

Team: System Solutions

# Proportional - Integral - Derivative Calculation

Test #1

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# TABLE OF CONTENTS

<b>TABLE OF CONTENTS</b> .....	<b>1</b>
<b>REVISION HISTORY</b> .....	<b>2</b>
<b>TEST PROCEDURE</b> .....	<b>3</b>
PURPOSE OF TEST .....	3
REQUIREMENTS .....	3
TEST IMPLEMENTATION .....	3
<i>Setup</i> .....	3
<i>Procedure</i> .....	4
<i>Results</i> .....	4
<b>CONCLUSION</b> .....	<b>4</b>

## Revision History

<b>Name</b>	<b>Date</b>	<b>Revision Made</b>	<b>Version Number</b>
Alexis Wilson	05/02/2020	Creation of Document	1.0

## Purpose of Test:

The purpose of this test is to verify that the Proportional-Integral-Derivative (PID) Calculation is taking the input from the Figure-of-Merit output and calculating an error signal. This test is the first test for the PID calculation since it is going to use default K values as well as a base equation that may need modified to give the desired outputs.

## Requirements:

To perform this test, one will need a working computer or laptop with a version of Vivado. The Vivado version that was used to run this test was version 2016.4; however, a newer version of Vivado should function very similarly to this. Also, to create the Vivado Project file, one will need to know the specifications of the board they are utilizing: the one xc7z010clg400-1 specific for the STEMLab 125-114 Red Pitaya boards is labelled xc7z010clg400-1.

## Test Implementation:

### Setup:

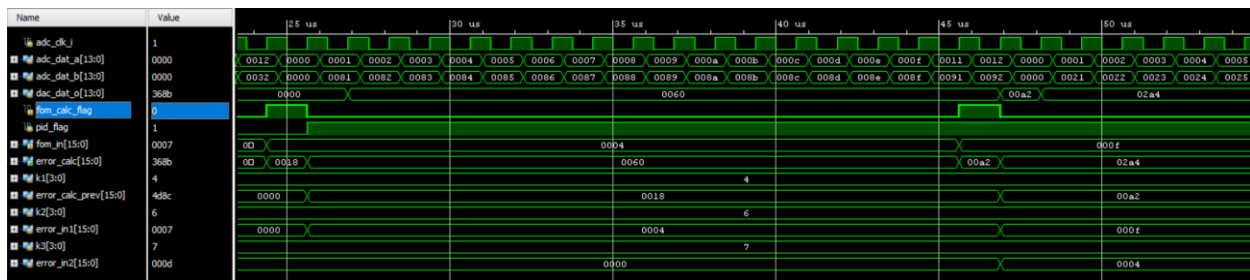
1. Open up Vivado version 2016.4
2. Create a new project specific for your Red Pitaya Board:
  - a. File -> new Project
  - b. Next
  - c. Title project: FPGA\_Data\_Acquisition\_And\_Control
  - d. Create File location
  - e. RTL Sources
  - f. Add/Create 4 source Files:
    - i. adc\_to\_dac\_wrapper.sv
    - ii. decimator.sv
    - iii. fig\_of\_merit.sv
    - iv. pid.sv
  - g. Add/Create a simulation file during source file creation
    - i. tb.sv
  - h. Add/Create 1 Constraint file:
    - i. RedPitaya.xdc
  - i. Search for specific board: xc7z010clg400-1
  - j. Finish: Let Vivado work its magic

## Procedure:

1. In `adc_to_dac_wrapper.sv`
  - a. Copy code from Appendix under `adc_to_dac_wrapper.sv`
2. In `decimator.sv`
  - a. Copy code from Appendix under `decimator.sv`
3. In `fig_of_merit.sv`
  - a. Copy code from Appendix under `fig_of_merit.sv`
4. In `pid.sv`
  - a. Copy code from Appendix under `pid.sv`
5. In `tb.sv`
  - a. Copy code from Appendix under `tb.sv`
6. In `RedPitaya.xdc`
  - a. Copy code from Appendix under `RedPitaya.xdc`
7. Run synthesis to check there is no errors
8. Once project synthesises with no critical warnings or errors:
  - a. Click Run Simulation
  - b. Behavioral Simulation
9. In behavioral Simulation:
  - a. Add all variables to waveform
10. Run waveform to completeness
  - a. The results of this test bench are shown in the screen-captures in the results section

## Results:

1. Output from the PID Calculation



## Conclusion:

The purpose of this test was to verify that the System Verilog code written for the Proportional-Integral-Derivative (PID) Calculation functions as expected with default K values. This test will prove that the PID calculation can be done by using the hardware interface verse the Software.

## Appendix:

### adc\_to\_dac\_wrapper.sv:

```
module adc_to_dac_wrapper(  
    // adc inputs  
    input adc_clk_i,  
    input [13:0] adc_dat_a,  
    input [13:0] adc_dat_b,  
    // dac output  
    output [13:0] dac_dat_o,  
  
    // AXI interface inputs and outputs  
    input s_axis_clk, // need axi clock for data transfer  
    input s_axis_resestn, // using axi reset  
    input s_axis_tready1,  
  
    output s_axis_tvalid1,  
    output [15:0] s_axis_tdata1  
);  
  
logic dec_out_flag1 = 0;  
logic dec_out_flag2 = 0;  
logic [15:0] dec_out1;  
logic [15:0] dec_out2;  
  
// decimator instantiation  
decimator decimator1 (  
    .clk(adc_clk_i),
```

```
.in1(adc_dat_a),  
.in2(adc_dat_b),  
.dec_out_flag1(dec_out_flag1),  
.dec_out_flag2(dec_out_flag2),  
.dec_out1(dec_out1),  
.dec_out2(dec_out2)  
);
```

```
logic [15:0] fom_calc;  
logic fom_calc_flag = 0;  
// FOM calculation instantiation  
fig_of_merit fig_of_merit1(  
    .clk(adc_clk_i),  
    .in1(dec_out1),  
    .in2(dec_out2),  
    .dec_out_flag1(dec_out_flag1),  
    .dec_out_flag2(dec_out_flag2),  
    .fom_calc_flag(fom_calc_flag),  
    .fom_calc(fom_calc)  
);
```

```
logic [15:0] fom_in = 0;  
logic [15:0] pid_calc = 0;  
logic error_flag = 0;  
logic pid_flag = 0;
```

```
// pid instantiation  
pid pid1(  

```

```
.clk(adc_clk_i),  
.reset(s_axis_resetsn),  
.fom_calc_flag(fom_calc_flag),  
.fom_in(fom_calc),  
.error_flag(pid_flag),  
.error_calc(pid_calc)  
);
```

```
logic [15:0] pid_out = 0;  
always @(posedge adc_clk_i)  
begin  
    if(pid_flag)  
        begin  
            pid_out = pid_calc;  
        end  
end
```

```
assign dac_dat_o = pid_out;
```

```
// declare internal signals equivalent to output
```

```
logic s_axis_tdata_1 = 0;  
logic s_axis_tready_1 = 0;  
logic ready1 = 0;  
logic s_axis_tvalid_1 = 0;  
logic valid1 = 0;
```

```
// Synchronization portion to separate clock domain aka FIFO
```

```
always_ff @ (posedge adc_clk_i)
```



```

begin
  if(s_axis_resetn)
    begin
      s_axis_tdata_1 <= 0;
      valid1 <= 0;
    end
  else
    begin
      // fom calculation data
      if(fom_calc_flag == 1)
        begin
          s_axis_tdata_1 <= fom_calc;
        end
      end
    end
  end
end

logic [1:0] valid_reg_sync1;
logic valid_ff_reg1;

always_ff @(posedge s_axis_clk)
begin
  if(valid1)
    begin
      valid_reg_sync1[0] <= valid1;
      valid_reg_sync1[1] <= valid_reg_sync1[0];
      valid_ff_reg1 <= valid_reg_sync1[1];
      s_axis_tvalid_1 <= valid_ff_reg1 ^ valid_reg_sync1[1];
    end
end

```

```
end
```

```
assign s_axis_tdata1 = s_axis_tdata_1;
```

```
assign s_axis_tvalid1 = s_axis_tvalid_1;
```

```
endmodule
```

### **decimator.sv:**

```
module decimator(
```

```
    input clk,
```

```
    input [13:0] in1,
```

```
    input [13:0] in2,
```

```
    output dec_out_flag1,
```

```
    output dec_out_flag2,
```

```
    output [15:0] dec_out1,
```

```
    output [15:0] dec_out2
```

```
);
```

```
logic [3:0] count1 = 0;
```

```
logic [19:0] accum_in1 = 0;
```

```
logic [19:0] accum_out1 = 0;
```

```
logic [15:0] dec_calc1 = 0;
```

```
logic flag1 = 0;
```

```
// Accumulator for Input 1
```

```
always_ff @(posedge clk)
```

```
begin
```

```
    // waits for an initial value to come into the system
```

```

if(count1 == 0 && in1 != 0)
begin
    accum_in1 = in1;
    count1++;
    flag1 = 0;
end
// As long as only 15 values have gone in aka countonly reaches 14 it enters this loop
else if (count1 != 15 && in1 != 0)
begin
    accum_in1 = accum_in1 + in1;
    count1++;
    flag1 = 0;
end
/* means this is the 16th value to be inputted
   assign the new accumulated value to output of accumulator
   and then reset */
else if(count1 == 15)
begin
    accum_out1 = accum_in1 + in1;
    count1++;
    accum_in1 = 0;
    flag1 = 1;
end
else
begin
    flag1 = 0;
end
end
end

