Project 1

Synchronous FIFO

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Digital Verification Using SystemVerilog and UVM

Table of Contents

Design without bugs with Assertions:

```
module FIFO(fifo_intf.DUT intf);
```

```
localparam max_fifo_addr = $clog2( intf.FIFO_DEPTH);
//ceiling log with base 2
//Depth mem word
reg [ intf.FIFO_WIDTH-1:0] mem [intf.FIFO_DEPTH-1:0];

reg [max_fifo_addr-1:0] wr_ptr, rd_ptr;
reg [max_fifo_addr:0] count; //4-bits
//WRITE
always @(posedge intf.clk or negedge intf.rst_n) begin
    if (!intf.rst_n) begin
        wr_ptr <= 0;
        intf.overflow<=0;
        intf.wr_ack<=0;
        intf.wr_en<=0;
    end
    else if(intf.wr_en && intf.rd_en && intf.empty
)begin
        mem[wr_ptr] <= intf.data_in;
        intf.wr_ack <= 1;
        wr_ptr <= wr_ptr + 1;
        intf.overflow<=0;

    end
    else if (intf.wr_en && !intf.full)
     begin
        mem[wr_ptr] <= intf.data_in;
        intf.wr_ack <= 1;
        wr_ptr <= (wr_ptr == intf.FIFO_DEPTH-1) ? 0 :
wr_ptr + 1;//adding checker to check the wraparound
        wr_ptr <= wr_ptr + 1;
        intf.overflow<=0;
    end
```

```
    else begin
        intf.wr_ack <= 0;
        if (intf.full && intf.wr_en)
            intf.overflow <= 1;
        else
            intf.overflow <= 0;
    end
end
//READ
always @(posedge intf.clk or negedge intf.rst_n) begin
    if (!intf.rst_n) begin
        rd_ptr <= 0;
        intf.underflow<=0;
        intf.data_out<=0;
        intf.rd_en<=0;
    end
    else if (intf.rd_en && (intf.full || !intf.empty))
    begin //read
        intf.data_out <= mem[rd_ptr];
        rd_ptr <= (rd_ptr == intf.FIFO_DEPTH-1) ? 0 :
rd_ptr + 1;//adding checker to check the wraparound
        rd_ptr <= rd_ptr + 1;
        intf.underflow<=0;
    end
        else if (intf.empty && intf.rd_en)
//bug==>adding underflow here not below
            intf.underflow  <= 1;
end

always @(posedge intf.clk or negedge intf.rst_n) begin
    if (!intf.rst_n) begin
        count <= 0;
```

```
    end
    else begin
        if  ( ({intf.wr_en, intf.rd_en} == 2'b10) &&
!intf.full)
            count <= count + 1;
        else if ( ({intf.wr_en, intf.rd_en} == 2'b01) &&
!intf.empty)
            count <= count - 1; //bug==>adding 2 cases
when write and read enable are asserted
        else if ( ({ intf.wr_en,  intf.rd_en} == 2'b11)
&& intf.full)
            count <= count - 1;
        else if ( ({ intf.wr_en,  intf.rd_en} == 2'b11)
&& intf.empty)
            count <= count + 1;

    end
end


assign intf.full = (count ==  intf.FIFO_DEPTH)? 1 : 0;
assign intf.empty = (count == 0)? 1 : 0;
assign intf.almostfull = (count ==  intf.FIFO_DEPTH-1)?
1 : 0; //bug FIFO_DEPTH-2 should be -1
assign intf.almostempty = (count == 1)? 1 : 0;

//Add assertions only in simulation, not in synthesis.
`ifdef SIM
//ASSERTIONS
always_comb begin
if(!intf.rst_n) begin
```

```
reset: assert final(count == 0 && wr_ptr==0 && rd_ptr==0
);
cvr_reset:cover final(count == 0 && wr_ptr==0 &&
rd_ptr==0);
end
end
property p1;
@(posedge intf.clk) disable iff(!intf.rst_n) (intf.wr_en
&& !intf.full) |=>(intf.wr_ack)
endproperty
wr_ack_assert: assert property(p1);
wr_ack_cvr: cover property(p1);

property p2;
@(posedge intf.clk) disable iff(!intf.rst_n) (intf.wr_en
&& intf.full) |=>(intf.overflow);
endproperty
overflow_assert: assert property(p2);
overflow_cvr: cover property(p2);

property p3;
@(posedge intf.clk) disable iff(!intf.rst_n) (intf.rd_en
&& intf.empty) |=>(intf.underflow);
endproperty
underflow_assert: assert property(p3);
underflow_cvr: cover property(p3);

property p4;
@(posedge intf.clk) disable iff(!intf.rst_n) (!count) |-
>(intf.empty);
endproperty
empty_assert: assert property(p4);
```

```
empty_cvr: cover property(p4);

property p5;
@(posedge intf.clk) disable iff(!intf.rst_n)
(count===intf.FIFO_DEPTH) |->(intf.full);
endproperty
full_assert: assert property(p5);
full_cvr: cover property(p5);

property p6;
@(posedge intf.clk) disable iff(!intf.rst_n)
(count===(intf.FIFO_DEPTH-1)) |->(intf.almostfull);
endproperty
almostfull_assert: assert property(p6);
almostfull_cvr: cover property(p6);

property p7;
@(posedge intf.clk) disable iff(!intf.rst_n) (count===1)
|->(intf.almostempty);
endproperty
almostempty_assert: assert property(p7);
almostempty_cvr: cover property(p7);

// Write pointer wraparound
property p8;
  @(posedge intf.clk) disable iff(!intf.rst_n)
    (wr_ptr == intf.FIFO_DEPTH-1 && intf.wr_en &&
!intf.full) |=> (wr_ptr == 0);
endproperty
pointer_wraparound_assert_write: assert property(p8);
pointer_wraparound_cvr_write:   cover property(p8);
```

```
// Read pointer wraparound
property p9;
  @(posedge intf.clk) disable iff(!intf.rst_n)
    (rd_ptr == intf.FIFO_DEPTH-1 && intf.rd_en &&
!intf.empty) |=> (rd_ptr == 0);
endproperty
pointer_wraparound_assert_read: assert property(p9);
pointer_wraparound_cvr_read:   cover property(p9);


property p10;
@(posedge intf.clk) disable iff(!intf.rst_n)
(wr_ptr<intf.FIFO_DEPTH) && (rd_ptr<intf.FIFO_DEPTH) &&
(count<=intf.FIFO_DEPTH);
endproperty
threshold_assert: assert property(p10);
threshold_cvr: cover property(p10);

`endif

endmodule
```

