Appendix

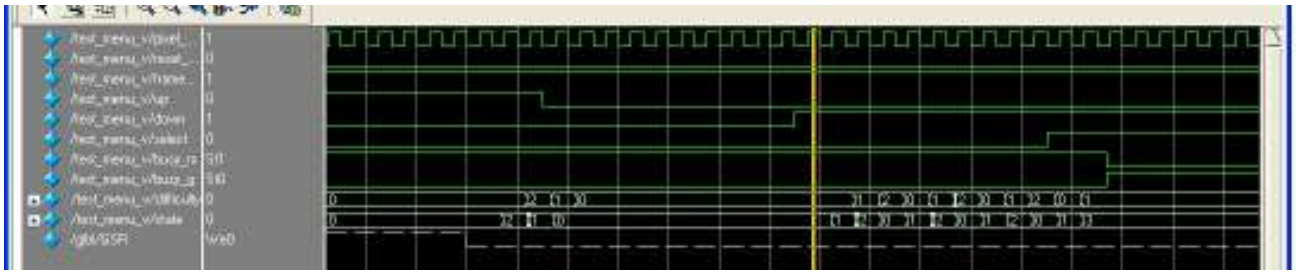


Figure 1. Test Bench for Menu FSM

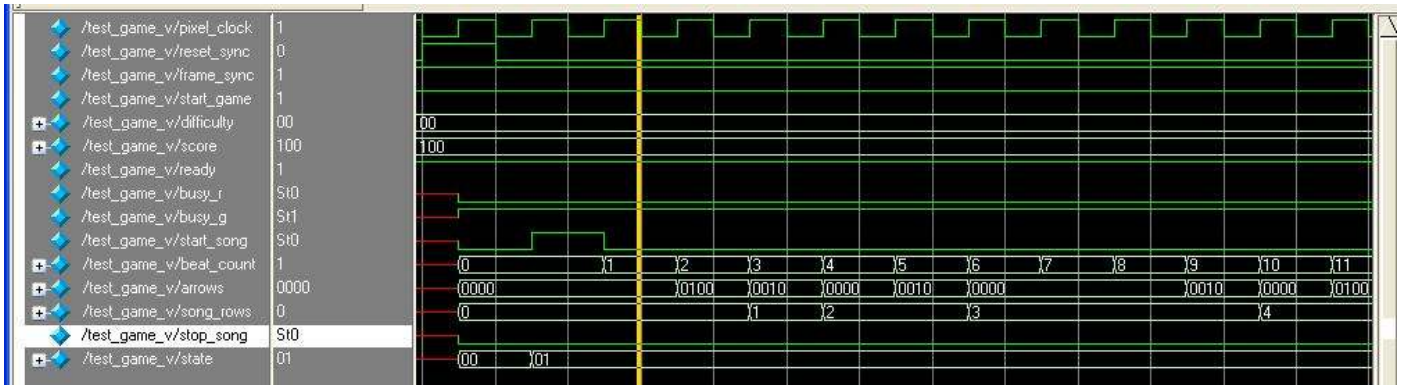


Figure 2. Test Bench #1 for Game FSM

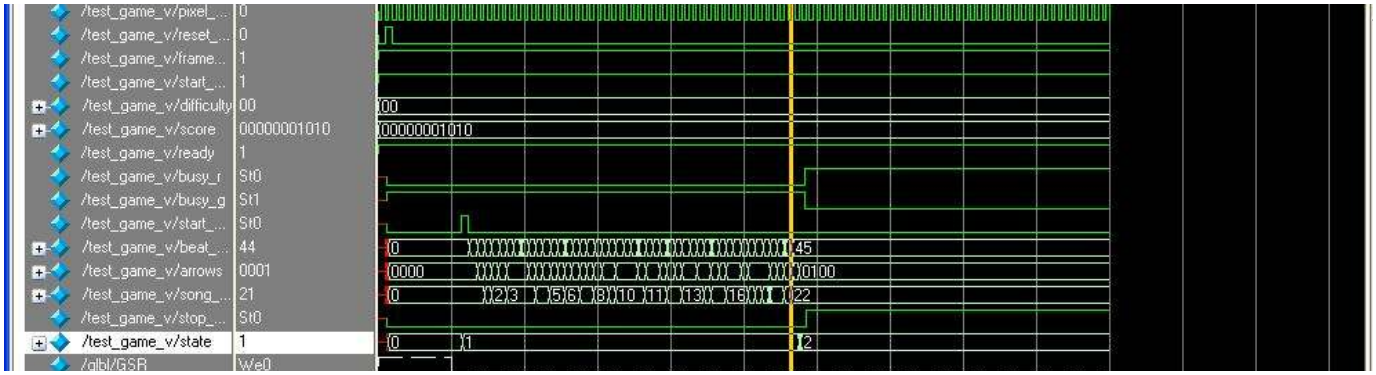


Figure 3. Test Bench #2 for Game FSM

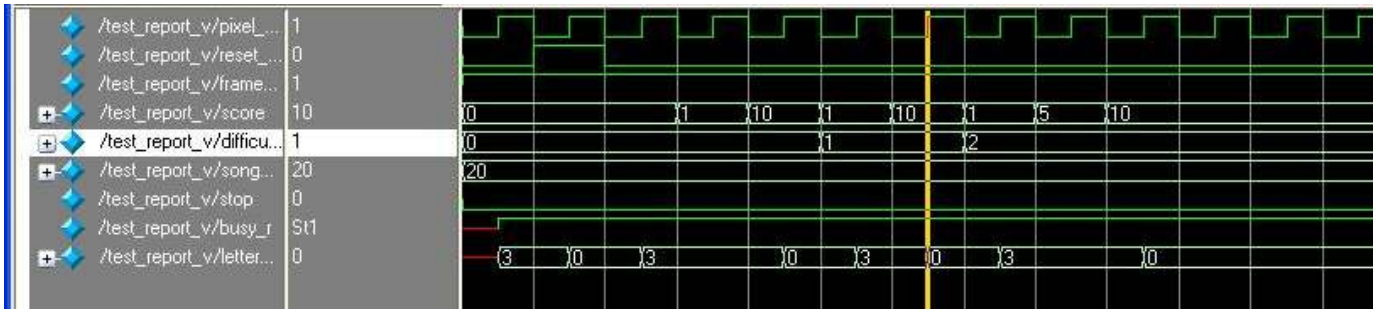


Figure 4. Test Bench for Report Module

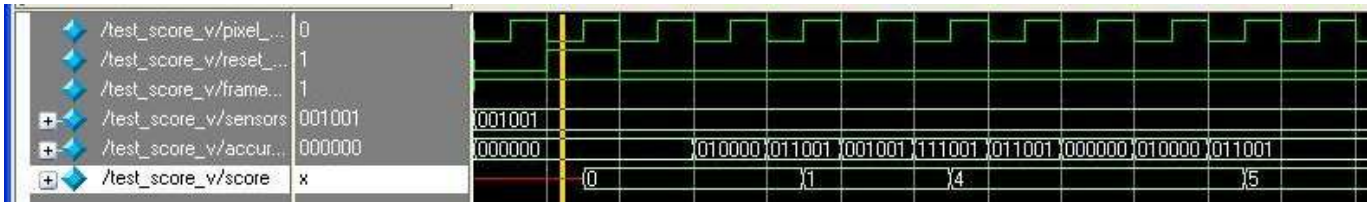


Figure 4. Test Bench for Score Keeper Module

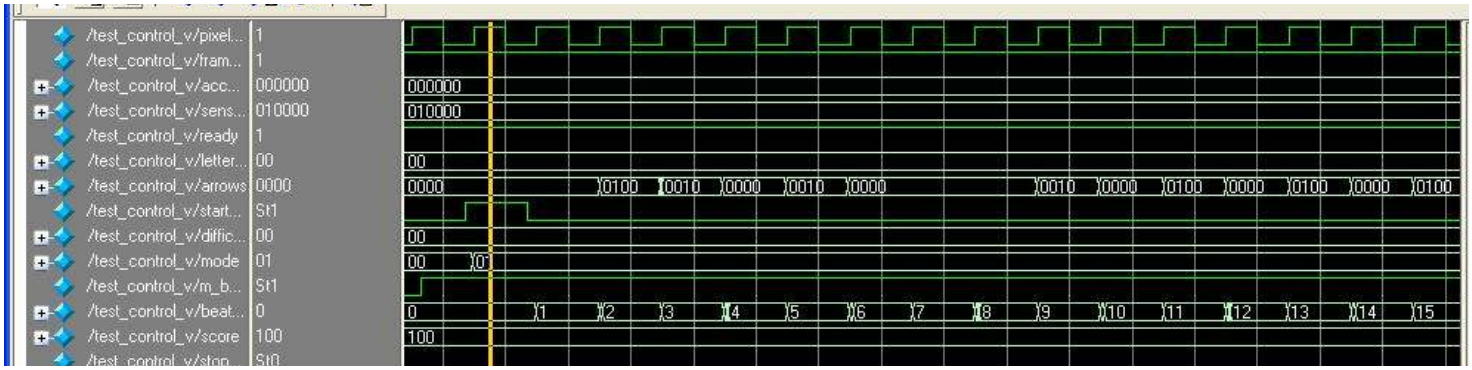


Figure 5. Test Bench #1 for Control Unit

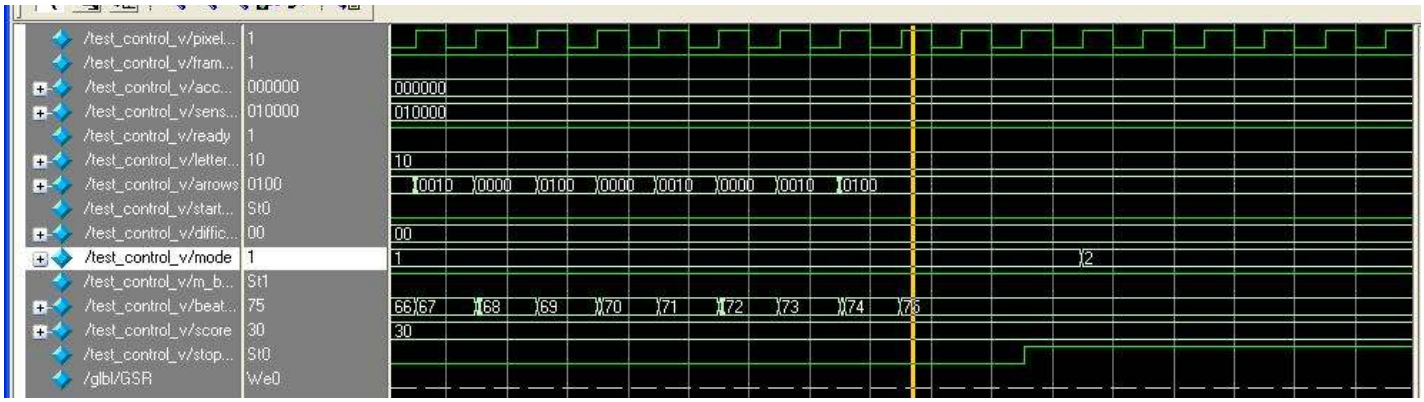


Figure 6. Test Bench #2 for Control Unit

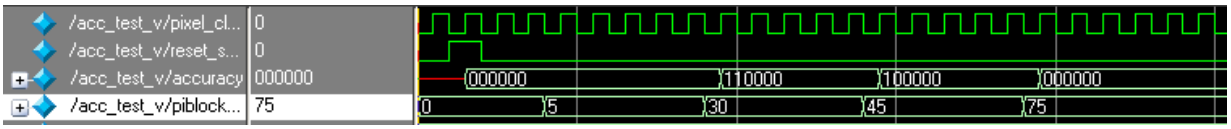


Figure 7. Test Bench for Accuracy Controller

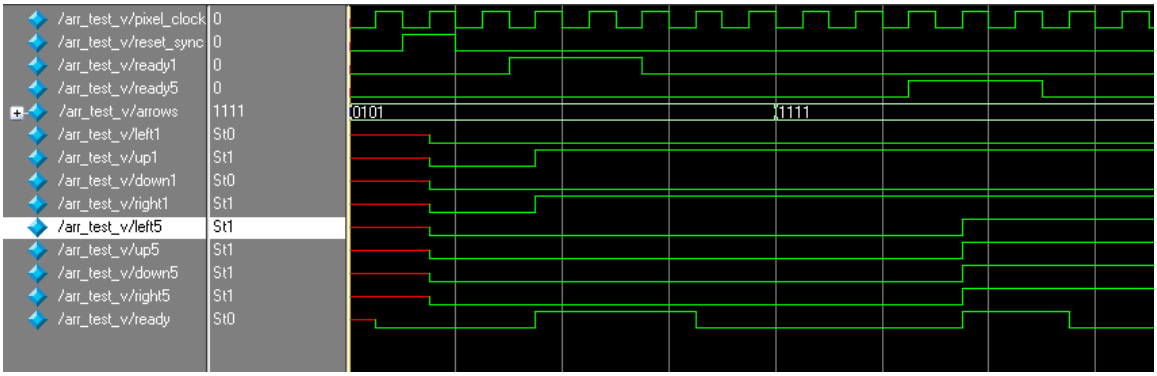


Figure 8. Test Bench for Arrow Controller

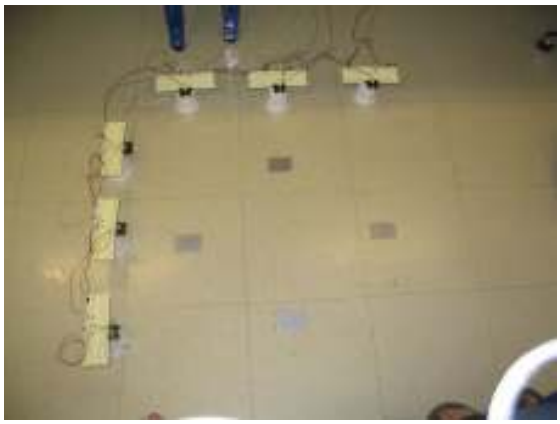


Figure 9:
Picture of the grid created by the 6 infrared sensors.

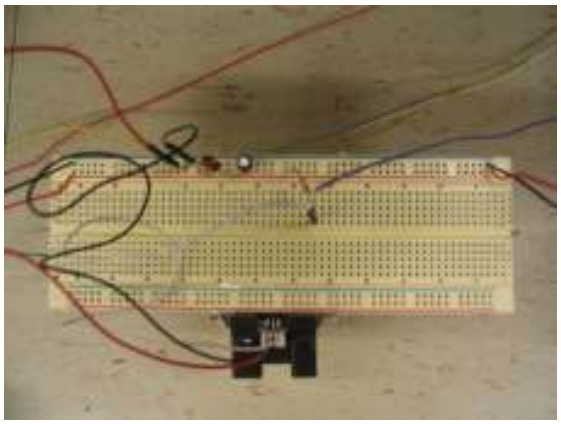


Figure 10:
Close up shot of the circuitry for each Sharp trigger.

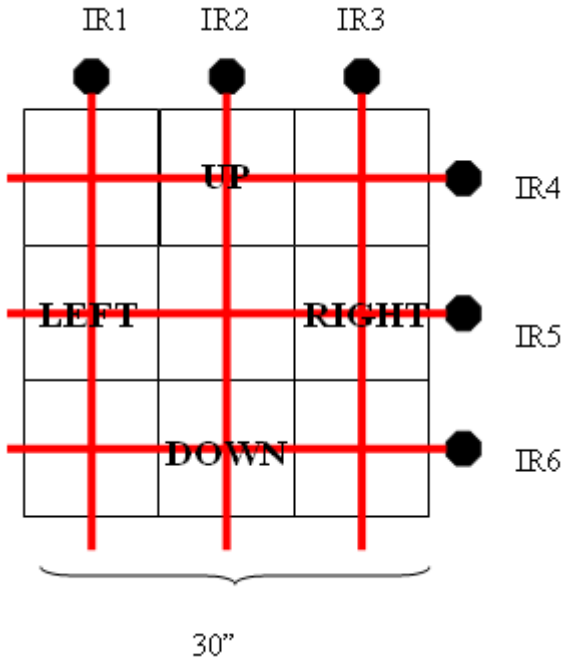


Figure 11: Picture of the sensors grid, and how it translates into up, down, right, left footwork.

Figures 12, 13, and 14: Screen shots, in respective order, of the menu screen, in game screen, and report card screen.