```

```

//Decimation for Input 1
always_ff @(posedge clk)
begin
    if(flag1 == 1)
        begin
            dec_calc1 = accum_out1 <<< 4;
        end
    end
end

// how dec_out is assigned until decimation is written
assign dec_out1 = dec_calc1;
assign dec_out_flag1 = flag1;

logic [3:0] count2 = 0;
logic [19:0] accum_in2 = 0;
logic [19:0] accum_out2 = 0;
logic [15:0] dec_calc2 = 0;
logic flag2 = 0;

// Accumulator for Input 2
always_ff @(posedge clk)
begin
    // waits for an initial value to come into the system
    if(count2 == 0 && in2 != 0)
        begin
            accum_in2 = in2;
            count2++;
            flag2 = 0;
        end
end

```

```

end
// As long as only 15 values have gone in aka countonly reaches 14 it enters this loop
else if (count2 != 15 && in2 != 0)
begin
    accum_in2 = accum_in2 + in2;
    count2++;
    flag2 = 0;
end
/* means this is the 16th value to be inputted
    assign the new accumulated value to output of accumulator
    and then reset */
else if(count2 == 15)
begin
    accum_out2 = accum_in2 + in2;
    count2++;
    accum_in2 = 0;
    flag2 = 1;
end
else
begin
    flag2 = 0;
end
end

// Decimation for Input 2
always_ff @(posedge clk)
begin
    if(flag2 == 1)

```

```

begin
    dec_calc2 = accum_out2 <<< 4;
end
end

// how dec_out is assigned until decimation is written
assign dec_out2 = dec_calc2;
assign dec_out_flag2 = flag2;

endmodule

```

### **fig\_of\_merit.sv:**

```

module fig_of_merit(
    input clk,
    input [15:0] in1,
    input [15:0] in2,
    input dec_out_flag1,
    input dec_out_flag2,
    output fom_calc_flag,
    output [15:0] fom_calc
    //output [13:0] dac_dat_o
);

//sets some base values to save calculation to
logic fom_flag;
logic [15:0] fom = 0;

always_ff @(posedge clk)
begin

```

```

// check there is an input and that there was no previous FOM calculaion
if(dec_out_flag1 == 1 && dec_out_flag2 == 1)
begin
    fom = in2/in1;
    fom_flag = 1;
end
else
begin
    fom_flag = 0;
end
end

assign fom_calc = fom;
assign fom_calc_flag = fom_flag;

endmodule

```

### **pid.sv:**

```

module pid(
    input clk,
    input reset,
    input fom_calc_flag,
    input [15:0] fom_in,

    output error_flag,
    output [15:0] error_calc
);

```

```

logic [3:0] k1 = 4'b0100;
logic [3:0] k2 = 4'b0110;
logic [3:0] k3 = 4'b0111;

logic pid_flag =0;

logic [15:0] error_calc_prev = 0;
logic [15:0] error_in1 = 0;
logic [15:0] error_in2 = 0;

assign error_calc = k1*error_calc_prev + (k2*fom_in - k2*error_in1) + k3*error_in2;

always @(posedge clk)
begin
    if(reset == 1)
    begin
        pid_flag <= 0;
        error_calc_prev <= 0;
        error_in1 <= 0;
        error_in2 <= 0;
    end

    if(fom_calc_flag == 1)
    begin
        pid_flag <= 1;
        error_in2 <= error_in1;
        error_in1 <= fom_in;
        error_calc_prev <= error_calc;
    end
end

```



```

        end
    else
        begin
            pid_flag <= 0;
            error_in2 <= error_in2;
            error_in1 <= error_in1;
            error_calc_prev <= error_calc_prev;
        end
    end
end

```

```

assign error_flag = pid_flag;

```

```

endmodule

```

### **tb.sv:**

```

module tb;
    // Inputs
    logic adc_clk_i;
    logic [13:0] adc_dat_a;
    logic [13:0] adc_dat_b;
    // Outputs
    logic [13:0] dac_dat_o; // not used in this section

    // Instantiate the Unit Under Test (UUT)
    adc_to_dac_wrapper #(.SIM_ONLY(1)) uut (
        .adc_clk_i(adc_clk_i),
        .adc_dat_a(adc_dat_a),
        .adc_dat_b(adc_dat_b),

```

```

        .dac_dat_o(dac_dat_o)
    );

parameter CLK_PRD = 1250; // 125 MHz clock
parameter HOLD_TIME = (CLK_PRD*0.3);
parameter MAX_SIM_TIME = (CLK_PRD*30);

initial #(MAX_SIM_TIME) $finish;

initial begin
    adc_clk_i <= 0;
    forever #(CLK_PRD/2) adc_clk_i = ~adc_clk_i;
end

initial begin
    // Initial adc value
    adc_dat_a = 14'b0000000000000000;
    adc_dat_b = 14'b0000000000000000;

    // Wait 100 ns for global reset to finish
    #100;
    @(posedge adc_clk_i); // align with clock edge
    #HOLD_TIME; // offset a hold time
    repeat(2) #CLK_PRD;

    adc_dat_a = 14'b0000000000000001;
    adc_dat_b = 14'b0000000001000001;
    #CLK_PRD;