Interface:

```
interface fifo_intf#(parameter FIFO_WIDTH = 16,
parameter FIFO_DEPTH = 8)(clk);
//INPUTS
input bit clk;
bit [FIFO_WIDTH-1:0] data_in;
bit wr_en,rst_n,rd_en;
//OUTPUTS
logic [FIFO_WIDTH-1:0] data_out;
```

```
logic
full,empty,almostfull,almostempty,overflow,underflow,wr_
ack;

modport DUT (input clk,data_in,rst_n,wr_en,rd_en,
 output
data_out,wr_ack,overflow,full,empty,almostfull,almostemp
ty,underflow);

modport TEST (input
clk,data_out,wr_ack,overflow,full,empty,almostfull,almos
tempty,
underflow,output data_in,rst_n,wr_en,rd_en);

modport mon (input
clk,data_in,rst_n,wr_en,rd_en,data_out,wr_ack,overflow,f
ull,
empty,almostfull,almostempty,underflow);
endinterface
```

Top:

```
module top();
```

```
bit clk;
initial begin
clk=0;
forever #1 clk=~clk;
end

fifo_intf intf(clk);
FIFO DUT(intf);
FIFO_tb TEST(intf);
monitor mon(intf);
endmodule
```

Shared Package:

```
package shared_pkg;
bit test_finished;  // signal refer to the end of the
testbench
int error_count,correct_count;
event trigger;
endpackage
```