Figures 15, 16, and 17:
Sensor Specification Sheets (3 pages)

SHARP GP2Y0D02YK

GP2Y0D02YK

Long Distance Measuring Sensor

■ Features

1. Less influence on the colors of reflected objects and their reflectivity, due to optical triangle measuring method
2. Distance judgement type
   Judgement distance:80cm (Detection range:20 to 150cm)
3. An external control circuit is not necessary
   Output can be connected directly to a microcomputer

■ Applications

1. For detection of human body and various types of objects in home appliances, OA equipment, etc

■ Absolute Maximum Ratings (Ta=25°C)

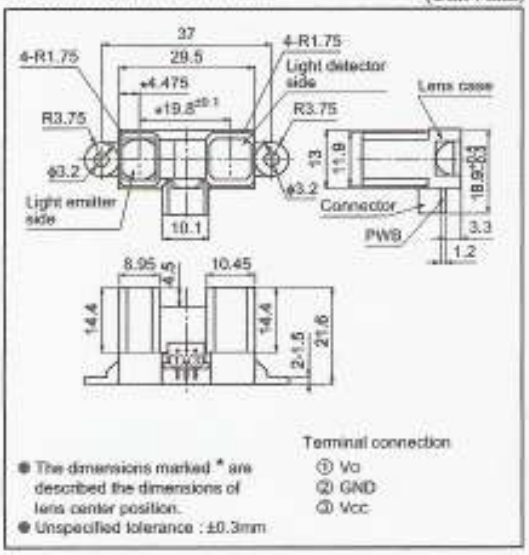
Parameter	Symbol	Rating	Unit
Supply voltage	V_{CC}	−0.3 to +7	V
*1 Output terminal voltage	V_O	−0.3 to V_{CC} +0.3	V
Operating temperature	T_{opr}	−10 to +60	°C
Storage temperature	T_{stg}	−40 to +70	°C

*1 Open collector output

■ Recommended Operating Conditions

Parameter	Symbol	Rating	Unit
Operating Supply voltage	V_{CC}	4.5 to 5.5	V

■ Outline Dimensions (Unit : mm)



SHARP GP2Y0D02YK

■ Electro-optical Characteristics

(Ta=25°C, Vcc=5V)

Parameter	Symbol	Conditions	MIN.	TYP.	MAX.	Unit
Distance measuring range	ΔL	*2 *4	20	–	150	cm
Output terminal voltage	VOH	*2 Output voltage at high level	Vcc–0.3	–	–	V
	VOL	*2 Output voltage at low level	–	–	0.6	V
Distance characteristics of output	VO	*2 *3 *5	70	80	90	cm
Average dissipation current	Icc	–	–	33	50	mA

Note) L:Distance to reflective object
*2 Using reflective object:White paper (Made by Kodak Co. Ltd. gray cards R-27 - white face, reflective ratio:90%)
*3 We ship the device after the following adjustment:Output switching distance L=80cm±10cm must be measured by the sensor
*4 Distance measuring range of the optical sensor system
*5 Output switching has a hysteresis width. The distance specified by V_O should be the one with which the output L switches to the output H

Fig.1 Internal Block Diagram

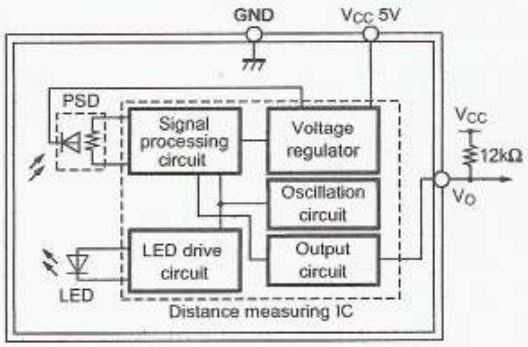
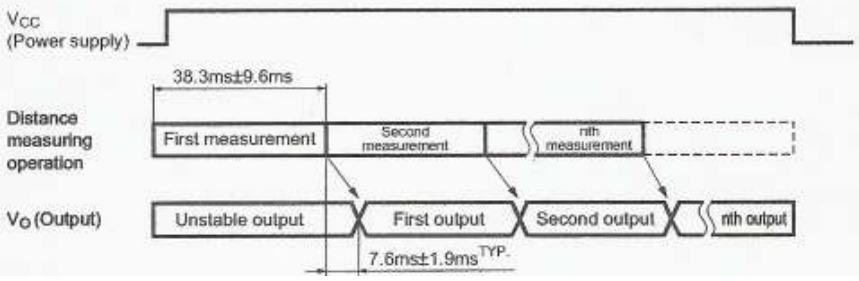
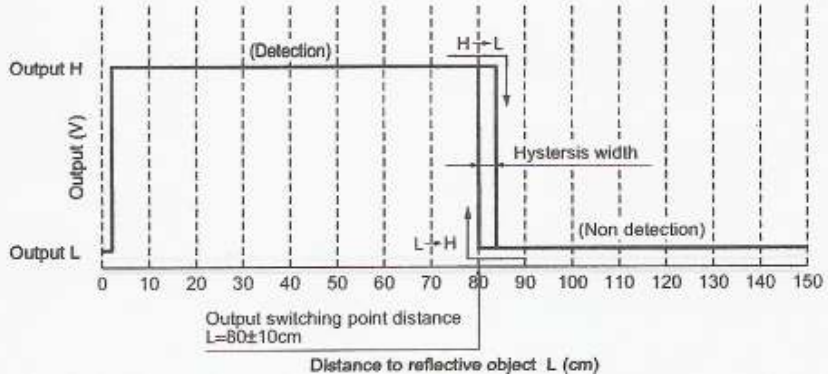


Fig.2 Timing Chart



SHARP GP2Y0D02YK

Fig.3 Distance Characteristics



Verilog Project Code

Labkit.v

```
//////////////////////////////////////////////////////////////////////////////////
//
//Sharmeen Browarek
//Anna Ayuso
//6.111 Final Project
//TA: Jae Lee
//
//////////////////////////////////////////////////////////////////////////////////

//////////////////////////////////////////////////////////////////////////////////
//
// 6.111 FPGA Labkit -- Template Toplevel Module for Lab 4 (Spring 2006)
//
//
// Created: March 13, 2006
// Author: Nathan Ickes
//
//////////////////////////////////////////////////////////////////////////////////


module labkit (beep, audio_reset_b, ac97_sdata_out, ac97_sdata_in, ac97_synch,
               ac97_bit_clock,

               vga_out_red, vga_out_green, vga_out_blue, vga_out_sync_b,
               vga_out_blank_b, vga_out_pixel_clock, vga_out_hsync,
               vga_out_vsync,

               tv_out_ycrcb, tv_out_reset_b, tv_out_clock, tv_out_i2c_clock,
               tv_out_i2c_data, tv_out_pal_ntsc, tv_out_hsync_b,
               tv_out_vsync_b, tv_out_blank_b, tv_out_subcar_reset,

               tv_in_ycrcb, tv_in_data_valid, tv_in_line_clock1,
               tv_in_line_clock2, tv_in_aef, tv_in_hff, tv_in_aff,
               tv_in_i2c_clock, tv_in_i2c_data, tv_in_fifo_read,
               tv_in_fifo_clock, tv_in_iso, tv_in_reset_b, tv_in_clock,

               ram0_data, ram0_address, ram0_adv_ld, ram0_clk, ram0_cen_b,
               ram0_ce_b, ram0_oe_b, ram0_we_b, ram0_bwe_b,

               ram1_data, ram1_address, ram1_adv_ld, ram1_clk, ram1_cen_b,
               ram1_ce_b, ram1_oe_b, ram1_we_b, ram1_bwe_b,

               clock_feedback_out, clock_feedback_in,

               flash_data, flash_address, flash_ce_b, flash_oe_b, flash_we_b,
               flash_reset_b, flash_sts, flash_byte_b,

               rs232_txd, rs232_rxd, rs232_rts, rs232_cts,

               mouse_clock, mouse_data, keyboard_clock, keyboard_data,

               clock_27mhz, clock1, clock2,
```

```
                disp_blank, disp_data_out, disp_clock, disp_rs, disp_ce_b,
                disp_reset_b, disp_data_in,

                button0, button1, button2, button3, button_enter, button_right,
                button_left, button_down, button_up,

                switch,

                led,

                user1, user2, user3, user4,

                daughtercard,

                systemace_data, systemace_address, systemace_ce_b,
                systemace_we_b, systemace_oe_b, systemace_irq, systemace_mpbrdy,

                analyzer1_data, analyzer1_clock,
                analyzer2_data, analyzer2_clock,
                analyzer3_data, analyzer3_clock,
                analyzer4_data, analyzer4_clock);

output beep, audio_reset_b, ac97_synch, ac97_sdata_out;
input  ac97_bit_clock, ac97_sdata_in;

output [7:0] vga_out_red, vga_out_green, vga_out_blue;
output vga_out_sync_b, vga_out_blank_b, vga_out_pixel_clock,
          vga_out_hsync, vga_out_vsync;

output [9:0] tv_out_ycrcb;
output tv_out_reset_b, tv_out_clock, tv_out_i2c_clock, tv_out_i2c_data,
          tv_out_pal_ntsc, tv_out_hsync_b, tv_out_vsync_b, tv_out_blank_b,
          tv_out_subcar_reset;

input  [19:0] tv_in_ycrcb;
input  tv_in_data_valid, tv_in_line_clock1, tv_in_line_clock2, tv_in_aef,
          tv_in_hff, tv_in_aff;
output tv_in_i2c_clock, tv_in_fifo_read, tv_in_fifo_clock, tv_in_iso,
          tv_in_reset_b, tv_in_clock;
inout  tv_in_i2c_data;

inout  [35:0] ram0_data;
output [18:0] ram0_address;
output ram0_adv_ld, ram0_clk, ram0_cen_b, ram0_ce_b, ram0_oe_b, ram0_we_b;
output [3:0] ram0_bwe_b;

inout  [35:0] ram1_data;
output [18:0] ram1_address;
output ram1_adv_ld, ram1_clk, ram1_cen_b, ram1_ce_b, ram1_oe_b, ram1_we_b;
output [3:0] ram1_bwe_b;

input  clock_feedback_in;
output clock_feedback_out;

inout  [15:0] flash_data;
```

```
    output [23:0] flash_address;
    output flash_ce_b, flash_oe_b, flash_we_b, flash_reset_b, flash_byte_b;
    input  flash_sts;

    output rs232_txd, rs232_rts;
    input  rs232_rxd, rs232_cts;

    input  mouse_clock, mouse_data, keyboard_clock, keyboard_data;

    input  clock_27mhz, clock1, clock2;

    output disp_blank, disp_clock, disp_rs, disp_ce_b, disp_reset_b;
    input  disp_data_in;
    output  disp_data_out;

    input  button0, button1, button2, button3, button_enter, button_right,
             button_left, button_down, button_up;
    input  [7:0] switch;
    output [7:0] led;

    inout [31:0] user1, user2, user3, user4;

    inout [43:0] daughtercard;

    inout  [15:0] systemace_data;
    output [6:0]  systemace_address;
    output systemace_ce_b, systemace_we_b, systemace_oe_b;
    input  systemace_irq, systemace_mpbrdy;

    output [15:0] analyzer1_data, analyzer2_data, analyzer3_data,
                          analyzer4_data;
    output analyzer1_clock, analyzer2_clock, analyzer3_clock, analyzer4_clock;

    ////////////////////////////////////////////////////////////////////////
    //
    // I/O Assignments
    //
    ////////////////////////////////////////////////////////////////////////

    // Audio Input and Output
    assign beep= 1'b0;
//  assign audio_reset_b = 1'b0;
//  assign ac97_synch = 1'b0;
//  assign ac97_sdata_out = 1'b0;

    // Video Output
    assign tv_out_ycrcb = 10'h0;
    assign tv_out_reset_b = 1'b0;
    assign tv_out_clock = 1'b0;
    assign tv_out_i2c_clock = 1'b0;
    assign tv_out_i2c_data = 1'b0;
    assign tv_out_pal_ntsc = 1'b0;
    assign tv_out_hsync_b = 1'b1;
    assign tv_out_vsync_b = 1'b1;
    assign tv_out_blank_b = 1'b1;
    assign tv_out_subcar_reset = 1'b0;
```

```
// Video Input
assign tv_in_i2c_clock = 1'b0;
assign tv_in_fifo_read = 1'b0;
assign tv_in_fifo_clock = 1'b0;
assign tv_in_iso = 1'b0;
assign tv_in_reset_b = 1'b0;
assign tv_in_clock = 1'b0;
assign tv_in_i2c_data = 1'bZ;

// SRAMs
assign ram0_data = 36'hZ;
assign ram0_address = 19'h0;
assign ram0_adv_ld = 1'b0;
assign ram0_clk = 1'b0;
assign ram0_cen_b = 1'b1;
assign ram0_ce_b = 1'b1;
assign ram0_oe_b = 1'b1;
assign ram0_we_b = 1'b1;
assign ram0_bwe_b = 4'hF;
assign ram1_data = 36'hZ;
assign ram1_address = 19'h0;
assign ram1_adv_ld = 1'b0;
assign ram1_clk = 1'b0;
assign ram1_cen_b = 1'b1;
assign ram1_ce_b = 1'b1;
assign ram1_oe_b = 1'b1;
assign ram1_we_b = 1'b1;
assign ram1_bwe_b = 4'hF;
assign clock_feedback_out = 1'b0;

// Flash ROM
assign flash_data = 16'hZ;
assign flash_address = 24'h0;
assign flash_ce_b = 1'b1;
assign flash_oe_b = 1'b1;
assign flash_we_b = 1'b1;
assign flash_reset_b = 1'b0;
assign flash_byte_b = 1'b1;

// RS-232 Interface
assign rs232_txd = 1'b1;
assign rs232_rts = 1'b1;

// LED Displays
assign disp_blank = 1'b1;
assign disp_clock = 1'b0;
assign disp_rs = 1'b0;
assign disp_ce_b = 1'b1;
assign disp_reset_b = 1'b0;
assign disp_data_out = 1'b0;

// Buttons, Switches, and Individual LEDs
//assign led = 8'hFF;

// User I/Os
```

```
  assign user1 = 32'hZ;
  assign user2 = 32'hZ;
//  assign user3 = 32'hZ;
//  assign user4 = 32'hZ;
        assign user3[31:6] = 26'b11111111111111111111111111;

  // Daughtercard Connectors
  assign daughtercard = 44'hZ;

  // SystemACE Microprocessor Port
  assign systemace_data = 16'hZ;
  assign systemace_address = 7'h0;
  assign systemace_ce_b = 1'b1;
  assign systemace_we_b = 1'b1;
  assign systemace_oe_b = 1'b1;

  // Logic Analyzer
  assign analyzer1_data = 16'h0;
  assign analyzer1_clock = 1'b1;

  assign analyzer3_data = 16'h0;
  assign analyzer3_clock = 1'b1;


  ////////////////////////////////////////////////////////////////////////////
  //
  // Lab 4 Components
  //
  ////////////////////////////////////////////////////////////////////////////

  //
  // Generate a 31.5MHz pixel clock from clock_27mhz
  //

  wire pclk, pixel_clock;
  DCM pixel_clock_dcm (.CLKIN(clock_27mhz), .CLKFX(pclk));
  // synthesis attribute CLKFX_DIVIDE of pixel_clock_dcm is 6
  // synthesis attribute CLKFX_MULTIPLY of pixel_clock_dcm is 7
  // synthesis attribute CLK_FEEDBACK of pixel_clock_dcm  is "NONE"
        // synthesis attribute CLKIN_PERIOD of pixel_clock_dcm is 37
  BUFG pixel_clock_buf (.I(pclk), .O(pixel_clock));

  //
  // VGA output signals
  //

  // Inverting the clock to the DAC provides half a clock period for signals
  // to propagate from the FPGA to the DAC.
  assign vga_out_pixel_clock = ~pixel_clock;

  // The composite sync signal is used to encode sync data in the green
  // channel analog voltage for older monitors.  It does not need to be
  // implemented for the monitors in the 6.111 lab, and can be left at 1'b1.
  //assign vga_out_sync_b = 1'b1;

  // The following assignments should be deleted and replaced with your own
```

```
// code to implement the Pong game.
//assign vga_out_red = 8'h0;
//assign vga_out_green = 8'h0;
//assign vga_out_blue = 8'h0;
//assign vga_out_blank_b = 1'b1;
//assign vga_out_hsync = 1'b0;
//assign vga_out_vsync = 1'b0;

        wire [9:0] pixel_count, line_count, piblock_y1, piblock_y2, piblock_y3,
                                            piblock_y4, piblock_y5, piblock_y6, piblock_y7, piblock_y8,
                                            piblock_y9, piblock_y10;
        wire ready1, ready2, ready3, ready4, ready5, ready6, ready7, ready8,
                        ready9, ready10, ready;
        wire up1, up2, up3, up4, up5, up6, up7, up8, up9, up10;
        wire down1, down2, down3, down4, down5, down6, down7, down8, down9,
                        down10;
        wire right1, right2, right3, right4, right5, right6, right7, right8,
                        right9, right10;
        wire left1, left2, left3, left4, left5, left6, left7, left8, left9,
                        left10;
        wire reset_sync, up_sync, down_sync, right_sync, left_sync, select;
        wire [5:0] sensors;
        wire [1:0] difficulty, mode, letter_score;
        wire [5:0] accuracy;
        wire [3:0] arrows;
        wire [23:0] rgb_out;
        wire vga_out_vsync;
        wire frame_sync, m_busy_g, start_game, stop, start_song;
        wire [9:0] beat_count;
        wire enable, enable2;
        wire [10:0] score;
        wire IR1, IR2, IR3, IR4, IR5, IR6, IR1_temp, IR2_temp, IR3_temp,
                        IR4_temp, IR5_temp, IR6_temp, up_temp, down_temp, right_temp,
                        left_temp;

        wire control_mode;

        assign frame_sync = ((pixel_count == 639) && (line_count == 479));
        assign vga_out_red = rgb_out[23:16];
        assign vga_out_green = rgb_out[15:8];
        assign vga_out_blue = rgb_out[7:0];

    assign analyzer2_data = {sensors[0], /*accuracy[1:0]*/2'b0, score[10:0], 2'b0};
    assign analyzer2_clock = vga_out_pixel_clock;

    assign analyzer4_data = {beat_count[9:0], arrows[3:0], ready, start_game};
    assign analyzer4_clock = vga_out_pixel_clock;

        assign reset_sync = sensors[5];

//      assign led[7:4] = 4'b1111;
        assign led[3] = ~sensors[0];
        assign led[2] = ~sensors[1];
        assign led[1] = ~sensors[2];
        assign led[0] = ~sensors[3];
```

```
//assign led[7:6] = ~difficulty;
//assign led[4:3] = ~letter_score;
//assign led[5] = 1'b1;
//assign led[2:0] = 1'b1;

assign led[7:4] = ~score[3:0];


//        assign mode = switch[3:2];

        Control_Unit      game_control(pixel_clock, frame_sync, accuracy, sensors, ready, letter_score,
        arrows, start_song, difficulty, mode, m_busy_g, beat_count, score, enable, stop);

        assign user4[31:26] = 6'b111111;
        wire [7:0] data;

        assign data = user4[25:18];


        audio roboto_song(reset_sync, pixel_clock, audio_reset_b, ac97_sdata_out, ac97_sdata_in,
                                                        ac97_synch, ac97_bit_clock, start_song, stop, user4[17:0],
data);

        Decode_IR_Sensors woohoo(pixel_clock, reset_sync, IR1, IR2, IR3, IR4, IR5, IR6, sensors[2],
                                                                sensors[1], sensors[3], sensors[0],
up_temp, down_temp, right_temp,
                                                                left_temp, control_mode);

        VGA my_VGA(.pixel_clock(pixel_clock), .reset_sync(reset_sync), .hsync(vga_out_hsync),
                                .vsync(vga_out_vsync), .sync_b(vga_out_sync_b), .blank_b(vga_out_blank_b),
                                .pixel_count(pixel_count), .line_count(line_count));

        GameDisplay game_screen(.pixel_clock(pixel_clock), .pixel_count(pixel_count),
                                .line_count(line_count), .rgb(rgb_out),
                                .reset_sync(reset_sync), .piblock_y1(piblock_y1), .piblock_y2(piblock_y2),
                                .piblock_y3(piblock_y3), .piblock_y4(piblock_y4), .piblock_y5(piblock_y5),
                                .piblock_y6(piblock_y6), .piblock_y7(piblock_y7), .piblock_y8(piblock_y8),
                                .piblock_y9(piblock_y9), .piblock_y10(piblock_y10),
                                .up1(up1), .up2(up2), .up3(up3), .up4(up4), .up5(up5), .up6(up6), .up7(up7),
                                .up8(up8), .up9(up9), .up10(up10), .down1(down1), .down2(down2),
.down3(down3),
                                .down4(down4), .down5(down5), .down6(down6), .down7(down7),
.down8(down8),
                                .down9(down9), .down10(down10), .right1(right1), .right2(right2),
.right3(right3),
                                .right4(right4), .right5(right5), .right6(right6), .right7(right7), .right8(right8),
                                .right9(right9), .right10(right10), .left1(left1), .left2(left2), .left3(left3),
                                .left4(left4), .left5(left5), .left6(left6), .left7(left7), .left8(left8),
                                .left9(left9), .left10(left10), .mode(mode), .letter_score(letter_score),
                                .difficulty(difficulty), .frame_sync(frame_sync), .start_game(start_game));

        accuracy_controller accuracy_c(pixel_clock, reset_sync, piblock_y1,
                                piblock_y2, piblock_y3, piblock_y4, piblock_y5,
                                piblock_y6, piblock_y7, piblock_y8, piblock_y9,
                                piblock_y10, accuracy,
                                up1, up2, up3, up4, up5, up6,          up7, up8, up9,
```

```
                                up10, down1, down2, down3, down4, down5,
                                down6, down7, down8, down9, down10, right1, right2,
                                right3, right4, right5, right6, right7, right8, right9,
                                right10, left1, left2, left3, left4, left5, left6, left7,
                                left8, left9, left10, control_mode);

arrow_controller arrow_c(pixel_clock, reset_sync, up1, up2, up3, up4, up5, up6,
                                up7, up8, up9, up10, down1, down2, down3, down4, down5,
                                down6, down7, down8, down9, down10, right1, right2,
                                right3, right4, right5, right6, right7, right8, right9,
                                right10, left1, left2, left3, left4, left5, left6, left7,
                                left8, left9, left10, ready1, ready2, ready3, ready4,
                                ready5, ready6, ready7, ready8, ready9, ready10, arrows,
                                ready);

divider menu_enable(pixel_clock, reset_sync, enable);

piblock piblock1(.pixel_clock(pixel_clock), .reset_sync(reset_sync), .piblock_y(piblock_y1),
                                .frame_sync(frame_sync), .ready(ready1), .ystart(10'd550),
                                .start_game(start_song));

piblock piblock2(.pixel_clock(pixel_clock), .reset_sync(reset_sync), .piblock_y(piblock_y2),
                                .frame_sync(frame_sync), .ready(ready2), .ystart(10'd490),
                                .start_game(start_song));

piblock piblock3(.pixel_clock(pixel_clock), .reset_sync(reset_sync), .piblock_y(piblock_y3),
                                .frame_sync(frame_sync), .ready(ready3), .ystart(10'd430),
                                .start_game(start_song));

piblock piblock4(.pixel_clock(pixel_clock), .reset_sync(reset_sync), .piblock_y(piblock_y4),
                                .frame_sync(frame_sync), .ready(ready4), .ystart(10'd370),
                                .start_game(start_song));

piblock piblock5(.pixel_clock(pixel_clock), .reset_sync(reset_sync), .piblock_y(piblock_y5),
                                .frame_sync(frame_sync), .ready(ready5), .ystart(10'd310),
                                .start_game(start_song));

piblock piblock6(.pixel_clock(pixel_clock), .reset_sync(reset_sync), .piblock_y(piblock_y6),
                                .frame_sync(frame_sync), .ready(ready6), .ystart(10'd250),
                                .start_game(start_song));

piblock piblock7(.pixel_clock(pixel_clock), .reset_sync(reset_sync), .piblock_y(piblock_y7),
                                .frame_sync(frame_sync), .ready(ready7), .ystart(10'd190),
                                .start_game(start_song));

piblock piblock8(.pixel_clock(pixel_clock), .reset_sync(reset_sync), .piblock_y(piblock_y8),
                                .frame_sync(frame_sync), .ready(ready8), .ystart(10'd130),
                                .start_game(start_song));

piblock piblock9(.pixel_clock(pixel_clock), .reset_sync(reset_sync), .piblock_y(piblock_y9),
                                .frame_sync(frame_sync), .ready(ready9), .ystart(10'd70),
                                .start_game(start_song));

piblock piblock10(.pixel_clock(pixel_clock), .reset_sync(reset_sync), .piblock_y(piblock_y10),
                                .frame_sync(frame_sync), .ready(ready10), .ystart(10'd10),
                                .start_game(start_song));
```

```
	debounce reset_debounce(.reset(1'b0), .clock(vga_out_pixel_clock), .noisy(~button_enter),
.clean(sensors[5]));
	defparam reset_debounce.DELAY = 270000;

	debounce up_debounce(.reset(1'b0), .clock(vga_out_pixel_clock), .noisy(~button_up), .clean(up_temp));

	debounce down_debounce(.reset(1'b0), .clock(vga_out_pixel_clock), .noisy(~button_down),
.clean(down_temp));

	debounce right_debounce(.reset(1'b0), .clock(vga_out_pixel_clock), .noisy(~button_right),
.clean(right_temp));

	debounce left_debounce(.reset(1'b0), .clock(vga_out_pixel_clock), .noisy(~button_left), .clean(left_temp));

	debounce select_debounce(.reset(1'b0), .clock(vga_out_pixel_clock), .noisy(~button0), .clean(sensors[4]));
	defparam select_debounce.DELAY = 270000;


	IRdebounce IRdbIR1(reset_sync, pixel_clock, IR1_temp, IR1);

	IRdebounce IRdbIR2(reset_sync, pixel_clock, IR2_temp, IR2);

	IRdebounce IRdbIR3(reset_sync, pixel_clock, IR3_temp, IR3);

	IRdebounce IRdbIR4(reset_sync, pixel_clock, IR4_temp, IR4);

	IRdebounce IRdbIR5(reset_sync, pixel_clock, IR5_temp, IR5);

	IRdebounce IRdbIR6(reset_sync, pixel_clock, IR6_temp, IR6);



	debounce dbIR1(.reset(1'b0), .clock(vga_out_pixel_clock), .noisy(user3[0]), .clean(IR1_temp));

	debounce dbIR2(.reset(1'b0), .clock(vga_out_pixel_clock), .noisy(user3[1]), .clean(IR2_temp));

	debounce dbIR3(.reset(1'b0), .clock(vga_out_pixel_clock), .noisy(user3[2]), .clean(IR3_temp));

	debounce dbIR4(.reset(1'b0), .clock(vga_out_pixel_clock), .noisy(user3[3]), .clean(IR4_temp));

	debounce dbIR5(.reset(1'b0), .clock(vga_out_pixel_clock), .noisy(user3[4]), .clean(IR5_temp));

	debounce dbIR6(.reset(1'b0), .clock(vga_out_pixel_clock), .noisy(user3[5]), .clean(IR6_temp));

	debounce dbcontrol_mode(.reset(1'b0), .clock(vga_out_pixel_clock), .noisy(switch[7]),
.clean(control_mode));


endmodule
```