```

```
adc_dat_a = 14'b000000000000010;
adc_dat_b = 14'b000000000100010;
#CLK_PRD;
adc_dat_a = 14'b000000000000011;
adc_dat_b = 14'b000000000100011;
#CLK_PRD;
adc_dat_a = 14'b000000000000100;
adc_dat_b = 14'b000000000100100;
#CLK_PRD;
adc_dat_a = 14'b000000000000101;
adc_dat_b = 14'b000000000100101;
#CLK_PRD;
adc_dat_a = 14'b000000000000110;
adc_dat_b = 14'b000000000100110;
#CLK_PRD;
adc_dat_a = 14'b000000000000111;
adc_dat_b = 14'b000000000100111;
#CLK_PRD;
adc_dat_a = 14'b000000000001000;
adc_dat_b = 14'b000000000101000;
#CLK_PRD;
adc_dat_a = 14'b000000000001001;
adc_dat_b = 14'b000000000101001;
#CLK_PRD;
adc_dat_a = 14'b000000000001010;
adc_dat_b = 14'b000000000101010;
#CLK_PRD;
adc_dat_a = 14'b000000000001011;
```

```
adc_dat_b = 14'b000000000101011;
#CLK_PRD;
adc_dat_a = 14'b00000000001100;
adc_dat_b = 14'b000000000101100;
#CLK_PRD;
adc_dat_a = 14'b00000000001101;
adc_dat_b = 14'b000000000101101;
#CLK_PRD;
adc_dat_a = 14'b00000000001110;
adc_dat_b = 14'b000000000101110;
#CLK_PRD;
adc_dat_a = 14'b00000000001111;
adc_dat_b = 14'b000000000101111;
#CLK_PRD;
adc_dat_a = 14'b00000000010001;
adc_dat_b = 14'b000000000110001;
#CLK_PRD;
adc_dat_a = 14'b00000000010010;
adc_dat_b = 14'b000000000110010;
#CLK_PRD;
adc_dat_a = 14'b000000000000000;
adc_dat_b = 14'b000000000000000;

#CLK_PRD;

adc_dat_a = 14'b000000000000001;
adc_dat_b = 14'b00000100000001;
#CLK_PRD;
```

```
adc_dat_a = 14'b000000000000010;
adc_dat_b = 14'b000000010000010;
#CLK_PRD;
adc_dat_a = 14'b000000000000011;
adc_dat_b = 14'b000000010000011;
#CLK_PRD;
adc_dat_a = 14'b000000000000100;
adc_dat_b = 14'b000000010000100;
#CLK_PRD;
adc_dat_a = 14'b000000000000101;
adc_dat_b = 14'b000000010000101;
#CLK_PRD;
adc_dat_a = 14'b000000000000110;
adc_dat_b = 14'b000000010000110;
#CLK_PRD;
adc_dat_a = 14'b000000000000111;
adc_dat_b = 14'b000000010000111;
#CLK_PRD;
adc_dat_a = 14'b000000000001000;
adc_dat_b = 14'b000000010001000;
#CLK_PRD;
adc_dat_a = 14'b000000000001001;
adc_dat_b = 14'b000000010001001;
#CLK_PRD;
adc_dat_a = 14'b000000000001010;
adc_dat_b = 14'b000000010001010;
#CLK_PRD;
adc_dat_a = 14'b000000000001011;
```

```
adc_dat_b = 14'b000000010001011;
#CLK_PRD;
adc_dat_a = 14'b000000000001100;
adc_dat_b = 14'b000000010001100;
#CLK_PRD;
adc_dat_a = 14'b000000000001101;
adc_dat_b = 14'b000000010001101;
#CLK_PRD;
adc_dat_a = 14'b000000000001110;
adc_dat_b = 14'b000000010001110;
#CLK_PRD;
adc_dat_a = 14'b000000000001111;
adc_dat_b = 14'b000000010001111;
#CLK_PRD;
adc_dat_a = 14'b000000000010001;
adc_dat_b = 14'b000000010010001;
#CLK_PRD;
adc_dat_a = 14'b000000000010010;
adc_dat_b = 14'b000000010010010;
#CLK_PRD;
adc_dat_a = 14'b000000000000000;
adc_dat_b = 14'b000000000000000;

#CLK_PRD;

adc_dat_a = 14'b000000000000001;
adc_dat_b = 14'b00000000100001;
#CLK_PRD;
```

```
adc_dat_a = 14'b000000000000010;
adc_dat_b = 14'b000000000100010;
#CLK_PRD;
adc_dat_a = 14'b000000000000011;
adc_dat_b = 14'b000000000100011;
#CLK_PRD;
adc_dat_a = 14'b000000000000100;
adc_dat_b = 14'b000000000100100;
#CLK_PRD;
adc_dat_a = 14'b000000000000101;
adc_dat_b = 14'b000000000100101;
#CLK_PRD;
adc_dat_a = 14'b000000000000110;
adc_dat_b = 14'b000000000100110;
#CLK_PRD;
adc_dat_a = 14'b000000000000111;
adc_dat_b = 14'b000000000100111;
#CLK_PRD;
adc_dat_a = 14'b000000000001000;
adc_dat_b = 14'b000000000101000;
#CLK_PRD;
adc_dat_a = 14'b000000000001001;
adc_dat_b = 14'b000000000101001;
#CLK_PRD;
adc_dat_a = 14'b000000000001010;
adc_dat_b = 14'b000000000101010;
#CLK_PRD;
adc_dat_a = 14'b000000000001011;
```

```
adc_dat_b = 14'b000000000101011;
#CLK_PRD;
adc_dat_a = 14'b000000000001100;
adc_dat_b = 14'b000000000101100;
#CLK_PRD;
adc_dat_a = 14'b000000000001101;
adc_dat_b = 14'b000000000101101;
#CLK_PRD;
adc_dat_a = 14'b000000000001110;
adc_dat_b = 14'b000000000101110;
#CLK_PRD;
adc_dat_a = 14'b000000000001111;
adc_dat_b = 14'b000000000101111;
#CLK_PRD;
adc_dat_a = 14'b000000000010001;
adc_dat_b = 14'b000000000110001;
#CLK_PRD;
adc_dat_a = 14'b000000000010010;
adc_dat_b = 14'b000000000110010;
#CLK_PRD;
adc_dat_a = 14'b000000000000000;
adc_dat_b = 14'b000000000000000;

#CLK_PRD;

adc_dat_a = 14'b000000000000001;
adc_dat_b = 14'b00000100000001;
#CLK_PRD;
```



```
adc_dat_a = 14'b000000000000010;
adc_dat_b = 14'b000000010000010;
#CLK_PRD;
adc_dat_a = 14'b000000000000011;
adc_dat_b = 14'b000000010000011;
#CLK_PRD;
adc_dat_a = 14'b000000000000100;
adc_dat_b = 14'b000000010000100;
#CLK_PRD;
adc_dat_a = 14'b000000000000101;
adc_dat_b = 14'b000000010000101;
#CLK_PRD;
adc_dat_a = 14'b000000000000110;
adc_dat_b = 14'b000000010000110;
#CLK_PRD;
adc_dat_a = 14'b000000000000111;
adc_dat_b = 14'b000000010000111;
#CLK_PRD;
adc_dat_a = 14'b000000000001000;
adc_dat_b = 14'b000000010001000;
#CLK_PRD;
adc_dat_a = 14'b000000000001001;
adc_dat_b = 14'b000000010001001;
#CLK_PRD;
adc_dat_a = 14'b000000000001010;
adc_dat_b = 14'b000000010001010;
#CLK_PRD;
adc_dat_a = 14'b000000000001011;
```

```
adc_dat_b = 14'b000000010001011;
#CLK_PRD;
adc_dat_a = 14'b000000000001100;
adc_dat_b = 14'b000000010001100;
#CLK_PRD;
adc_dat_a = 14'b000000000001101;
adc_dat_b = 14'b000000010001101;
#CLK_PRD;
adc_dat_a = 14'b000000000001110;
adc_dat_b = 14'b000000010001110;
#CLK_PRD;
adc_dat_a = 14'b000000000001111;
adc_dat_b = 14'b000000010001111;
#CLK_PRD;
adc_dat_a = 14'b000000000010001;
adc_dat_b = 14'b000000010010001;
#CLK_PRD;
adc_dat_a = 14'b000000000010010;
adc_dat_b = 14'b000000010010010;
#CLK_PRD;
adc_dat_a = 14'b000000000000000;
adc_dat_b = 14'b000000000000000;

#CLK_PRD

adc_dat_a = 14'b000000000000001;
adc_dat_b = 14'b00000000100001;
#CLK_PRD;
```

```
adc_dat_a = 14'b000000000000010;
adc_dat_b = 14'b000000000100010;
#CLK_PRD;
adc_dat_a = 14'b000000000000011;
adc_dat_b = 14'b000000000100011;
#CLK_PRD;
adc_dat_a = 14'b000000000000100;
adc_dat_b = 14'b000000000100100;
#CLK_PRD;
adc_dat_a = 14'b000000000000101;
adc_dat_b = 14'b000000000100101;
#CLK_PRD;
adc_dat_a = 14'b000000000000110;
adc_dat_b = 14'b000000000100110;
#CLK_PRD;
adc_dat_a = 14'b000000000000111;
adc_dat_b = 14'b000000000100111;
#CLK_PRD;
adc_dat_a = 14'b000000000001000;
adc_dat_b = 14'b000000000101000;
#CLK_PRD;
adc_dat_a = 14'b000000000001001;
adc_dat_b = 14'b000000000101001;
#CLK_PRD;
adc_dat_a = 14'b000000000001010;
adc_dat_b = 14'b000000000101010;
#CLK_PRD;
adc_dat_a = 14'b000000000001011;
```

```
adc_dat_b = 14'b000000000101011;
#CLK_PRD;
adc_dat_a = 14'b000000000001100;
adc_dat_b = 14'b000000000101100;
#CLK_PRD;
adc_dat_a = 14'b000000000001101;
adc_dat_b = 14'b000000000101101;
#CLK_PRD;
adc_dat_a = 14'b000000000001110;
adc_dat_b = 14'b000000000101110;
#CLK_PRD;
adc_dat_a = 14'b000000000001111;
adc_dat_b = 14'b000000000101111;
#CLK_PRD;
adc_dat_a = 14'b000000000010001;
adc_dat_b = 14'b000000000110001;
#CLK_PRD;
adc_dat_a = 14'b000000000010010;
adc_dat_b = 14'b000000000110010;
#CLK_PRD;
adc_dat_a = 14'b000000000000000;
adc_dat_b = 14'b000000000000000;

#CLK_PRD;

adc_dat_a = 14'b000000000000001;