Transaction:

```
package transaction_pkg;
parameter FIFO_WIDTH = 16;
parameter FIFO_DEPTH = 8;
```

```
class FIFO_transaction;
//INPUTS
rand bit clk;
rand bit [FIFO_WIDTH-1:0] data_in;
rand bit wr_en,rst_n,rd_en;
//OUTPUTS
logic [FIFO_WIDTH-1:0] data_out;
logic
full,empty,almostfull,almostempty,overflow,underflow,wr_
ack;
int RD_EN_ON_DIST , WR_EN_ON_DIST;

//CONSTRUCTOR
function new(int Read=30, int Write=70);
RD_EN_ON_DIST=Read;
WR_EN_ON_DIST=Write;
endfunction
//CONSTRAINTS
constraint g{
    rst_n dist{1:/90,0:/10};
    wr_en dist{1:/WR_EN_ON_DIST, 0:/(100-
WR_EN_ON_DIST)};
    rd_en dist{1:/RD_EN_ON_DIST, 0:/(100-
RD_EN_ON_DIST)};
}
endclass
endpackage
```

Coverage Collector:

```
package func_pkg;
import transaction_pkg::*;
```

```
class FIFO_coverage ;

FIFO_transaction F_cvg_txn=new();

covergroup cvr_grp;

write_enable: coverpoint F_cvg_txn.wr_en {
    bins wr_enable_low={0};
    bins wr_enable_high={1};
}
read_enable: coverpoint F_cvg_txn.rd_en{
    bins rd_enable_low={0};
    bins rd_enable_high={1};
}
FULL: coverpoint F_cvg_txn.full{
    bins Full_low={0};
    bins Full_high={1};
}
EMPTY: coverpoint F_cvg_txn.empty{
    bins Empty_low={0};
    bins Empty_high={1};
}
ALMOSTFULL: coverpoint F_cvg_txn.almostfull{
    bins Almostfull_low={0};
    bins Almostfull_high={1};
}
ALMOSTEMPTY: coverpoint F_cvg_txn.almostempty{
    bins Almostempty_low={0};
    bins Almostempty_high={1};
}
OVERFLOW: coverpoint F_cvg_txn.overflow{
    bins Overflow_low={0};
```

```
    bins Overflow_high={1};
}
UNDERFLOW: coverpoint F_cvg_txn.underflow{
    bins Underflow_low={0};
    bins Underflow_high={1};
}
Write_ack: coverpoint F_cvg_txn.wr_ack{
    bins write_acknowledge_low={0};
    bins write_acknowledge_high={1};
}

rd_en_with_wr_enable_full: cross read_enable,
write_enable, FULL {
    ignore_bins read_enable_with_full_high=
       binsof(read_enable) intersect {1} && binsof(FULL)
intersect {1};
}

rd_en_with_wr_enable_empty: cross
read_enable,write_enable,EMPTY{
    ignore_bins write_enable_with_empty_high=
       binsof(write_enable) intersect {1} &&
binsof(EMPTY) intersect {1};
       }
rd_en_with_wr_enable_almostfull: cross read_enable,
write_enable,ALMOSTFULL;
rd_en_with_wr_enable_almostempty: cross
read_enable,write_enable,ALMOSTEMPTY;
rd_en_with_wr_enable_underflow: cross read_enable,
write_enable, UNDERFLOW {
   ignore_bins read_with_underflow =
       binsof(read_enable) intersect {0} &&
```

```
        binsof(UNDERFLOW) intersect {1};
}

rd_en_with_wr_enable_overflow: cross read_enable,
write_enable, OVERFLOW {
   ignore_bins write_with_overflow =
        binsof(write_enable) intersect {0} &&
        binsof(OVERFLOW) intersect {1};
}

rd_en_with_wr_enable_wr_ack: cross read_enable,
write_enable, Write_ack {
   ignore_bins write_with_wr_ack =
        binsof(write_enable) intersect {0} &&
        binsof(Write_ack) intersect {1};
}
endgroup
//CONSTRUCTOR
function new();
cvr_grp=new();
endfunction

function void sample_data(FIFO_transaction F_txn);
F_cvg_txn=F_txn;
cvr_grp.sample();
endfunction
endclass
endpackage
```

