

ROUTER 1X3 DESIGN

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BRN 25**

Project Schedule:

S. No.	Topic	Date of Release	Status	Page No.
1.	Router FIFO	27.07.22	Completed	2
2.	Router Synchronizer	29.07.22	Completed	8
3.	Router Controller	01.08.22	Completed	15
4.	Router Register	02.08.22	Completed	23
5.	Router Top	07.08.22	Completed	30
6.	Synthesis Report	07.08.22	Completed	41

1. Sub-block : Router FIFO

Design Code:

```
module router_fifo(input clock,
                    resetn,
                    write_enb,
                    soft_reset,
                    read_enb,
                    lfd_state,
                    input [7:0] data_in,
                    output empty,full,
                    output reg [7:0] data_out);

    reg [8:0] mem [0:15];
    reg [4:0] wr_ptr,rd_ptr;
    reg [6:0] fifo_counter;
    reg lfd_tmp;
    integer i;

    // Logic for lfd_state
    always@(posedge clock)
    begin
        if(!resetn)
            lfd_tmp <= 0;
        else
            lfd_tmp <= lfd_state;
    end

    // Logic for read and write pointer
    always@(posedge clock)
    begin
        if(!resetn)
            begin
                wr_ptr <= 0;
                rd_ptr <= 0;
            end
        else if(soft_reset)
            begin
                wr_ptr <= 0;
                rd_ptr <= 0;
            end
        else
            begin
                if(!full && write_enb)
                    wr_ptr <= wr_ptr + 1'b1;
                if(!empty && read_enb)
                    rd_ptr <= rd_ptr + 1'b1;
            end
    end

    // Logic for FIFO counter
    always@(posedge clock)
    begin
        if(!resetn)
            fifo_counter <= 0;
        else if(soft_reset)
            fifo_counter <= 0;
        else if(read_enb && !empty)
            begin
                if(mem[rd_ptr[3:0]][8] == 1'b1)
                    fifo_counter <= mem[rd_ptr[3:0]][7:2] + 1'b1;
                else if(fifo_counter)
                    fifo_counter <= fifo_counter - 1'b1;
            end
    end
end
```

```

// Logic for read operation
always@(posedge clock)
begin
    if(!resetn)
        data_out <= 0;
    else if(soft_reset)
        data_out <= 8'bzz;
    else if(!fifo_counter && empty)
        data_out <= 8'bzz;
    else if(read_enb && !empty)
        data_out <= mem[rd_ptr[3:0]][7:0];
end

// Logic for write operation
always@(posedge clock)
begin
    if(!resetn)
        for(i=0;i<16;i=i+1)
            mem[i] <= 0;
    else if(soft_reset)
        for(i=0;i<16;i=i+1)
            mem[i] <= 0;
    else if(write_enb && !full)
        mem[wr_ptr[3:0]] <= {lfld_tmp,data_in};
end

// Logic for empty and full
assign empty = (wr_ptr==rd_ptr)?1'b1:1'b0;
assign full = (wr_ptr==~rd_ptr[4],rd_ptr[3:0])?1'b1:1'b0;

endmodule

```

Simulation Code:

```

module router_fifo_tb();
parameter T = 10,
TIMEOUT = 30,
PAYLOAD_LENGTH = 6'd14,
ADDRESS = 2'd1;
reg clock_tb,resetn_tb,write_enb_tb,soft_reset_tb,read_enb_tb,lfld_state_tb;
reg [7:0] data_in_tb;
wire full_tb, empty_tb;
wire [7:0] data_out_tb;

integer i,j,k;
reg [7:0] header,payload,parity;

router_fifo
DUT(clock_tb,resetn_tb,write_enb_tb,soft_reset_tb,read_enb_tb,lfld_state_tb,data_in_tb,e
mpty_tb,full_tb,data_out_tb);

initial
begin
    clock_tb = 1'b0;
    forever #(T/2) clock_tb = ~clock_tb;
end

task initialize;
begin
    resetn_tb = 1;
    soft_reset_tb = 0;
    write_enb_tb = 0;
    read_enb_tb = 0;
end
endtask

task resetn_ip;

```

```

begin
  @(negedge clock_tb);
  resetn_tb = 1'b0;
  @(negedge clock_tb);
  resetn_tb = 1'b1;
end
endtask

task soft_reset_ip;
begin
  @(negedge clock_tb);
  soft_reset_tb = 1'b1;
#TIMEOUT;
  @(negedge clock_tb);
  soft_reset_tb = 1'b0;
end
endtask

task write;
begin
  lfd_state_tb = 1'b1;
  @(negedge clock_tb);
  header = {PAYLOAD_LENGTH,ADDRESS};
  data_in_tb = header;
  @(negedge clock_tb);
  lfd_state_tb = 1'b0;
  write_enb_tb = 1'b1;
  parity = 0;
  for(i=0;i<PAYLOAD_LENGTH;i=i+1)
    begin
      @(negedge clock_tb);
      payload = ${random}%256;
      parity = payload ^ parity;
      data_in_tb = payload;
    end
  @(negedge clock_tb);
  data_in_tb = parity;
end
endtask

task read(input j,k);
begin
  write_enb_tb = j;
  read_enb_tb = k;
end
endtask

initial
begin
  initialize;
  resetn_ip;
#20;
  write;
#20;
  for(i=0;i<PAYLOAD_LENGTH + 2;i=i+1)
    begin
      read(1'b0,1'b1);
#15;
    end
  read(1'b0,1'b0);
#20;
  resetn_ip;
#10;
  write;
#30;
  soft_reset_ip;
#30;

```

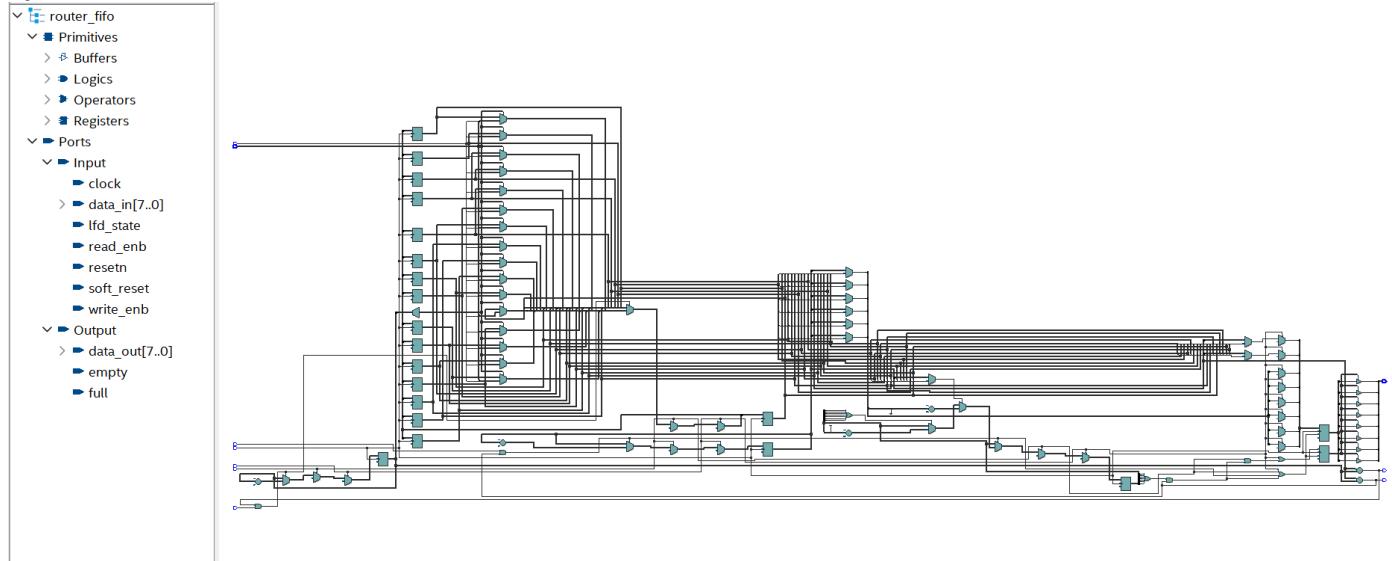
```

$finish;
end

initial
$monitor("Data Input = %b, Data_output = %b, Reset = %b, Soft Reset = %b, Write
Enable = %b, Read Enable = %b,Lfd State = %b, FIFO Counter = %b, Empty = %b, Full =
%b",
data_in_tb,data_out_tb,resetn_tb,soft_reset_tb,write_enb_tb,read_enb_tb,lfd_state_tb,DU
T fifo_counter,empty_tb,full_tb);
endmodule

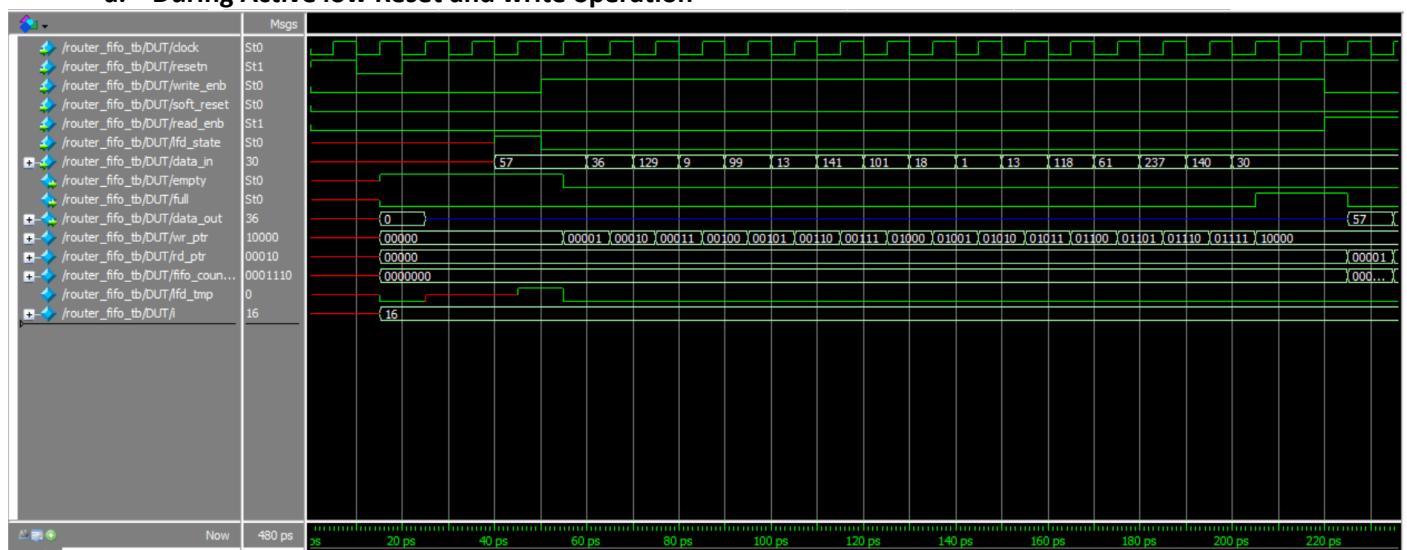
```

Synthesis Circuit:

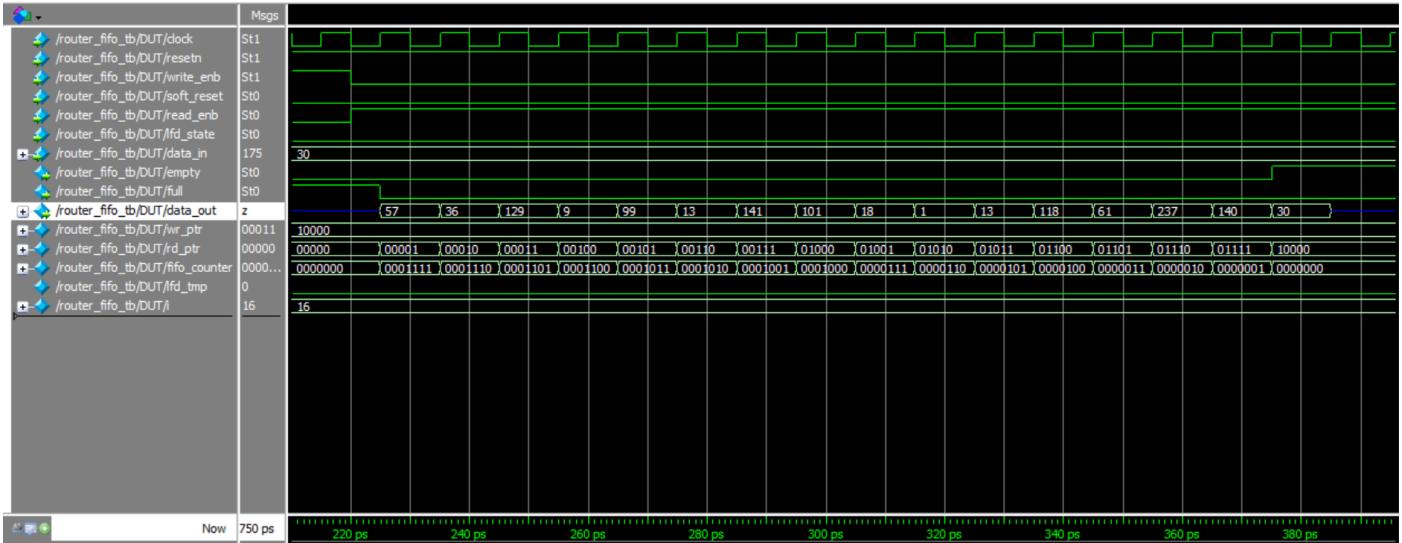


Simulation Waveform:

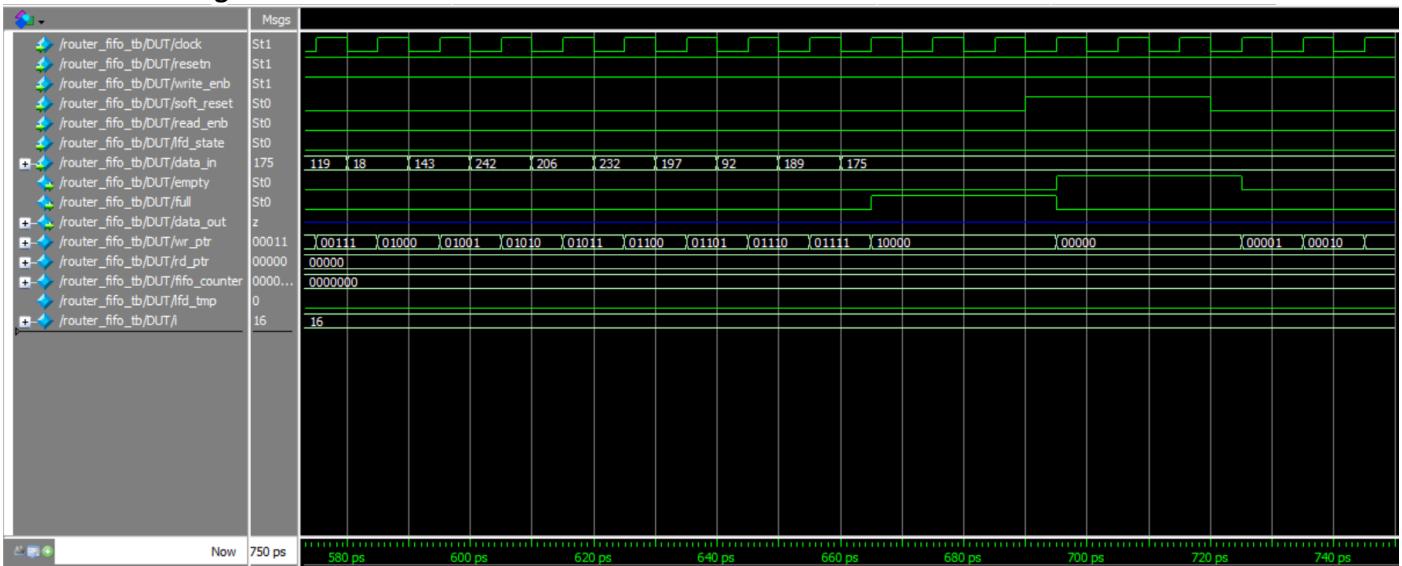
a. During Active low Reset and write operation



b. During Read operation



c. During Soft Reset



Transcript:

2. Sub-Block : Router Synchronizer

Design Code:

```
module router_sync(input clock,
                    resetn,
                    detect_addr,
                    write_enb_reg,
                    read_enb_0,
                    read_enb_1,
                    read_enb_2,
                    empty_0,
                    empty_1,
                    empty_2,
                    full_0,
                    full_1,
                    full_2,
                    input [1:0] data_in,
                    output reg fifo_full,
                    soft_reset_0,
                    soft_reset_1,
                    soft_reset_2,
                    output vld_out_0,
                    vld_out_1,
                    vld_out_2,
                    output reg [2:0] write_enb);

reg[1:0] fifo_addr;
reg[4:0] timer_0,timer_1,timer_2;

// Logic for storing address
always@(posedge clock)
begin
  if(!resetn)
    fifo_addr <= 0;
  else if(detect_addr)
    fifo_addr <= data_in;
end

// Logic for fifo full status
always@(*)
begin
  if(!resetn)
    fifo_full = 0;
  else
    begin
      case(fifo_addr)
        2'b00 : fifo_full = full_0;
        2'b01 : fifo_full = full_1;
        2'b10 : fifo_full = full_2;
        default: fifo_full = 0;
      endcase
    end
end

// Logic for write enable
always@(*)
begin
  if(!resetn)
    write_enb = 0;
  else if(write_enb_reg)
    begin
      case(fifo_addr)
        2'b00 : write_enb = 3'b001;
        2'b01 : write_enb = 3'b010;
      endcase
    end
end
```

```

        2'b10 : write_enb = 3'b100;
        default : write_enb = 3'b0;
    endcase
end
else
    write_enb = 0;
end

// Logic for valid out signal
assign vld_out_0 = ~empty_0;
assign vld_out_1 = ~empty_1;
assign vld_out_2 = ~empty_2;

// Logic for soft reset 0
always@(posedge clock)
begin
    if(!resetn)
        begin
            soft_reset_0 <= 0;
            timer_0 <= 0;
        end
    else if(~vld_out_0)
        begin
            soft_reset_0 <= 0;
            timer_0 <= 0;
        end
    else if(read_enb_0)
        begin
            soft_reset_0 <= 0;
            timer_0 <= 0;
        end
    else
        begin
            if(timer_0 == 5'd29)
                begin
                    soft_reset_0 <= 1'b1;
                    timer_0 <= 0;
                end
            else
                begin
                    timer_0 <= timer_0 + 1'b1;
                    soft_reset_0 <= 0;
                end
        end
    end
end

// Logic for soft reset 1
always@(posedge clock)
begin
    if(!resetn)
        begin
            soft_reset_1 <= 0;
            timer_1 <= 0;
        end
    else if(~vld_out_1)
        begin
            soft_reset_1 <= 0;
            timer_1 <= 0;
        end
    else if(read_enb_1)
        begin
            soft_reset_1 <= 0;
            timer_1 <= 0;
        end
    else
        begin
            if(timer_1 == 5'd29)

```

```

        begin
            soft_reset_1 <= 1'b1;
            timer_1 <= 0;
        end
    else
        begin
            timer_1 <= timer_1 + 1'b1;
            soft_reset_1 <= 0;
        end
    end
end

// Logic for soft reset 2
always@(posedge clock)
begin
    if(!resetn)
        begin
            soft_reset_2 <= 0;
            timer_2 <= 0;
        end
    else if(~vld_out_2)
        begin
            soft_reset_2 <= 0;
            timer_2 <= 0;
        end
    else if(read_enb_2)
        begin
            soft_reset_2 <= 0;
            timer_2 <= 0;
        end
    else
        begin
            if(timer_2 == 5'd29)
                begin
                    soft_reset_2 <= 1'b1;
                    timer_2 <= 0;
                end
            else
                begin
                    timer_2 <= timer_2 + 1'b1;
                    soft_reset_2 <= 0;
                end
        end
    end
end
endmodule

```

Simulation Code:

```

module router_sync_tb();
    reg
clock_tb,resetn_tb,detect_add_tb,write_enb_reg_tb,read_enb_0_tb,read_enb_1_tb,read_enb_
2_tb,empty_0_tb,empty_1_tb,empty_2_tb,full_0_tb,full_1_tb,full_2_tb;
    reg [1:0] data_in_tb;
    wire
fifo_full_tb,soft_reset_0_tb,soft_reset_1_tb,soft_reset_2_tb,vld_out_0_tb,vld_out_1_tb,
vld_out_2_tb;
    wire [2:0] write_enb_tb;

parameter T = 10,
TIMEOUT = 30;

router_sync DUT(clock_tb,
                  resetn_tb,
                  detect_add_tb,
                  write_enb_reg_tb,
                  read_enb_0_tb,
                  read_enb_1_tb,

```

```

        read_enb_2_tb,
        empty_0_tb,
        empty_1_tb,
        empty_2_tb,
        full_0_tb,
        full_1_tb,
        full_2_tb,
        data_in_tb,
        fifo_full_tb,
        soft_reset_0_tb,
        soft_reset_1_tb,
        soft_reset_2_tb,
        vld_out_0_tb,
        vld_out_1_tb,
        vld_out_2_tb,
        write_enb_tb);

integer i,m;

initial
begin
    clock_tb = 1'b0;
    forever #(T/2) clock_tb = ~clock_tb;
end

task resetn_ip;
begin
    @(negedge clock_tb);
    resetn_tb = 1'b0;
    @(negedge clock_tb);
    resetn_tb = 1'b1;
end
endtask

task initialize;
begin
    resetn_tb = 1'b1;
    detect_add_tb = 1'b0;
    write_enb_reg_tb = 1'b0;
    read_enb_0_tb = 1'b0;
    read_enb_1_tb = 1'b0;
    read_enb_2_tb = 1'b0;
    empty_0_tb = 1'b0;
    empty_1_tb = 1'b0;
    empty_2_tb = 1'b0;
    full_0_tb = 1'b0;
    full_1_tb = 1'b0;
    full_2_tb = 1'b0;
end
endtask

task address_ip(input [1:0] addr_tb);
begin
    @(negedge clock_tb);
    detect_add_tb = 1'b1;
    data_in_tb = addr_tb;
    @(negedge clock_tb);
    detect_add_tb = 1'b0;
end
endtask

task write_enb_ip;
begin
    @(negedge clock_tb);
    write_enb_reg_tb = 1'b1;
    @(negedge clock_tb);
    write_enb_reg_tb = 1'b0;

```

```

    end
endtask

task fifo_full_ip;
begin
    full_0_tb = 1'b0;
    full_1_tb = 1'b1;
    full_2_tb = 1'b0;
end
endtask

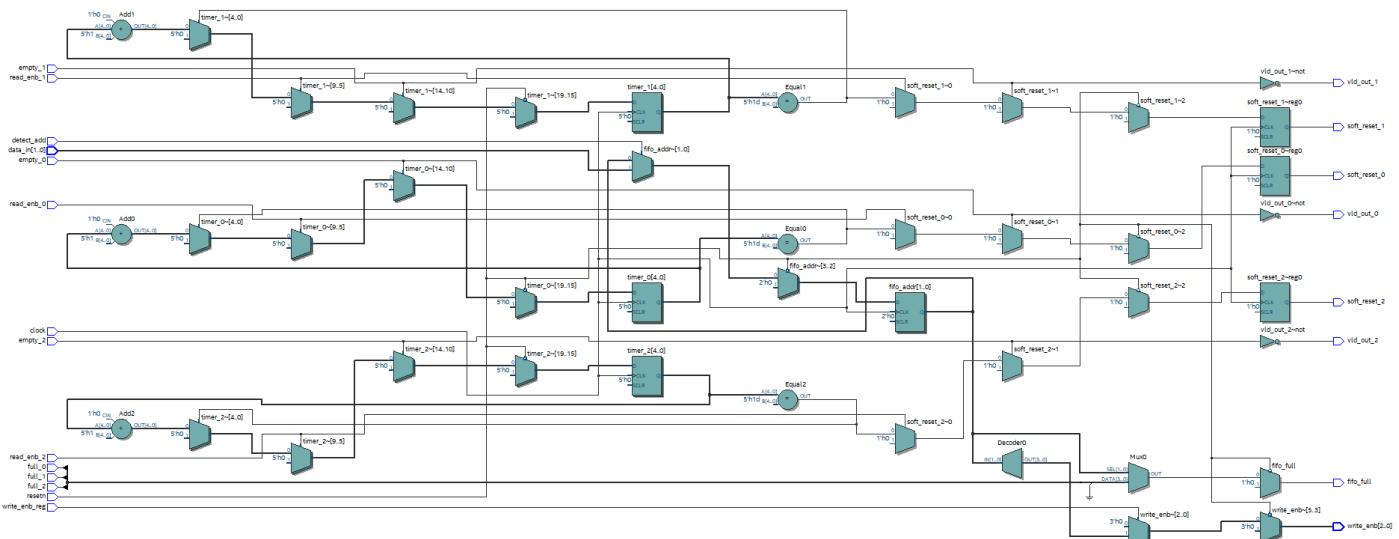
task empty_ip(input [3:0] j,k);
begin
    empty_0_tb = j[0];
    empty_1_tb = j[1];
    empty_2_tb = j[2];
    read_enb_0_tb = k[0];
    read_enb_1_tb = k[1];
    read_enb_2_tb = k[2];
end
endtask

initial
begin
    initialize;
    resetn_ip;
#10;
m = 1;
for(i=0;i<3;i=i+1)
begin
    address_ip(i);
    write_enb_ip;
    fifo_full_ip;
    empty_ip(m,0);
#10;
    empty_ip(0,0);
#10;
    empty_ip(0,m);
#10;
    empty_ip(0,0);
    m = m*2;
end
#700;
$finish;
end

initial
$monitor("Inputs : Detect Address = %b, Data in = %b, Write Enable Reg = %b,
Empty_0 = %b, Empty_1 = %b, Empty_2 = %b, Full_0 = %b, Full_1 = %b, Full_2 = %b,
ReadEnable_0 = %b, ReadEnable_1 = %b, ReadEnable_2 = %b \nOutputs : Fifo Address = %b,
Write Enable = %b,Fifo Full = %b, ValidOut_0 = %b, ValidOut_1 = %b, ValidOut_2 = %b,
SoftReset_0 = %b, SoftReset_1 = %B, SoftReset_2 = %b",
detect_add_tb,data_in_tb,write_enb_reg_tb,empty_0_tb,empty_1_tb,empty_2_tb,full_0_tb,full_1_tb,full_2_tb,read_enb_0_tb,read_enb_1_tb,read_enb_2_tb,DUT.fifo_addr,
write_enb_tb,fifo_full_tb,vld_out_0_tb,vld_out_1_tb,vld_out_2_tb,soft_reset_0_tb,soft_reset_1_tb,soft_reset_2_tb);
endmodule

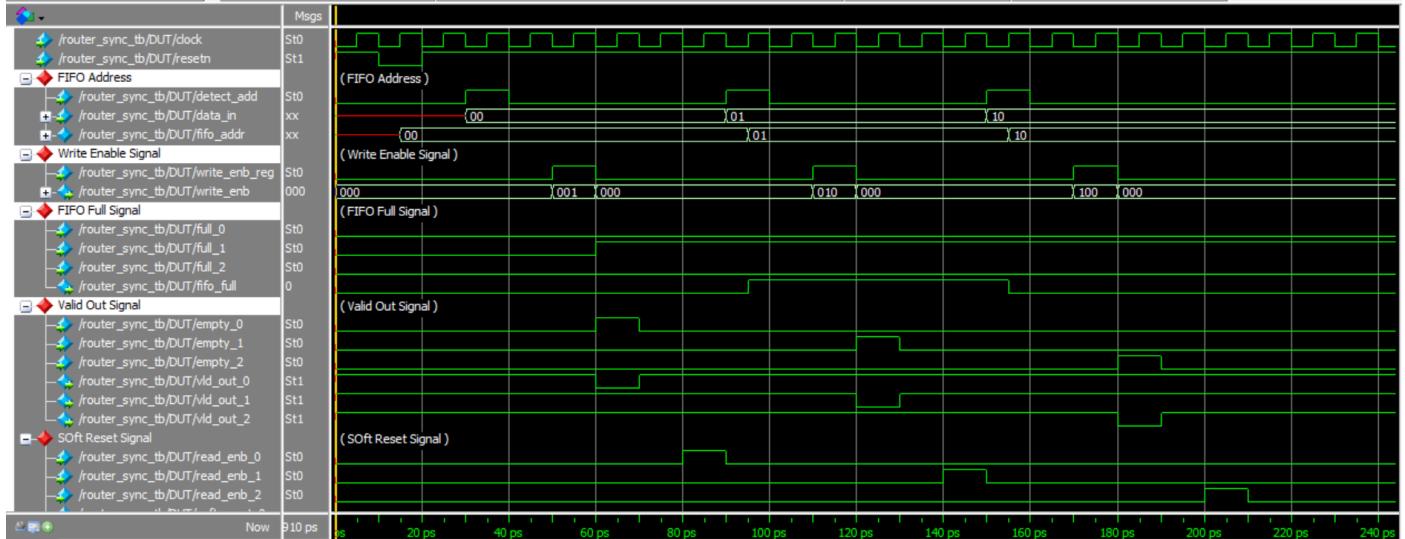
```

Synthesis Circuit:

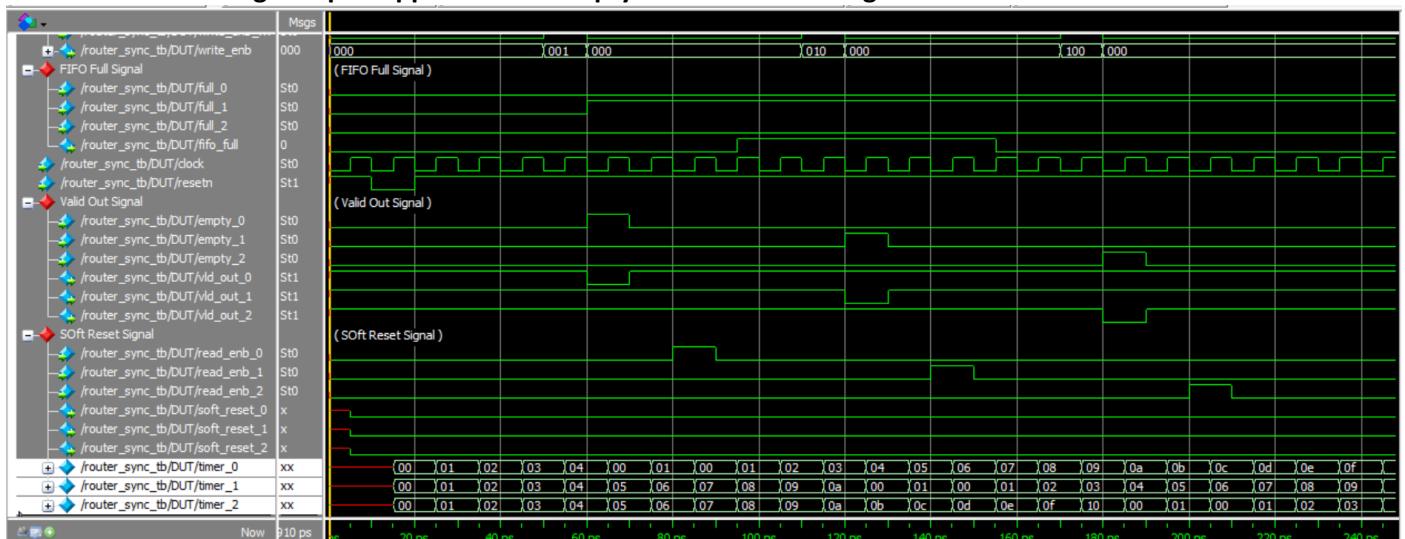


Simulation Waveform:

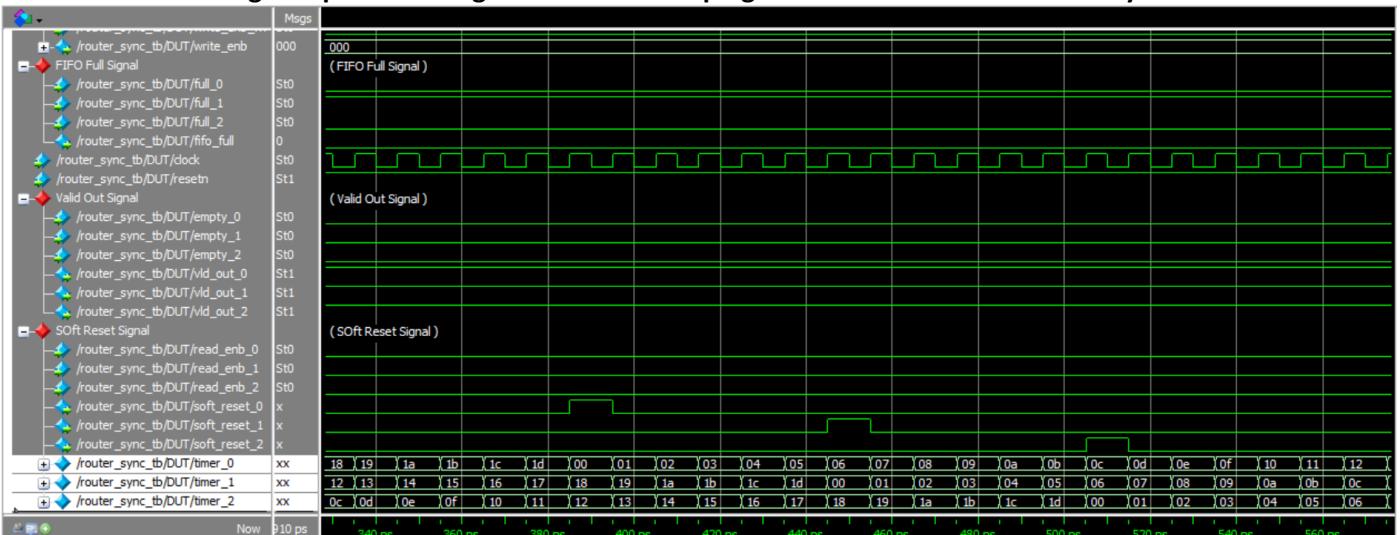
a. FIFO Address, Write Enable Signal, FIFO Full Signal, Valid Out Signal



b. Soft Reset Signal upon application of empty and read enable signal



c. Soft Reset Signal upon asserting valid out and keeping read enable low for 30 clock cycles



Transcript:

3. Sub-Block : Router Controller

Design Code:

```
module router_fsm(input clock,
                  resetn,
                  pkt_valid,
                  parity_done,
                  soft_reset_0,
                  soft_reset_1,
                  soft_reset_2,
                  fifo_full,
                  low_pkt_valid,
                  fifo_empty_0,
                  fifo_empty_1,
                  fifo_empty_2,
                  input [1:0] data_in,
                  output busy,
                  detect_add,
                  ld_state,
                  laf_state,
                  full_state,
                  write_enb_reg,
                  rst_int_reg,
                  lfd_state);

parameter DECODE_ADDRESS = 3'b000,
            LOAD_FIRST_DATA = 3'b001,
            LOAD_DATA = 3'b010,
            FIFO_FULL_STATE = 3'b011,
            LOAD_AFTER_FULL = 3'b100,
            LOAD_PARITY = 3'b101,
            CHECK_PARITY_ERROR = 3'b110,
            WAIT_TILL_EMPTY = 3'b111;

reg [1:0] addr;
reg [2:0] present_state, next_state;

// Present State Logic
always@(posedge clock)
  begin
    if(!resetn)
      present_state <= DECODE_ADDRESS;
    else if((soft_reset_0 && data_in == 2'b00) || (soft_reset_1 && data_in == 2'b01)
    || (soft_reset_2 && data_in == 2'b10))
      present_state <= DECODE_ADDRESS;
    else
      present_state <= next_state;
  end

// Logic for storing the address
always@(posedge clock)
  begin
    if(!resetn)
      addr <= 0;
    else if((soft_reset_0 && data_in == 2'b00) || (soft_reset_1 && data_in == 2'b01)
    || (soft_reset_2 && data_in == 2'b10))
      addr <= 0;
    if(present_state == DECODE_ADDRESS && data_in != 2'b11)
      addr <= data_in;
  end

// Next State Logic
always@(*)
  begin
    if(addr != 2'b11)
```

```

begin
    next_state = DECODE_ADDRESS;
    case(present_state)
        DECODE_ADDRESS: begin
            if((pkt_valid && (data_in[1:0]==0) && fifo_empty_0) ||
               (pkt_valid && (data_in[1:0]==1) && fifo_empty_1) ||
               (pkt_valid && (data_in[1:0]==2) && fifo_empty_2))
                next_state = LOAD_FIRST_DATA;
            else if((pkt_valid && (data_in[1:0]==0) && !fifo_empty_0) ||
                     (pkt_valid && (data_in[1:0]==1) && !fifo_empty_1) ||
                     (pkt_valid && (data_in[1:0]==2) && !fifo_empty_2))
                next_state = WAIT_TILL_EMPTY;
            end
        end
        LOAD_FIRST_DATA: next_state = LOAD_DATA;
        LOAD_DATA: begin
            if(fifo_full)
                next_state = FIFO_FULL_STATE;
            else if(!fifo_full && !pkt_valid)
                next_state = LOAD_PARITY;
            else
                next_state = LOAD_DATA;
            end
        begin
            if(!fifo_full)
                next_state = LOAD_AFTER_FULL;
            else
                next_state = FIFO_FULL_STATE;
            end
        begin
            if(!parity_done && !low_pkt_valid)
                next_state = LOAD_DATA;
            else if(!parity_done && low_pkt_valid)
                next_state = LOAD_PARITY;
            else if(parity_done)
                next_state = DECODE_ADDRESS;
            end
        end
        next_state = CHECK_PARITY_ERROR;
        if(fifo_full)
            next_state = FIFO_FULL_STATE;
        begin
            if((fifo_empty_0 && (addr == 0)) ||
               (fifo_empty_1 && (addr == 1)) ||
               (fifo_empty_2 && (addr == 2)))
                next_state = LOAD_FIRST_DATA;
            else
                next_state = WAIT_TILL_EMPTY;
        end
        next_state = DECODE_ADDRESS;
    endcase
end
else
    next_state = DECODE_ADDRESS;
end

// Logic for output logic
assign detect_add = (present_state == DECODE_ADDRESS) ? 1'b1 : 1'b0;
assign ld_state = (present_state == LOAD_DATA) ? 1'b1 : 1'b0;
assign lfd_state = (present_state == LOAD_FIRST_DATA) ? 1'b1 : 1'b0;
assign laf_state = (present_state == LOAD_AFTER_FULL) ? 1'b1 : 1'b0;
assign full_state = (present_state == FIFO_FULL_STATE) ? 1'b1 : 1'b0;
assign write_enb_reg = ((present_state == LOAD_DATA) ||
                        (present_state == LOAD_AFTER_FULL) ||
                        (present_state == LOAD_PARITY)) ? 1'b1 : 1'b0;
assign rst_int_reg = (present_state == CHECK_PARITY_ERROR) ? 1'b1 : 1'b0;
assign busy = ((present_state == LOAD_DATA) || (present_state == DECODE_ADDRESS)) ?
1'b0 : 1'b1;

```

```
endmodule
```

Simulation Code:

```
module router_fsm_tb();
    reg clock_tb,
    resetn_tb,pkt_valid_tb,parity_done_tb,soft_reset_0_tb,soft_reset_1_tb,soft_reset_2_tb,fifo_full_tb,low_pkt_valid_tb,fifo_empty_0_tb,fifo_empty_1_tb,fifo_empty_2_tb;
    reg [1:0] data_in_tb;
    wire
busy_tb,detect_add_tb,ld_state_tb,laf_state_tb,full_state_tb,write_enb_reg_tb,rst_int_r
eg_tb,lfid_state_tb;

parameter T = 10, ADDRESS = 2'd1;

router_fsm DUT(clock_tb,
                  resetn_tb,
                  pkt_valid_tb,
                  parity_done_tb,
                  soft_reset_0_tb,
                  soft_reset_1_tb,
                  soft_reset_2_tb,
                  fifo_full_tb,
                  low_pkt_valid_tb,
                  fifo_empty_0_tb,
                  fifo_empty_1_tb,
                  fifo_empty_2_tb,
                  data_in_tb,
                  busy_tb,
                  detect_add_tb,
                  ld_state_tb,
                  laf_state_tb,
                  full_state_tb,
                  write_enb_reg_tb,
                  rst_int_reg_tb,
                  lfid_state_tb);

initial
begin
    clock_tb = 1'b0;
    forever #(T/2) clock_tb = ~clock_tb;
end

task resetn_ip;
    begin
        @(negedge clock_tb);
        resetn_tb = 1'b0;
        @(negedge clock_tb);
        resetn_tb = 1'b1;
    end
endtask

task soft_reset_ip(input [2:0] j);
    begin
        @(negedge clock_tb);
        soft_reset_0_tb = j[0];
        soft_reset_1_tb = j[1];
        soft_reset_2_tb = j[2];
        @(negedge clock_tb);
        soft_reset_0_tb = 0;
        soft_reset_1_tb = 0;
        soft_reset_2_tb = 0;
    end
endtask

task initialize;
    begin

```

```

resetn_tb = 1'b1;
pkt_valid_tb = 1'b0;
parity_done_tb = 1'b0;
soft_reset_0_tb = 1'b0;
soft_reset_1_tb = 1'b0;
soft_reset_2_tb = 1'b0;
fifo_full_tb = 1'b0;
low_pkt_valid_tb = 1'b0;
fifo_empty_0_tb = 1'b0;
fifo_empty_1_tb = 1'b0;
fifo_empty_2_tb = 1'b0;
end
endtask

task DA_LFD_LD_LP_CPE_DA;
begin
    pkt_valid_tb = 1'b1;
    data_in_tb = 2'b01;
    fifo_empty_1_tb = 1'b1;
    #20 pkt_valid_tb = 1'b0;
    low_pkt_valid_tb = 1'b1;
    #20 fifo_empty_1_tb = 1'b0;
    low_pkt_valid_tb = 1'b0;
end
endtask

task DA_LFD_LD_FFS_LAF_LP_CPE_DA;
begin
    pkt_valid_tb = 1'b1;
    data_in_tb = 2'b10;
    fifo_empty_2_tb = 1'b1;
    #40 fifo_full_tb = 1'b1;
    pkt_valid_tb = 1'b0;
    low_pkt_valid_tb = 1'b1;
    #30 fifo_full_tb = 1'b0;
    parity_done_tb = 1'b0;
    #50 low_pkt_valid_tb = 1'b0;
    fifo_empty_2_tb = 1'b0;
end
endtask

task DA_LFD_LD_FFS_LAF_LD_LP_CPE_DA;
begin
    pkt_valid_tb = 1'b1;
    data_in_tb = 2'b00;
    fifo_empty_0_tb = 1'b1;
    #40 fifo_full_tb = 1'b1;
    #30 fifo_full_tb = 1'b0;
    #30 pkt_valid_tb = 1'b0;
    low_pkt_valid_tb = 1'b1;
    #20 fifo_empty_0_tb = 1'b0;
    low_pkt_valid_tb = 1'b0;
end
endtask

task DA_LFD_LD_LP_CPE_FFS_LAF_DA;
begin
    pkt_valid_tb = 1'b1;
    data_in_tb = 2'b10;
    fifo_empty_2_tb = 1'b1;
    #50 pkt_valid_tb = 1'b0;
    low_pkt_valid_tb = 1'b1;
    #10 fifo_full_tb = 1'b1;
    #10 parity_done_tb = 1'b1;
    #20 fifo_full_tb = 1'b0;
    #50 parity_done_tb = 1'b0;
    low_pkt_valid_tb = 1'b0;

```

```

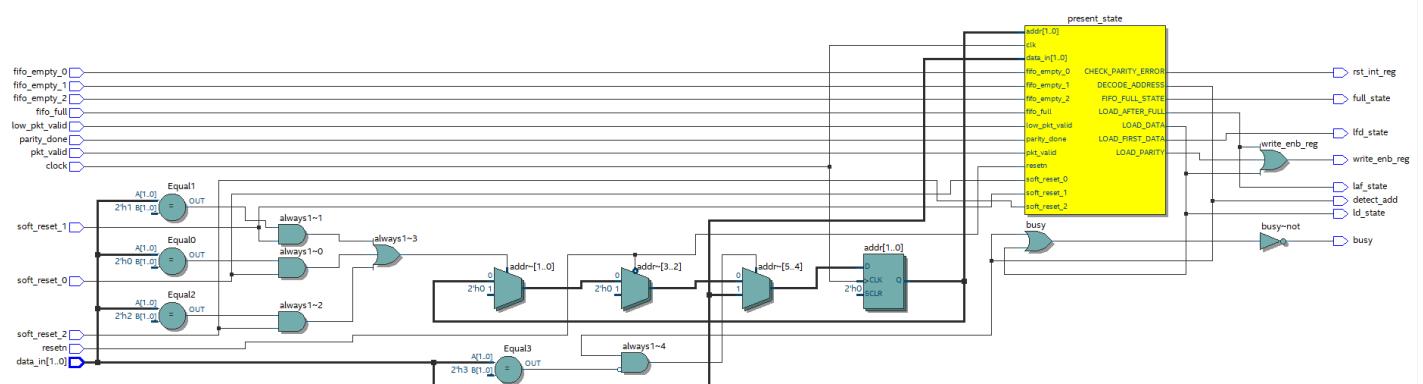
    fifo_empty_2_tb = 1'b0;
  end
endtask

task DA_WTE_LFD_LD_LP_CPE_DA;
begin
  pkt_valid_tb = 1'b1;
  data_in_tb = 2'b00;
  fifo_empty_0_tb = 1'b0;
#40 fifo_empty_0_tb = 1'b1;
#20 pkt_valid_tb = 1'b0;
  low_pkt_valid_tb = 1'b1;
#20 fifo_empty_0_tb = 1'b0;
  low_pkt_valid_tb = 1'b0;
end
endtask

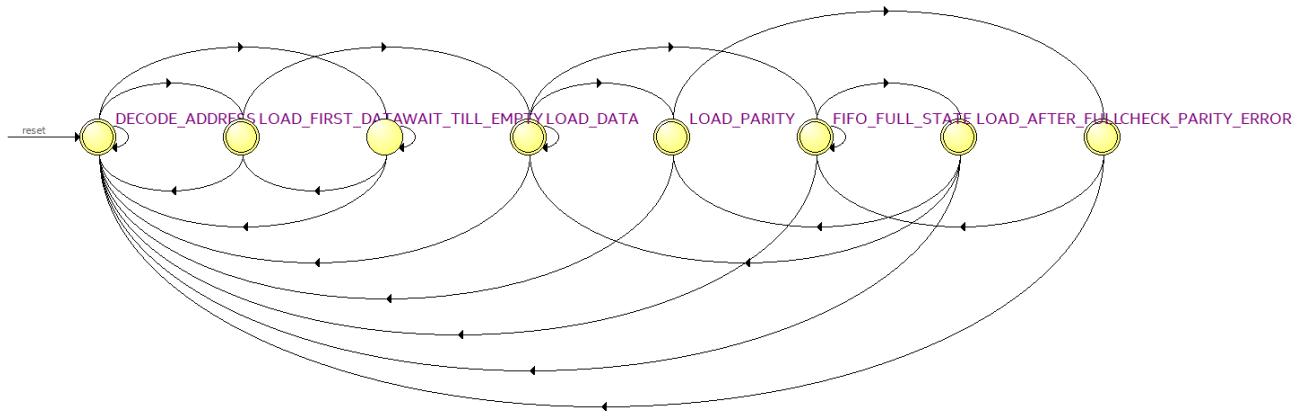
initial
begin
  initialize;
#20;
  resetn_ip;
#20;
  data_in_tb = ADDRESS;
  soft_reset_ip(3'b010);
#20;
  DA_LFD_LD_LP_CPE_DA;
#100;
  DA_WTE_LFD_LD_LP_CPE_DA;
#100;
  DA_LFD_LD_FFS_LAF_LP_CPE_DA;
#100;
  DA_LFD_LD_FFS_LAF_LD_LP_CPE_DA;
#100;
  DA_LFD_LD_LP_CPE_FFS_LAF_DA;
#100;
$finish;
end
endmodule