adc_dat_b = 14'b000000000100001;
#CLK_PRD;
```

```
adc_dat_a = 14'b00000000000010;
adc_dat_b = 14'b00000000100010;
#CLK_PRD;
adc_dat_a = 14'b00000000000011;
adc_dat_b = 14'b00000000100011;
#CLK_PRD;
adc_dat_a = 14'b00000000000100;
adc_dat_b = 14'b00000000100100;
#CLK_PRD;
adc_dat_a = 14'b00000000000101;
adc_dat_b = 14'b00000000100101;
#CLK_PRD;
adc_dat_a = 14'b00000000000110;
adc_dat_b = 14'b00000000100110;
#CLK_PRD;
adc_dat_a = 14'b00000000000111;
adc_dat_b = 14'b00000000100111;
#CLK_PRD
adc_dat_a = 14'b0000000001000;
adc_dat_b = 14'b00000000101000;
#CLK_PRD;
adc_dat_a = 14'b0000000001001;
adc_dat_b = 14'b00000000101001;
#CLK_PRD;
adc_dat_a = 14'b0000000001010;
adc_dat_b = 14'b00000000101010;
#CLK_PRD;
adc_dat_a = 14'b0000000001011;
```

```
adc_dat_b = 14'b00000000101011;
#CLK_PRD;
adc_dat_a = 14'b00000000001100;
adc_dat_b = 14'b00000000101100;
#CLK_PRD;
adc_dat_a = 14'b00000000001101;
adc_dat_b = 14'b00000000101101;
#CLK_PRD;
adc_dat_a = 14'b00000000001110;
adc_dat_b = 14'b00000000101110;
#CLK_PRD;
adc_dat_a = 14'b00000000001111;
adc_dat_b = 14'b00000000101111;
#CLK_PRD;
adc_dat_a = 14'b00000000010001;
adc_dat_b = 14'b00000000110001;
#CLK_PRD;
adc_dat_a = 14'b00000000010010;
adc_dat_b = 14'b00000000110010;
#CLK_PRD;
adc_dat_a = 14'b00000000000000;
adc_dat_b = 14'b00000000000000;

#CLK_PRD;

adc_dat_a = 14'b00000000000001;
adc_dat_b = 14'b00000100000001;
#CLK_PRD;
```

```
adc_dat_a = 14'b00000000000010;
adc_dat_b = 14'b00000010000010;
#CLK_PRD;
adc_dat_a = 14'b00000000000011;
adc_dat_b = 14'b00000010000011;
#CLK_PRD;
adc_dat_a = 14'b00000000000100;
adc_dat_b = 14'b00000010000100;
#CLK_PRD;
adc_dat_a = 14'b00000000000101;
adc_dat_b = 14'b00000010000101;
#CLK_PRD;
adc_dat_a = 14'b00000000000110;
adc_dat_b = 14'b00000010000110;
#CLK_PRD;
adc_dat_a = 14'b00000000000111;
adc_dat_b = 14'b00000010000111;
#CLK_PRD
adc_dat_a = 14'b00000000001000;
adc_dat_b = 14'b00000010001000;
#CLK_PRD;
adc_dat_a = 14'b00000000001001;
adc_dat_b = 14'b00000010001001;
#CLK_PRD;
adc_dat_a = 14'b00000000001010;
adc_dat_b = 14'b00000010001010;
#CLK_PRD;
adc_dat_a = 14'b00000000001011;
```

```
adc_dat_b = 14'b00000010001011;
#CLK_PRD;
adc_dat_a = 14'b00000000001100;
adc_dat_b = 14'b00000010001100;
#CLK_PRD;
adc_dat_a = 14'b00000000001101;
adc_dat_b = 14'b00000010001101;
#CLK_PRD;
adc_dat_a = 14'b00000000001110;
adc_dat_b = 14'b00000010001110;
#CLK_PRD;
adc_dat_a = 14'b00000000001111;
adc_dat_b = 14'b00000010001111;
#CLK_PRD;
adc_dat_a = 14'b00000000010001;
adc_dat_b = 14'b00000010010001;
#CLK_PRD;
adc_dat_a = 14'b00000000010010;
adc_dat_b = 14'b00000010010010;
#CLK_PRD;
adc_dat_a = 14'b00000000000000;
adc_dat_b = 14'b00000000000000;

#CLK_PRD

adc_dat_a = 14'b00000000000001;
adc_dat_b = 14'b00000000100001;
#CLK_PRD;
```



```
adc_dat_a = 14'b00000000000010;
adc_dat_b = 14'b00000000100010;
#CLK_PRD;
adc_dat_a = 14'b00000000000011;
adc_dat_b = 14'b00000000100011;
#CLK_PRD;
adc_dat_a = 14'b00000000000100;
adc_dat_b = 14'b00000000100100;
#CLK_PRD;
adc_dat_a = 14'b00000000000101;
adc_dat_b = 14'b00000000100101;
#CLK_PRD;
adc_dat_a = 14'b00000000000110;
adc_dat_b = 14'b00000000100110;
#CLK_PRD;
adc_dat_a = 14'b00000000000111;
adc_dat_b = 14'b00000000100111;
#CLK_PRD
adc_dat_a = 14'b00000000001000;
adc_dat_b = 14'b00000000101000;
#CLK_PRD;
adc_dat_a = 14'b00000000001001;
adc_dat_b = 14'b00000000101001;
#CLK_PRD;
adc_dat_a = 14'b00000000001010;
adc_dat_b = 14'b00000000101010;
#CLK_PRD;
adc_dat_a = 14'b00000000001011;
```

```
adc_dat_b = 14'b00000000101011;
#CLK_PRD;
adc_dat_a = 14'b00000000001100;
adc_dat_b = 14'b00000000101100;
#CLK_PRD;
adc_dat_a = 14'b00000000001101;
adc_dat_b = 14'b00000000101101;
#CLK_PRD;
adc_dat_a = 14'b00000000001110;
adc_dat_b = 14'b00000000101110;
#CLK_PRD;
adc_dat_a = 14'b00000000001111;
adc_dat_b = 14'b00000000101111;
#CLK_PRD;
adc_dat_a = 14'b00000000010001;
adc_dat_b = 14'b00000000110001;
#CLK_PRD;
adc_dat_a = 14'b00000000010010;
adc_dat_b = 14'b00000000110010;
#CLK_PRD;
adc_dat_a = 14'b00000000000000;
adc_dat_b = 14'b00000000000000;

#CLK_PRD;

adc_dat_a = 14'b000000000000001;
adc_dat_b = 14'b00000000100001;
#CLK_PRD;
```

```
adc_dat_a = 14'b000000000000010;
adc_dat_b = 14'b000000000100010;
#CLK_PRD;
adc_dat_a = 14'b000000000000011;
adc_dat_b = 14'b000000000100011;
#CLK_PRD;
adc_dat_a = 14'b000000000000100;
adc_dat_b = 14'b000000000100100;
#CLK_PRD;
adc_dat_a = 14'b000000000000101;
adc_dat_b = 14'b000000000100101;
#CLK_PRD;
adc_dat_a = 14'b000000000000110;
adc_dat_b = 14'b000000000100110;
#CLK_PRD;
adc_dat_a = 14'b000000000000111;
adc_dat_b = 14'b000000000100111;
#CLK_PRD;
adc_dat_a = 14'b000000000001000;
adc_dat_b = 14'b000000000101000;
#CLK_PRD;
adc_dat_a = 14'b000000000001001;
adc_dat_b = 14'b000000000101001;
#CLK_PRD;
adc_dat_a = 14'b000000000001010;
adc_dat_b = 14'b000000000101010;
#CLK_PRD;
adc_dat_a = 14'b000000000001011;
```

```
adc_dat_b = 14'b000000000101011;
#CLK_PRD;
adc_dat_a = 14'b00000000001100;
adc_dat_b = 14'b000000000101100;
#CLK_PRD;
adc_dat_a = 14'b00000000001101;
adc_dat_b = 14'b000000000101101;
#CLK_PRD;
adc_dat_a = 14'b00000000001110;
adc_dat_b = 14'b000000000101110;
#CLK_PRD;
adc_dat_a = 14'b00000000001111;
adc_dat_b = 14'b000000000101111;
#CLK_PRD;
adc_dat_a = 14'b000000000010001;
adc_dat_b = 14'b000000000110001;
#CLK_PRD;
adc_dat_a = 14'b000000000010010;
adc_dat_b = 14'b000000000110010;
#CLK_PRD;
adc_dat_a = 14'b000000000000000;
adc_dat_b = 14'b000000000000000;

#CLK_PRD;

adc_dat_a = 14'b000000000000001;
adc_dat_b = 14'b00000100000001;
#CLK_PRD;
```

```
adc_dat_a = 14'b000000000000010;
adc_dat_b = 14'b000000010000010;
#CLK_PRD;
adc_dat_a = 14'b000000000000011;
adc_dat_b = 14'b000000010000011;
#CLK_PRD;
adc_dat_a = 14'b000000000000100;
adc_dat_b = 14'b000000010000100;
#CLK_PRD;
adc_dat_a = 14'b000000000000101;
adc_dat_b = 14'b000000010000101;
#CLK_PRD;
adc_dat_a = 14'b000000000000110;
adc_dat_b = 14'b000000010000110;
#CLK_PRD;
adc_dat_a = 14'b000000000000111;
adc_dat_b = 14'b000000010000111;
#CLK_PRD;
adc_dat_a = 14'b000000000001000;
adc_dat_b = 14'b000000010001000;
#CLK_PRD;
adc_dat_a = 14'b000000000001001;
adc_dat_b = 14'b000000010001001;
#CLK_PRD;
adc_dat_a = 14'b000000000001010;
adc_dat_b = 14'b000000010001010;
#CLK_PRD;
adc_dat_a = 14'b000000000001011;
```

```
adc_dat_b = 14'b000000010001011;
#CLK_PRD;
adc_dat_a = 14'b000000000001100;
adc_dat_b = 14'b000000010001100;
#CLK_PRD;
adc_dat_a = 14'b000000000001101;
adc_dat_b = 14'b000000010001101;
#CLK_PRD;
adc_dat_a = 14'b000000000001110;
adc_dat_b = 14'b000000010001110;
#CLK_PRD;
adc_dat_a = 14'b000000000001111;
adc_dat_b = 14'b000000010001111;
#CLK_PRD;
adc_dat_a = 14'b000000000010001;
adc_dat_b = 14'b000000010010001;
#CLK_PRD;
adc_dat_a = 14'b000000000010010;
adc_dat_b = 14'b000000010010010;
#CLK_PRD;
adc_dat_a = 14'b000000000000000;
adc_dat_b = 14'b000000000000000;

#CLK_PRD

adc_dat_a = 14'b000000000000001;
adc_dat_b = 14'b00000000100001;
#CLK_PRD;
```

```
adc_dat_a = 14'b000000000000010;