Testbench:

```
import scoreboard_pkg::*;
```

```
import transaction_pkg::*;
import shared_pkg::*;
module FIFO_tb(fifo_intf.TEST intf);
FIFO_transaction fifo_tr;
integer i;

initial begin
    fifo_tr=new();
            intf.rst_n = 1;
            intf.rst_n = 0;
            -> trigger;
         @(negedge intf.clk);
            intf.rst_n = 1;
        //READ
        for (i=0;i<10000;i=i+1)begin
        assert(fifo_tr.randomize());
        intf.data_in=fifo_tr.data_in;
        intf.rst_n = fifo_tr.rst_n;
        intf.rd_en = fifo_tr.rd_en;
        intf.wr_en = fifo_tr.wr_en;
        -> trigger;
        $display("rd_en=%d,wr_en=%d",fifo_tr.rd_en,fifo_tr.wr_e
n);
        @(negedge intf.clk);
        end
    test_finished=1;
    -> trigger;
    end
endmodule
```

Scoreboard:

```
package scoreboard_pkg;
import transaction_pkg::*;
```

```
import shared_pkg::*;
import func_pkg::*;
class FIFO_scoreboard;
localparam max_fifo_addr = $clog2(FIFO_DEPTH);
logic [FIFO_WIDTH-1:0] data_out_ref;
logic
full_ref,empty_ref,almostfull_ref,almostempty_ref,overfl
ow_ref,underflow_ref,wr_ack_ref;
reg [FIFO_WIDTH-1:0] mem [FIFO_DEPTH-1:0];
reg [max_fifo_addr-1:0] wr_ptr, rd_ptr;
reg [max_fifo_addr:0] count;

function void comb_flags();
   full_ref       = (count == FIFO_DEPTH) ? 1 : 0;
   empty_ref      = (count == 0) ? 1 : 0;
   almostfull_ref = (count == FIFO_DEPTH-1) ? 1 : 0;
   almostempty_ref= (count == 1) ? 1 : 0;
endfunction



function void check_data(FIFO_transaction tr);
      // Run the reference model
      reference_model(tr);
      if((data_out_ref==tr.data_out)&&({full_ref,empty_r
ef,almostfull_ref,almostempty_ref,underflow_ref,overflow
_ref}=={tr.full,tr.empty,tr.almostfull,tr.almostempty,tr
.underflow,tr.overflow}))
      begin
            correct_count++;
$display("rst_n=%0d data_in=%0d data_out=%0d
data_out_ref=%0d wr_ack=%0d wr_ack_ref=%0d overflow=%0d
```

```
overflow_ref=%0d full=%0d full_ref=%0d empty=%0d
empty_ref=%0d almostfull=%0d almostfull_ref=%0d
almostempty=%0d almostempty_ref=%0d underflow=%0d
underflow_ref=%0d wr_en=%0d rd_en=%0d count=%0d",
         tr.rst_n, tr.data_in, tr.data_out,
data_out_ref,
         tr.wr_ack, wr_ack_ref, tr.overflow,
overflow_ref,
         tr.full, full_ref, tr.empty, empty_ref,
         tr.almostfull, almostfull_ref, tr.almostempty,
almostempty_ref,
         tr.underflow, underflow_ref, tr.wr_en,
tr.rd_en, count);


      end
      else begin
             error_count++;
            $display("Error ==> correct_count=%d,
error_count=%d, data_in=%d, data_out_ref=%d,
tr.data_out=%d
",correct_count,error_count,tr.data_in,data_out_ref,tr.d
ata_out);
      end
endfunction

function void reference_model(FIFO_transaction ref_tr);

//REFRENCE FOR WRITE
if (!ref_tr.rst_n) begin
            wr_ptr=0;
            full_ref=0;
```

```
            wr_ack_ref=0;
            empty_ref=1;
            overflow_ref=0;

      end
      else if (ref_tr.wr_en && !full_ref)
      begin
            mem[wr_ptr] = ref_tr.data_in;
            wr_ack_ref = 1;
            wr_ptr <= wr_ptr + 1;
            overflow_ref=0;
      end
      else begin
            wr_ack_ref = 0;
            if (full_ref & ref_tr.wr_en)
                  overflow_ref = 1;
            else
                  overflow_ref = 0;
      end

//REFRENCE FOR READ
      if (!ref_tr.rst_n) begin
            rd_ptr = 0;
            data_out_ref = 0;
            empty_ref = 1;
            almostempty_ref = 0;
            underflow_ref = 0;
      end
      else if(empty_ref && ref_tr.rd_en)
                  underflow_ref  = 1;
      else if (ref_tr.rd_en && !empty_ref ) begin
            data_out_ref = mem[rd_ptr];
```

```
            rd_ptr = rd_ptr + 1;
            underflow_ref=0;
      end

//COUNTER
if (!ref_tr.rst_n) begin
            count = 0;
      end
      else begin
            if    ( ({ref_tr.wr_en, ref_tr.rd_en} ==
2'b10) && !full_ref)
                  count = count + 1;
            else if ( ({ref_tr.wr_en, ref_tr.rd_en} ==
2'b01) && !empty_ref)
                  count = count - 1;
            else if     ( ({ref_tr.wr_en, ref_tr.rd_en}
== 2'b11) && empty_ref)
                  count = count + 1;
            else if     ( ({ref_tr.wr_en, ref_tr.rd_en}
== 2'b11) && full_ref)
                  count = count - 1;

      end
      //calling flags
            comb_flags();
endfunction
endclass
endpackage
```