Accuracy Controller

```
`timescale 1ns / 1ps

//////////////////////////////////////////////////////////////////////////////////
//
//Sharmeen Browarek
//Anna Ayuso
//6.111 Final Project
//TA: Jae Lee
//
//////////////////////////////////////////////////////////////////////////////////
//This module is in charge of sending the control unit a 6-bit accuracy signal.  The range of accuracy
//for the moving arrows is determined by comparing the dynamic piblocks to the static ones at the
//top of the screen.  Each time a block nears the top, a 2-bit signal is sent to the control unit, along
//with 4 bits that designate which arrows of that block are lit.
//There are two sets of ranges because a delay had to be factored in when the user is playing in the
//sensors mode.
module accuracy_controller(pixel_clock, reset_sync, piblock_y1,
                                                        piblock_y2, piblock_y3, piblock_y4, piblock_y5,
                                                        piblock_y6, piblock_y7, piblock_y8, piblock_y9,
                                                        piblock_y10, accuracy,
                                                        up1, up2, up3, up4, up5, up6,          up7, up8, up9,
                                                        up10, down1, down2, down3, down4, down5,
                                                        down6, down7, down8, down9, down10, right1,
right2,
                                                        right3, right4, right5, right6, right7, right8, right9,
                                                        right10, left1, left2, left3, left4, left5, left6, left7,
                                                        left8, left9, left10, control_mode);

input pixel_clock, reset_sync, control_mode;
input [9:0] piblock_y1, piblock_y2, piblock_y3, piblock_y4,
                                        piblock_y5, piblock_y6, piblock_y7, piblock_y8,
                                        piblock_y9, piblock_y10;
input up1, up2, up3, up4, up5, up6, up7, up8, up9, up10;
input down1, down2, down3, down4, down5, down6, down7, down8, down9,
                down10;
input right1, right2, right3, right4, right5, right6, right7, right8,
                right9, right10;
input left1, left2, left3, left4, left5, left6, left7, left8, left9,
                left10;

output [5:0] accuracy;

reg [5:0] accuracy;

reg [9:0] range1, range2, range3, range4, range5;

always @ (posedge pixel_clock)
        begin
                if (reset_sync)
                        begin
                                accuracy <= 6'd0;
                                range1 <= 10'd10;
                                range2 <= 10'd15;
                                range3 <= 10'd40;
                                range4 <= 10'd55;
```

```
                        range5 <= 10'd60;
                end
        if (control_mode == 1)
                begin
                        range1 <= 10'd510;
                        range2 <= 10'd515;
                        range3 <= 10'd545;
                        range4 <= 10'd565;
                        range5 <= 10'd570;
                end
        if (control_mode == 0)
                begin
                        range1 <= 10'd10;
                        range2 <= 10'd25;
                        range3 <= 10'd40;
                        range4 <= 10'd50;
                        range5 <= 10'd60;
                end
//check for piblock 1
        if ((piblock_y1 >= range1) && (piblock_y1 < range2))
                begin
                        accuracy[5:4] <= 2'd1;
                        accuracy[3] <= left1;
                        accuracy[2] <= up1;
                        accuracy[1] <= down1;
                        accuracy[0] <= right1;
                end
        else if ((piblock_y1 >= range2) && (piblock_y1 < range3))
                begin
                        accuracy[5:4] <= 2'd3;
                        accuracy[3] <= left1;
                        accuracy[2] <= up1;
                        accuracy[1] <= down1;
                        accuracy[0] <= right1;
                end
        else if ((piblock_y1 >= range3) && (piblock_y1 < range4))
                begin
                        accuracy[5:4] <= 2'd2;
                        accuracy[3] <= left1;
                        accuracy[2] <= up1;
                        accuracy[1] <= down1;
                        accuracy[0] <= right1;
                end
        else if ((piblock_y1 >= range4) && (piblock_y1 < range4))
                begin
                        accuracy[5:4] <= 2'd1;
                        accuracy[3] <= left1;
                        accuracy[2] <= up1;
                        accuracy[1] <= down1;
                        accuracy[0] <= right1;
                end


//check for piblock 2
        if ((piblock_y2 >= range1) && (piblock_y2 < range2))
                begin
```

```
                        accuracy[5:4] <= 2'd1;
                        accuracy[3] <= left2;
                        accuracy[2] <= up2;
                        accuracy[1] <= down2;
                        accuracy[0] <= right2;
                end
        else if ((piblock_y2 >= range2) && (piblock_y2 < range3))
                begin
                        accuracy[5:4] <= 2'd3;
                        accuracy[3] <= left2;
                        accuracy[2] <= up2;
                        accuracy[1] <= down2;
                        accuracy[0] <= right2;
                end
        else if ((piblock_y2 >= range3) && (piblock_y2 < range4))
                begin
                        accuracy[5:4] <= 2'd2;
                        accuracy[3] <= left2;
                        accuracy[2] <= up2;
                        accuracy[1] <= down2;
                        accuracy[0] <= right2;
                end
        else if ((piblock_y2 >= range4) && (piblock_y2 < range4))
                begin
                        accuracy[5:4] <= 2'd1;
                        accuracy[3] <= left2;
                        accuracy[2] <= up2;
                        accuracy[1] <= down2;
                        accuracy[0] <= right2;
                end


//check for piblock 3
        if ((piblock_y3 >= range1) && (piblock_y3 < range2))
                begin
                        accuracy[5:4] <= 2'd1;
                        accuracy[3] <= left3;
                        accuracy[2] <= up3;
                        accuracy[1] <= down3;
                        accuracy[0] <= right3;
                end
        else if ((piblock_y3 >= range2) && (piblock_y3 < range3))
                begin
                        accuracy[5:4] <= 2'd3;
                        accuracy[3] <= left3;
                        accuracy[2] <= up3;
                        accuracy[1] <= down3;
                        accuracy[0] <= right3;
                end
        else if ((piblock_y3 >= range3) && (piblock_y3 < range4))
                begin
                        accuracy[5:4] <= 2'd2;
                        accuracy[3] <= left3;
                        accuracy[2] <= up3;
                        accuracy[1] <= down3;
                        accuracy[0] <= right3;
```

```
                end
        else if ((piblock_y3 >= range4) && (piblock_y3 < range4))
                begin
                        accuracy[5:4] <= 2'd1;
                        accuracy[3] <= left3;
                        accuracy[2] <= up3;
                        accuracy[1] <= down3;
                        accuracy[0] <= right3;
                end


//check for piblock 4
        if ((piblock_y4 >= range1) && (piblock_y4 < range2))
                begin
                        accuracy[5:4] <= 2'd1;
                        accuracy[3] <= left4;
                        accuracy[2] <= up4;
                        accuracy[1] <= down4;
                        accuracy[0] <= right4;
                end
        else if ((piblock_y4 >= range2) && (piblock_y4 < range3))
                begin
                        accuracy[5:4] <= 2'd3;
                        accuracy[3] <= left4;
                        accuracy[2] <= up4;
                        accuracy[1] <= down4;
                        accuracy[0] <= right4;
                end
        else if ((piblock_y4 >= range3) && (piblock_y4 < range4))
                begin
                        accuracy[5:4] <= 2'd2;
                        accuracy[3] <= left4;
                        accuracy[2] <= up4;
                        accuracy[1] <= down4;
                        accuracy[0] <= right4;
                end
        else if ((piblock_y4 >= range4) && (piblock_y4 < range4))
                begin
                        accuracy[5:4] <= 2'd1;
                        accuracy[3] <= left4;
                        accuracy[2] <= up4;
                        accuracy[1] <= down4;
                        accuracy[0] <= right4;
                end


//check for piblock 5
        if ((piblock_y5 >= range1) && (piblock_y5 < range2))
                begin
                        accuracy[5:4] <= 2'd1;
                        accuracy[3] <= left5;
                        accuracy[2] <= up5;
                        accuracy[1] <= down5;
                        accuracy[0] <= right5;
                end
        else if ((piblock_y5 >= range2) && (piblock_y5 < range3))
```

```
                begin
                        accuracy[5:4] <= 2'd3;
                        accuracy[3] <= left5;
                        accuracy[2] <= up5;
                        accuracy[1] <= down5;
                        accuracy[0] <= right5;
                end
        else if ((piblock_y5 >= range3) && (piblock_y5 < range4))
                begin
                        accuracy[5:4] <= 2'd2;
                        accuracy[3] <= left5;
                        accuracy[2] <= up5;
                        accuracy[1] <= down5;
                        accuracy[0] <= right5;
                end
        else if ((piblock_y5 >= range4) && (piblock_y5 < range4))
                begin
                        accuracy[5:4] <= 2'd1;
                        accuracy[3] <= left5;
                        accuracy[2] <= up5;
                        accuracy[1] <= down5;
                        accuracy[0] <= right5;
                end


//check for piblock 6
        if ((piblock_y6 >= range1) && (piblock_y6 < range2))
                begin
                        accuracy[5:4] <= 2'd1;
                        accuracy[3] <= left6;
                        accuracy[2] <= up6;
                        accuracy[1] <= down6;
                        accuracy[0] <= right6;
                end
        else if ((piblock_y6 >= range2) && (piblock_y6 < range3))
                begin
                        accuracy[5:4] <= 2'd3;
                        accuracy[3] <= left6;
                        accuracy[2] <= up6;
                        accuracy[1] <= down6;
                        accuracy[0] <= right6;
                end
        else if ((piblock_y6 >= range3) && (piblock_y6 < range4))
                begin
                        accuracy[5:4] <= 2'd2;
                        accuracy[3] <= left6;
                        accuracy[2] <= up6;
                        accuracy[1] <= down6;
                        accuracy[0] <= right6;
                end
        else if ((piblock_y6 >= range4) && (piblock_y6 < range4))
                begin
                        accuracy[5:4] <= 2'd1;
                        accuracy[3] <= left6;
                        accuracy[2] <= up6;
                        accuracy[1] <= down6;
```

```
                        accuracy[0] <= right6;
                end


//check for piblock 7
                if ((piblock_y7 >= range1) && (piblock_y7 < range2))
                        begin
                                accuracy[5:4] <= 2'd1;
                                accuracy[3] <= left7;
                                accuracy[2] <= up7;
                                accuracy[1] <= down7;
                                accuracy[0] <= right7;
                        end
                else if ((piblock_y7 >= range2) && (piblock_y7 < range3))
                        begin
                                accuracy[5:4] <= 2'd3;
                                accuracy[3] <= left7;
                                accuracy[2] <= up7;
                                accuracy[1] <= down7;
                                accuracy[0] <= right7;
                        end
                else if ((piblock_y7 >= range3) && (piblock_y7 < range4))
                        begin
                                accuracy[5:4] <= 2'd2;
                                accuracy[3] <= left7;
                                accuracy[2] <= up7;
                                accuracy[1] <= down7;
                                accuracy[0] <= right7;
                        end
                else if ((piblock_y7 >= range4) && (piblock_y7 < range4))
                        begin
                                accuracy[5:4] <= 2'd1;
                                accuracy[3] <= left7;
                                accuracy[2] <= up7;
                                accuracy[1] <= down7;
                                accuracy[0] <= right7;
                        end


//check for piblock 8
                if ((piblock_y8 >= range1) && (piblock_y8 < range2))
                        begin
                                accuracy[5:4] <= 2'd1;
                                accuracy[3] <= left8;
                                accuracy[2] <= up8;
                                accuracy[1] <= down8;
                                accuracy[0] <= right8;
                        end
                else if ((piblock_y8 >= range2) && (piblock_y8 < range3))
                        begin
                                accuracy[5:4] <= 2'd3;
                                accuracy[3] <= left8;
                                accuracy[2] <= up8;
                                accuracy[1] <= down8;
                                accuracy[0] <= right8;
                        end
```

```
                else if ((piblock_y8 >= range3) && (piblock_y8 < range4))
                        begin
                                accuracy[5:4] <= 2'd2;
                                accuracy[3] <= left8;
                                accuracy[2] <= up8;
                                accuracy[1] <= down8;
                                accuracy[0] <= right8;
                        end
                else if ((piblock_y8 >= range4) && (piblock_y8 < range4))
                        begin
                                accuracy[5:4] <= 2'd1;
                                accuracy[3] <= left8;
                                accuracy[2] <= up8;
                                accuracy[1] <= down8;
                                accuracy[0] <= right8;
                        end


//check for piblock 9
                if ((piblock_y9 >= range1) && (piblock_y9 < range2))
                        begin
                                accuracy[5:4] <= 2'd1;
                                accuracy[3] <= left9;
                                accuracy[2] <= up9;
                                accuracy[1] <= down9;
                                accuracy[0] <= right9;
                        end
                else if ((piblock_y9 >= range2) && (piblock_y9 < range3))
                        begin
                                accuracy[5:4] <= 2'd3;
                                accuracy[3] <= left9;
                                accuracy[2] <= up9;
                                accuracy[1] <= down9;
                                accuracy[0] <= right9;
                        end
                else if ((piblock_y9 >= range3) && (piblock_y9 < range4))
                        begin
                                accuracy[5:4] <= 2'd2;
                                accuracy[3] <= left9;
                                accuracy[2] <= up9;
                                accuracy[1] <= down9;
                                accuracy[0] <= right9;
                        end
                else if ((piblock_y9 >= range4) && (piblock_y9 < range4))
                        begin
                                accuracy[5:4] <= 2'd1;
                                accuracy[3] <= left9;
                                accuracy[2] <= up9;
                                accuracy[1] <= down9;
                                accuracy[0] <= right9;
                        end


//check for piblock 10
                if ((piblock_y10 >= range1) && (piblock_y10 < range2))
                        begin
```

```
                        accuracy[5:4] <= 2'd1;
                        accuracy[3] <= left10;
                        accuracy[2] <= up10;
                        accuracy[1] <= down10;
                        accuracy[0] <= right10;
                end
        else if ((piblock_y10 >= range2) && (piblock_y10 < range3))
                begin
                        accuracy[5:4] <= 2'd3;
                        accuracy[3] <= left10;
                        accuracy[2] <= up10;
                        accuracy[1] <= down10;
                        accuracy[0] <= right10;
                end
        else if ((piblock_y10 >= range3) && (piblock_y10 < range4))
                begin

                        accuracy[5:4] <= 2'd2;
                        accuracy[3] <= left10;
                        accuracy[2] <= up10;
                        accuracy[1] <= down10;
                        accuracy[0] <= right10;
                end
        else if ((piblock_y10 >= range4) && (piblock_y10 < range4))
                begin
                        accuracy[5:4] <= 2'd1;
                        accuracy[3] <= left10;
                        accuracy[2] <= up10;
                        accuracy[1] <= down10;
                        accuracy[0] <= right10;
                end

        if ((piblock_y1 <= range1 || piblock_y1 >= range5) &&
                        (piblock_y2 <= range1 || piblock_y2 >= range5) &&
                        (piblock_y3 <= range1 || piblock_y3 >= range5) &&
                        (piblock_y4 <= range1 || piblock_y4 >= range5) &&
                        (piblock_y5 <= range1 || piblock_y5 >= range5) &&
                        (piblock_y6 <= range1 || piblock_y6 >= range5) &&
                        (piblock_y7 <= range1 || piblock_y7 >= range5) &&
                        (piblock_y8 <= range1 || piblock_y8 >= range5) &&
                        (piblock_y9 <= range1 || piblock_y9 >= range5) &&
                        (piblock_y10 <= range1 || piblock_y10 >= range5))
                accuracy[5:4] <= 2'd0;

        end

endmodule
```