adc_dat_b = 14'b000000000100010;
#CLK_PRD;
adc_dat_a = 14'b000000000000011;
adc_dat_b = 14'b000000000100011;
#CLK_PRD;
adc_dat_a = 14'b000000000000100;
adc_dat_b = 14'b000000000100100;
#CLK_PRD;
adc_dat_a = 14'b000000000000101;
adc_dat_b = 14'b000000000100101;
#CLK_PRD;
adc_dat_a = 14'b000000000000110;
adc_dat_b = 14'b000000000100110;
#CLK_PRD;
adc_dat_a = 14'b000000000000111;
adc_dat_b = 14'b000000000100111;
#CLK_PRD;
adc_dat_a = 14'b000000000001000;
adc_dat_b = 14'b000000000101000;
#CLK_PRD;
adc_dat_a = 14'b000000000001001;
adc_dat_b = 14'b000000000101001;
#CLK_PRD;
adc_dat_a = 14'b000000000001010;
adc_dat_b = 14'b000000000101010;
#CLK_PRD;
adc_dat_a = 14'b000000000001011;
```

```
adc_dat_b = 14'b000000000101011;
#CLK_PRD;
adc_dat_a = 14'b000000000001100;
adc_dat_b = 14'b000000000101100;
#CLK_PRD;
adc_dat_a = 14'b000000000001101;
adc_dat_b = 14'b000000000101101;
#CLK_PRD;
adc_dat_a = 14'b000000000001110;
adc_dat_b = 14'b000000000101110;
#CLK_PRD;
adc_dat_a = 14'b000000000001111;
adc_dat_b = 14'b000000000101111;
#CLK_PRD;
adc_dat_a = 14'b000000000010001;
adc_dat_b = 14'b000000000110001;
#CLK_PRD;
adc_dat_a = 14'b000000000010010;
adc_dat_b = 14'b000000000110010;
#CLK_PRD;
adc_dat_a = 14'b000000000000000;
adc_dat_b = 14'b000000000000000;

#CLK_PRD;

adc_dat_a = 14'b000000000000001;
adc_dat_b = 14'b000000000100001;
#CLK_PRD;
```



```
adc_dat_a = 14'b000000000000010;
adc_dat_b = 14'b000000000100010;
#CLK_PRD;
adc_dat_a = 14'b000000000000011;
adc_dat_b = 14'b000000000100011;
#CLK_PRD;
adc_dat_a = 14'b000000000000100;
adc_dat_b = 14'b000000000100100;
#CLK_PRD;
adc_dat_a = 14'b000000000000101;
adc_dat_b = 14'b000000000100101;
#CLK_PRD;
adc_dat_a = 14'b000000000000110;
adc_dat_b = 14'b000000000100110;
#CLK_PRD;
adc_dat_a = 14'b000000000000111;
adc_dat_b = 14'b000000000100111;
#CLK_PRD;
adc_dat_a = 14'b000000000001000;
adc_dat_b = 14'b000000000101000;
#CLK_PRD;
adc_dat_a = 14'b000000000001001;
adc_dat_b = 14'b000000000101001;
#CLK_PRD;
adc_dat_a = 14'b000000000001010;
adc_dat_b = 14'b000000000101010;
#CLK_PRD;
adc_dat_a = 14'b000000000001011;
```

```
adc_dat_b = 14'b000000000101011;
#CLK_PRD;
adc_dat_a = 14'b000000000001100;
adc_dat_b = 14'b000000000101100;
#CLK_PRD;
adc_dat_a = 14'b000000000001101;
adc_dat_b = 14'b000000000101101;
#CLK_PRD;
adc_dat_a = 14'b000000000001110;
adc_dat_b = 14'b000000000101110;
#CLK_PRD;
adc_dat_a = 14'b000000000001111;
adc_dat_b = 14'b000000000101111;
#CLK_PRD;
adc_dat_a = 14'b000000000010001;
adc_dat_b = 14'b000000000110001;
#CLK_PRD;
adc_dat_a = 14'b000000000010010;
adc_dat_b = 14'b000000000110010;
#CLK_PRD;
adc_dat_a = 14'b000000000000000;
adc_dat_b = 14'b000000000000000;

#CLK_PRD;

adc_dat_a = 14'b000000000000001;
adc_dat_b = 14'b00000100000001;
#CLK_PRD;
```

```
adc_dat_a = 14'b000000000000010;
adc_dat_b = 14'b000000010000010;
#CLK_PRD;
adc_dat_a = 14'b000000000000011;
adc_dat_b = 14'b000000010000011;
#CLK_PRD;
adc_dat_a = 14'b000000000000100;
adc_dat_b = 14'b000000010000100;
#CLK_PRD;
adc_dat_a = 14'b000000000000101;
adc_dat_b = 14'b000000010000101;
#CLK_PRD;
adc_dat_a = 14'b000000000000110;
adc_dat_b = 14'b000000010000110;
#CLK_PRD;
adc_dat_a = 14'b000000000000111;
adc_dat_b = 14'b000000010000111;
#CLK_PRD;
adc_dat_a = 14'b000000000001000;
adc_dat_b = 14'b000000010001000;
#CLK_PRD;
adc_dat_a = 14'b000000000001001;
adc_dat_b = 14'b000000010001001;
#CLK_PRD;
adc_dat_a = 14'b000000000001010;
adc_dat_b = 14'b000000010001010;
#CLK_PRD;
adc_dat_a = 14'b000000000001011;
```

```
adc_dat_b = 14'b000000010001011;
#CLK_PRD;
adc_dat_a = 14'b000000000001100;
adc_dat_b = 14'b000000010001100;
#CLK_PRD;
adc_dat_a = 14'b000000000001101;
adc_dat_b = 14'b000000010001101;
#CLK_PRD;
adc_dat_a = 14'b000000000001110;
adc_dat_b = 14'b000000010001110;
#CLK_PRD;
adc_dat_a = 14'b000000000001111;
adc_dat_b = 14'b000000010001111;
#CLK_PRD;
adc_dat_a = 14'b000000000010001;
adc_dat_b = 14'b000000010010001;
#CLK_PRD;
adc_dat_a = 14'b000000000010010;
adc_dat_b = 14'b000000010010010;
#CLK_PRD;
adc_dat_a = 14'b000000000000000;
adc_dat_b = 14'b000000000000000;

#CLK_PRD

adc_dat_a = 14'b000000000000001;
adc_dat_b = 14'b00000000100001;
#CLK_PRD;
```

```
adc_dat_a = 14'b000000000000010;
adc_dat_b = 14'b000000000100010;
#CLK_PRD;
adc_dat_a = 14'b000000000000011;
adc_dat_b = 14'b000000000100011;
#CLK_PRD;
adc_dat_a = 14'b000000000000100;
adc_dat_b = 14'b000000000100100;
#CLK_PRD;
adc_dat_a = 14'b000000000000101;
adc_dat_b = 14'b000000000100101;
#CLK_PRD;
adc_dat_a = 14'b000000000000110;
adc_dat_b = 14'b000000000100110;
#CLK_PRD;
adc_dat_a = 14'b000000000000111;
adc_dat_b = 14'b000000000100111;
#CLK_PRD;
adc_dat_a = 14'b000000000001000;
adc_dat_b = 14'b000000000101000;
#CLK_PRD;
adc_dat_a = 14'b000000000001001;
adc_dat_b = 14'b000000000101001;
#CLK_PRD;
adc_dat_a = 14'b000000000001010;
adc_dat_b = 14'b000000000101010;
#CLK_PRD;
adc_dat_a = 14'b000000000001011;
```

```
adc_dat_b = 14'b000000000101011;
#CLK_PRD;
adc_dat_a = 14'b00000000001100;
adc_dat_b = 14'b000000000101100;
#CLK_PRD;
adc_dat_a = 14'b00000000001101;
adc_dat_b = 14'b000000000101101;
#CLK_PRD;
adc_dat_a = 14'b00000000001110;
adc_dat_b = 14'b000000000101110;
#CLK_PRD;
adc_dat_a = 14'b00000000001111;
adc_dat_b = 14'b000000000101111;
#CLK_PRD;
adc_dat_a = 14'b00000000010001;
adc_dat_b = 14'b000000000110001;
#CLK_PRD;
adc_dat_a = 14'b00000000010010;
adc_dat_b = 14'b000000000110010;
#CLK_PRD;
adc_dat_a = 14'b000000000000000;
adc_dat_b = 14'b000000000000000;

#CLK_PRD;

adc_dat_a = 14'b000000000000001;
adc_dat_b = 14'b000000000100001;
#CLK_PRD;
```

```
adc_dat_a = 14'b000000000000010;
adc_dat_b = 14'b000000000100010;
#CLK_PRD;
adc_dat_a = 14'b000000000000011;
adc_dat_b = 14'b000000000100011;
#CLK_PRD;
adc_dat_a = 14'b000000000000100;
adc_dat_b = 14'b000000000100100;
#CLK_PRD;
adc_dat_a = 14'b000000000000101;
adc_dat_b = 14'b000000000100101;
#CLK_PRD;
adc_dat_a = 14'b000000000000110;
adc_dat_b = 14'b000000000100110;
#CLK_PRD;
adc_dat_a = 14'b000000000000111;
adc_dat_b = 14'b000000000100111;
#CLK_PRD;
adc_dat_a = 14'b000000000001000;
adc_dat_b = 14'b000000000101000;
#CLK_PRD;
adc_dat_a = 14'b000000000001001;
adc_dat_b = 14'b000000000101001;
#CLK_PRD;
adc_dat_a = 14'b000000000001010;
adc_dat_b = 14'b000000000101010;
#CLK_PRD;
adc_dat_a = 14'b000000000001011;
```

```
adc_dat_b = 14'b000000000101011;
#CLK_PRD;
adc_dat_a = 14'b000000000001100;
adc_dat_b = 14'b000000000101100;
#CLK_PRD;
adc_dat_a = 14'b000000000001101;
adc_dat_b = 14'b000000000101101;
#CLK_PRD;
adc_dat_a = 14'b000000000001110;
adc_dat_b = 14'b000000000101110;
#CLK_PRD;
adc_dat_a = 14'b000000000001111;
adc_dat_b = 14'b000000000101111;
#CLK_PRD;
adc_dat_a = 14'b000000000010001;
adc_dat_b = 14'b000000000110001;
#CLK_PRD;
adc_dat_a = 14'b000000000010010;
adc_dat_b = 14'b000000000110010;
#CLK_PRD;
adc_dat_a = 14'b000000000000000;
adc_dat_b = 14'b000000000000000;

#CLK_PRD;

adc_dat_a = 14'b000000000000001;
adc_dat_b = 14'b00000100000001;
#CLK_PRD;