Monitor:

```
import shared_pkg::*;
```

```
import transaction_pkg::*;
import scoreboard_pkg::*;
import func_pkg::*;
module monitor(fifo_intf.mon intf);

FIFO_transaction tr= new();
FIFO_scoreboard sb= new();
FIFO_coverage cov= new();

initial begin
    forever begin

        wait (trigger.triggered);
            @(negedge intf.clk);
            //input
            tr.data_in=intf.data_in;
            tr.wr_en=intf.wr_en;
            tr.rst_n=intf.rst_n;
            tr.rd_en=intf.rd_en;
            //output
            tr.data_out=intf.data_out;
            tr.full=intf.full;
            tr.empty=intf.empty;
            tr.almostfull=intf.almostfull;
            tr.almostempty=intf.almostempty;
            tr.overflow=intf.overflow;
            tr.underflow=intf.underflow;
            tr.wr_ack=intf.wr_ack;




fork

        //PROCESS_1
```

```
        begin
        cov.sample_data(tr);
        end
        //PROCESS_2
        begin
        sb.check_data(tr);
        end

join
    if (test_finished==1)begin
    //$display("tr.data_in=%d,intf.data_in=%d,tr.data_out=%d,in
tf.data_out=%d",tr.data_in,intf.data_in,tr.data_out,intf.data_o
ut);
     $display("error_count=%d,
correct_count=%d",error_count,correct_count);
     $stop;
                end
        end
    end
endmodule
```