```

Synthesis Circuit:

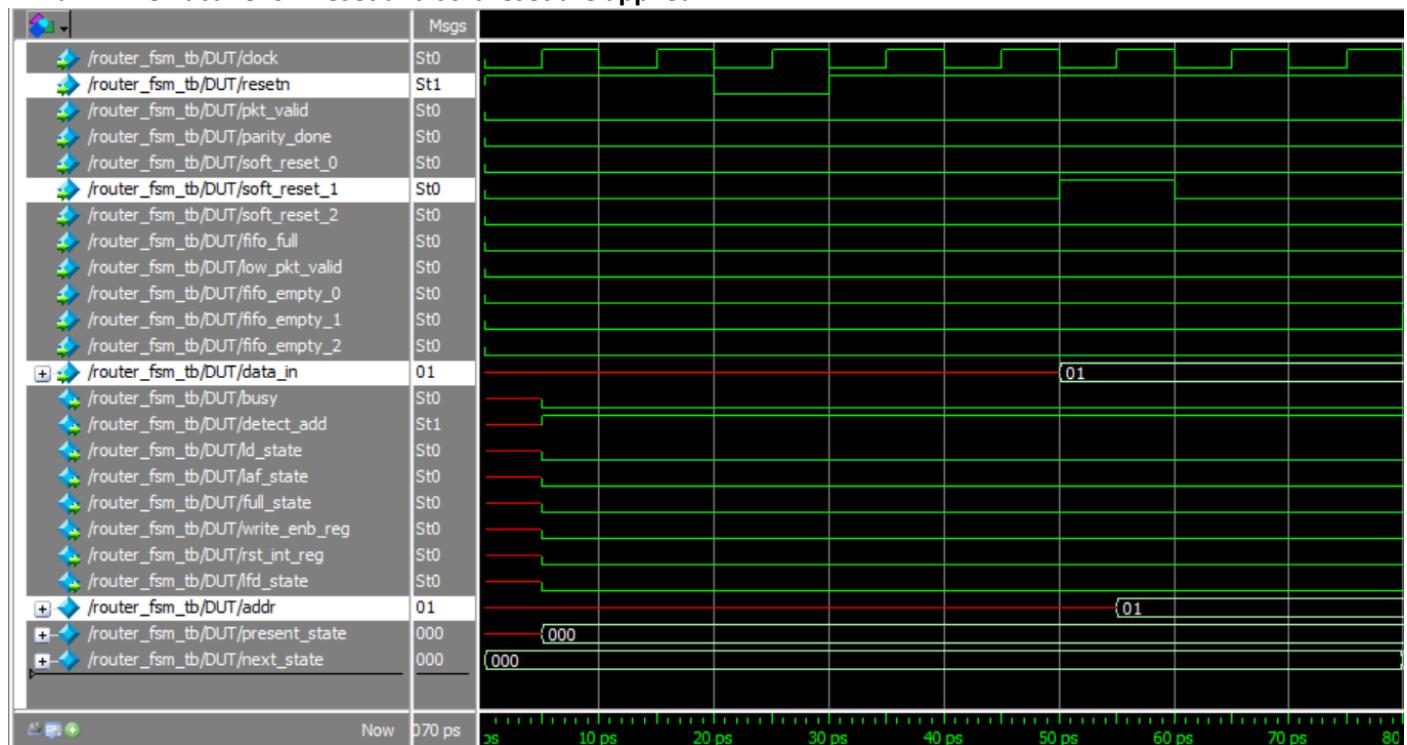


State Transition Diagram:

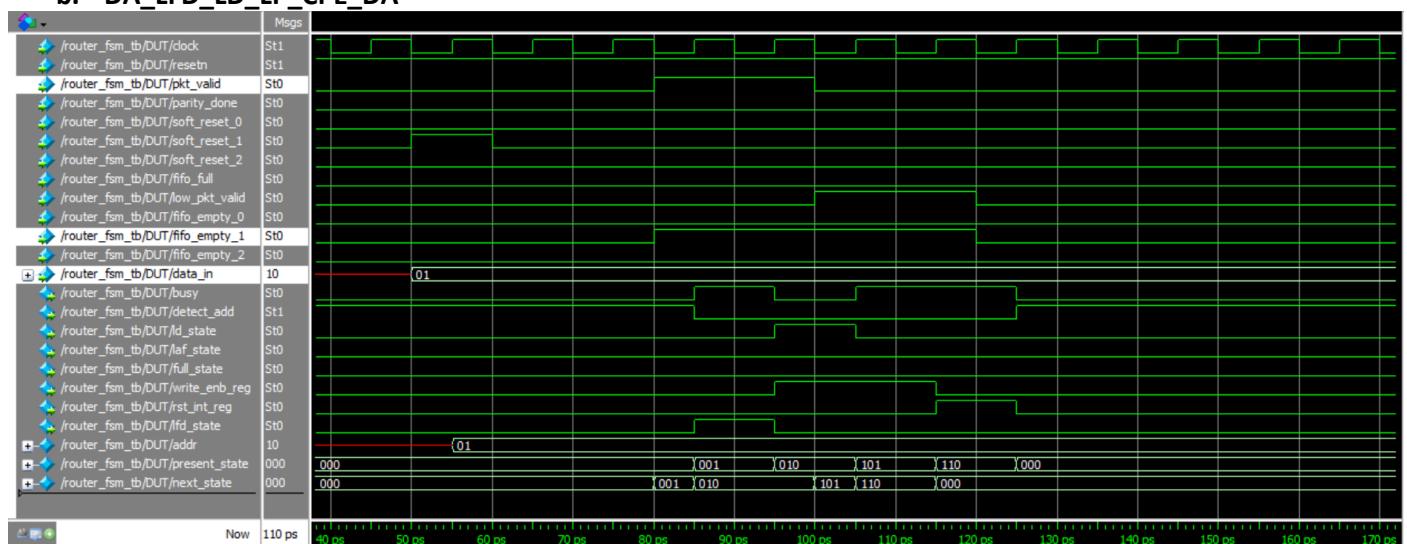


Simulation Waveform:

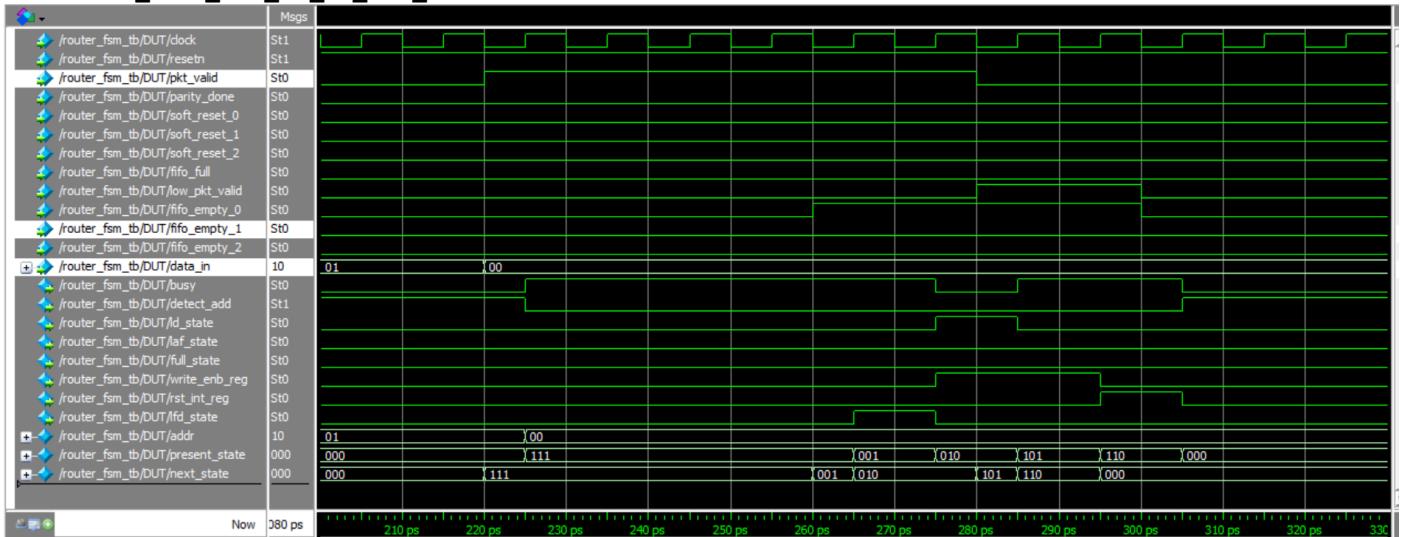
a. When active low reset and soft reset are applied