Arrow Controller

```
`timescale 1ns / 1ps

//////////////////////////////////////////////////////////////////////////////////
//
//Sharmeen Browarek
//Anna Ayuso
//6.111 Final Project
//TA: Jae Lee
//
//////////////////////////////////////////////////////////////////////////////////

//This module is in charge of interpreting the arrows signal from the control unit.  Whenever a dynamic //piblock is
reset, it sends a ready signal to the control unit.  In return, the control unit sends the 4-bit
//signal designating the new assignment for which arrows are lit.  The arrow controller takes in this
//signal and sends it to the correct dynamic piblock on the screen.

module arrow_controller(pixel_clock, reset_sync, up1, up2, up3, up4, up5, up6,
                                                                    up7, up8, up9, up10, down1, down2, down3, down4,
down5,
                                                                    down6, down7, down8, down9, down10, right1,
right2,
                                                                    right3, right4, right5, right6, right7, right8, right9,
                                                                    right10, left1, left2, left3, left4, left5, left6, left7,
                                                                    left8, left9, left10, ready1, ready2, ready3, ready4,
                                                                    ready5, ready6, ready7, ready8, ready9, ready10,
arrows,
                                                                    ready);
input pixel_clock, reset_sync;
input [3:0] arrows;
input ready1, ready2, ready3, ready4, ready5, ready6, ready7, ready8,
                                ready9, ready10;

output up1, up2, up3, up4, up5, up6, up7, up8, up9, up10;
output down1, down2, down3, down4, down5, down6, down7, down8, down9,
                                down10;
output right1, right2, right3, right4, right5, right6, right7, right8,
                                right9, right10;
output left1, left2, left3, left4, left5, left6, left7, left8, left9,
                                left10;
output ready;

reg up1, up2, up3, up4, up5, up6, up7, up8, up9, up10;
reg down1, down2, down3, down4, down5, down6, down7, down8, down9,
                                down10;
reg right1, right2, right3, right4, right5, right6, right7, right8,
                                right9, right10;
reg left1, left2, left3, left4, left5, left6, left7, left8, left9,
                                left10;
reg ready;
reg left, up, down, right;

reg ready1_temp, ready2_temp, ready3_temp, ready4_temp, ready5_temp,
                                ready6_temp, ready7_temp, ready8_temp, ready9_temp, ready10_temp,
                                ready_flag;
```

```
/*assign left = arrows[3];
assign up = arrows[2];
assign down = arrows[1];
assign right = arrows[0];*/

always @ (posedge pixel_clock)
	begin
		if (reset_sync)
			begin
			ready <= 0;
			up1 <= 0;
			up2 <= 0;
			up3 <= 0;
			up4 <= 0;
			up5 <= 0;
			up6 <= 0;
			up7 <= 0;
			up8 <= 0;
			up9 <= 0;
			up10 <= 0;
			down1 <= 0;
			down2 <= 0;
			down3 <= 0;
			down4 <= 0;
			down5 <= 0;
			down6 <= 0;
			down7 <= 0;
			down8 <= 0;
			down9 <= 0;
			down10 <= 0;
			right1 <= 0;
			right2 <= 0;
			right3 <= 0;
			right4 <= 0;
			right5 <= 0;
			right6 <= 0;
			right7 <= 0;
			right8 <= 0;
			right9 <= 0;
			right10 <= 0;
			left1 <= 0;
			left2 <= 0;
			left3 <= 0;
			left4 <= 0;
			left5 <= 0;
			left6 <= 0;
			left7 <= 0;
			left8 <= 0;
			left9 <= 0;
			left10 <= 0;
			end
	else if (ready_flag)
		begin
		ready <= 1;
```

```
if (ready1_temp)
        begin
                up1 <= arrows[2];
                down1 <= arrows[1];
                right1 <= arrows[0];
                left1 <= arrows[3];
        end
if (ready2_temp)
        begin
                up2 <= arrows[2];
                down2 <= arrows[1];
                right2 <= arrows[0];
                left2 <= arrows[3];
        end
if (ready3_temp)
        begin
                up3 <= arrows[2];
                down3 <= arrows[1];
                right3 <= arrows[0];
                left3 <= arrows[3];
        end
if (ready4_temp)
        begin
                up4 <= arrows[2];
                down4 <= arrows[1];
                right4 <= arrows[0];
                left4 <= arrows[3];
        end
if (ready5_temp)
        begin
                up5 <= arrows[2];
                down5 <= arrows[1];
                right5 <= arrows[0];
                left5 <= arrows[3];
        end
if (ready6_temp)
        begin
                up6 <= arrows[2];
                down6 <= arrows[1];
                right6 <= arrows[0];
                left6 <= arrows[3];
        end
if (ready7_temp)
        begin
                up7 <= arrows[2];
                down7 <= arrows[1];
                right7 <= arrows[0];
                left7 <= arrows[3];
        end
if (ready8_temp)
        begin
                up8 <= arrows[2];
                down8 <= arrows[1];
                right8 <= arrows[0];
                left8 <= arrows[3];
        end
```

```
                if (ready9_temp)
                        begin
                                up9 <= arrows[2];
                                down9 <= arrows[1];
                                right9 <= arrows[0];
                                left9 <= arrows[3];
                        end
                if (ready10_temp)
                        begin
                                up10 <= arrows[2];
                                down10 <= arrows[1];
                                right10 <= arrows[0];
                                left10 <= arrows[3];
                        end
                end
                else
                        ready <= 0;
        end



always @ (ready1 or ready2 or ready3 or ready4 or ready5 or
                        ready6 or ready7 or ready8 or ready9 or ready10)
        begin
        ready1_temp = 0;
        ready2_temp = 0;
        ready3_temp = 0;
        ready4_temp = 0;
        ready5_temp = 0;
        ready6_temp = 0;
        ready7_temp = 0;
        ready8_temp = 0;
        ready9_temp = 0;
        ready10_temp = 0;
        ready_flag = 0;
                if (ready1 || ready2 || ready3 || ready4 ||
                        ready5 || ready6 || ready7 || ready8 ||
                        ready9 || ready10)
                        ready_flag = 1;
                if (ready1)
                        ready1_temp = 1;
                if (ready2)
                        ready2_temp = 1;
                if (ready3)
                        ready3_temp = 1;
                if (ready4)
                        ready4_temp = 1;
                if (ready5)
                        ready5_temp = 1;
                if (ready6)
                        ready6_temp = 1;
                if (ready7)
                        ready7_temp = 1;
                if (ready8)
                        ready8_temp = 1;
```

```
                if (ready9)
                        ready9_temp = 1;
                if (ready10)
                        ready10_temp = 1;
        end

endmodule
```