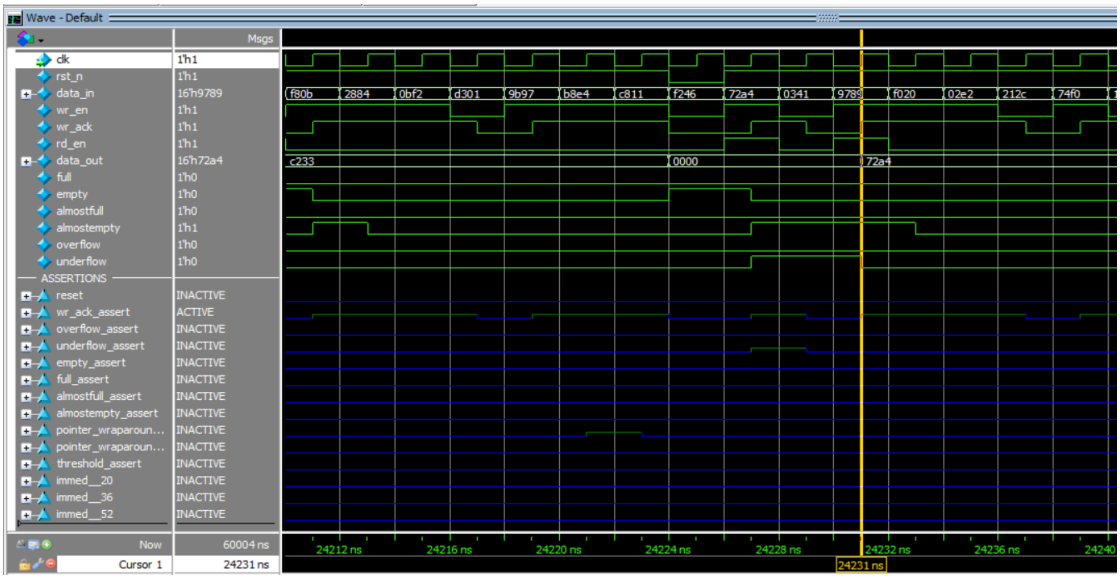
```
# rst_n=1 data_in=19573 data_out=7417 data_out_ref=7417 wr_ack=0 wr_ack_ref=0 overflow=0 overflow_ref=0 full=1 full_ref=1 empty=0 empty_ref=0 almostfull=0 almostfull_ref=0 almostempty=0 almostempty_ref=0 underflow=0
 underflow_ref=0 wr_en=0 rd_en=0 count=8
# rst_n=1 data_in=34853 data_out=7417 data_out_ref=7417 wr_ack=0 wr_ack_ref=0 overflow=1 overflow_ref=1 full=1 full_ref=1 empty=0 empty_ref=0 almostfull=0 almostfull_ref=0 almostempty=0 almostempty_ref=0 underflow=0
 underflow_ref=0 wr_en=1 rd_en=0 count=8
# rst_n=1 data_in=11814 data_out=7417 data_out_ref=7417 wr_ack=0 wr_ack_ref=0 overflow=0 overflow_ref=0 full=1 full_ref=1 empty=0 empty_ref=0 almostfull=0 almostfull_ref=0 almostempty=0 almostempty_ref=0 underflow=0
 underflow_ref=0 wr_en=0 rd_en=0 count=8
# rst_n=1 data_in=33242 data_out=7417 data_out_ref=7417 wr_ack=0 wr_ack_ref=0 overflow=1 overflow_ref=1 full=1 full_ref=1 empty=0 empty_ref=0 almostfull=0 almostfull_ref=0 almostempty=0 almostempty_ref=0 underflow=0
 underflow_ref=0 wr_en=1 rd_en=0 count=8
# rst_n=1 data_in=37631 data_out=7417 data_out_ref=7417 wr_ack=0 wr_ack_ref=0 overflow=0 overflow_ref=0 full=1 full_ref=1 empty=0 empty_ref=0 almostfull=0 almostfull_ref=0 almostempty=0 almostempty_ref=0 underflow=0
 underflow_ref=0 wr_en=0 rd_en=0 count=8
# rst_n=1 data_in=15871 data_out=7417 data_out_ref=7417 wr_ack=0 wr_ack_ref=0 overflow=1 overflow_ref=1 full=1 full_ref=1 empty=0 empty_ref=0 almostfull=0 almostfull_ref=0 almostempty=0 almostempty_ref=0 underflow=0
 underflow_ref=0 wr_en=1 rd_en=0 count=8
# rst_n=1 data_in=1720 data_out=7417 data_out_ref=7417 wr_ack=0 wr_ack_ref=0 overflow=1 overflow_ref=1 full=1 full_ref=1 empty=0 empty_ref=0 almostfull=0 almostfull_ref=0 almostempty=0 almostempty_ref=0 underflow=0
underflow_ref=0 wr_en=1 rd_en=0 count=8
# rst_n=1 data_in=20853 data_out=7417 data_out_ref=7417 wr_ack=0 wr_ack_ref=0 overflow=1 overflow_ref=1 full=1 full_ref=1 empty=0 empty_ref=0 almostfull=0 almostfull_ref=0 almostempty=0 almostempty_ref=0 underflow=0
 underflow_ref=0 wr_en=1 rd_en=0 count=8
# rst_n=1 data_in=44157 data_out=7417 data_out_ref=7417 wr_ack=0 wr_ack_ref=0 overflow=0 overflow_ref=0 full=1 full_ref=1 empty=0 empty_ref=0 almostfull=0 almostfull_ref=0 almostempty=0 almostempty_ref=0 underflow=0
 underflow_ref=0 wr_en=0 rd_en=0 count=8
# rst_n=1 data_in=20158 data_out=10954 data_out_ref=10954 wr_ack=0 wr_ack_ref=0 overflow=1 overflow_ref=1 full=0 full_ref=0 empty=0 empty_ref=0 almostfull=1 almostfull_ref=1 almostempty=0 almostempty_ref=0 underflow
=0 underflow_ref=0 wr_en=1 rd_en=1 count=7
# rst_n=1 data_in=4529 data_out=10954 data_out_ref=10954 wr_ack=1 wr_ack_ref=1 overflow=0 overflow_ref=0 full=1 full_ref=1 empty=0 empty_ref=0 almostfull=0 almostfull_ref=0 almostempty=0 almostempty_ref=0 underflow=
0 underflow_ref=0 wr_en=1 rd_en=0 count=8
# rst_n=1 data_in=38863 data_out=10954 data_out_ref=10954 wr_ack=0 wr_ack_ref=0 overflow=1 overflow_ref=1 full=1 full_ref=1 empty=0 empty_ref=0 almostfull=0 almostfull_ref=0 almostempty=0 almostempty_ref=0 underflow
=0 underflow_ref=0 wr_en=1 rd_en=0 count=8
# rst_n=1 data_in=2443 data_out=10954 data_out_ref=10954 wr_ack=0 wr_ack_ref=0 overflow=1 overflow_ref=1 full=1 full_ref=1 empty=0 empty_ref=0 almostfull=0 almostfull_ref=0 almostempty=0 almostempty_ref=0 underflow=
0 underflow_ref=0 wr_en=1 rd_en=0 count=8
# rst_n=1 data_in=23036 data_out=10954 data_out_ref=10954 wr_ack=0 wr_ack_ref=0 overflow=1 overflow_ref=1 full=1 full_ref=1 empty=0 empty_ref=0 almostfull=0 almostfull_ref=0 almostempty=0 almostempty_ref=0 underflow
=0 underflow_ref=0 wr_en=1 rd_en=0 count=8
# rst_n=1 data_in=27578 data_out=43737 data_out_ref=43737 wr_ack=0 wr_ack_ref=0 overflow=1 overflow_ref=1 full=0 full_ref=0 empty=0 empty_ref=0 almostfull=1 almostfull_ref=1 almostempty=0 almostempty_ref=0 underflow
=0 underflow_ref=0 wr_en=1 rd_en=1 count=7
```