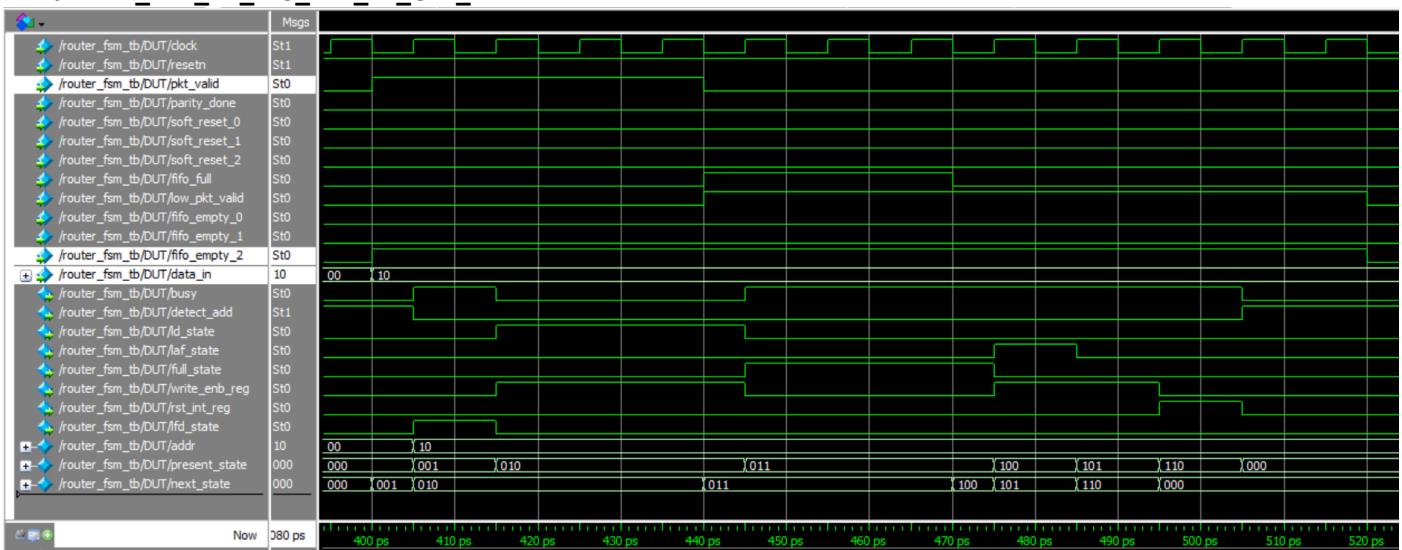
b. DA LFD LD LP CPE DA



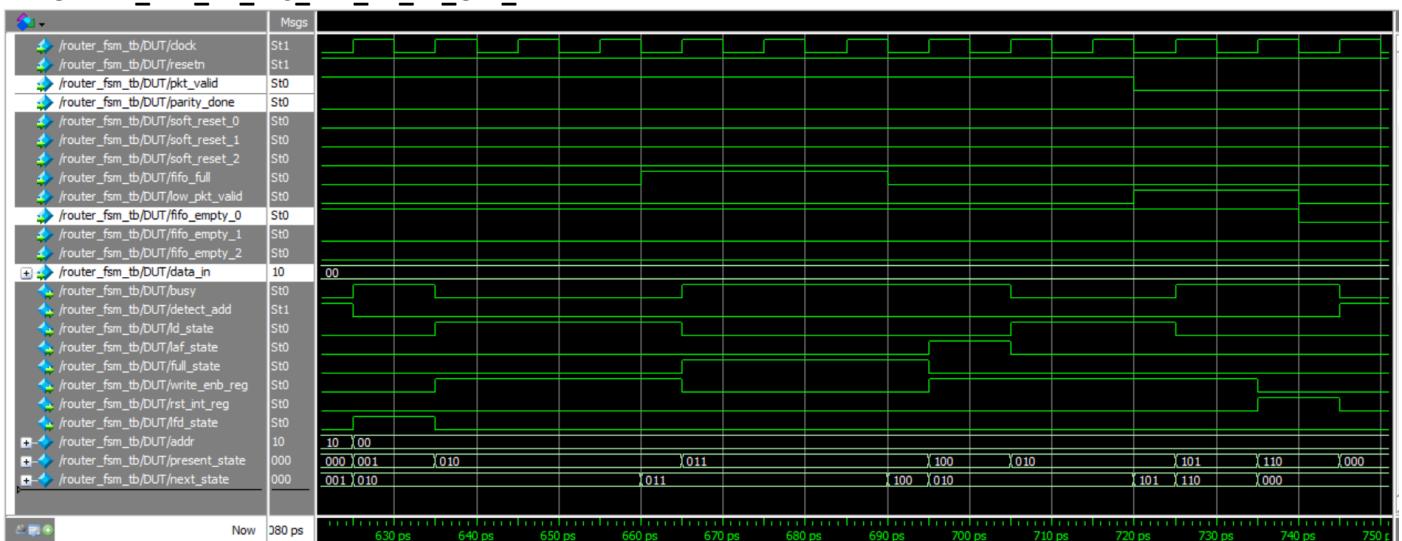
c. DA_WTE_LFD_LD_LP_CPE_DA



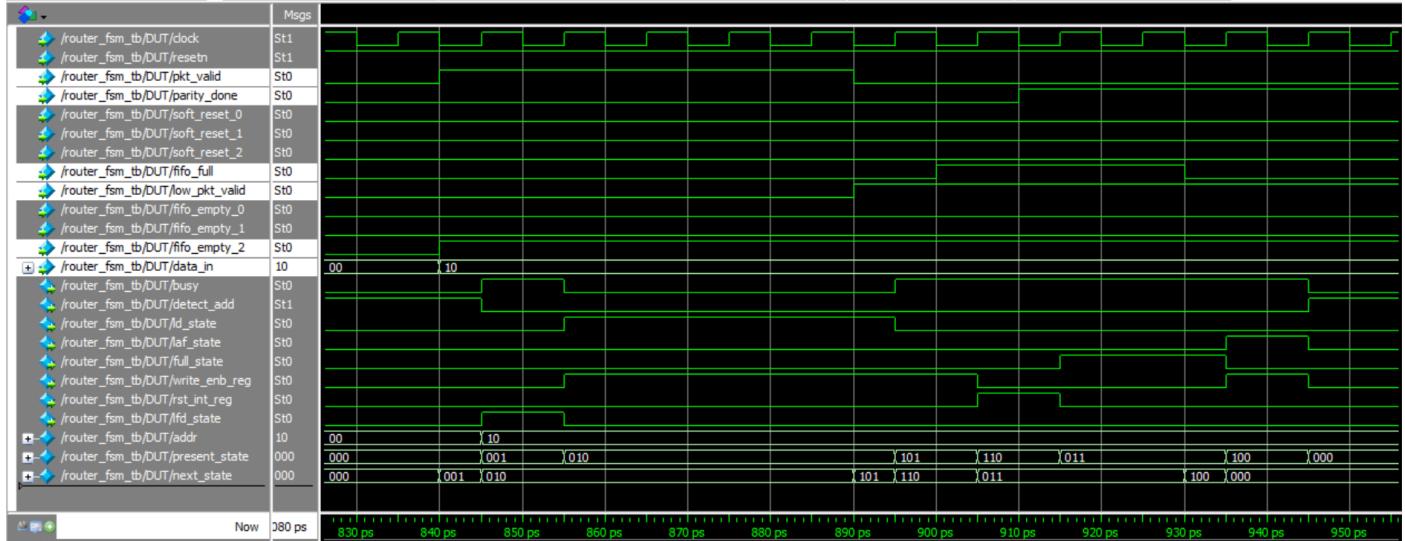
d. DA_LFD_LD_FFS_LAF_LD_LP_CPE_DA



e. DA_LFD_LD_FFS_LAF_LD_LP_CPE_DA



f. DA_LFD_LD_LP_CPE_FFS_LAF_DA



4. Sub-Block : Router Register

Design Code:

```
module router_reg (input clock,
                    resetn,
                    pkt_valid,
                    fifo_full,
                    rst_int_reg,
                    detect_add,
                    ld_state,
                    laf_state,
                    full_state,
                    lfd_state,
                    input [7:0] data_in,
                    output reg parity_done,
                    low_pkt_valid,
                    err,
                    output reg [7:0] dout);

    reg [7:0] header_byte, fifo_full_state_byte, internal_parity, packet_parity;

    // Logic to store header byte and FIFO full state byte
    always@(posedge clock)
        begin
            if(!resetn)
                begin
                    header_byte <= 0;
                    fifo_full_state_byte <= 0;
                end
            else if(detect_add && pkt_valid)
                header_byte <= data_in;
            else if(ld_state && fifo_full)
                fifo_full_state_byte <= data_in;
        end

    // Logic for dout
    always@(posedge clock)
        begin
            if(!resetn)
                dout <= 0;
            else if(lfd_state)
                dout <= header_byte;
            else if(laf_state)
                dout <= fifo_full_state_byte;
            else if(ld_state && !fifo_full)
                dout <= data_in;
        end

    // Logic for parity_done
    always@(posedge clock)
        begin
            if(!resetn)
                parity_done <= 0;
            else if(detect_add)
                parity_done <= 0;
            else if((ld_state && !pkt_valid && !fifo_full) || (laf_state && low_pkt_valid
&& !parity_done))
                parity_done <= 1'b1;
        end

    // Logic for low_pkt_valid
    always@(posedge clock)
        begin
            if(!resetn)
                low_pkt_valid <= 0;
```

```

    else if(ld_state && !pkt_valid)
        low_pkt_valid <= 1'b1;
    else if(rst_int_reg)
        low_pkt_valid <= 0;
end

// Logic for internal_parity
always@(posedge clock)
begin
    if(!resetn)
        internal_parity <= 0;
    else if(detect_add)
        internal_parity <= 0;
    else if(lfd_state)
        internal_parity <= internal_parity ^ header_byte;
    else if(ld_state && pkt_valid && !full_state)
        internal_parity <= internal_parity ^ data_in;
end

// Logic for packet_parity
always@(posedge clock)
begin
    if(!resetn)
        packet_parity <= 0;
    else if((ld_state && !pkt_valid && !fifo_full) || (laf_state && low_pkt_valid
&& !parity_done))
        packet_parity <= data_in;
end

// Logic for err
always@(posedge clock)
begin
    if(!resetn)
        err <= 0;
    else if(parity_done && (internal_parity != packet_parity))
        err <= 1'b1;
    else
        err <= 0;
end
endmodule

```

Simulation Code:

```

module router_reg_tb();
    reg
clock,resetn,pkt_valid,fifo_full,rst_int_reg,detect_add,ld_state,laf_state,full_state,l
fd_state;
    reg [7:0] data_in;
    wire parity_done,low_pkt_valid,err;
    wire [7:0] dout;

    parameter T = 10;

    integer i;

    router_reg DUT (clock,
                    resetn,
                    pkt_valid,
                    fifo_full,
                    rst_int_reg,
                    detect_add,
                    ld_state,
                    laf_state,
                    full_state,
                    lfd_state,
                    data_in,
                    parity_done,
                    low_pkt_valid,

```

```

        err,
        dout);

initial
begin
    clock = 1'b0;
    forever #(T/2) clock = ~clock;
end

task initialize;
begin
    resetn = 1'b1;
    pkt_valid = 1'b0;
    fifo_full = 1'b0;
    rst_int_reg = 1'b0;
    detect_add = 1'b0;
    ld_state = 1'b0;
    laf_state = 1'b0;
    full_state = 1'b0;
    lfd_state = 1'b0;
    data_in = 0;
end
endtask

task resetn_ip;
begin
    @(negedge clock);
    resetn = 1'b0;
    @(negedge clock);
    resetn = 1'b1;
end
endtask

task good_packet;
reg [7:0] header, payload, parity;
reg [5:0] payload_len;
reg [1:0] addr;
begin
    @(negedge clock);
    parity = 0;
    payload_len = 6'd4;
    addr = 2'd1;
    header = {payload_len,addr};
    pkt_valid = 1'b1;
    detect_add = 1'b1;
    parity = parity ^ header;
    data_in = header;
    @(negedge clock);
    detect_add = 0;
    lfd_state = 1'b1;
    for(i=0;i<payload_len;i=i+1)
begin
    @(negedge clock);
    lfd_state = 0;
    ld_state = 1;
    payload = {$random} % 256;
    parity = parity ^ payload;
    data_in = payload;
end
    @(negedge clock);
    pkt_valid = 0;
    data_in = parity;
    @(negedge clock);
    ld_state = 0;
    rst_int_reg = 1'b1;
    @(negedge clock);
    rst_int_reg = 1'b0;

```

```

    detect_add = 1'b1;
  end
endtask

task overflow_packet;
  reg [7:0] header, payload, parity;
  reg [5:0] payload_len;
  reg [1:0] addr;
begin
  @(negedge clock);
  parity = 0;
  payload_len = 6'd16;
  addr = 2'd2;
  header = {payload_len,addr};
  pkt_valid = 1'b1;
  detect_add = 1'b1;
  parity = parity ^ header;
  data_in = header;
  @(negedge clock);
  detect_add = 0;
  lfd_state = 1'b1;
  for(i=0;i<15;i=i+1)
  begin
    @(negedge clock);
    lfd_state = 0;
    ld_state = 1;
    payload = {$random} % 256;
    parity = parity ^ payload;
    data_in = payload;
  end
  @(negedge clock);
  payload = 8'b11110000;
  parity = parity ^ payload;
  data_in = payload;
  fifo_full = 1'b1;
  full_state = 1'b1;
  #30 fifo_full = 0;
  full_state = 0;
  ld_state = 0;
  @(negedge clock);
  laf_state = 1'b1;
  @(negedge clock);
  laf_state = 0;
  ld_state = 1'b1;
  @(negedge clock);
  pkt_valid = 0;
  data_in = parity;
  @(negedge clock);
  ld_state = 0;
  rst_int_reg = 1'b1;
  @(negedge clock);
  rst_int_reg = 1'b0;
  detect_add = 1'b1;
end
endtask

task corrupted_packet;
  reg [7:0] header, payload, parity;
  reg [5:0] payload_len;
  reg [1:0] addr;
begin
  @(negedge clock);
  parity = 0;
  payload_len = 6'd4;
  addr = 2'd1;
  header = {payload_len,addr};
  pkt_valid = 1'b1;

```

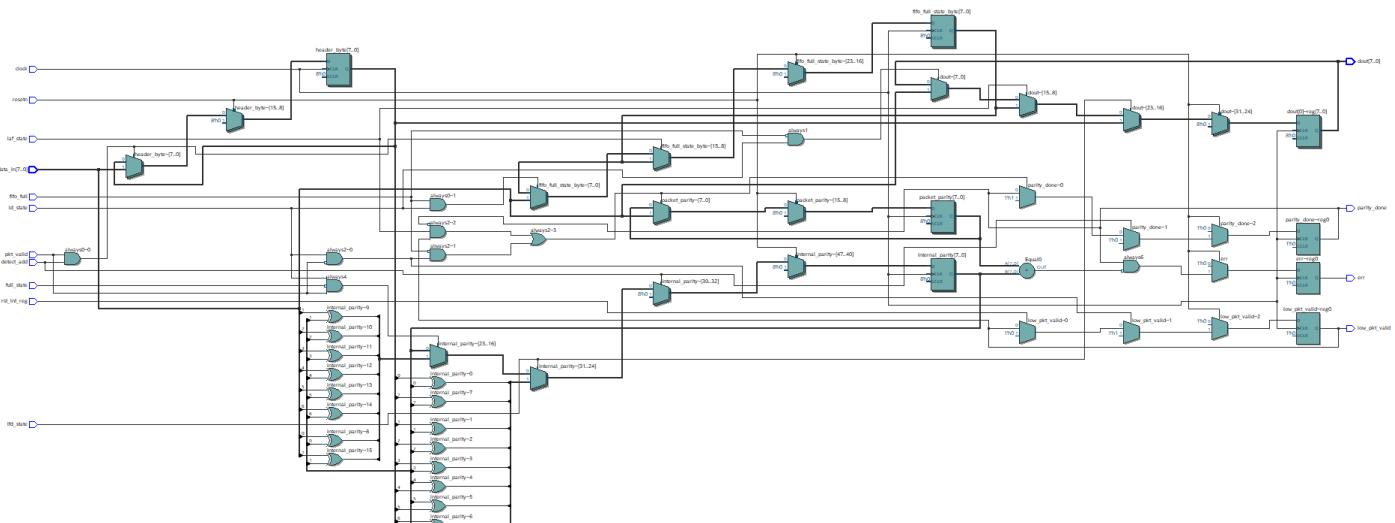
```

detect_add = 1'b1;
parity = parity ^ header;
data_in = header;
@(negedge clock);
detect_add = 0;
lfd_state = 1'b1;
for(i=0;i<payload_len;i=i+1)
begin
    @(negedge clock);
    lfd_state = 0;
    ld_state = 1;
    payload = {$random} % 256;
    parity = parity ^ payload;
    data_in = payload;
end
@(negedge clock);
pkt_valid = 0;
data_in = ~parity;
@(negedge clock);
ld_state = 0;
rst_int_reg = 1'b1;
@(negedge clock);
rst_int_reg = 1'b0;
detect_add = 1'b1;
end
endtask

initial
begin
    initialize;
    #20;
    resetn_ip;
    #20;
    good_packet;
    #200;
    corrupted_packet;
    #200;
    overflow_packet;
    #200;
    $finish;
end
endmodule

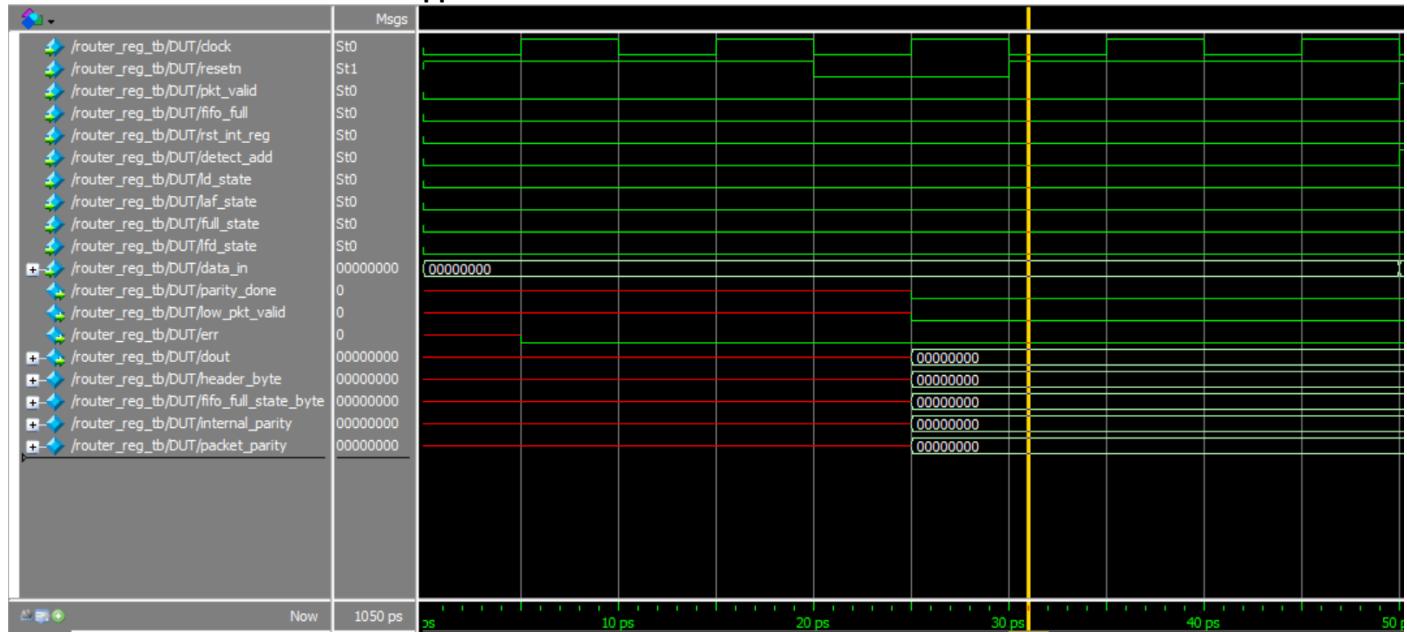
```

Synthesis Circuit:

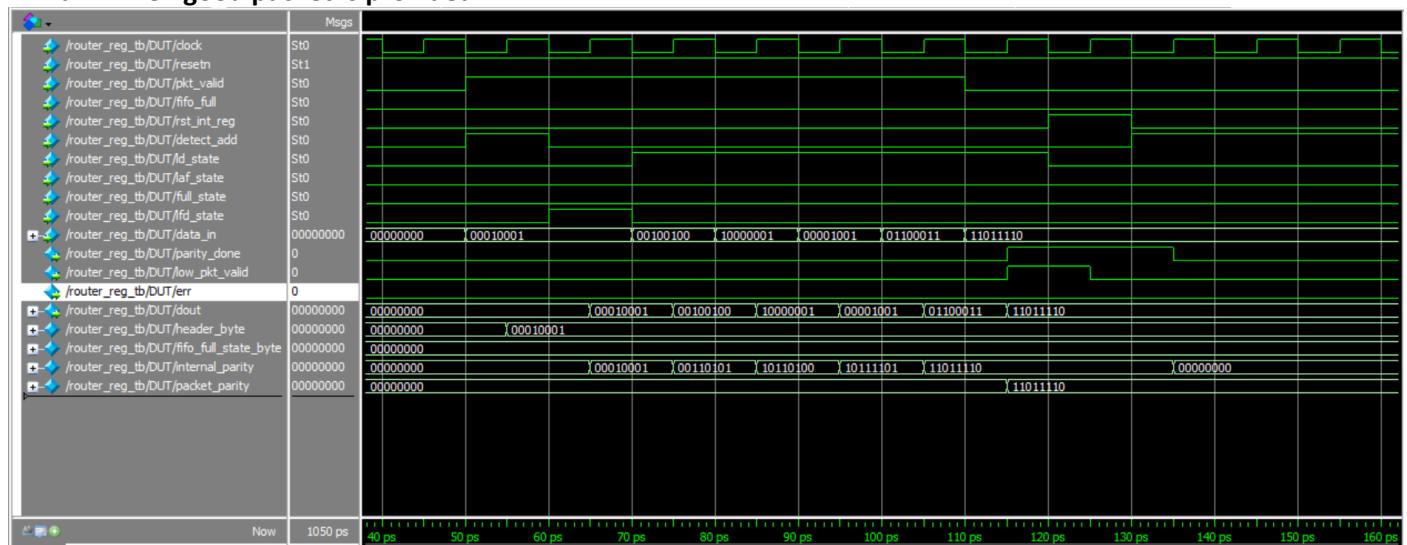


Simulation Waveform:

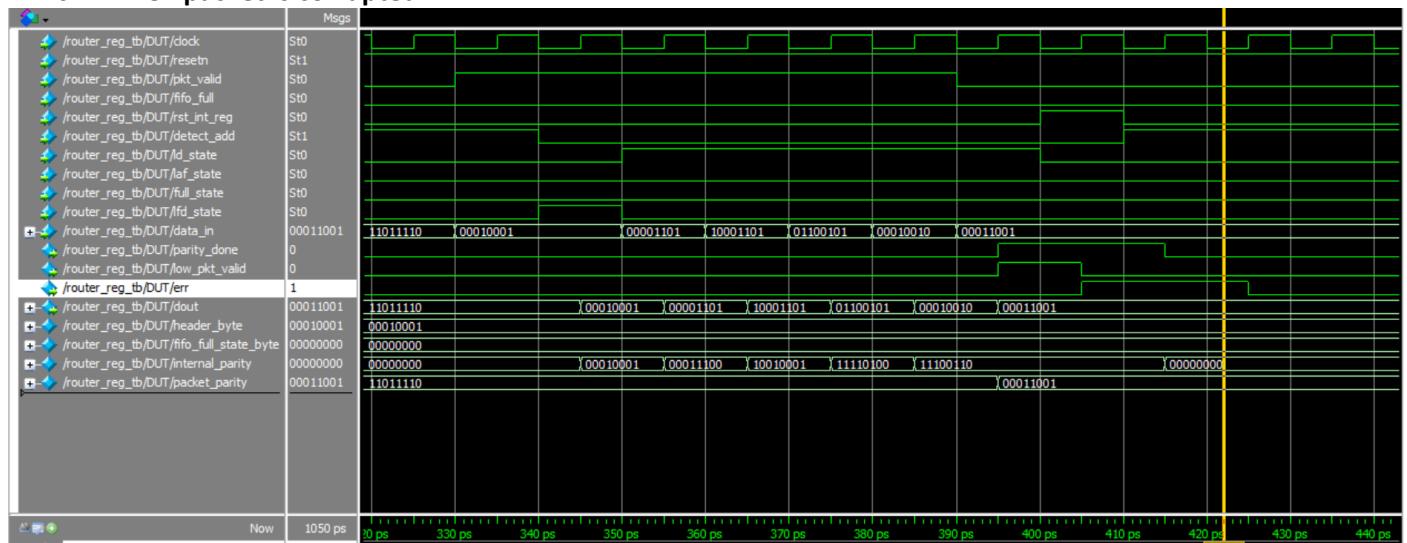
a. When active low reset is applied



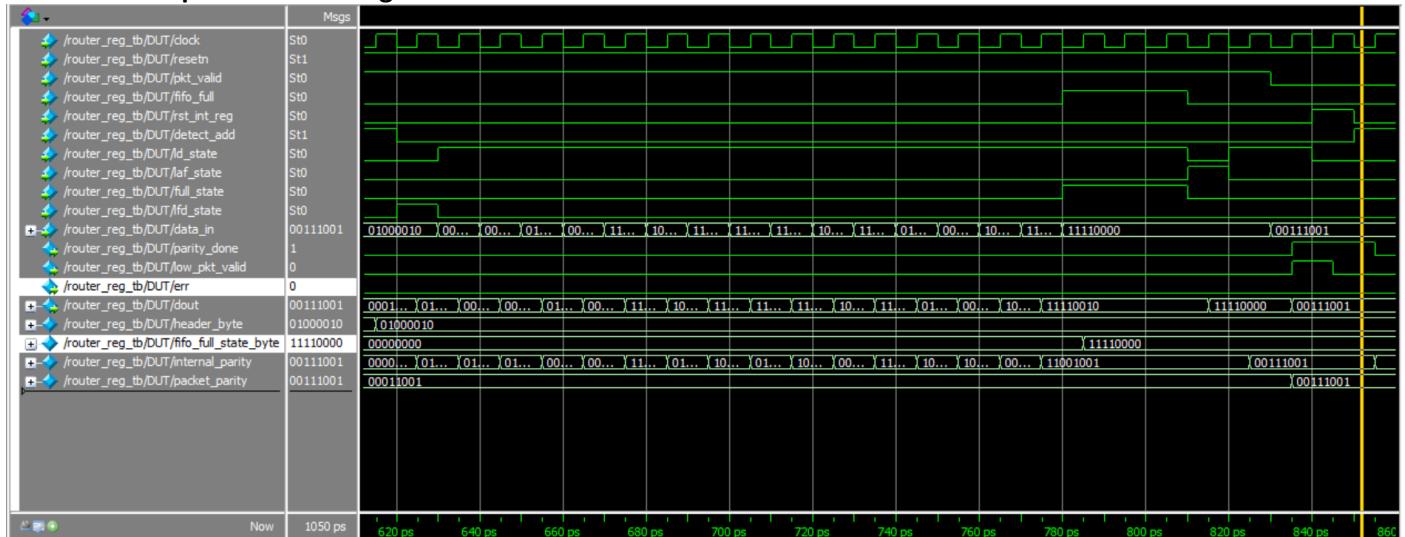
b. When good packet is provided



c. When packet is corrupted



d. When packet size is larger than FIFO size



5. Router Top Block

Design Code:

```
module router_top(input clock,
                  resetn,
                  read_enb_0,
                  read_enb_1,
                  read_enb_2,
                  pkt_valid,
                  input [7:0] data_in,
                  output vld_out_0,
                  vld_out_1,
                  vld_out_2,
                  err,
                  busy,
                  output [7:0] data_out_0,
                  data_out_1,
                  data_out_2);

  wire [2:0] write_enb;
  wire [7:0] dout;
  wire parity_done,soft_reset_0,soft_reset_1,soft_reset_2,fifo_full,low_pkt_valid,detect_add,l
d_state,laf_state,full_state,write_enb_reg,rst_int_reg,lfd_state,empty_0,empty_1,empty_
2,full_0,full_1,full_2;

  router_fsm
FSM(clock,resetn,pkt_valid,parity_done,soft_reset_0,soft_reset_1,soft_reset_2,fifo_full
,low_pkt_valid,empty_0,empty_1,empty_2,data_in[1:0],busy,detect_add,ld_state,laf_state
,full_state,write_enb_reg,rst_int_reg,lfd_state);

  router_sync
Synchronizer(clock,resetn,detect_add,write_enb_reg,read_enb_0,read_enb_1,read_enb_2,emp
ty_0,empty_1,empty_2,full_0,full_1,full_2,data_in[1:0],fifo_full,soft_reset_0,soft_rese
t_1,soft_reset_2,vld_out_0,vld_out_1,vld_out_2,write_enb);

  router_reg
Register(clock,resetn,pkt_valid,fifo_full,rst_int_reg,detect_add,ld_state,laf_state,ful
l_state,lfd_state,data_in,parity_done,low_pkt_valid,err,dout);

  router_fifo
FIFO_0(clock,resetn,write_enb[0],soft_reset_0,read_enb_0,lfd_state,dout,empty_0,
full_0,data_out_0);

  router_fifo
FIFO_1(clock,resetn,write_enb[1],soft_reset_1,read_enb_1,lfd_state,dout,empty_1,
full_1,data_out_1);

  router_fifo
FIFO_2(clock,resetn,write_enb[2],soft_reset_2,read_enb_2,lfd_state,dout,empty_2,
full_2,data_out_2);

endmodule
```

Simulation Code:

```
module router_top_tb();
  reg clock,resetn,read_enb_0,read_enb_1,read_enb_2,pkt_valid;
  reg [7:0] data_in;
  wire vld_out_0,vld_out_1,vld_out_2,err,busy;
  wire [7:0] data_out_0,data_out_1,data_out_2;
```

```

event e1,e2;

parameter T = 10;

router_top DUT(clock,
                 resetn,
                 read_enb_0,
                 read_enb_1,
                 read_enb_2,
                 pkt_valid,
                 data_in,
                 vld_out_0,
                 vld_out_1,
                 vld_out_2,
                 err,
                 busy,
                 data_out_0,
                 data_out_1,
                 data_out_2);

initial
begin
    clock = 1'b0;
    forever #(T/2) clock = ~clock;
end

task initialize;
begin
    resetn = 1'b1;
    read_enb_0 = 0;
    read_enb_1 = 0;
    read_enb_2 = 0;
    pkt_valid = 0;
    data_in = 0;
end
endtask

task reset_ip;
begin
    @(negedge clock);
    resetn = 1'b0;
    @(negedge clock);
    resetn = 1'b1;
end
endtask

task payload_14_15(input [5:0]d1,input [1:0]a1);
    reg [7:0] header, payload, parity;
    reg [5:0] payload_len;
    reg [1:0] addr;
    integer i;
    begin
        @(negedge clock);
        wait(!busy)
        @(negedge clock);
        parity = 0;
        payload_len = d1;
        addr = a1;
        header = {payload_len,addr};
        parity = parity ^ header;
        pkt_valid = 1'b1;
        data_in = header;
        @(negedge clock);
        wait(!busy)
        for(i=0;i<payload_len;i=i+1)
        begin
            @(negedge clock);

```

```

        wait(!busy)
        payload = i;
        parity = parity ^ payload;
        data_in = payload;
    end
    wait(!busy)
    @(negedge clock);
    pkt_valid = 0;
    data_in = parity;
end
endtask

task payload_16_17(input [5:0]d2,input [1:0]a2);
    reg [7:0] header, payload, parity;
    reg [5:0] payload_len;
    reg [1:0] addr;
    integer i;
    begin
        @(negedge clock);
        wait(!busy)
        parity = 0;
        payload_len = d2;
        addr = a2;
        header = {payload_len,addr};
        parity = parity ^ header;
        @(negedge clock);
        pkt_valid = 1'b1;
        data_in = header;
        @(negedge clock);
        wait(!busy)
        for(i=0;i<payload_len;i=i+1)
            begin
                @(negedge clock);
                wait(!busy)
                payload = i;
                parity = parity ^ payload;
                data_in = payload;
            end
        ->e1;
        wait(!busy)
        @(negedge clock);
        pkt_valid = 0;
        data_in = parity;
    end
endtask

task random_packet(input [5:0]d3,input [1:0]a3);
    reg [7:0] header, payload, parity;
    reg [5:0] payload_len;
    reg [1:0] addr;
    integer i;
    begin
        ->e2;
        @(negedge clock);
        wait(!busy)
        parity = 0;
        payload_len = d3;
        addr = a3;
        header = {payload_len,addr};
        parity = parity ^ header;
        @(negedge clock);
        pkt_valid = 1'b1;
        data_in = header;
        @(negedge clock);
        wait(!busy)
        for(i=0;i<payload_len;i=i+1)
            begin

```

```

@(negedge clock);
wait(!busy)
payload = i;
parity = parity ^ payload;
data_in = payload;
end
endtask

initial
begin
forever
begin
@(e1)
begin
@(negedge clock);
read_enb_1 = 1'b1;
wait(!vld_out_1)
@(negedge clock);
read_enb_1 = 0;
end
end
end

initial
begin
forever
begin
@(e2)
begin
wait(vld_out_2)
@(negedge clock);
read_enb_2 = 1'b1;
wait(!vld_out_2)
@(negedge clock);
read_enb_2 = 0;
end
end
end

initial
begin
initialize;
reset_ip;
repeat (2) @(negedge clock);

// Packet Size = 16bytes
// DA-LFD-LD-LP-CPE-DA
payload_14_15(6'd14,2'd0);
@(negedge clock);
read_enb_0 = 1'b1;
wait(!vld_out_0)
@(negedge clock);
read_enb_0 = 0;
#100;

// Packet Size = 17bytes
// DA-LFD-LD-LP-CPE-FFS-LAF-DA
payload_14_15(6'd15,2'd0);
@(negedge clock);
wait(busy)
@(negedge clock);
read_enb_0 = 1'b1;

