) {walk = 0; walkCount--;}
               animWalk(s, terrain, wormsTurn, &walk);
               if(walk == 7) {walkCount--; state = STANDING;}
            }

            else {state = STANDING;}
         }

         else{s[wormsTurn].flip = LEFT; state = STANDING;}

         centerScreen(s[wormsTurn].h, s[wormsTurn].v);
      }
   break;

    case WALKING_RIGHT:
      if((animCount % 40) == 0)
      {
         s[9].shown = 0; // do not show the projectile
         s[8].shown = 0; // do not display reticle
```

```
        if(s[wormsTurn].flip == RIGHT)
        {
            if(walkCount > 0)
            {
                if(walk == 7) {walk = 0; walkCount--;}
                animWalk(s, terrain, wormsTurn, &walk);
                if(walk == 7) {walkCount--; state = STANDING;}
            }
            else {state = STANDING;}
        }

        else{s[wormsTurn].flip = RIGHT; state = STANDING;}
        centerScreen(s[wormsTurn].h, s[wormsTurn].v);
    }
break;

case ANGLE_UP:
    if(angle[wormsTurn] > -90) {angle[wormsTurn] -= ANGLE_INC;}
    state = STANDING;
break;


case ANGLE_DOWN:
    if(angle[wormsTurn] < 90) {angle[wormsTurn] += ANGLE_INC;}
    state = STANDING;
break;

case POWER_UP:
    power[wormsTurn] += 1;
    state = STANDING;
break;

case POWER_DOWN:
    if(power[wormsTurn] > 0) {power[wormsTurn] -= 1;}
    state = STANDING;
break;

case CHANGE_WEAPON:
    if(weapon[wormsTurn] == BAZOOKA) {weapon[wormsTurn] = BAT;}
    else if(weapon[wormsTurn] == BAT) {weapon[wormsTurn] = BAZOOKA;}
    state = STANDING;
break;

case BAZOOKA_PROJECTILE:
```

```
      if ((animCount % 40) == 0)
      {
         collisionPos = animProjectile(s,terrain, wormsTurn, &projAnim, angle[wormsTurn],
power[wormsTurn], &vx, &vy);

         if(collisionPos >= 0)
         {
            drawDamage(terrain, collisionPos);
            smoothTerrain(terrain,1);
            drawTerrain(terrain, GAMEBOARD_LENGTH, 0);
            projAnim = 0;

            for(i = 0; i < 4; i++)
            {
               distance = collisionPos - s[i].h;
               if (distance < 0) {distance = -distance;}
               if ( distance < DAMAGE_RADIUS ) {wormHealth[i] -= DAMAGE_RADIUS -
distance + 10;}
               if ( distance < BULLSEYE) {wormHealth[i] -= 15;}
               if ( wormHealth[i] <= 0 ) {s[i].shown = 0;}
            }

            nextGame = selectNextWorm(&wormsTurn, wormHealth);
            walkCount = MAX_STEPS;
            state = STANDING;
         }
      }
      centerScreen(s[9].h, s[9].v);
   break;

   case SWING_BAT:
      if((animCount % 10) == 0)
      {
         animSwing(s, wormsTurn, &swing);
         if(swing == 5) {hitWorm = findHitWorm(s, wormsTurn); state = BAT_PROJECTILE;}
      }
   break;

   case BAT_PROJECTILE:
      if(hitWorm == wormsTurn)
      {
         nextGame = selectNextWorm(&wormsTurn, wormHealth);
         state = STANDING;
      }
```

```
        else // a worm has been hit
        {
            if ((animCount % 40) == 0)
            {
                collisionPos = animFlyingWorm(s,terrain, hitWorm, wormsTurn, &projAnim,
angle[wormsTurn], power[wormsTurn], &vx, &vy);
                if(collisionPos >= 0)
                {
                    projAnim = 0;
                    wormHealth[hitWorm] -= 25;
                    if ( wormHealth[hitWorm] <= 0 ) {s[hitWorm].shown = 0;}
                    nextGame = selectNextWorm(&wormsTurn, wormHealth);

         walkCount = MAX_STEPS;
                    state = STANDING;
                }
            }
            centerScreen(s[hitWorm].h, s[hitWorm].v);
        }
    break;

    } // end switch
    animCount++;
    updateSprites(s);

// Pause
    int count = 8000;
    while(count) {count--;};
   }// End gamemode while
} // End infinite loop while

 return 0;
}
```