Transcript:

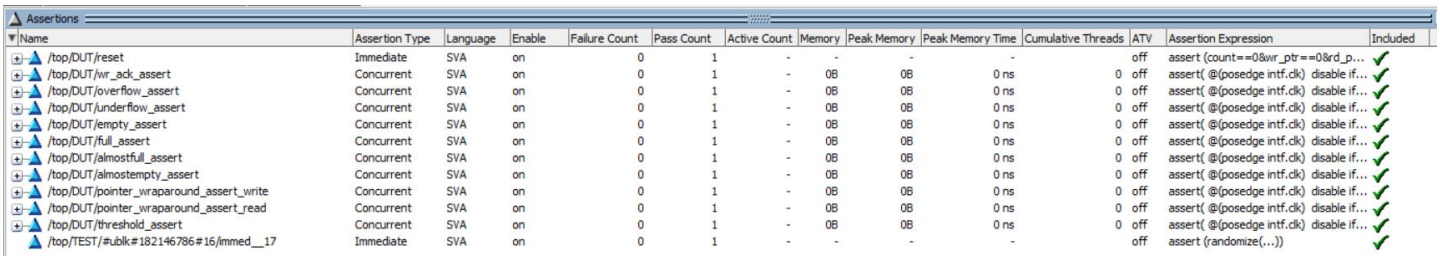
Do file:

```
vlib work
vlog +define+SIM shared_pkg.sv interface.sv FIFO.sv FIFO_TRANSACTIONS.sv func_cov_collection.sv  Monitor.sv  scoreboard.sv testbench_fifo.sv
top.sv +cover -covercells
vsim -voptargs=+acc work.top -cover
coverage save FIFO.ucdb -onexit -du work.FIFO
add wave -position insertpoint sim:/top/intf/*
add wave /top/DUT/reset /top/DUT/wr_ack_assert /top/DUT/overflow_assert /top/DUT/underflow_assert /top/DUT/empty_assert /top/DUT/full_assert
/top/DUT/almostfull_assert /top/DUT/almostempty_assert /top/DUT/pointer_wraparound_assert_write /top/DUT/pointer_wraparound_assert_read
/top/DUT/threshold_assert /top/TEST/#ublk#182146786#19/immed__20 /top/TEST/#ublk#182146786#35/immed__36 /top/TEST/#ublk#182146786#51/immed__52
run -all
coverage report -detail -cvg -directive -comments -file F_cover_fifo.txt -noa -all
quit -sim
vcover report FIFO.ucdb -details -all -output coverage_rpt_FIFO.txt
```