```

```

wait(!vld_out_0)
@(negedge clock);
read_enb_0 = 0;
#100;

// Packet Size = 18bytes
// DA-LFD-LD-FFS-LAF-LP-CPE-DA
payload_16_17(6'd16,2'd1);
wait(!vld_out_1)
@(negedge clock);
read_enb_1 = 0;
#100;

// Packet Size = 19bytes
// DA-LFD-LD-FFS-LAF-LD-LP-CPE-DA
payload_16_17(6'd17,2'd1);
wait(!vld_out_1)
@(negedge clock);
read_enb_1 = 0;
#100;

// Packet Size = 24bytes
// DA-LFD-LD-LP-CPE-DA
random_packet(6'd22,2'd2);
wait(!vld_out_2)
@(negedge clock);
read_enb_2 = 0;
#100;

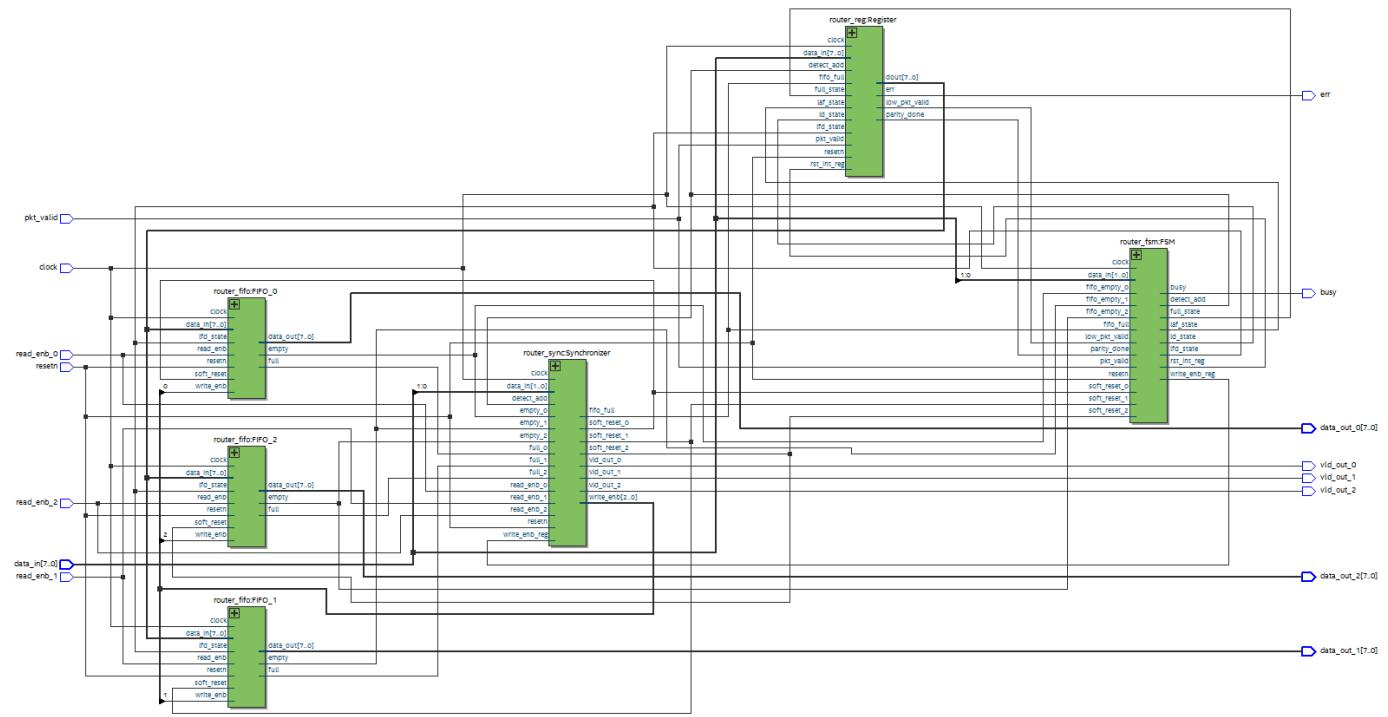
$finish;

end

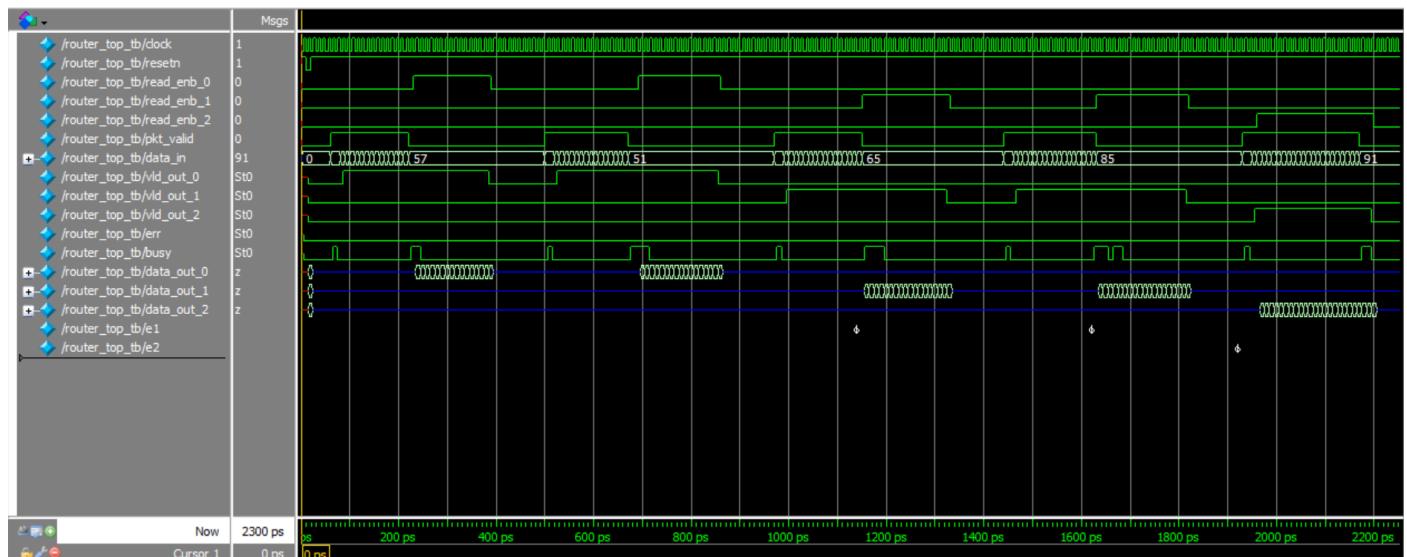
initial
$monitor("Data Input = %d, data_out_0 = %d, data_out_1 = %d, data_out_2 = %d,
Busy = %b, Error = %b",
data_in,data_out_0,data_out_1,data_out_2,busy,err);
endmodule

```

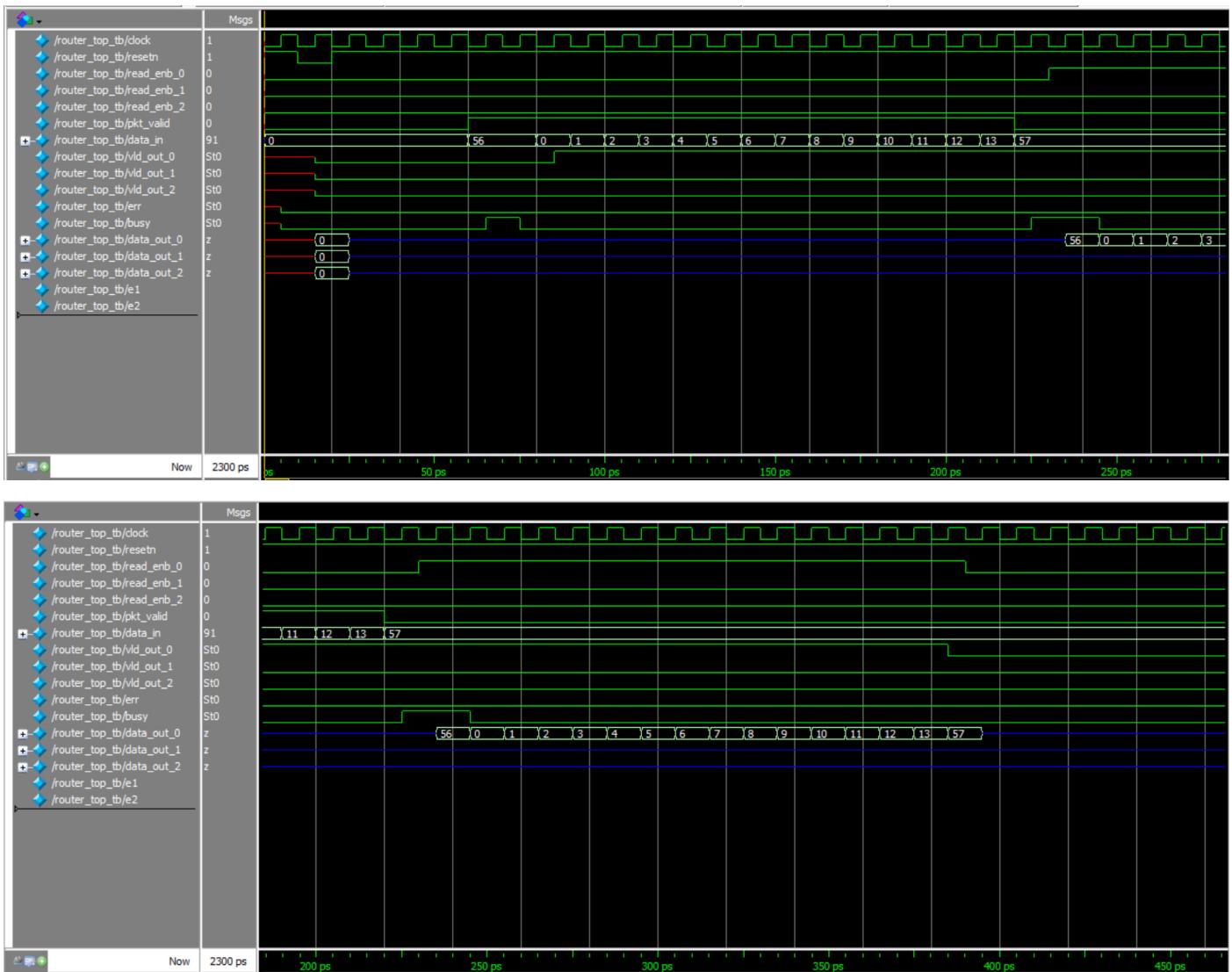
Synthesis Circuit:



Simulation Waveform:



a. Packet Size = 16 bytes

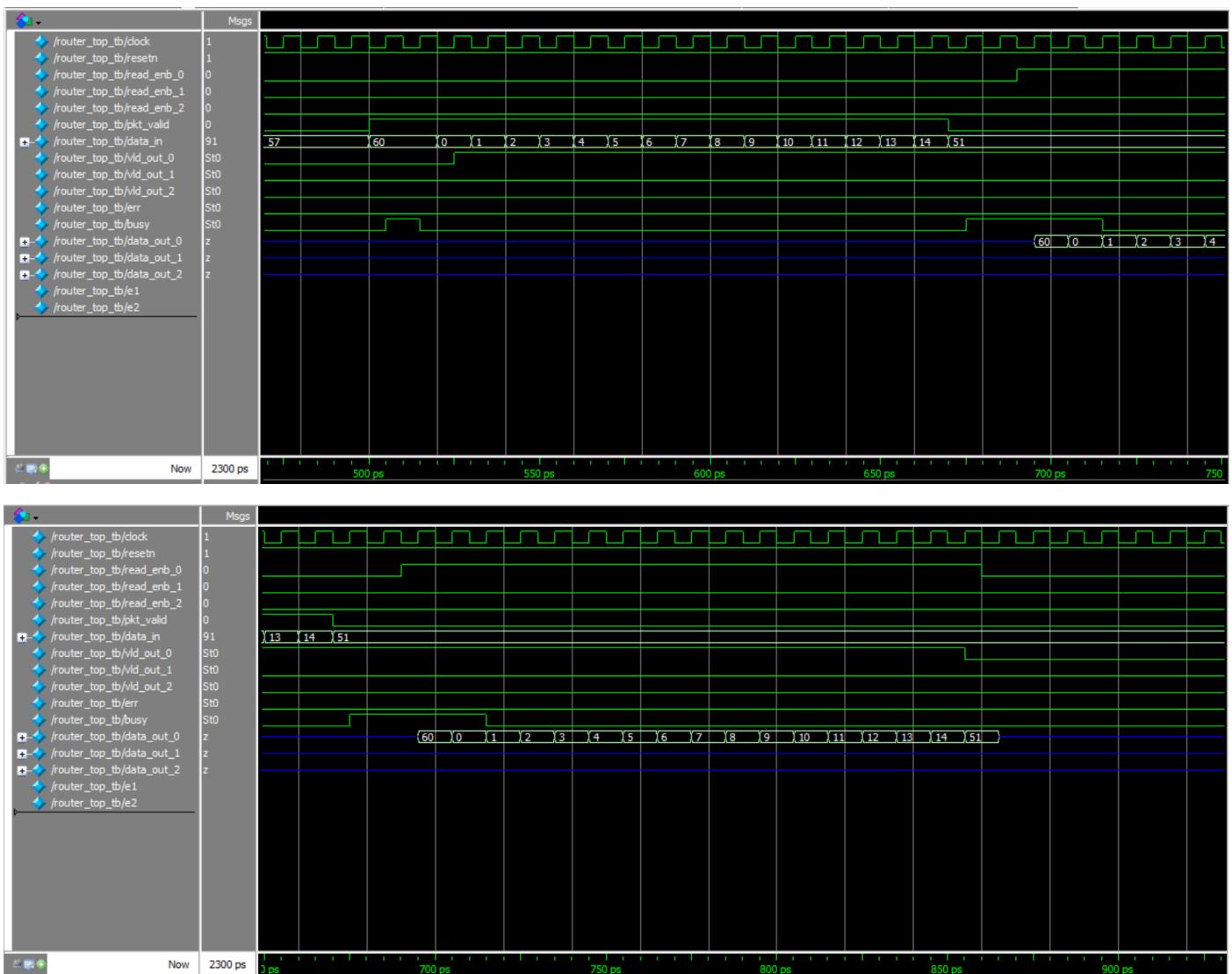


```

Data Input = 0, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 56, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 56, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 1, Error = 0
Data Input = 56, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 0, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 1, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 2, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 3, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 4, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 5, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 6, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 7, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 8, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 9, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 10, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 11, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 12, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 13, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 57, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 57, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 1, Error = 0
Data Input = 57, data_out_0 = 56, data_out_1 = z, data_out_2 = z, Busy = 1, Error = 0
Data Input = 57, data_out_0 = 0, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 57, data_out_0 = 1, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 57, data_out_0 = 2, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 57, data_out_0 = 3, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 57, data_out_0 = 4, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 57, data_out_0 = 5, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 57, data_out_0 = 6, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 57, data_out_0 = 7, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 57, data_out_0 = 8, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 57, data_out_0 = 9, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 57, data_out_0 = 10, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 57, data_out_0 = 11, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 57, data_out_0 = 12, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 57, data_out_0 = 13, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 57, data_out_0 = 57, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 57, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0

```

b. Packet Size = 17 bytes

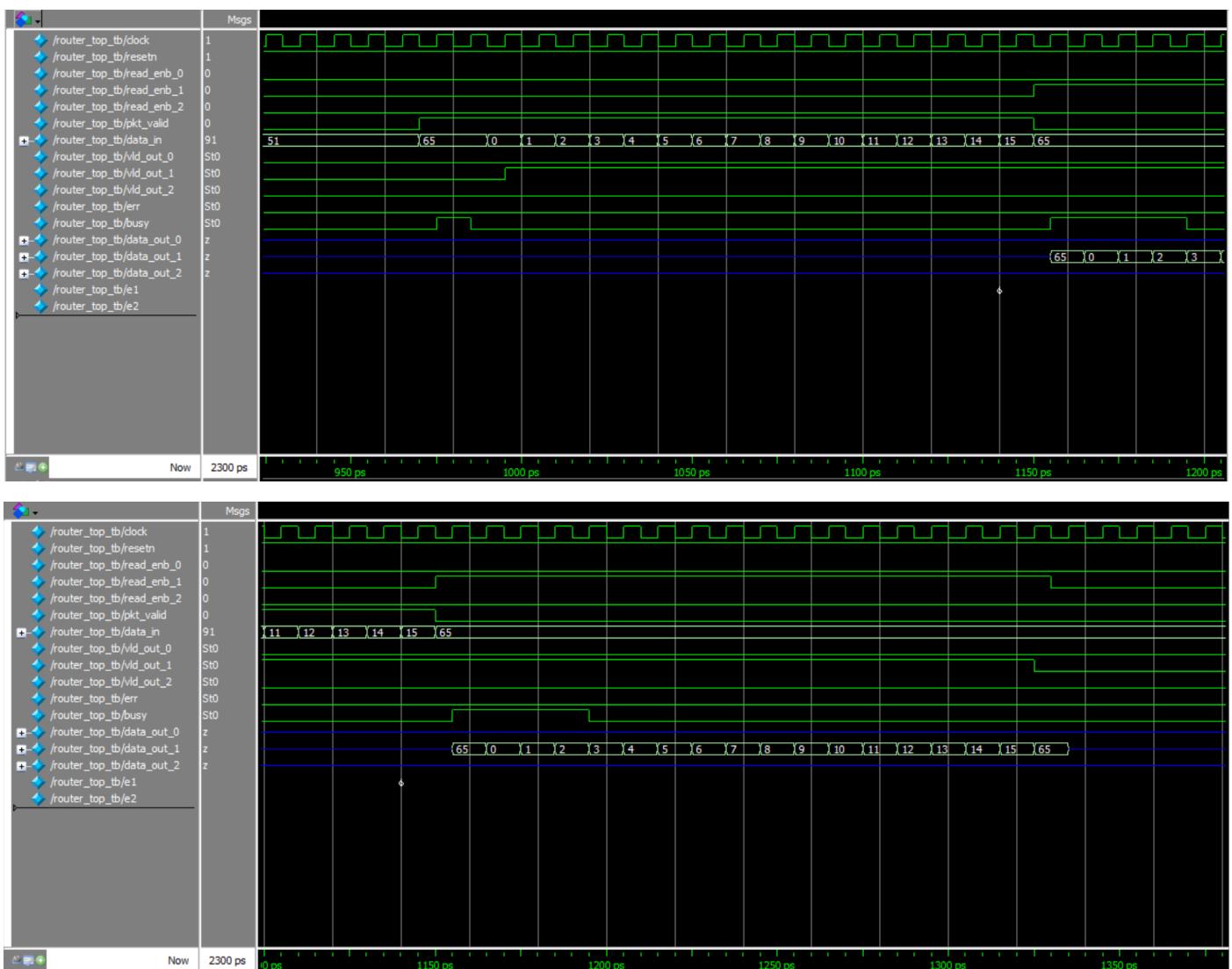


```

Data Input = 60, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 0, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 1, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 2, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 3, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 4, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 5, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 6, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 7, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 8, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 9, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 10, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 11, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 12, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 13, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 14, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 51, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 51, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 1, Error = 0
Data Input = 51, data_out_0 = 60, data_out_1 = z, data_out_2 = z, Busy = 1, Error = 0
Data Input = 51, data_out_0 = 0, data_out_1 = z, data_out_2 = z, Busy = 1, Error = 0
Data Input = 51, data_out_0 = 1, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 51, data_out_0 = 2, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 51, data_out_0 = 3, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 51, data_out_0 = 4, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 51, data_out_0 = 5, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 51, data_out_0 = 6, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 51, data_out_0 = 7, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 51, data_out_0 = 8, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 51, data_out_0 = 9, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 51, data_out_0 = 10, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 51, data_out_0 = 11, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 51, data_out_0 = 12, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 51, data_out_0 = 13, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 51, data_out_0 = 14, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 51, data_out_0 = 51, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 51, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0