Audio

```
/**

Anna Ayuso
Audio module
handles playing the Mr. Roboto song

adapted from:

The 6.111 SFX (sound effects module), fall 2005
By Eric Fellheimer
AC'97 Sound driver by Nathan Ickes

reset - stop playing sound and go idle
audio_reset_b, ac97* - feed directly to corresponding signal in labkit
play - pulse high to start a sound effect
mode - selects with of the 4 sound effects to play (latched in on rising edge of play)


**/

module Audio(reset, clock_27mhz, audio_reset_b, ac97_sdata_out, ac97_sdata_in, ac97_synch, ac97_bit_clock,
             play, stop, address, data);

  parameter VOL_PARAM = 5'd30;

  input reset, clock_27mhz;
  output audio_reset_b;
  output ac97_sdata_out;
  input ac97_sdata_in;
  output ac97_synch;
  input ac97_bit_clock;

  //sfx interface

  input play; //start playing selected effect
              input stop;

              input [7:0] data;
              output [17:0] address;

  wire ready;
  wire [7:0] command_address;
  wire [15:0] command_data;
  wire command_valid;

  wire [19:0] left_out_data;
  wire [19:0] right_out_data;
  wire [19:0] left_in_data, right_in_data;
  wire [4:0] volume;
  wire source;

  //hard code volume/source
  assign volume = VOL_PARAM; //a reasonable volume
  assign source = 1'b1; //microphone
```

```
//
// Reset controller
//
reg audio_reset_b;
reg [9:0] reset_count;

//////////////////////////////////////////////////////////////////////
//
// Reset Generation
//
// A shift register primitive is used to generate an active-high reset
// signal that remains high for 16 clock cycles after configuration finishes
// and the FPGA's internal clocks begin toggling.
//
//////////////////////////////////////////////////////////////////////

wire one_time_reset;
SRL16 reset_sr (.D(1'b0), .CLK(clock_27mhz), .Q(one_time_reset), .A0(1'b1), .A1(1'b1), .A2(1'b1), .A3(1'b1));
defparam reset_sr.INIT = 16'hFFFF;

always @(posedge clock_27mhz) begin
  if (one_time_reset)
        begin
          audio_reset_b <= 1'b0;
          reset_count <= 0;
        end
  else if (reset_count == 1023)
        audio_reset_b <= 1'b1;
  else
        reset_count <= reset_count+1;
end

ac97 ac97(ready, command_address, command_data, command_valid,
            left_out_data, 1'b1, right_out_data, 1'b1, left_in_data,
            right_in_data, ac97_sdata_out, ac97_sdata_in, ac97_synch,
            ac97_bit_clock);

ac97commands cmds(clock_27mhz, ready, command_address, command_data,
                        command_valid, volume, source);


sound_fsm sound_fsm(reset, clock_27mhz, play, ready, left_out_data, right_out_data, stop, address, data);

endmodule

module sound_fsm(reset, clock_27mhz, play, ready, left_out_data, right_out_data, stop, address, data);

input reset, clock_27mhz;
input ready;
input play;
        input stop;


output [19:0] left_out_data;
output [19:0] right_out_data;
```

```
        input [7:0] data;
        output [17:0] address;

    parameter S_IDLE = 2'd0;
    parameter S_START = 2'd1;
    parameter S_PLAY = 2'd2;

    reg [19:0] left_out_data;

    reg [1:0] state = S_IDLE;


    //control signals for effects modules
    wire done;
    wire  start;
    wire [19:0] pcm_out;

    reg done_cur;
        reg stop_playing;

    reg old_ready;
    always @ (posedge clock_27mhz)
        old_ready <= reset ? 0 : ready;

    assign next_sample = (ready && ~old_ready);


    //instantiate the FX modules

    MrRoboto    fx3(reset, clock_27mhz, next_sample, pcm_out, start, done, address, data);


    always @ (posedge clock_27mhz)
    if(reset || stop)
//                  begin
        state <= S_IDLE;
//                  stop_playing <= 0;
//                  end
/*      else if (stop)
                    begin
                    stop_playing <= 1;
                    state <= S_IDLE;
                    end
        else if (stop_playing)
                    state <= S_IDLE;*/

    else
      case (state)
       S_IDLE:
         if(play)
         begin
           state <= S_START;
         end
       S_START : state <= S_PLAY;
       S_PLAY: state <= done_cur ? S_IDLE : state;
```

```
      default: state <= S_IDLE;
     endcase

   assign start = (state == S_START);


   always @(done)
                        done_cur = done;



   always @(state or pcm_out)

               if(state == S_PLAY)

                        left_out_data = pcm_out;



              else
                //left_out_data = square_data;
        left_out_data = 20'h00000;
                        // left_out_data = left_out_data;
    //end always

   assign right_out_data = left_out_data; //mono output

endmodule


module ac97 (ready,
                command_address, command_data, command_valid,
                left_data, left_valid,
                right_data, right_valid,
                left_in_data, right_in_data,
                ac97_sdata_out, ac97_sdata_in, ac97_synch, ac97_bit_clock);

   output ready;
   input [7:0] command_address;
   input [15:0] command_data;
   input command_valid;
   input [19:0] left_data, right_data;
   input left_valid, right_valid;
   output [19:0] left_in_data, right_in_data;

   input ac97_sdata_in;
   input ac97_bit_clock;
   output ac97_sdata_out;
   output ac97_synch;

   reg ready;

   reg ac97_sdata_out;
   reg ac97_synch;

   reg [7:0] bit_count;
```

```
reg [19:0] l_cmd_addr;
reg [19:0] l_cmd_data;
reg [19:0] l_left_data, l_right_data;
reg l_cmd_v, l_left_v, l_right_v;
reg [19:0] left_in_data, right_in_data;

initial begin
  ready <= 1'b0;
  // synthesis attribute init of ready is "0";
  ac97_sdata_out <= 1'b0;
  // synthesis attribute init of ac97_sdata_out is "0";
  ac97_synch <= 1'b0;
  // synthesis attribute init of ac97_synch is "0";

  bit_count <= 8'h00;
  // synthesis attribute init of bit_count is "0000";
  l_cmd_v <= 1'b0;
  // synthesis attribute init of l_cmd_v is "0";
  l_left_v <= 1'b0;
  // synthesis attribute init of l_left_v is "0";
  l_right_v <= 1'b0;
  // synthesis attribute init of l_right_v is "0";

  left_in_data <= 20'h00000;
  // synthesis attribute init of left_in_data is "00000";
  right_in_data <= 20'h00000;
  // synthesis attribute init of right_in_data is "00000";
end

always @(posedge ac97_bit_clock) begin
  // Generate the sync signal
  if (bit_count == 255)
        ac97_synch <= 1'b1;
  if (bit_count == 15)
        ac97_synch <= 1'b0;

  // Generate the ready signal
  if (bit_count == 128)
        ready <= 1'b1;
  if (bit_count == 2)
        ready <= 1'b0;

  // Latch user data at the end of each frame. This ensures that the
  // first frame after reset will be empty.
  if (bit_count == 255)
        begin
          l_cmd_addr <= {command_address, 12'h000};
          l_cmd_data <= {command_data, 4'h0};
          l_cmd_v <= command_valid;
          l_left_data <= left_data;
          l_left_v <= left_valid;
          l_right_data <= right_data;
          l_right_v <= right_valid;
        end
```

```
    if ((bit_count >= 0) && (bit_count <= 15))
          // Slot 0: Tags
          case (bit_count[3:0])
            4'h0: ac97_sdata_out <= 1'b1;      // Frame valid
            4'h1: ac97_sdata_out <= l_cmd_v;   // Command address valid
            4'h2: ac97_sdata_out <= l_cmd_v;   // Command data valid
            4'h3: ac97_sdata_out <= l_left_v;  // Left data valid
            4'h4: ac97_sdata_out <= l_right_v; // Right data valid
            default: ac97_sdata_out <= 1'b0;
          endcase

    else if ((bit_count >= 16) && (bit_count <= 35))
          // Slot 1: Command address (8-bits, left justified)
          ac97_sdata_out <= l_cmd_v ? l_cmd_addr[35-bit_count] : 1'b0;

    else if ((bit_count >= 36) && (bit_count <= 55))
          // Slot 2: Command data (16-bits, left justified)
          ac97_sdata_out <= l_cmd_v ? l_cmd_data[55-bit_count] : 1'b0;

    else if ((bit_count >= 56) && (bit_count <= 75))
          begin
            // Slot 3: Left channel
            ac97_sdata_out <= l_left_v ? l_left_data[19] : 1'b0;
            l_left_data <= { l_left_data[18:0], l_left_data[19] };
          end
    else if ((bit_count >= 76) && (bit_count <= 95))
          // Slot 4: Right channel
            ac97_sdata_out <= l_right_v ? l_right_data[95-bit_count] : 1'b0;
    else
          ac97_sdata_out <= 1'b0;

    bit_count <= bit_count+1;

  end // always @ (posedge ac97_bit_clock)

  always @(negedge ac97_bit_clock) begin
    if ((bit_count >= 57) && (bit_count <= 76))
          // Slot 3: Left channel
          left_in_data <= { left_in_data[18:0], ac97_sdata_in };
    else if ((bit_count >= 77) && (bit_count <= 96))
          // Slot 4: Right channel
          right_in_data <= { right_in_data[18:0], ac97_sdata_in };
  end

endmodule

////////////////////////////////////////////////////////////////////////////////

module ac97commands (clock, ready, command_address, command_data,
                     command_valid, volume, source);

  input clock;
  input ready;
  output [7:0] command_address;
  output [15:0] command_data;
  output command_valid;
```

```
input [4:0] volume;
input source;

reg [23:0] command;
reg command_valid;

reg old_ready;
reg done;
reg [3:0] state;

initial begin
  command <= 4'h0;
  // synthesis attribute init of command is "0";
  command_valid <= 1'b0;
  // synthesis attribute init of command_valid is "0";
  done <= 1'b0;
  // synthesis attribute init of done is "0";
  old_ready <= 1'b0;
  // synthesis attribute init of old_ready is "0";
  state <= 16'h0000;
  // synthesis attribute init of state is "0000";
end

assign command_address = command[23:16];
assign command_data = command[15:0];

wire [4:0] vol;
assign vol = 31-volume;

always @(posedge clock) begin
  if (ready && (!old_ready))
        state <= state+1;

  case (state)
        4'h0: // Read ID
          begin
            command <= 24'h80_0000;
            command_valid <= 1'b1;
          end
        4'h1: // Read ID
          command <= 24'h80_0000;
        4'h2: // Master volume
          command <= { 8'h02, 3'b000, vol, 3'b000, vol };
        4'h3: // Aux volume
          command <= { 8'h04, 3'b000, vol, 3'b000, vol };
        4'h4: // Mono volume
          command <= 24'h06_8000;
        4'h5: // PCM volume
          command <= 24'h18_0808;
        4'h6: // Record source select
          if (source)
            command <= 24'h1A_0000; // microphone
          else
            command <= 24'h1A_0404; // line-in
        4'h7: // Record gain
          command <= 24'h1C_0000;
```

```
            4'h8: // Line in gain
              command <= 24'h10_8000;
            //4'h9: // Set jack sense pins
              //command <= 24'h72_3F00;
            4'hA: // Set beep volume
              command <= 24'h0A_0000;
            //4'hF: // Misc control bits
              //command <= 24'h76_8000;
            default:
              command <= 24'h80_0000;
        endcase // case(state)

        old_ready <= ready;

    end // always @ (posedge clock)

endmodule // ac97commands



module MrRoboto (reset, clock, next_sample, pcm_data, start, done, address, data);

    input reset;
    input clock;
    input next_sample;
    input start;

    output [19:0] pcm_data;
    output done;

            input [7:0] data;
            output [17:0] address;



    reg old_ready;
    reg [19:0] pcm_data;
    reg [17:0] count;
            reg [3:0] hold_count;
            wire [17:0] address;
            wire [7:0] data;
            //reg [2:0] hold_count;


            parameter LAST_COUNT = 209566;  //the amount of lines of memory


//          roboto m(address,clock,data);

    always @ (posedge clock)
    begin
      if(reset || start)
                                begin
                count <= 0;       //count goes from 0 to the number of samples of the song
                        hold_count <= 0;  //hold count counts to 9, this is how long samples are held for
                        end           //because of downsampling
```

```
    else if (next_sample)
                    begin


            count <= (~done && hold_count == 8) ? count + 1 : count;  //because it's downsampled by 10,
                    hold_count <= (hold_count == 8) ? 0: hold_count + 1;  //should be counting to 9, however
                                    //using 9 resulted in the song being slowed down
                    end
                    else
                            begin
                            count <= count;
                            hold_count <= hold_count;
                            end

  end


  assign done = (count >= LAST_COUNT);
          assign address = count;




  ////////////////////////////////////////////////////////
  //  Now actually output tone...
  ////////////////////////////////////////////////////////



 always @ (posedge clock)
 begin
  if(start)
  begin
  pcm_data <= {data, 12'd0};
  end


  if(next_sample)
          pcm_data <= {data, 12'd0};   //end of the song padded with 0's to increase volume
  begin

  end



 end

endmodule
```

Character String Display

```
//
// File:   cstringdisp.v
// Date:   24-Oct-05
// Author: I. Chuang, C. Terman
```

```
//
// Display an ASCII encoded character string in a video window at some
// specified x,y pixel location.
//
// INPUTS:
//
//   vclock       - video pixel clock
//   hcount       - horizontal (x) location of current pixel
//   vcount       - vertical (y) location of current pixel
//   cstring      - character string to display (8 bit ASCII for each char)
//   cx,cy        - pixel location (upper left corner) to display string at
//
// OUTPUT:
//
//   pixel        - video pixel value to display at current location
//
// PARAMETERS:
//
//   NCHAR        - number of characters in string to display
//   NCHAR_BITS   - number of bits to specify NCHAR
//
// pixel should be OR'ed (or XOR'ed) to your video data for display.
//
// Each character is 8x12, but pixels are doubled horizontally and vertically
// so fonts are magnified 2x.  On an XGA screen (1024x768) you can fit
// 64 x 32 such characters.
//
// Needs font_rom.v and font_rom.ngo
//
// For different fonts, you can change font_rom.  For different string
// display colors, change the assignment to cpixel.


//////////////////////////////////////////////////////////////////////////////
//
// video character string display
//
//////////////////////////////////////////////////////////////////////////////

module char_string_display (vclock,hcount,vcount,pixel,cstring,cx,cy);

  parameter NCHAR = 1;  // number of 8-bit characters in cstring
  parameter NCHAR_BITS = 7; // number of bits in NCHAR
            parameter mscale = 1;
            parameter dscale = 1;

  input vclock;    // 65MHz clock
  input [10:0] hcount;       // horizontal index of current pixel (0..1023)
  input [9:0]        vcount; // vertical index of current pixel (0..767)
  output [2:0] pixel;          // char display's pixel
  input [NCHAR*8-1:0] cstring;     // character string to display
  input [10:0] cx;
  input [9:0] cy;

  // 1 line x 8 character display (8 x 12 pixel-sized characters)
```

```
  wire [10:0] hoff = mscale*(hcount-1-cx)/dscale;
  wire [9:0]  voff = mscale*(vcount-cy)/dscale;
  wire [NCHAR_BITS-1:0] column = NCHAR-1-hoff[NCHAR_BITS-1+4:4];  // < NCHAR
  wire [2:0]  h = hoff[3:1];          // 0 .. 7
  wire [3:0]  v = voff[4:1];                  // 0 .. 11

  // look up character to display (from character string)
  reg [7:0]  char;
  integer  n;
  always @( *)
    for (n=0 ; n<8 ; n = n+1 )                  // 8 bits per character (ASCII)
      char[n] <= cstring[column*8+n];

  // look up raster row from font rom
  wire reverse = char[7];
  wire [10:0] font_addr = char[6:0]*12 + v;    // 12 bytes per character
  wire [7:0]  font_byte;
  font_rom f(font_addr,vclock,font_byte);

  // generate character pixel if we're in the right h,v area
  wire [2:0] cpixel = (font_byte[7 - h] ^ reverse) ? 7 : 0;
  wire dispflag = ((hcount > cx) & (vcount >= cy) & (hcount <= cx+NCHAR*16/mscale*dscale)
                    & (vcount < cy + 24/mscale*dscale));
  wire [2:0] pixel = dispflag ? cpixel : 0;

endmodule
```

Control Unit

```
//Anna Ayuso
//Control Unit, major FSM for system
//this module controls the logic of the game


module Control_Unit(pixel_clock, frame_sync, accuracy, sensors, ready, letter_score,
        arrows, start_song, difficulty, mode, m_busy_g, beat_count, score, enable, stop);

input pixel_clock, ready, frame_sync, enable;
input [5:0] sensors;
input [5:0] accuracy;

output [1:0] difficulty, mode;
output [1:0] letter_score;
output [3:0] arrows;
output start_song, stop;
output m_busy_g;
output [9:0] beat_count;
output [10:0] score;

reg [1:0] mode;

wire [9:0] beat_count, song_rows;
wire [10:0] score;
wire r_busy_r, g_busy_r, g_busy_g, m_busy_m, m_busy_g, enable, fail;
wire [1:0] difficulty, letter_score;


//instantiations of the four submodules

Score_Keeper sk(pixel_clock, sensors[5], frame_sync, sensors, accuracy, score, g_busy_r);

Report_FSM rfsm(pixel_clock, sensors[5],frame_sync, score, difficulty, r_busy_r,
letter_score, song_rows, g_busy_r, fail);

Game_FSM gfsm(pixel_clock, sensors[5], frame_sync, m_busy_g, difficulty, score,
ready, g_busy_r, g_busy_g,
    start_song, beat_count, arrows, song_rows, stop, fail, letter_score);

Menu_FSM mfsm(pixel_clock, sensors[5], enable, sensors[2], sensors[1],
sensors[4], m_busy_m, m_busy_g, difficulty);


parameter menufsm = 0;
parameter gamefsm = 1;
parameter reportfsm = 2;

reg [1:0] state, nextstate;
reg change_mode;

always @ (posedge pixel_clock)
        begin

        if (sensors[5])
```

```
                begin
                state <= menufsm;
                mode <= 2'd0;
                end
        else if (frame_sync)

                begin
                state <= nextstate;
                if (change_mode)
                        begin
                        if (mode == 2'd0)
                                mode <= 2'd1;
                        else if (mode == 2'd1)
                                mode <= 2'd2;
                        else
                                mode <= 2'd2;
                        end
                else mode <= mode;
                end
        end


always @ (state)
        begin                   //this fsm changes states based on busy signals from
        change_mode = 0;        //the minor fsms, the output is the current mode of the system
                                //the progression is menu->game->report card
        case(state)

                menufsm:   begin
                                if (m_busy_m == 1)
                                        nextstate = menufsm;
                                else
                                        begin
                                        nextstate = gamefsm;
                                        change_mode = 1;
                                        end
                                end

                gamefsm:  begin
                                if (g_busy_g == 1)
                                        nextstate = gamefsm;
                                else
                                        begin
                                        nextstate = reportfsm;
                                        change_mode = 1;
                                        end
                                end

                reportfsm:          nextstate = reportfsm;

                default:   nextstate = menufsm;

                endcase
                end

endmodule
```

Debounce

```
// Switch Debounce Module
// use your system clock for the clock input
// to produce a synchronous, debounced output

//All of the inputs to the FPGA are sent through this module, which outputs a clean version of the signal.
//Basically, this module filters out any noise.

module debounce (reset, clock, noisy, clean);
  parameter DELAY = 400000;   // .01 sec with a 27Mhz clock
  input reset, clock, noisy;
  output clean;

  reg [18:0] count;
  reg new, clean;

  always @(posedge clock)
    if (reset)
      begin
            count <= 0;
            new <= noisy;
            clean <= noisy;
      end
    else if (noisy != new)
      begin
            new <= noisy;
            count <= 0;
      end
    else if (count == DELAY)
      clean <= new;
    else
      count <= count+1;

endmodule
```