```



```
adc_dat_a = 14'b000000000000010;
adc_dat_b = 14'b000000010000010;
#CLK_PRD;
adc_dat_a = 14'b000000000000011;
adc_dat_b = 14'b000000010000011;
#CLK_PRD;
adc_dat_a = 14'b000000000000100;
adc_dat_b = 14'b000000010000100;
#CLK_PRD;
adc_dat_a = 14'b000000000000101;
adc_dat_b = 14'b000000010000101;
#CLK_PRD;
adc_dat_a = 14'b000000000000110;
adc_dat_b = 14'b000000010000110;
#CLK_PRD;
adc_dat_a = 14'b000000000000111;
adc_dat_b = 14'b000000010000111;
#CLK_PRD;
adc_dat_a = 14'b000000000001000;
adc_dat_b = 14'b000000010001000;
#CLK_PRD;
adc_dat_a = 14'b000000000001001;
adc_dat_b = 14'b000000010001001;
#CLK_PRD;
adc_dat_a = 14'b000000000001010;
adc_dat_b = 14'b000000010001010;
#CLK_PRD;
adc_dat_a = 14'b000000000001011;
```

```
adc_dat_b = 14'b000000010001011;
#CLK_PRD;
adc_dat_a = 14'b000000000001100;
adc_dat_b = 14'b000000010001100;
#CLK_PRD;
adc_dat_a = 14'b000000000001101;
adc_dat_b = 14'b000000010001101;
#CLK_PRD;
adc_dat_a = 14'b000000000001110;
adc_dat_b = 14'b000000010001110;
#CLK_PRD;
adc_dat_a = 14'b000000000001111;
adc_dat_b = 14'b000000010001111;
#CLK_PRD;
adc_dat_a = 14'b000000000010001;
adc_dat_b = 14'b000000010010001;
#CLK_PRD;
adc_dat_a = 14'b000000000010010;
adc_dat_b = 14'b000000010010010;
#CLK_PRD;
adc_dat_a = 14'b000000000000000;
adc_dat_b = 14'b000000000000000;

#CLK_PRD

adc_dat_a = 14'b000000000000001;
adc_dat_b = 14'b00000000100001;
#CLK_PRD;
```

```
adc_dat_a = 14'b000000000000010;
adc_dat_b = 14'b000000000100010;
#CLK_PRD;
adc_dat_a = 14'b000000000000011;
adc_dat_b = 14'b000000000100011;
#CLK_PRD;
adc_dat_a = 14'b000000000000100;
adc_dat_b = 14'b000000000100100;
#CLK_PRD;
adc_dat_a = 14'b000000000000101;
adc_dat_b = 14'b000000000100101;
#CLK_PRD;
adc_dat_a = 14'b000000000000110;
adc_dat_b = 14'b000000000100110;
#CLK_PRD;
adc_dat_a = 14'b000000000000111;
adc_dat_b = 14'b000000000100111;
#CLK_PRD;
adc_dat_a = 14'b000000000001000;
adc_dat_b = 14'b000000000101000;
#CLK_PRD;
adc_dat_a = 14'b000000000001001;
adc_dat_b = 14'b000000000101001;
#CLK_PRD;
adc_dat_a = 14'b000000000001010;
adc_dat_b = 14'b000000000101010;
#CLK_PRD;
adc_dat_a = 14'b000000000001011;
```

```
adc_dat_b = 14'b000000000101011;
#CLK_PRD;
adc_dat_a = 14'b000000000001100;
adc_dat_b = 14'b000000000101100;
#CLK_PRD;
adc_dat_a = 14'b000000000001101;
adc_dat_b = 14'b000000000101101;
#CLK_PRD;
adc_dat_a = 14'b000000000001110;
adc_dat_b = 14'b000000000101110;
#CLK_PRD;
adc_dat_a = 14'b000000000001111;
adc_dat_b = 14'b000000000101111;
#CLK_PRD;
adc_dat_a = 14'b000000000010001;
adc_dat_b = 14'b000000000110001;
#CLK_PRD;
adc_dat_a = 14'b000000000010010;
adc_dat_b = 14'b000000000110010;
#CLK_PRD;
adc_dat_a = 14'b000000000000000;
adc_dat_b = 14'b000000000000000;

#CLK_PRD;

adc_dat_a = 14'b000000000000001;
adc_dat_b = 14'b000000000100001;
#CLK_PRD;
```

```
adc_dat_a = 14'b000000000000010;
adc_dat_b = 14'b000000000100010;
#CLK_PRD;
adc_dat_a = 14'b000000000000011;
adc_dat_b = 14'b000000000100011;
#CLK_PRD;
adc_dat_a = 14'b000000000000100;
adc_dat_b = 14'b000000000100100;
#CLK_PRD;
adc_dat_a = 14'b000000000000101;
adc_dat_b = 14'b000000000100101;
#CLK_PRD;
adc_dat_a = 14'b000000000000110;
adc_dat_b = 14'b000000000100110;
#CLK_PRD;
adc_dat_a = 14'b000000000000111;
adc_dat_b = 14'b000000000100111;
#CLK_PRD;
adc_dat_a = 14'b000000000001000;
adc_dat_b = 14'b000000000101000;
#CLK_PRD;
adc_dat_a = 14'b000000000001001;
adc_dat_b = 14'b000000000101001;
#CLK_PRD;
adc_dat_a = 14'b000000000001010;
adc_dat_b = 14'b000000000101010;
#CLK_PRD;
adc_dat_a = 14'b000000000001011;
```

```
adc_dat_b = 14'b000000000101011;
#CLK_PRD;
adc_dat_a = 14'b000000000001100;
adc_dat_b = 14'b000000000101100;
#CLK_PRD;
adc_dat_a = 14'b000000000001101;
adc_dat_b = 14'b000000000101101;
#CLK_PRD;
adc_dat_a = 14'b000000000001110;
adc_dat_b = 14'b000000000101110;
#CLK_PRD;
adc_dat_a = 14'b000000000001111;
adc_dat_b = 14'b000000000101111;
#CLK_PRD;
adc_dat_a = 14'b000000000010001;
adc_dat_b = 14'b000000000110001;
#CLK_PRD;
adc_dat_a = 14'b000000000010010;
adc_dat_b = 14'b000000000110010;
#CLK_PRD;
adc_dat_a = 14'b000000000000000;
adc_dat_b = 14'b000000000000000;

#CLK_PRD;

adc_dat_a = 14'b000000000000001;
adc_dat_b = 14'b00000100000001;
#CLK_PRD;
```

```
adc_dat_a = 14'b000000000000010;
adc_dat_b = 14'b000000010000010;
#CLK_PRD;
adc_dat_a = 14'b000000000000011;
adc_dat_b = 14'b000000010000011;
#CLK_PRD;
adc_dat_a = 14'b000000000000100;
adc_dat_b = 14'b000000010000100;
#CLK_PRD;
adc_dat_a = 14'b000000000000101;
adc_dat_b = 14'b000000010000101;
#CLK_PRD;
adc_dat_a = 14'b000000000000110;
adc_dat_b = 14'b000000010000110;
#CLK_PRD;
adc_dat_a = 14'b000000000000111;
adc_dat_b = 14'b000000010000111;
#CLK_PRD;
adc_dat_a = 14'b000000000001000;
adc_dat_b = 14'b000000010001000;
#CLK_PRD;
adc_dat_a = 14'b000000000001001;
adc_dat_b = 14'b000000010001001;
#CLK_PRD;
adc_dat_a = 14'b000000000001010;
adc_dat_b = 14'b000000010001010;
#CLK_PRD;
adc_dat_a = 14'b000000000001011;
```

```
adc_dat_b = 14'b000000010001011;
#CLK_PRD;
adc_dat_a = 14'b000000000001100;
adc_dat_b = 14'b000000010001100;
#CLK_PRD;
adc_dat_a = 14'b000000000001101;
adc_dat_b = 14'b000000010001101;
#CLK_PRD;
adc_dat_a = 14'b000000000001110;
adc_dat_b = 14'b000000010001110;
#CLK_PRD;
adc_dat_a = 14'b000000000001111;
adc_dat_b = 14'b000000010001111;
#CLK_PRD;
adc_dat_a = 14'b000000000010001;
adc_dat_b = 14'b000000010010001;
#CLK_PRD;
adc_dat_a = 14'b000000000010010;
adc_dat_b = 14'b000000010010010;
#CLK_PRD;
adc_dat_a = 14'b000000000000000;
adc_dat_b = 14'b000000000000000;

#CLK_PRD

adc_dat_a = 14'b000000000000001;
adc_dat_b = 14'b00000000100001;
#CLK_PRD;
```



```
adc_dat_a = 14'b000000000000010;
adc_dat_b = 14'b000000000100010;
#CLK_PRD;
adc_dat_a = 14'b000000000000011;
adc_dat_b = 14'b000000000100011;
#CLK_PRD;
adc_dat_a = 14'b000000000000100;
adc_dat_b = 14'b000000000100100;
#CLK_PRD;
adc_dat_a = 14'b000000000000101;
adc_dat_b = 14'b000000000100101;
#CLK_PRD;
adc_dat_a = 14'b000000000000110;
adc_dat_b = 14'b000000000100110;
#CLK_PRD;
adc_dat_a = 14'b000000000000111;
adc_dat_b = 14'b000000000100111;
#CLK_PRD;
adc_dat_a = 14'b000000000001000;
adc_dat_b = 14'b000000000101000;
#CLK_PRD;
adc_dat_a = 14'b000000000001001;
adc_dat_b = 14'b000000000101001;
#CLK_PRD;
adc_dat_a = 14'b000000000001010;
adc_dat_b = 14'b000000000101010;
#CLK_PRD;
adc_dat_a = 14'b000000000001011;
```

```

adc_dat_b = 14'b000000000101011;
#CLK_PRD;
adc_dat_a = 14'b00000000001100;
adc_dat_b = 14'b000000000101100;
#CLK_PRD;
adc_dat_a = 14'b00000000001101;
adc_dat_b = 14'b000000000101101;
#CLK_PRD;
adc_dat_a = 14'b00000000001110;
adc_dat_b = 14'b000000000101110;
#CLK_PRD;
adc_dat_a = 14'b00000000001111;
adc_dat_b = 14'b000000000101111;
#CLK_PRD;
adc_dat_a = 14'b00000000010001;
adc_dat_b = 14'b000000000110001;
#CLK_PRD;
adc_dat_a = 14'b00000000010010;
adc_dat_b = 14'b000000000110010;
#CLK_PRD;
adc_dat_a = 14'b000000000000000;
adc_dat_b = 14'b000000000000000;

repeat(40) #CLK_PRD;

$finish;

end

endmodule