```

c. Packet Size = 18 bytes

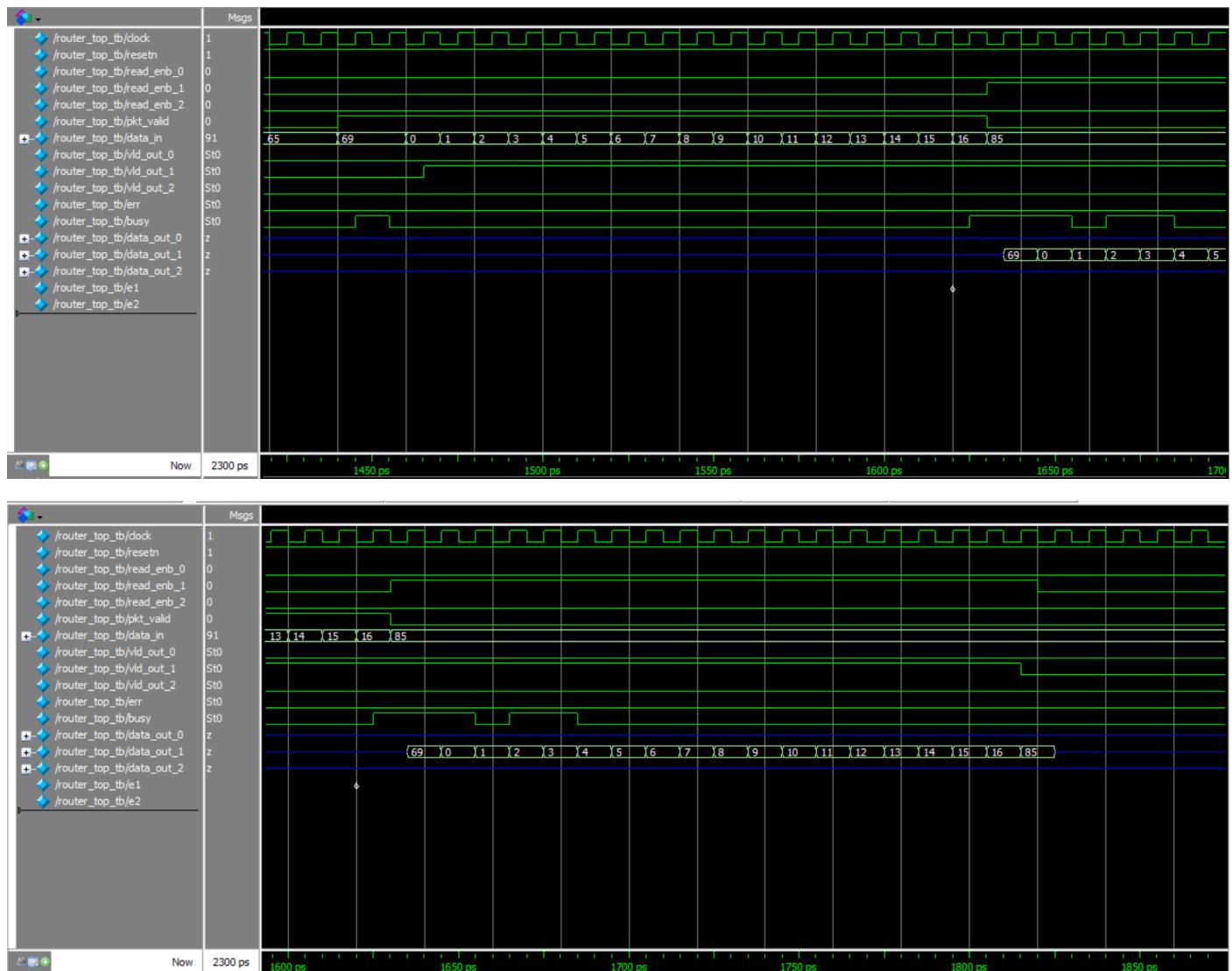


```

Data Input = 65, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 0, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 1, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 2, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 3, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 4, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 5, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 6, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 7, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 8, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 9, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 10, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 11, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 12, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 13, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 14, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 15, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = 65, data_out_2 = z, Busy = 1, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = 0, data_out_2 = z, Busy = 1, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = 1, data_out_2 = z, Busy = 1, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = 2, data_out_2 = z, Busy = 1, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = 3, data_out_2 = z, Busy = 0, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = 4, data_out_2 = z, Busy = 0, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = 5, data_out_2 = z, Busy = 0, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = 6, data_out_2 = z, Busy = 0, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = 7, data_out_2 = z, Busy = 0, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = 8, data_out_2 = z, Busy = 0, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = 9, data_out_2 = z, Busy = 0, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = 10, data_out_2 = z, Busy = 0, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = 11, data_out_2 = z, Busy = 0, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = 12, data_out_2 = z, Busy = 0, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = 13, data_out_2 = z, Busy = 0, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = 14, data_out_2 = z, Busy = 0, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = 15, data_out_2 = z, Busy = 0, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = 65, data_out_2 = z, Busy = 0, Error = 0
Data Input = 65, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0

```

d. Packet Size = 19 bytes

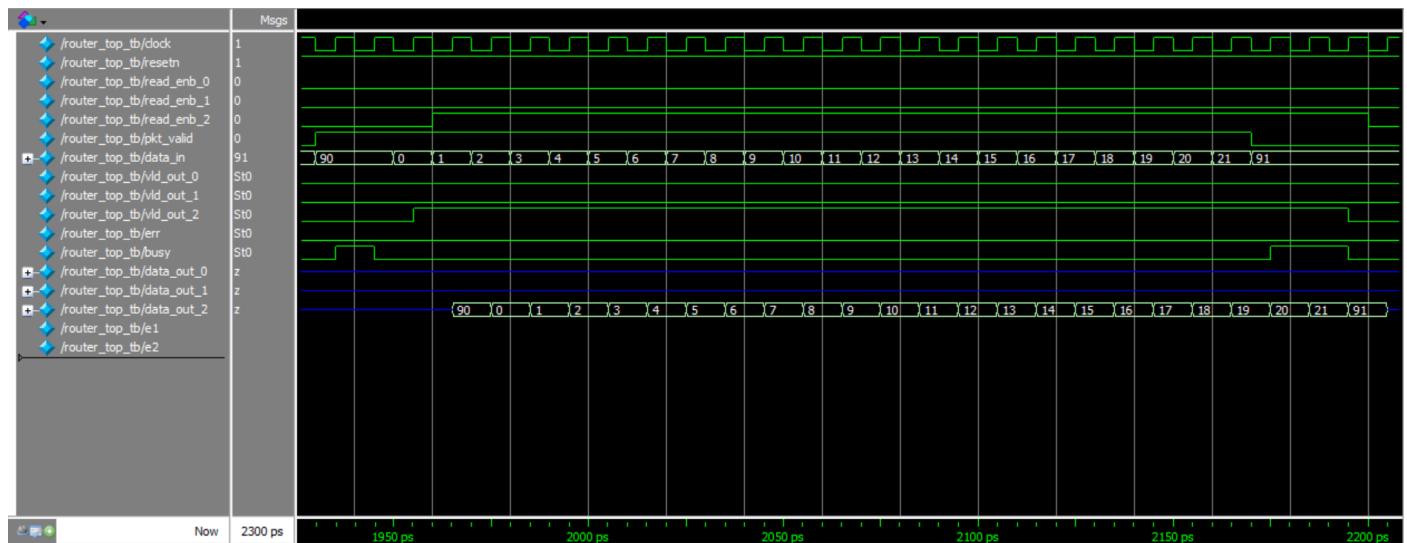


```

Data Input = 69, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 0, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 1, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 2, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 3, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 4, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 5, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 6, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 7, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 8, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 9, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 10, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 11, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 12, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 13, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 14, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 15, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 16, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 1, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 1, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = 69, data_out_2 = z, Busy = 1, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = 0, data_out_2 = z, Busy = 1, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = 1, data_out_2 = z, Busy = 0, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = 2, data_out_2 = z, Busy = 1, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = 3, data_out_2 = z, Busy = 1, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = 4, data_out_2 = z, Busy = 0, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = 5, data_out_2 = z, Busy = 0, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = 6, data_out_2 = z, Busy = 0, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = 7, data_out_2 = z, Busy = 0, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = 8, data_out_2 = z, Busy = 0, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = 9, data_out_2 = z, Busy = 0, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = 10, data_out_2 = z, Busy = 0, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = 11, data_out_2 = z, Busy = 0, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = 12, data_out_2 = z, Busy = 0, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = 13, data_out_2 = z, Busy = 0, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = 14, data_out_2 = z, Busy = 0, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = 15, data_out_2 = z, Busy = 0, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = 16, data_out_2 = z, Busy = 0, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = 85, data_out_2 = z, Busy = 0, Error = 0
Data Input = 85, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0

```

e. Packet Size = 24 bytes



```
Data Input = 90, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 0, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 1, data_out_0 = z, data_out_1 = z, data_out_2 = z, Busy = 0, Error = 0
Data Input = 1, data_out_0 = z, data_out_1 = z, data_out_2 = 90, Busy = 0, Error = 0
Data Input = 2, data_out_0 = z, data_out_1 = z, data_out_2 = 90, Busy = 0, Error = 0
Data Input = 2, data_out_0 = z, data_out_1 = z, data_out_2 = 0, Busy = 0, Error = 0
Data Input = 3, data_out_0 = z, data_out_1 = z, data_out_2 = 0, Busy = 0, Error = 0
Data Input = 3, data_out_0 = z, data_out_1 = z, data_out_2 = 1, Busy = 0, Error = 0
Data Input = 4, data_out_0 = z, data_out_1 = z, data_out_2 = 1, Busy = 0, Error = 0
Data Input = 4, data_out_0 = z, data_out_1 = z, data_out_2 = 2, Busy = 0, Error = 0
Data Input = 5, data_out_0 = z, data_out_1 = z, data_out_2 = 2, Busy = 0, Error = 0
Data Input = 5, data_out_0 = z, data_out_1 = z, data_out_2 = 3, Busy = 0, Error = 0
Data Input = 6, data_out_0 = z, data_out_1 = z, data_out_2 = 3, Busy = 0, Error = 0
Data Input = 6, data_out_0 = z, data_out_1 = z, data_out_2 = 4, Busy = 0, Error = 0
Data Input = 7, data_out_0 = z, data_out_1 = z, data_out_2 = 4, Busy = 0, Error = 0
Data Input = 7, data_out_0 = z, data_out_1 = z, data_out_2 = 5, Busy = 0, Error = 0
Data Input = 8, data_out_0 = z, data_out_1 = z, data_out_2 = 5, Busy = 0, Error = 0
Data Input = 8, data_out_0 = z, data_out_1 = z, data_out_2 = 6, Busy = 0, Error = 0
Data Input = 9, data_out_0 = z, data_out_1 = z, data_out_2 = 6, Busy = 0, Error = 0
Data Input = 9, data_out_0 = z, data_out_1 = z, data_out_2 = 7, Busy = 0, Error = 0
Data Input = 10, data_out_0 = z, data_out_1 = z, data_out_2 = 7, Busy = 0, Error = 0
Data Input = 10, data_out_0 = z, data_out_1 = z, data_out_2 = 8, Busy = 0, Error = 0
Data Input = 11, data_out_0 = z, data_out_1 = z, data_out_2 = 8, Busy = 0, Error = 0
Data Input = 11, data_out_0 = z, data_out_1 = z, data_out_2 = 9, Busy = 0, Error = 0
Data Input = 12, data_out_0 = z, data_out_1 = z, data_out_2 = 9, Busy = 0, Error = 0
Data Input = 12, data_out_0 = z, data_out_1 = z, data_out_2 = 10, Busy = 0, Error = 0
Data Input = 13, data_out_0 = z, data_out_1 = z, data_out_2 = 10, Busy = 0, Error = 0
Data Input = 13, data_out_0 = z, data_out_1 = z, data_out_2 = 11, Busy = 0, Error = 0
Data Input = 14, data_out_0 = z, data_out_1 = z, data_out_2 = 11, Busy = 0, Error = 0
Data Input = 14, data_out_0 = z, data_out_1 = z, data_out_2 = 12, Busy = 0, Error = 0
Data Input = 15, data_out_0 = z, data_out_1 = z, data_out_2 = 12, Busy = 0, Error = 0
Data Input = 15, data_out_0 = z, data_out_1 = z, data_out_2 = 13, Busy = 0, Error = 0
Data Input = 16, data_out_0 = z, data_out_1 = z, data_out_2 = 13, Busy = 0, Error = 0
Data Input = 16, data_out_0 = z, data_out_1 = z, data_out_2 = 14, Busy = 0, Error = 0
Data Input = 17, data_out_0 = z, data_out_1 = z, data_out_2 = 14, Busy = 0, Error = 0
Data Input = 17, data_out_0 = z, data_out_1 = z, data_out_2 = 15, Busy = 0, Error = 0
Data Input = 18, data_out_0 = z, data_out_1 = z, data_out_2 = 15, Busy = 0, Error = 0
Data Input = 19, data_out_0 = z, data_out_1 = z, data_out_2 = 16, Busy = 0, Error = 0
Data Input = 19, data_out_0 = z, data_out_1 = z, data_out_2 = 17, Busy = 0, Error = 0
Data Input = 20, data_out_0 = z, data_out_1 = z, data_out_2 = 17, Busy = 0, Error = 0
Data Input = 20, data_out_0 = z, data_out_1 = z, data_out_2 = 18, Busy = 0, Error = 0
Data Input = 21, data_out_0 = z, data_out_1 = z, data_out_2 = 18, Busy = 0, Error = 0
Data Input = 21, data_out_0 = z, data_out_1 = z, data_out_2 = 19, Busy = 0, Error = 0
Data Input = 91, data_out_0 = z, data_out_1 = z, data_out_2 = 19, Busy = 0, Error = 0
Data Input = 91, data_out_0 = z, data_out_1 = z, data_out_2 = 20, Busy = 1, Error = 0
Data Input = 91, data_out_0 = z, data_out_1 = z, data_out_2 = 21, Busy = 1, Error = 0
Data Input = 91, data_out_0 = z, data_out_1 = z, data_out_2 = 91, Busy = 0, Error = 0
Data Input = 91, data_out_0 = z, data_out_1 = z, data_out_2 = 0, Busy = 0, Error = 0
```

Synthesis Report:

Resource	Usage
Total logic elements	1104
-- Combinational with no register	499
-- Register only	488
-- Combinational with a register	117
Logic element usage by number of LUT inputs	
-- 4 input functions	426
-- 3 input functions	63
-- 2 input functions	109
-- 1 input functions	18
-- 0 input functions	0
Logic elements by mode	
-- normal mode	1032
-- arithmetic mode	72
-- qfbk mode	0
-- register cascade mode	0
-- synchronous clear/load mode	86
-- asynchronous clear/load mode	0
Total registers	605
Total logic cells in carry chains	87
I/O pins	43
Maximum fan-out node	clock
Maximum fan-out	605
Total fan-out	3994
Average fan-out	3.48