Decode IR Sensors

```
//////////////////////////////////////////////////////////////////////////////////
//
//Sharmeen Browarek
//Anna Ayuso
//6.111 Final Project
//TA: Jae Lee
//
//////////////////////////////////////////////////////////////////////////////////

//This module decodes the ouputs of the 6 sensors and decides when the user is in the up, down,
//right and left positions on the grid.

module Decode_IR_Sensors(pixel_clock, reset_sync, IR1, IR2, IR3, IR4, IR5, IR6, up, down, left, right,
                                                                    up_temp, down_temp, right_temp,
left_temp, control_mode);

        input reset_sync, pixel_clock;
        input IR1, IR2, IR3, IR4, IR5, IR6, up_temp, down_temp, right_temp, left_temp;
        input control_mode;

        output up, down, left, right;

        wire up_deb, down_deb, right_deb, left_deb;

        reg up, down, left, right;

        assign up_temp2 =           (IR2 && IR4);
        assign down_temp2 = (IR2 && IR6);
        assign left_temp2 = (IR3 && IR5);
        assign right_temp2 = (IR1 && IR5);
//      assign reset = (IR1 && IR4);
//      assign select = (IR3 && IR4);

        IRdebounce dbIRup(.reset(reset_sync), .clock(pixel_clock), .noisy(up_temp2), .extraclean(up_deb));

        IRdebounce dbIRdown(.reset(reset_sync), .clock(pixel_clock), .noisy(down_temp2),
.extraclean(down_deb));

        IRdebounce dbIRright(.reset(reset_sync), .clock(pixel_clock), .noisy(right_temp2), .extraclean(right_deb));

        IRdebounce dbIRleft(.reset(reset_sync), .clock(pixel_clock), .noisy(left_temp2), .extraclean(left_deb));


        always @ (posedge pixel_clock)
                if (reset_sync)
                        begin
                        up <= up_temp;
                        down <= down_temp;
                        right <= right_temp;
                        left <= left_temp;
                        end
                else if (control_mode == 1)
                        begin
                        up <= up_deb;
```

```
                down <= down_deb;
                right <= right_deb;
                left <= left_deb;
                end
        else if (control_mode == 0)
                begin
                up <= up_temp;
                down <= down_temp;
                right <= right_temp;
                left <= left_temp;
                end
endmodule
```

Divider

```
`timescale 1ns / 1ps
//////////////////////////////////////////////////////////////////////////////////
//
//Sharmeen Browarek
//Anna Ayuso
//6.111 Final Project
//TA: Jae Lee
//
//////////////////////////////////////////////////////////////////////////////////

//This module outputs an enable signal every half second which is sent to the control unit.

module divider(pixel_clock, reset_sync, enable);
	input pixel_clock, reset_sync;
	output enable;

	wire enable;
	reg [24:0] count;

	parameter maxcount = 15145000;

	assign enable
		= (count == (maxcount - 1));

	always@(posedge pixel_clock)
	begin
		if (reset_sync == 1) begin
			count <= 25'd0;
			end

		else if (count == maxcount) begin
			count <= 25'd0;
			end

		else begin
			count <= count + 1;
			end
	end

endmodule
```

Font ROM

```
/*****************************************************************************
*   This file is owned and controlled by Xilinx and must be used            *
*   solely for design, simulation, implementation and creation of           *
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*   expressly prohibited.                                                   *
*                                                                           *
*   (c) Copyright 1995-2004 Xilinx, Inc.                                    *
*   All rights reserved.                                                    *
*****************************************************************************/
// The synopsys directives "translate_off/translate_on" specified below are
// supported by XST, FPGA Compiler II, Mentor Graphics and Synplicity synthesis
// tools. Ensure they are correct for your synthesis tool(s).

// You must compile the wrapper file font_rom.v when simulating
// the core, font_rom. When compiling the wrapper file, be sure to
// reference the XilinxCoreLib Verilog simulation library. For detailed
// instructions, please refer to the "CORE Generator Help".

`timescale 1ns/1ps

module font_rom(
        addr,
        clk,
        dout);


input [10 : 0] addr;
input clk;
output [7 : 0] dout;

// synopsys translate_off

    BLKMEMSP_V6_1 #(
                11,     // c_addr_width
                "0",    // c_default_data
```

```
                1536,     // c_depth
                0,        // c_enable_rlocs
                0,        // c_has_default_data
                0,        // c_has_din
                0,        // c_has_en
                0,        // c_has_limit_data_pitch
                0,        // c_has_nd
                0,        // c_has_rdy
                0,        // c_has_rfd
                0,        // c_has_sinit
                0,        // c_has_we
                18,       // c_limit_data_pitch
                "font_rom.mif",   // c_mem_init_file
                0,        // c_pipe_stages
                0,        // c_reg_inputs
                "0",      // c_sinit_value
                8,        // c_width
                0,        // c_write_mode
                "0",      // c_ybottom_addr
                1,        // c_yclk_is_rising
                1,        // c_yen_is_high
                "hierarchy1",       // c_yhierarchy
                0,        // c_ymake_bmm
                "16kx1",// c_yprimitive_type
                1,        // c_ysinit_is_high
                "1024",  // c_ytop_addr
                0,        // c_yuse_single_primitive
                1,        // c_ywe_is_high
                1)        // c_yydisable_warnings
        inst (
                .ADDR(addr),
                .CLK(clk),
                .DOUT(dout),
                .DIN(),
                .EN(),
                .ND(),
                .RFD(),
                .RDY(),
                .SINIT(),
                .WE());


// synopsys translate_on

// FPGA Express black box declaration
// synopsys attribute fpga_dont_touch "true"
// synthesis attribute fpga_dont_touch of font_rom is "true"

// XST black box declaration
// box_type "black_box"
// synthesis attribute box_type of font_rom is "black_box"

endmodule
```

Game_FSM

```
//Anna Ayuso
//Game Play Minor FSM
//this module controls the arrows that are sent to the video
//this module only continues outputting arrows if the song hasn't ended
//and the score is high enough


module Game_FSM(pixel_clock, reset_sync, frame_sync, start_game, difficulty,
                                                score, ready, busy_r, busy_g, start_song, beat_count, arrows,
                                                song_rows, stop_song, fail, letter_score);

        input pixel_clock, reset_sync, frame_sync, ready, start_game;
        input [1:0] difficulty;
        input [10:0] score;
        input [1:0] letter_score;

        output busy_r, busy_g, start_song, stop_song, fail;
        output [9:0] beat_count;
        output [3:0] arrows;
        output [9:0] song_rows;

        reg busy_r, busy_g, start_song, stop_song;
        reg [9:0] beat_count;
        reg [3:0] arrows;
        reg [10:0] min_score;
        reg [9:0] song_rows;

        reg t_busy_r, t_busy_g, t_start_song, inc_count, t_stop_song;

        reg [3:0] song [0:99];
        reg load_song, flip_ls;
        reg fail;

        parameter initialize = 0;
        parameter move_arrows = 1;
        parameter goto_report = 2;

        reg [1:0] state, nextstate;


        always @ (posedge pixel_clock)
                begin

                if (reset_sync)
                        begin
                        state <= initialize;
                        busy_g <= 1;
                        busy_r <= 0;
                        start_song <= 0;
                        beat_count <= 10'd0;
                        load_song <= 1;
                        arrows <= 4'd0;

                        min_score <= 11'd0;
```

```
            song_rows <= 10'd0;
            stop_song <= 0;
            buffer3 <= 0;

            end

        else if (frame_sync  && start_game)    //start_game will be high when the menu fsm
            begin                       //is in the goto game state

            if (flip_ls)
                load_song <= 0;
            if (load_song)              //the song is loaded once based on the difficulty
                begin                   //selected
                arrows <= 4'd0;
                case (difficulty)     //the song is stored as an array of registers
                0:
                        begin
                        song[0] =  4'b0000;
                        song[1] =  4'b0100;
                        song[2] =  4'b0010;
                        song[3] =  4'b0000;
                        song[4] =  4'b0010;
                        song[5] =  4'b0000;
                        song[6] =  4'b0000;
                        song[7] =  4'b0000;
                        song[8] =  4'b0010;
                        song[9] =  4'b0000;
                        song[10] =      4'b0100;
                        song[11] =      4'b0000;
                        song[12] =      4'b0100;
                        song[13] =      4'b0000;
                        song[14] =      4'b0100;
                        song[15] =      4'b0000;
                        song[16] =      4'b0100;
                        song[17] =      4'b0000;
                        song[18] =      4'b0010;
                        song[19] =      4'b0010;
                        song[20] =      4'b0000;
                        song[21] =      4'b0000;
                        song[22] =      4'b0000;
                        song[23] =      4'b1000;
                        song[24] =      4'b0000;
                        song[25] =      4'b0000;
                        song[26] =      4'b0100;
                        song[27] =      4'b0000;
                        song[28] =      4'b0010;
                        song[29] =      4'b0000;
                        song[30] =      4'b0000;
                        song[31] =      4'b1000;
                        song[32] =      4'b1000;
                        song[33] =      4'b0000;
                        song[34] =      4'b0001;
                        song[35] =      4'b0000;
                        song[36] =      4'b0000;
                        song[37] =      4'b0001;
                        song[38] =      4'b0010;
```

```
song[39] =      4'b0010;
song[40] =      4'b0010;
song[41] =      4'b0000;
song[42] =      4'b0010;
song[43] =      4'b0001;
song[44] =      4'b0010;
song[45] =      4'b0100;
song[46] =      4'b0010;
song[47] =      4'b0000;
song[48] =      4'b0001;
song[49] =      4'b0010;
song[50] =      4'b0000;
song[51] =      4'b0100;
song[52] =      4'b0000;
song[53] =      4'b0010;
song[54] =      4'b0000;
song[55] =      4'b0100;
song[56] =      4'b0000;
song[57] =      4'b0100;
song[58] =      4'b1000;
song[59] =      4'b0010;
song[60] =      4'b0010;
song[61] =      4'b0000;
song[62] =      4'b0000;
song[63] =      4'b0001;
song[64] =      4'b0001;
song[65] =      4'b0100;
song[66] =      4'b0010;
song[67] =      4'b0000;
song[68] =      4'b0100;
song[69] =      4'b0000;
song[70] =      4'b0010;
song[71] =      4'b0000;
song[72] =      4'b0010;
song[73] =      4'b0100;
song[74] =      4'b0100;
song[75] =      4'b0100;
song[76] =      4'b0000;
song[77] =      4'b0010;
song[78] =      4'b0001;
song[79] =      4'b0001;
song[80] =      4'b0100;
song[81] =      4'b1000;
song[82] =      4'b0010;
song[83] =      4'b1000;
song[84] =      4'b0001;
song[85] =      4'b0001;
song[86] =      4'b1000;
song[87] =      4'b0100;
song[88] =      4'b0010;
song[89] =      4'b0100;
song[90] =      4'b1000;
song[91] =      4'b0000;
song[92] =      4'b0001;
song[93] =      4'b0100;
song[94] =      4'b1000;
```

```
song[95] =      4'b0000;
song[96] =      4'b0010;
song[97] =      4'b0100;
song[98] =      4'b0000;
song[99] =      4'b0001;


end

1:
begin
        song[0] = 4'b0000;
        song[1] = 4'b0100;
        song[2] = 4'b0010;
        song[3] = 4'b0000;
        song[4] = 4'b0010;
        song[5] = 4'b0000;
        song[6] = 4'b0000;
        song[7] = 4'b0000;
        song[8] = 4'b0010;
        song[9] = 4'b0000;
        song[10] =      4'b0100;
        song[11] =      4'b0000;
        song[12] =      4'b0100;
        song[13] =      4'b0000;
        song[14] =      4'b0100;
        song[15] =      4'b0000;
        song[16] =      4'b0100;
        song[17] =      4'b0000;
        song[18] =      4'b0010;
        song[19] =      4'b0010;
        song[20] =      4'b0000;
        song[21] =      4'b0000;
        song[22] =      4'b0000;
        song[23] =      4'b1000;
        song[24] =      4'b0000;
        song[25] =      4'b0000;
        song[26] =      4'b0100;
        song[27] =      4'b0000;
        song[28] =      4'b0010;
        song[29] =      4'b0000;
        song[30] =      4'b0000;
        song[31] =      4'b1000;
        song[32] =      4'b1000;
        song[33] =      4'b0000;
        song[34] =      4'b0001;
        song[35] =      4'b0000;
        song[36] =      4'b0000;
        song[37] =      4'b0001;
        song[38] =      4'b0010;
        song[39] =      4'b0010;
        song[40] =      4'b0010;
        song[41] =      4'b0000;
        song[42] =      4'b0010;
        song[43] =      4'b0001;
        song[44] =      4'b0010;
```

```
song[45] =      4'b0100;
song[46] =      4'b0010;
song[47] =      4'b0000;
song[48] =      4'b0001;
song[49] =      4'b0010;
song[50] =      4'b0000;
song[51] =      4'b0100;
song[52] =      4'b0000;
song[53] =      4'b0010;
song[54] =      4'b0000;
song[55] =      4'b0100;
song[56] =      4'b0000;
song[57] =      4'b0100;
song[58] =      4'b1000;
song[59] =      4'b0010;
song[60] =      4'b0010;
song[61] =      4'b0000;
song[62] =      4'b0000;
song[63] =      4'b0001;
song[64] =      4'b0001;
song[65] =      4'b0100;
song[66] =      4'b0010;
song[67] =      4'b0000;
song[68] =      4'b0100;
song[69] =      4'b0000;
song[70] =      4'b0010;
song[71] =      4'b0000;
song[72] =      4'b0010;
song[73] =      4'b0100;
song[74] =      4'b0100;
song[75] =      4'b0100;
song[76] =      4'b0000;
song[77] =      4'b0010;
song[78] =      4'b0001;
song[79] =      4'b0001;
song[80] =      4'b0100;
song[81] =      4'b1000;
song[82] =      4'b0010;
song[83] =      4'b1000;
song[84] =      4'b0001;
song[85] =      4'b0001;
song[86] =      4'b1000;
song[87] =      4'b0100;
song[88] =      4'b0010;
song[89] =      4'b0100;
song[90] =      4'b1000;
song[91] =      4'b0000;
song[92] =      4'b0001;
song[93] =      4'b0100;
song[94] =      4'b1000;
song[95] =      4'b0000;
song[96] =      4'b0010;
song[97] =      4'b0100;
song[98] =      4'b0000;
song[99] =      4'b0001;
```

```
        end
2:
        begin
        song[0] =  4'b0000;
        song[1] =  4'b0100;
        song[2] =  4'b0010;
        song[3] =  4'b0000;
        song[4] =  4'b0010;
        song[5] =  4'b0000;
        song[6] =  4'b0000;
        song[7] =  4'b0000;
        song[8] =  4'b0010;
        song[9] =  4'b0000;
        song[10] =      4'b0100;
        song[11] =      4'b0000;
        song[12] =      4'b0100;
        song[13] =      4'b0000;
        song[14] =      4'b0100;
        song[15] =      4'b0000;
        song[16] =      4'b0100;
        song[17] =      4'b0000;
        song[18] =      4'b0010;
        song[19] =      4'b0010;
        song[20] =      4'b0000;
        song[21] =      4'b0000;
        song[22] =      4'b0000;
        song[23] =      4'b1000;
        song[24] =      4'b0000;
        song[25] =      4'b0000;
        song[26] =      4'b0100;
        song[27] =      4'b0000;
        song[28] =      4'b0010;
        song[29] =      4'b0000;
        song[30] =      4'b0000;
        song[31] =      4'b1000;
        song[32] =      4'b1000;
        song[33] =      4'b0000;
        song[34] =      4'b0001;
        song[35] =      4'b0000;
        song[36] =      4'b0000;
        song[37] =      4'b0001;
        song[38] =      4'b0010;
        song[39] =      4'b0010;
        song[40] =      4'b0010;
        song[41] =      4'b0000;
        song[42] =      4'b0010;
        song[43] =      4'b0001;
        song[44] =      4'b0010;
        song[45] =      4'b0100;
        song[46] =      4'b0010;
        song[47] =      4'b0000;
        song[48] =      4'b0001;
        song[49] =      4'b0010;
        song[50] =      4'b0000;
        song[51] =      4'b0100;
```

```
                song[52] =      4'b0000;
                song[53] =      4'b0010;
                song[54] =      4'b0000;
                song[55] =      4'b0100;
                song[56] =      4'b0000;
                song[57] =      4'b0100;
                song[58] =      4'b1000;
                song[59] =      4'b0010;
                song[60] =      4'b0010;
                song[61] =      4'b0000;
                song[62] =      4'b0000;
                song[63] =      4'b0001;
                song[64] =      4'b0001;
                song[65] =      4'b0100;
                song[66] =      4'b0010;
                song[67] =      4'b0000;
                song[68] =      4'b0100;
                song[69] =      4'b0000;
                song[70] =      4'b0010;
                song[71] =      4'b0000;
                song[72] =      4'b0010;
                song[73] =      4'b0100;
                song[74] =      4'b0100;
                song[75] =      4'b0100;
                song[76] =      4'b0000;
                song[77] =      4'b0010;
                song[78] =      4'b0001;
                song[79] =      4'b0001;
                song[80] =      4'b0100;
                song[81] =      4'b1000;
                song[82] =      4'b0010;
                song[83] =      4'b1000;
                song[84] =      4'b0001;
                song[85] =      4'b0001;
                song[86] =      4'b1000;
                song[87] =      4'b0100;
                song[88] =      4'b0010;
                song[89] =      4'b0100;
                song[90] =      4'b1000;
                song[91] =      4'b0000;
                song[92] =      4'b0001;
                song[93] =      4'b0100;
                song[94] =      4'b1000;
                song[95] =      4'b0000;
                song[96] =      4'b0010;
                song[97] =      4'b0100;
                song[98] =      4'b0000;
                song[99] =      4'b0001;


                end
endcase
end

else arrows <= song[beat_count];
```

```
                        state <= nextstate;
                        busy_g <= t_busy_g;
                        busy_r <= t_busy_r;
                        start_song <= t_start_song;
                        stop_song <= t_stop_song;


                        //the beat count is incremented when the inc_count flag
                        //in the fsm is set high
                        if (inc_count)
                                beat_count <= beat_count + 1;
                        else
                                beat_count <= beat_count;




                        //song rows is a count of the beats (i.e. elements of song array)
                        //that have atleast one arrow, this is for score keeping
                        if ((arrows[0] || arrows[1] || arrows[2] || arrows[3]) && inc_count)
                                song_rows <= song_rows + 1;
                        else
                                song_rows <= song_rows;




                end


  always @ (state)
                begin
                        t_busy_r = 0;
                        t_busy_g = 1;
                        t_start_song = 0;
                        t_stop_song = 0;
                        inc_count = 0;
                        flip_ls = 0;
                        fail = 0;
//                      arrows = 4'd0;


                case(state)

                        initialize:   begin
                                                t_start_song = 1;  //tells audio to start music
                                                nextstate = move_arrows;
                                                flip_ls = 1;            //the song is only loaded once
                                                end

                        move_arrows:  begin
                                                if (beat_count >= 115)  //the song ends
                                                        nextstate = goto_report;
                                                else if (ready)  //ready is from the video, signals that
```

```
                                        begin    //video is ready for the next set of arrows
                                        if (song_rows <= 15 || letter_score != 2'd3)   //checks if the
score is
                                                begin                                   //high
enough
                                                inc_count = 1;
        //                                      arrows = song[beat_count];
                                                nextstate = move_arrows;
                                                end
                                        else
                                                begin
                                                fail = 1;
                                                nextstate = goto_report;
                                                end
                                        end
                                else nextstate = move_arrows;



                                end

        goto_report:   begin
                                                t_busy_r = 1;
                                                t_busy_g = 0;
                                                t_stop_song = 1;
                                                nextstate = goto_report;

                                end


        default:   nextstate = initialize;

        endcase
                end


endmodule
```