```

## red\_Pitaya.xdc:

```
#
# $Id: red_pitaya.xdc 961 2014-01-21 11:40:39Z matej.oblak $
#
# @brief Red Pitaya location constraints.
#
# @Author Matej Oblak
#
# (c) Red Pitaya http://www.redpitaya.com
#

#####
# IO constraints                                     #
#####

### ADC

# ADC data
set_property IOSTANDARD LVCMOS18 [get_ports {adc_dat_a[*]}]
set_property IOB TRUE [get_ports {adc_dat_a[*]}]

#set_property IOSTANDARD LVCMOS18 [get_ports {adc_dat_b[*]}]
#set_property IOB TRUE [get_ports {adc_dat_b[*]}]

# ADC 0 data
set_property PACKAGE_PIN V17 [get_ports {adc_dat_a[0]}]
set_property PACKAGE_PIN U17 [get_ports {adc_dat_a[1]}]
set_property PACKAGE_PIN Y17 [get_ports {adc_dat_a[2]}]
set_property PACKAGE_PIN W16 [get_ports {adc_dat_a[3]}]
set_property PACKAGE_PIN Y16 [get_ports {adc_dat_a[4]}]
```

```

set_property PACKAGE_PIN W15 [get_ports {adc_dat_a[5]}]
set_property PACKAGE_PIN W14 [get_ports {adc_dat_a[6]}]
set_property PACKAGE_PIN Y14 [get_ports {adc_dat_a[7]}]
set_property PACKAGE_PIN W13 [get_ports {adc_dat_a[8]}]
set_property PACKAGE_PIN V12 [get_ports {adc_dat_a[9]}]
set_property PACKAGE_PIN V13 [get_ports {adc_dat_a[10]}]
set_property PACKAGE_PIN T14 [get_ports {adc_dat_a[11]}]
set_property PACKAGE_PIN T15 [get_ports {adc_dat_a[12]}]
set_property PACKAGE_PIN V15 [get_ports {adc_dat_a[13]}]
#set_property PACKAGE_PIN T16 [get_ports {adc_dat_i[0][14]}]
#set_property PACKAGE_PIN V16 [get_ports {adc_dat_i[0][15]}]

```

# ADC 1 data

```

set_property PACKAGE_PIN T17 [get_ports {adc_dat_b[0]}]
set_property PACKAGE_PIN R16 [get_ports {adc_dat_b[1]}]
set_property PACKAGE_PIN R18 [get_ports {adc_dat_b[2]}]
set_property PACKAGE_PIN P16 [get_ports {adc_dat_b[3]}]
set_property PACKAGE_PIN P18 [get_ports {adc_dat_b[4]}]
set_property PACKAGE_PIN N17 [get_ports {adc_dat_b[5]}]
set_property PACKAGE_PIN R19 [get_ports {adc_dat_b[6]}]
set_property PACKAGE_PIN T20 [get_ports {adc_dat_b[7]}]
set_property PACKAGE_PIN T19 [get_ports {adc_dat_b[8]}]
set_property PACKAGE_PIN U20 [get_ports {adc_dat_b[9]}]
set_property PACKAGE_PIN V20 [get_ports {adc_dat_b[10]}]
set_property PACKAGE_PIN W20 [get_ports {adc_dat_b[11]}]
set_property PACKAGE_PIN W19 [get_ports {adc_dat_b[12]}]
set_property PACKAGE_PIN Y19 [get_ports {adc_dat_b[13]}]
#set_property PACKAGE_PIN W18 [get_ports {adc_dat_i[1][14]}]
#set_property PACKAGE_PIN Y18 [get_ports {adc_dat_i[1][15]}]

```

```

#set_property IOSTANDARD DIFF_HSTL_I_18 [get_ports adc_clk_i[*]]

```

```

#set_property PACKAGE_PIN U18 [get_ports adc_clk_i[1]]