Image

```
`timescale 1ns / 1ps
//////////////////////////////////////////////////////////////////////////////////
//
//Sharmeen Browarek
//Anna Ayuso
//6.111 Final Project
//TA: Jae Lee
//
//////////////////////////////////////////////////////////////////////////////////

//image display modules that will set the pixels to display the
//designated image within a set pixel range.

module image(pixel_clock, reset_sync, frame_sync, pixel_count, line_count,
                                        bitmap_rgb);

input pixel_clock, reset_sync, frame_sync;
input [9:0] pixel_count, line_count;

output [23:0] bitmap_rgb;

wire bitmapb, bitmapc, bitmape, bitmapf;
wire imgenable;
wire [16:0] count;

imgrectangle rect_img1(pixel_count, line_count, imgenable);

image_counter counter_img1(pixel_clock, reset_sync, imgenable, count);

beavera img2(count, pixel_clock, bitmapb);
beaverb img3(count, pixel_clock, bitmapc);

beaverc img5(count, pixel_clock, bitmape);
beaverd img6(count, pixel_clock, bitmapf);

image_loop imgloop(pixel_clock, reset_sync, frame_sync, bitmap_rgb,
                                                        bitmapb, bitmapc, bitmape, bitmapf);

endmodule



//this module counts through the pixels of the image.  It outputs the address to denote which part
//of the image is supposed to be displayed when.

module image_counter(pixel_clock, reset_sync, imgenable, count); //addr = count
input pixel_clock, reset_sync, imgenable;

output [16:0] count;

reg [16:0] count;

parameter maxcount = 27594;

always@(posedge pixel_clock)
```

```
	begin
		if (reset_sync == 1) begin
			count <= 17'd0;
			end

		else if (count == maxcount) begin
			count <= 17'd0;
			end

		else if (imgenable == 1)
			count <= count + 1;
	end
endmodule


//this internal module decides where the picture will be located.  It outputs an intital location
//and a height and width of the image, these are sent to the image counter.

module imgrectangle (x, y, imgenable);

input [9:0] x, y;

output imgenable;

reg imgenable;

parameter init_x = 10'd397;
parameter init_y = 10'd140;

parameter width = 10'd146;
parameter height = 10'd189;


always@(x or y)
	begin
		if ((x >= init_x && x < (init_x + width))
			&&
			(y >= init_y && y < (init_y + height)))
			imgenable = 1;
		else
			imgenable = 0;
	end
endmodule



//this is the third internal module.  It loops between the four images to simulate a dancing beaver on the
//screen.  The beaver changes images every 8th note of the song.

module image_loop (pixel_clock, reset_sync, frame_sync, bitmap_rgb,
                                                    bitmapb, bitmapc, bitmape, bitmapf);

input pixel_clock, frame_sync, reset_sync;
input bitmapb, bitmapc, bitmape, bitmapf;

output [23:0] bitmap_rgb;
```

```
reg [23:0] bitmap_rgb;
reg [7:0] count;
parameter maxcount = 186;

wire [23:0] rgb_outb2 = {24{bitmapb}};
wire [23:0] rgb_outb3 = {24{bitmapc}};
wire [23:0] rgb_outb5 = {24{bitmape}};
wire [23:0] rgb_outb6 = {24{bitmapf}};

assign b = (((count < 8'd31) && (count >= 8'd0)) || (count == maxcount));
assign c = (((count < 8'd62) && (count >= 8'd31)) || ((count < 8'd186) && (count >= 8'd155)));
assign e = (((count < 8'd93) && (count >= 8'd62)) || ((count < 8'd155) && (count >= 8'd124)));
assign f = ((count < 8'd124) && (count >= 8'd93));


always @ (posedge pixel_clock)
	begin
		if (reset_sync)
			count <= 8'd0;
		if (frame_sync)
			begin
				if(count == maxcount)
					begin
						count <= 8'd0;
					end
				else
					begin
						count <= count + 1;
					end
			end
		if (b)
			begin
				bitmap_rgb <= rgb_outb2;
			end
		if (c)
			begin
				bitmap_rgb <= rgb_outb3;
			end
		if (e)
			begin
				bitmap_rgb <= rgb_outb5;
			end
		if (f)
			begin
				bitmap_rgb <= rgb_outb6;
			end
	end

endmodule
```

IR Debounce

```
`timescale 1ns / 1ps
//////////////////////////////////////////////////////////////////////////////////
//
//Sharmeen Browarek
//Anna Ayuso
//6.111 Final Project
//TA: Jae Lee
//
//////////////////////////////////////////////////////////////////////////////////

//This module uses logic from the debounce and divider modules to simulate a high pass filter.
//It's used to get rid of the continuous pulses sent from the infrared signals, to avoid any glitches
//during the game.

module IRdebounce (reset, clock, noisy, extraclean);

input reset, clock, noisy;
output extraclean;

parameter delay = 6100000;
parameter sensor_high = 6099990;


reg [24:0] delay_count;
reg [24:0] sensor_count;
reg extraclean;



	always@(posedge clock)
	begin
		if (reset == 1)
			begin
				delay_count <= 25'd0;
				sensor_count <= 25'd0;
			end

		if (delay_count == delay)
			begin
			delay_count <= 25'd0;
				if (sensor_count >= sensor_high)
					begin
						extraclean <= 1;
						sensor_count <= 25'd0;
					end
				else
					begin
						extraclean <= 0;
						sensor_count <= 25'd0;
					end
			end

		else
			begin
			delay_count <= delay_count + 1;
```

```
                        if (noisy)
                                sensor_count <= sensor_count + 1;
                end
        end

endmodule
```

Menu FSM

```
//Anna Ayuso
//Menu Minor FSM
//this module will allow the user to toggle between different
//difficulty levels on the menu screen


module Menu_FSM(pixel_clock, reset_sync, enable, up, down, select, busy_m, busy_g, difficulty);

	input pixel_clock, reset_sync, up, down, select, enable;
	output busy_m, busy_g;
	output [1:0] difficulty;

	reg busy_m, busy_g;
	reg [1:0] difficulty;
	reg [1:0] state, nextstate;

	reg t_busy_m, t_busy_g;
	reg [1:0] t_difficulty;
	reg up_temp, down_temp;

	parameter easy = 0;
	parameter med = 1;
	parameter hard = 2;
	parameter goto_game = 3;


	always @ (posedge pixel_clock)
		begin

		if (reset_sync)
			begin
			state <= easy; //initial state is easy
			busy_m <= 1;
			busy_g <= 0;
			difficulty <= 2'd0;
			up_temp <= up;
			down_temp <= down;
			end
		else if (enable)    //states transition on an enable signal that pulses
			begin                  //every half second
			state <= nextstate;
			busy_m <= t_busy_m;
			busy_g <= t_busy_g;
			up_temp <= up;
			down_temp <= down;
			if (t_difficulty != 2'b11)  //difficulty is 3 after the user has
				difficulty <= t_difficulty;  //selected a level, so difficulty
			else                           //is held constant after it is
				difficulty <= difficulty;    //selected
			end
		end



	always @ (state)
```

```
begin
        t_busy_m = 1;
        t_busy_g = 0;
        t_difficulty = 2'b11;

case(state)

        easy:   begin
                                t_difficulty = 2'd0;
                                if (select)
                                        begin
                                        nextstate = goto_game;
                                        end
                                else if (up_temp)
                                        begin
                                        nextstate = hard;
                                        end
                                else if (down_temp)
                                        begin
                                        nextstate = med;
                                        end
                                else
                                        begin
                                        nextstate = easy;
                                        end
                                end

        med:  begin
                                t_difficulty = 2'd1;
                                if (select)
                                        begin
                                        nextstate = goto_game;
                                        end
                                else if (up_temp)
                                        begin
                                        nextstate = easy;
                                        end
                                else if (down_temp)
                                        begin
                                        nextstate = hard;
                                        end
                                else
                                        nextstate = med;
                                end

        hard:   begin
                                t_difficulty = 2'd2;
                                if (select)
                                        begin
                                        nextstate = goto_game;
                                        end
                                else if (up_temp)
                                        begin
                                        nextstate = med;
                                        end
                                else if (down_temp)
```

```
                                        begin
                                        nextstate = easy;
                                        end
                                else
                                        nextstate = hard;
                                end

                goto_game:
                                begin           //this state is reached after user
                                t_busy_m = 0;       //makes a selection, difficulty from
                                t_busy_g = 1;       //the previous state is held constant
                                nextstate = goto_game; //fsm forever loops in this state until a reset
                                end


                default:  nextstate = easy;

                endcase
                        end


endmodule
```

Piblock

```
`timescale 1ns / 1ps

//////////////////////////////////////////////////////////////////////////////////
//
//Sharmeen Browarek
//Anna Ayuso
//6.111 Final Project
//TA: Jae Lee
//
//////////////////////////////////////////////////////////////////////////////////

//This module is in charge of the dynamic y-direction value of each piblock that is moving up the screen.

module piblock(pixel_clock, reset_sync, piblock_y, frame_sync,
                                                ready, ystart, start_game);

input pixel_clock, reset_sync, frame_sync, start_game;
input [9:0] ystart;

output [9:0] piblock_y;
output ready;

reg [9:0] piblock_y;

parameter ystop = 9;

assign ready = (piblock_y == 10'd500);

always @ (posedge pixel_clock)
        begin
                if (reset_sync || start_game)
                        begin
                                piblock_y <= ystart;
                        end
                else if (frame_sync)
                begin
                        if (piblock_y > ystop)
                                begin
                                        piblock_y <=  piblock_y - 2;
                                end
                        else
                                begin
                                        piblock_y <= 10'd606;
                                end
                end
        end
endmodule
```

Report FSM

```
//Anna Ayuso
//report module
//this module converts a score into a letter score (A, B, C, F) for the game
//to gage the user's performance


module Report_FSM(pixel_clock, reset_sync, frame_sync, score,
                                                    difficulty, busy_r, letter_score, song_rows, stop, fail);

        input pixel_clock, reset_sync, frame_sync, stop, fail;
        input [10:0] score;
        input [1:0] difficulty;
        input [9:0] song_rows;

        output busy_r;
        output [1:0] letter_score;

        reg busy_r;
        reg [1:0] letter_score;
        reg [5:0] buffer1, buffer2, buffer3;


        parameter easy = 0;
        parameter med = 1;
        parameter hard = 2;

        always @ (posedge pixel_clock)
                begin


                if (reset_sync)
                        begin
                        busy_r <= 1;
                        letter_score <= 2'd0;
                        buffer1 <= 10;
                        buffer2 <= 10;
                        buffer3 <= 10;
                        end

                else if (stop)
                        begin
                        letter_score <= letter_score;
                        end

                else  if (frame_sync)                                   //buffers are set that determine
                        begin                           //how many arrows a user can have missed
                        busy_r <= 1;                                    //to still maintain a certain score
                                if (difficulty == 0) //easy     //as difficulty increases, the buffer
                                        begin                   //decreases
                                        buffer1 <= 10;
                                        buffer2 <= 10;
                                        buffer3 <= 7;
                                        end
                                else if (difficulty == 1)       //medium
                                        begin
```

```
                        buffer1 <= 7;
                        buffer2 <= 7;
                        buffer3 <= 5;
                        end
                else if (difficulty == 2)       //hard
                        begin
                        buffer1 <= 5;
                        buffer2 <= 5;
                        buffer3 <= 2;
                        end
                else
                        begin
                        buffer1 <= buffer1;
                        buffer2 <= buffer2;
                        buffer3 <= buffer3;
                        end

                if (fail)
                        letter_score <= 2'd3;     //letter scores are set
                else if (song_rows <= 10)         //based on score ranges
                        letter_score <= 2'd0;
                else if (score >= (((song_rows - 15) * 3) - buffer1))
                        letter_score <= 2'd0;
                else if (score >= (((song_rows - 8) * 2) - buffer2))
                        letter_score <= 2'd1;
                else if (score > ((song_rows - 8) - buffer3))
                        letter_score <= 2'd2;
                else
                        letter_score <= 2'd3;

        end


end



endmodule
```

Score Keeper

```
//Anna Ayuso
//score keeper
//this module continually computes the score given an accuracy signal from
//the video component and the user inputs from the IR sensors


module Score_Keeper(pixel_clock, reset_sync, frame_sync, sensors, accuracy, score, stop);

	input pixel_clock, reset_sync, frame_sync, stop;

	input [5:0] accuracy;  //the first two bits of the accuracy signal correspond to
	input [5:0] sensors;				//an accuracy of either 0, 1, 2, or 3
							//the next 4 bits correspond to what arrows
							//the accuracy refers to, the first two bits
							//accuracy looks like this 0001231000012310000...

	output [10:0] score;

	reg [10:0] score;
	reg inc;

	always @ (posedge pixel_clock)
		begin

		if (reset_sync)
			begin
			score <= 11'd0;
			inc <= 0;
			end
		else if (stop)
			begin
			score <= score;
			end
		else if (frame_sync)
			begin
			if (accuracy[5:4] == 2'd0)  //when accuracy indicator is set to 0,
				inc <= 0;	//inc flag is set to 0 to allow scoring again
			else if (inc != 1 && accuracy[5:4] != 2'd0  && sensors[3:0] != 4'd0)
				//if the score hasn't been incremented yet, the accuracy indicator
				//is nonzero, and there is input from the user...
				begin

				if (accuracy[5:4] == 2'd1 && ((sensors[3] == 1  && accuracy[3] == 1) ||
					(sensors[2] == 1  && accuracy[2] == 1) ||
					 (sensors[1] == 1  && accuracy[1] == 1) ||
					(sensors[0] == 1  && accuracy[0] == 1)))

				//if the accuracy indicator is 1, and any of the user inputs and accuracy arrows
				//match, increment score, and set inc flag to 1 to indicate that the score
				//has already been incremented
					begin
					score <= score + 1;
					inc <= 1;
					end
```

```
                else if    (accuracy[5:4] == 2'd2 && ((sensors[3] == 1  && accuracy[3] == 1) ||
                                (sensors[2] == 1  && accuracy[2] == 1) ||
                                (sensors[1] == 1  && accuracy[1] == 1) ||
                                (sensors[0] == 1  && accuracy[0] == 1)))
                //if the accuracy indicator is 2, and any of the user inputs and accuracy arrows
                //match, increment score by 2, and set inc flag to 1 to indicate that the score
                //has already been incremented
                        begin
                        score <= score + 2;
                        inc <= 1;
                        end
                else if (accuracy[5:4] == 2'd3 && ((sensors[3] == 1  && accuracy[3] == 1) ||
                                (sensors[2] == 1  && accuracy[2] == 1) ||
                                (sensors[1] == 1  && accuracy[1] == 1) ||
                                (sensors[0] == 1  && accuracy[0] == 1)))
                //if the accuracy indicator is 3, and any of the user inputs and accuracy arrows
                //match, increment score by 3, and set inc flag to 1 to indicate that the score
                //has already been incremented
                        begin
                        score <= score + 3;
                        inc <= 1;
                        end
                else
                        score <= score;


                        end
        else score <= score;
    end
end

endmodule
```

VGA

```
`timescale 1ns / 1ps

//////////////////////////////////////////////////////////////////////////////////
//
//Sharmeen Browarek
//Anna Ayuso
//6.111 Final Project
//TA: Jae Lee
//
//////////////////////////////////////////////////////////////////////////////////

//This module controls the pixel count and the line count of the video gate array (display screen).
//It sends its outputs to the game display module, which assigns the correct color value to each pixel
//address.

module VGA (pixel_clock, reset_sync, hsync, vsync, sync_b,
                                        blank_b, pixel_count, line_count);

input pixel_clock; // 25.175 MHz pixel clock
input reset_sync; // system reset

output hsync; // horizontal sync
output vsync; // vertical sync
output sync_b; // hardwired to Vdd
output blank_b; // composite blank
output [9:0] pixel_count; // number of the current pixel
output [9:0] line_count; // number of the current line

// 640x480 75Hz parameters

//parameter PIXELS = 800;
//parameter LINES = 525;
//parameter HACTIVE_VIDEO = 640;
//parameter HFRONT_PORCH = 16;
//parameter HSYNC_PERIOD = 96;
//parameter HBACK_PORCH = 48;
//parameter VACTIVE_VIDEO = 480;
//parameter VFRONT_PORCH = 11;
//parameter VSYNC_PERIOD = 2;
//parameter VBACK_PORCH = 31;


parameter PIXELS = 832;
parameter LINES = 520;
parameter HACTIVE_VIDEO = 640;
parameter HFRONT_PORCH = 24;
parameter HSYNC_PERIOD = 40;
parameter HBACK_PORCH = 128;
parameter VACTIVE_VIDEO = 480;
parameter VFRONT_PORCH = 9;
parameter VSYNC_PERIOD = 3;
parameter VBACK_PORCH = 28;

// current pixel count
```

```
reg [9:0] pixel_count = 10'b0;
reg [9:0] line_count = 10'b0;

// registered outputs

reg hsync = 1'b1;
reg vsync = 1'b1;
reg blank_b = 1'b1;

wire sync_b; // connected to Vdd
wire pixel_clock;
wire [9:0] next_pixel_count;
wire [9:0] next_line_count;


        always @ (posedge pixel_clock)
                begin
                        if (reset_sync)
                                begin
                                        pixel_count <= 10'b0;
                                        line_count <= 10'b0;
                                        hsync <= 1'b1;
                                        vsync <= 1'b1;
                                        blank_b <= 1'b1;
                                end
                        else
                                begin
                                        pixel_count <= next_pixel_count;
                                        line_count <= next_line_count;
                                        hsync <=
                                                (next_pixel_count < HACTIVE_VIDEO +
HFRONT_PORCH) |
                                                (next_pixel_count >=
HACTIVE_VIDEO+HFRONT_PORCH+
                                                HSYNC_PERIOD);
                                        vsync <=
                                                (next_line_count < VACTIVE_VIDEO+VFRONT_PORCH) |
                                                (next_line_count >=
VACTIVE_VIDEO+VFRONT_PORCH+
                                                VSYNC_PERIOD);
// this is the and of hblank and vblank
                                        blank_b <=
                                                (next_pixel_count < HACTIVE_VIDEO) &
                                                (next_line_count < VACTIVE_VIDEO);
                                end
                end

// next state is computed with combinational logic

        assign next_pixel_count = (pixel_count == PIXELS-1) ?
        10'h000 : pixel_count + 1'b1;

        assign next_line_count = (pixel_count == PIXELS-1) ?
        (line_count == LINES-1) ? 10'h000 :
        line_count + 1'b1 : line_count;
```

```
// since we are providing hsync and vsync to the display, we
// can hardwire composite sync to Vdd.

        assign sync_b = 1'b1;

endmodule
```

Verilog Testbench Code

Test Control

```
`timescale 1ns / 1ps

////////////////////////////////////////////////////////////////////////////////
// Anna Ayuso
//created to test the control unit
//-ensures that when select goes high, the major fsm transitions to the game state
//-verifies that in the game state, arrows are being outputted
//-when the score is too low,the major fsm transitions to the final report state
////////////////////////////////////////////////////////////////////////////////

module test_control_v;

	// Inputs
	reg pixel_clock;
	reg frame_sync;
	reg [5:0] accuracy;
	reg [5:0] sensors;
	reg ready;

	// Outputs
	wire [1:0] letter_score;
	wire [3:0] arrows;
	wire start_song;
	wire [1:0] difficulty;
	wire [1:0] mode;
	wire m_busy_g;
	wire [9:0] beat_count;
	wire [10:0] score;
	wire stop_song;

	// Instantiate the Unit Under Test (UUT)
	Control_Unit uut (
		.pixel_clock(pixel_clock),
		.frame_sync(frame_sync),
		.accuracy(accuracy),
		.sensors(sensors),
		.ready(ready),
		.letter_score(letter_score),
		.arrows(arrows),
		.start_song(start_song),
		.difficulty(difficulty),
		.mode(mode),
		.m_busy_g(m_busy_g),
		.beat_count(beat_count),
		.score(score),
		.stop_song(stop_song)
	);


	always #5 pixel_clock = ~pixel_clock;
	initial begin
		// Initialize Inputs
		pixel_clock = 0;
```

```
        frame_sync = 1;
        accuracy = 0;
        sensors = 0;
        ready = 1;

        // Wait 100 ns for global reset to finish
        #10;
        sensors[5] = 1;

        #10;
        sensors[5] = 0;

        #10;
        sensors[4] = 1;



        // Add stimulus here

    end

endmodule
```

Test Game

```
`timescale 1ns / 1ps

////////////////////////////////////////////////////////////////////////////////
// Anna Ayuso
//created to test the game fsm
//-tested with the score hardcoded to 10
//-arrows should be changing while in the move arrows state
//
////////////////////////////////////////////////////////////////////////////////

module test_game_v;

	// Inputs
	reg pixel_clock;
	reg reset_sync;
	reg frame_sync;
	reg start_game;
	reg [1:0] difficulty;
	reg [10:0] score;
	reg ready;

	// Outputs
	wire busy_r;
	wire busy_g;
	wire start_song;
	wire [9:0] beat_count;
	wire [3:0] arrows;
	wire [9:0] song_rows;
	wire stop_song;
	wire [1:0] state;

	// Instantiate the Unit Under Test (UUT)
	Game_FSM uut (
		.pixel_clock(pixel_clock),
		.reset_sync(reset_sync),
		.frame_sync(frame_sync),
		.start_game(start_game),
		.difficulty(difficulty),
		.score(score),
		.ready(ready),
		.busy_r(busy_r),
		.busy_g(busy_g),
		.start_song(start_song),
		.beat_count(beat_count),
		.arrows(arrows),
		.song_rows(song_rows),
		.stop_song(stop_song),
		.state(state)
	);

	always #5 pixel_clock = ~pixel_clock;
	initial begin
		// Initialize Inputs
		pixel_clock = 0;
```

```
        reset_sync = 0;
        frame_sync = 1;
        start_game = 1;
        difficulty = 0;
        score = 10;
        ready = 1;

        // Wait 100 ns for global reset to finish
        #10;
        reset_sync = 1;

        #10;
        reset_sync = 0;

        // Add stimulus here

    end

endmodule
```

Test Menu

```
`timescale 1ns / 1ps

////////////////////////////////////////////////////////////////////////////////
// Anna Ayuso
//created to test the menu fsm
//-up and down signals are altered to make sure
//the fsm changes states correctly, difficulty should be changing accoringly
//-when select goes high, difficulty should remain the same and the busy signal
//should go low
//
////////////////////////////////////////////////////////////////////////////////

module test_menu_v;

	// Inputs
	reg pixel_clock;
	reg reset_sync;
	reg frame_sync;
	reg up;
	reg down;
	reg select;


	// Outputs
	wire busy_m;
	wire busy_g;
	wire [1:0] difficulty,state;

	// Instantiate the Unit Under Test (UUT)
	Menu_FSM uut (
		.pixel_clock(pixel_clock),
		.reset_sync(reset_sync),
		.frame_sync(frame_sync),
		.up(up),
		.down(down),
		.select(select),
		.busy_m(busy_m),
		.busy_g(busy_g),
		.difficulty(difficulty),
		.state(state)
	);

	always #5 pixel_clock = ~pixel_clock;
	initial begin
		// Initialize Inputs
		pixel_clock = 0;
		reset_sync = 0;
		frame_sync = 1;
		up = 0;
		down = 0;
		select = 0;


		// Wait 100 ns for global reset to finish
```

```
                #10;
                reset_sync = 1;

                #10
                reset_sync = 0;

                #10
                up = 1;

                #100
                up = 0;

                #100
                down = 1;

                #100
                select = 1;


                // Add stimulus here

        end

endmodule
```

Test Report

```
`timescale 1ns / 1ps

////////////////////////////////////////////////////////////////////////////////
// Anna Ayuso
//created to test the report module
//-ensures that the proper letter score is outputted
//when the score in a certain range
//
////////////////////////////////////////////////////////////////////////////////

module test_report_v;

	// Inputs
	reg pixel_clock;
	reg reset_sync;
	reg frame_sync;
	reg [10:0] score;
	reg [1:0] difficulty;
	reg [9:0] song_rows;
	reg stop;

	// Outputs
	wire busy_r;
	wire [1:0] letter_score;

	// Instantiate the Unit Under Test (UUT)
	Report_FSM uut (
		.pixel_clock(pixel_clock),
		.reset_sync(reset_sync),
		.frame_sync(frame_sync),
		.score(score),
		.difficulty(difficulty),
		.busy_r(busy_r),
		.letter_score(letter_score),
		.song_rows(song_rows),
		.stop(stop)
	);


	always #5 pixel_clock = ~pixel_clock;
	initial begin
		// Initialize Inputs
		pixel_clock = 0;
		reset_sync = 0;
		frame_sync = 1;
		score = 0;
		difficulty = 0;
		song_rows = 20;
		stop = 0;

		// Wait 100 ns for global reset to finish
		#10;
		reset_sync = 1;
```

```
                #10
                reset_sync = 0;

                #10
                score = 1;

                #10
                score = 10;

                #10
                difficulty = 1;
                score = 1;

                #10
                score = 10;

                #10
                difficulty = 2;
                score = 1;

                #10
                score = 5 ;

                #10
                score = 10;


                // Add stimulus here

        end

endmodule
```

Test Score

```
`timescale 1ns / 1ps

////////////////////////////////////////////////////////////////////////////////
// Anna Ayuso
//created to test the score keeper
//-should increment the score when there is a match in the arrows and the accuracy signal
//-score shouldn't increment again until the accuracy signal goes back to 0
//-more points should be given when the accuracy is higher
//
////////////////////////////////////////////////////////////////////////////////

module test_score_v;

	// Inputs
	reg pixel_clock;
	reg reset_sync;
	reg frame_sync;
	reg [5:0] sensors;
	reg [5:0] accuracy;

	// Outputs
	wire [10:0] score;

	// Instantiate the Unit Under Test (UUT)
	Score_Keeper uut (
		.pixel_clock(pixel_clock),
		.reset_sync(reset_sync),
		.frame_sync(frame_sync),
		.sensors(sensors),
		.accuracy(accuracy),
		.score(score)
	);


	always #5 pixel_clock = ~pixel_clock;
	initial begin
		// Initialize Inputs
		pixel_clock = 0;
		reset_sync = 0;
		frame_sync = 1;
		sensors = 4'b1001;
		accuracy = 0;

		// Wait 100 ns for global reset to finish
		#10;
		reset_sync = 1;

		#10
		reset_sync = 0;

		#10
		accuracy = 6'b010000;

		#10
```

```
                accuracy = 6'b011001;

                #10
                accuracy = 6'b001001;

                #10
                accuracy = 6'b111001;

                #10
                accuracy = 6'b011001;

                #10
                accuracy = 6'b000000;

                #10
                accuracy = 6'b010000;

                #10
                accuracy = 6'b011001;



                // Add stimulus here

        end

endmodule
```

Other Code (Audio Matlab script, Audio Java script, Image Matlab conversion script)

Java script for Audio

```
//Anna Ayuso
//this java code takes in csv files
//and downsamples the song by 10
//the code then writes the downsampled
//song to a coe file to be loaded onto
//the ROM through verilog



import java.io.BufferedReader;
import java.io.BufferedWriter;
import java.io.FileReader;
import java.io.FileWriter;
import java.io.FilterWriter;

import com.Ostermiller.util.*;

public class downsample {

	public static void main(String args[]) {
		BufferedReader in;
		String[][] values = {};



		String[] downsampled = new String[100000];


		try {

		in = new BufferedReader(new FileReader("downsamplefile2"));
		values = CSVParser.parse(in);


		}
		catch (Exception e) {};




		int a = values[0].length;


//		System.out.println(samp);
		int temp = 0;
		long avg;
		for (int i = 0; i < a; i++) {
		//	System.out.println("i = " + i);
		//	System.out.println(values[0][i]);
			if (i%10 == 0 && i != 0){

					avg = (temp + Integer.parseInt(values[0][i]))/10;
```

```
                        //      System.out.println("TEMP " + temp);
                        //      System.out.println("AVG = " + avg);
                                String dec_st = "";
                                if (avg < 0) {          //converts negative numbers to binary, and then converts
back
                                                                                        //to a positive number
                                        String entry = convert2Bin(avg);
                                        int  dec = convert2Dec(entry);
                                        dec_st = Integer.toString(dec);
                                }
                                else {
                                        dec_st = Long.toString(avg);
                                }


                                downsampled[(i/10) - 1] = dec_st /*Long.toString(avg)*/ + ",";
                        //      downsampled[(i/6) - 1] = avg;
                                temp = 0;
                        }
                        else {
                                temp = temp + Integer.parseInt(values[0][i]);
                        }

                }









                try {
                CSVPrinter csvp = new CSVPrinter(new BufferedWriter(new FileWriter("ds10_2")));
                        for (int i = 0; i < downsampled.length; i++) {
                                csvp.writeln(downsampled[i]);
                        }



                }
                catch (Exception e) {};




        }

        public static String convert2Bin(long l) {
                Long lg = new Long(l);
                Integer i = lg.intValue();
                String binstr = Integer.toBinaryString(i);

                int length = binstr.length();

                if (length > 8) {
```

```
                int a = length - 8;
                binstr = binstr.substring(a);
            }
            else {
                int a = 8 - length;
                for (int j = 0; j < a; j++) {
                    binstr = "0" + binstr;
                }
            }

            return binstr;

        }

        public static int convert2Dec(String s) {

            int dec = 0;
            if (s.charAt(0) == '1') {
                dec = dec + 128;
            }
            if (s.charAt(1) == '1') {
                dec = dec + 64;
            }
            if (s.charAt(2) == '1') {
                dec = dec + 32;
            }
            if (s.charAt(3) == '1') {
                dec = dec + 16;
            }
            if (s.charAt(4) == '1') {
                dec = dec + 8;
            }
            if (s.charAt(5) == '1') {
                dec = dec + 4;
            }
            if (s.charAt(6) == '1') {
                dec = dec + 2;
            }
            if (s.charAt(7) == '1') {
                dec = dec + 1;
            }
            return dec;
        }
}
```

Matlab – Audio conversion script

```
%Anna Ayuso
%matlab code used to convert a music sample in wav form
%to a csv file that can be processed with java code
```

```
[y,Fs,bits] = wavread('MrRoboto5', [1, 1000000]);
a = y(:,1);
a = floor(a * 128);
csvwrite('downsamplefile', a');

[y1,Fs1,bits1] = wavread('MrRoboto5', [1000001, 2000000]);
a1 = y1(:,1);
a1 = floor(a1 * 128);
csvwrite('downsamplefile1', a1');


[y2,Fs2,bits2] = wavread('MrRoboto5', [2000001, 2068992]);
a2 = y2(:,1);
a2 = floor(a2 * 128);
csvwrite('downsamplefile2', a2');
```

Matlab – Image conversion script

```
A = imread('beavers.bmp', 'bmp');

fid = fopen('beaver.coe', 'w');
fprintf(fid, 'memory_initialization_radix=16;\nmemory_initalization_vector=\n');

for m=1:384
   for n=1:512
      for v=1:3
         fprintf(fid, '%x', A(m,n,v)/16);
      end
      fprintf(fid, ',');
   end
   fprintf(fid, '\n');
end

fclose(fid);
```