```

```
#set_property PACKAGE_PIN U19 [get_ports adc_clk_i[0]]
```

```
# Output ADC clock
```

```
#set_property IOSTANDARD LVCMOS18 [get_ports {adc_clk_o[*]}]
```

```
#set_property SLEW FAST [get_ports {adc_clk_o[*]}]
```

```
#set_property DRIVE 8 [get_ports {adc_clk_o[*]}]
```

```
#set_property IOB TRUE [get_ports {adc_clk_o[*]}]
```

```
#set_property PACKAGE_PIN N20 [get_ports {adc_clk_o[0]}]
```

```
#set_property PACKAGE_PIN P20 [get_ports {adc_clk_o[1]}]
```

```
# ADC clock stabilizer
```

```
#set_property IOSTANDARD LVCMOS18 [get_ports adc_cdc_o]
```

```
#set_property PACKAGE_PIN V18 [get_ports adc_cdc_o]
```

```
#set_property SLEW FAST [get_ports adc_cdc_o]
```

```
#set_property DRIVE 8 [get_ports adc_cdc_o]
```

```
### DAC
```

```
# data
```

```
set_property IOSTANDARD LVCMOS33 [get_ports {dac_dat_o[*]}]
```

```
set_property SLEW SLOW [get_ports {dac_dat_o[*]}]
```

```
set_property DRIVE 4 [get_ports {dac_dat_o[*]}]
```

```
#set_property IOB TRUE [get_ports {dac_dat_o[*]}]
```

```
set_property PACKAGE_PIN M19 [get_ports {dac_dat_o[0]}]
```

```
set_property PACKAGE_PIN M20 [get_ports {dac_dat_o[1]}]
```

```
set_property PACKAGE_PIN L19 [get_ports {dac_dat_o[2]}]
```

```
set_property PACKAGE_PIN L20 [get_ports {dac_dat_o[3]}]
```

```
set_property PACKAGE_PIN K19 [get_ports {dac_dat_o[4]}]
```

```
set_property PACKAGE_PIN J19 [get_ports {dac_dat_o[5]}]
```

```
set_property PACKAGE_PIN J20 [get_ports {dac_dat_o[6]}]
```

```
set_property PACKAGE_PIN H20 [get_ports {dac_dat_o[7]}]
set_property PACKAGE_PIN G19 [get_ports {dac_dat_o[8]}]
set_property PACKAGE_PIN G20 [get_ports {dac_dat_o[9]}]
set_property PACKAGE_PIN F19 [get_ports {dac_dat_o[10]}]
set_property PACKAGE_PIN F20 [get_ports {dac_dat_o[11]}]
set_property PACKAGE_PIN D20 [get_ports {dac_dat_o[12]}]
set_property PACKAGE_PIN D19 [get_ports {dac_dat_o[13]}]
```

```
# control
```

```
#set_property IOSTANDARD LVCMOS33 [get_ports dac*_o]
#set_property SLEW FAST [get_ports dac*_o]
#set_property DRIVE 8 [get_ports dac*_o]
#set_property IOB TRUE [get_ports dac*_o]
```

```
#set_property PACKAGE_PIN M17 [get_ports dac_wrt_o]
#set_property PACKAGE_PIN N16 [get_ports dac_sel_o]
#set_property PACKAGE_PIN M18 [get_ports dac_clk_o]
#set_property PACKAGE_PIN N15 [get_ports dac_rst_o]
```

```
### PWM DAC
```

```
#set_property IOSTANDARD LVCMOS18 [get_ports {dac_pwm_o[*]}]
#set_property SLEW FAST [get_ports {dac_pwm_o[*]}]
#set_property DRIVE 12 [get_ports {dac_pwm_o[*]}]
#set_property IOB TRUE [get_ports {dac_pwm_o[*]}]
```

```
#set_property PACKAGE_PIN T10 [get_ports {dac_pwm_o[0]}]
#set_property PACKAGE_PIN T11 [get_ports {dac_pwm_o[1]}]
#set_property PACKAGE_PIN P15 [get_ports {dac_pwm_o[2]}]
#set_property PACKAGE_PIN U13 [get_ports {dac_pwm_o[3]}]
```

```
### XADC
```

```
#set_property IOSTANDARD LVCMOS33 [get_ports {vinp_i[*]}]
```

```

#set_property IOSTANDARD LVCMOS33 [get_ports {vinn_i[*]}]

#AD0
#set_property PACKAGE_PIN C20 [get_ports {vinp_i[1]}]
#set_property PACKAGE_PIN B20 [get_ports {vinn_i[1]}]

#AD1
#set_property PACKAGE_PIN E17 [get_ports {vinp_i[2]}]
#set_property PACKAGE_PIN D18 [get_ports {vinn_i[2]}]

#AD8
#set_property PACKAGE_PIN B19 [get_ports {vinp_i[0]}]
#set_property PACKAGE_PIN A20 [get_ports {vinn_i[0]}]

#AD9
#set_property PACKAGE_PIN E18 [get_ports {vinp_i[3]}]
#set_property PACKAGE_PIN E19 [get_ports {vinn_i[3]}]

#V_0
#set_property PACKAGE_PIN K9 [get_ports {vinp_i[4]}]
#set_property PACKAGE_PIN L10 [get_ports {vinn_i[4]}]

### Expansion connector
#set_property IOSTANDARD LVCMOS33 [get_ports {exp_p_io[*]}]
#set_property IOSTANDARD LVCMOS33 [get_ports {exp_n_io[*]}]
#set_property SLEW    FAST    [get_ports {exp_p_io[*]}]
#set_property SLEW    FAST    [get_ports {exp_n_io[*]}]
#set_property DRIVE   8       [get_ports {exp_p_io[*]}]
#set_property DRIVE   8       [get_ports {exp_n_io[*]}]

#set_property PACKAGE_PIN G17 [get_ports {exp_p_io[0]}]
#set_property PACKAGE_PIN G18 [get_ports {exp_n_io[0]}]
#set_property PACKAGE_PIN H16 [get_ports {exp_p_io[1]}]
#set_property PACKAGE_PIN H17 [get_ports {exp_n_io[1]}]
#set_property PACKAGE_PIN J18 [get_ports {exp_p_io[2]}]
#set_property PACKAGE_PIN H18 [get_ports {exp_n_io[2]}]
#set_property PACKAGE_PIN K17 [get_ports {exp_p_io[3]}]

```

```
#set_property PACKAGE_PIN K18 [get_ports {exp_n_io[3]}]
#set_property PACKAGE_PIN L14 [get_ports {exp_p_io[4]}]
#set_property PACKAGE_PIN L15 [get_ports {exp_n_io[4]}]
#set_property PACKAGE_PIN L16 [get_ports {exp_p_io[5]}]
#set_property PACKAGE_PIN L17 [get_ports {exp_n_io[5]}]
#set_property PACKAGE_PIN K16 [get_ports {exp_p_io[6]}]
#set_property PACKAGE_PIN J16 [get_ports {exp_n_io[6]}]
#set_property PACKAGE_PIN M14 [get_ports {exp_p_io[7]}]
#set_property PACKAGE_PIN M15 [get_ports {exp_n_io[7]}]
```

```
#set_property PULLDOWN TRUE [get_ports {exp_p_io[0]}]
#set_property PULLDOWN TRUE [get_ports {exp_n_io[0]}]
#set_property PULLUP TRUE [get_ports {exp_p_io[7]}]
#set_property PULLUP TRUE [get_ports {exp_n_io[7]}]
```

### ### SATA connector

```
#set_property IOSTANDARD LVCMOS18 [get_ports {daisy_p_o[*]}]
#set_property IOSTANDARD LVCMOS18 [get_ports {daisy_n_o[*]}]
#set_property IOSTANDARD LVCMOS18 [get_ports {daisy_p_i[*]}]
#set_property IOSTANDARD LVCMOS18 [get_ports {daisy_n_i[*]}]
```

```
#set_property PACKAGE_PIN T12 [get_ports {daisy_p_o[0]}]
#set_property PACKAGE_PIN U12 [get_ports {daisy_n_o[0]}]
#set_property PACKAGE_PIN U14 [get_ports {daisy_p_o[1]}]
#set_property PACKAGE_PIN U15 [get_ports {daisy_n_o[1]}]
#set_property PACKAGE_PIN P14 [get_ports {daisy_p_i[0]}]
#set_property PACKAGE_PIN R14 [get_ports {daisy_n_i[0]}]
#set_property PACKAGE_PIN N18 [get_ports {daisy_p_i[1]}]
#set_property PACKAGE_PIN P19 [get_ports {daisy_n_i[1]}]
```

### ### LED

```
#set_property IOSTANDARD LVCMOS33 [get_ports {led_o[*]}]
```



```

#set_property SLEW    SLOW    [get_ports {led_o[*]}]
#set_property DRIVE   4      [get_ports {led_o[*]}]

#set_property PACKAGE_PIN F16  [get_ports {led_o[0]}]
#set_property PACKAGE_PIN F17  [get_ports {led_o[1]}]
#set_property PACKAGE_PIN G15  [get_ports {led_o[2]}]
#set_property PACKAGE_PIN H15  [get_ports {led_o[3]}]
#set_property PACKAGE_PIN K14  [get_ports {led_o[4]}]
#set_property PACKAGE_PIN G14  [get_ports {led_o[5]}]
#set_property PACKAGE_PIN J15  [get_ports {led_o[6]}]
#set_property PACKAGE_PIN J14  [get_ports {led_o[7]}]

#####
# Clock constraints                                #
#####

#NET "adc_clk" TNM_NET = "adc_clk";
#TIMESPEC TS_adc_clk = PERIOD "adc_clk" 125 MHz;
create_clock -period 8.000 -name adc_clk [get_ports adc_clk_i]

#set_input_delay -clock adc_clk 3.400 [get_ports adc_dat_i[*][*]]
#create_clock -period 4.000 -name rx_clk [get_ports daisy_p_i[1]]

#set_false_path -from [get_clocks adc_clk] -to [get_clocks dac_clk_o]
#set_false_path -from [get_clocks adc_clk] -to [get_clocks dac_clk_2x]
#set_false_path -from [get_clocks adc_clk] -to [get_clocks dac_clk_2p]
#set_false_path -from [get_clocks clk_fpga_0] -to [get_clocks adc_clk]
#set_false_path -from [get_clocks clk_fpga_0] -to [get_clocks dac_clk_1x]
#set_false_path -from [get_clocks clk_fpga_0] -to [get_clocks dac_clk_2x]
#set_false_path -from [get_clocks clk_fpga_0] -to [get_clocks dac_clk_2p]
#set_false_path -from [get_clocks clk_fpga_0] -to [get_clocks ser_clk]
#set_false_path -from [get_clocks clk_fpga_0] -to [get_clocks pdm_clk]

```

```
#set_false_path -from [get_clocks dac_clk_o] -to [get_clocks dac_clk_2x]
```

```
#set_false_path -from [get_clocks dac_clk_o] -to [get_clocks dac_clk_2p]
```