Simulation:



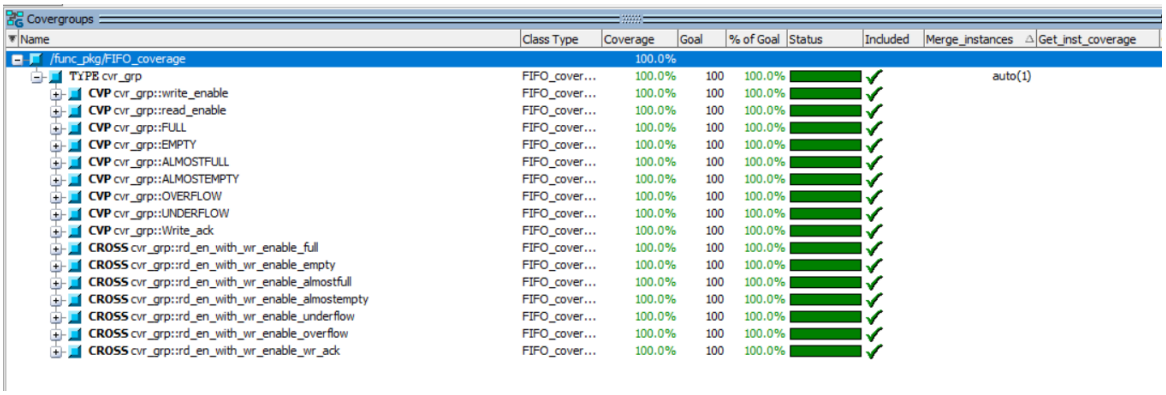
Assertions:



Assertions

Name	Assertion Type	Language	Enable	Failure Count	Pass Count	Active Count	Memory	Peak Memory	Peak Memory Time	Cumulative Threads	ATV	Assertion Expression	Included
/top/DUT/reset	Immediate	SVA	on	0	1	-	-	-	-		off	assert (count==0&wr_ptr==0&rd_p...	✓
/top/DUT/wr_ack_assert	Concurrent	SVA	on	0	1	-	0B	0B	0 ns	0	off	assert(@(posedge intf.clk) disable if...	✓
/top/DUT/overflow_assert	Concurrent	SVA	on	0	1	-	0B	0B	0 ns	0	off	assert(@(posedge intf.clk) disable if...	✓
/top/DUT/underflow_assert	Concurrent	SVA	on	0	1	-	0B	0B	0 ns	0	off	assert(@(posedge intf.clk) disable if...	✓
/top/DUT/empty_assert	Concurrent	SVA	on	0	1	-	0B	0B	0 ns	0	off	assert(@(posedge intf.clk) disable if...	✓
/top/DUT/full_assert	Concurrent	SVA	on	0	1	-	0B	0B	0 ns	0	off	assert(@(posedge intf.clk) disable if...	✓
/top/DUT/almostfull_assert	Concurrent	SVA	on	0	1	-	0B	0B	0 ns	0	off	assert(@(posedge intf.clk) disable if...	✓
/top/DUT/almostempty_assert	Concurrent	SVA	on	0	1	-	0B	0B	0 ns	0	off	assert(@(posedge intf.clk) disable if...	✓
/top/DUT/pointer_wraparound_assert_write	Concurrent	SVA	on	0	1	-	0B	0B	0 ns	0	off	assert(@(posedge intf.clk) disable if...	✓
/top/DUT/pointer_wraparound_assert_read	Concurrent	SVA	on	0	1	-	0B	0B	0 ns	0	off	assert(@(posedge intf.clk) disable if...	✓
/top/DUT/threshold_assert	Concurrent	SVA	on	0	1	-	0B	0B	0 ns	0	off	assert(@(posedge intf.clk) disable if...	✓
/top/TEST/#ublk#182146786#16/immed__17	Immediate	SVA	on	0	1	-	-	-	-		off	assert (randomize(...))	✓

Functional coverage:



Covergroups

Name	Class Type	Coverage	Goal	% of Goal	Status	Included	Merge_instances	Get_inst_coverage
/func_pkg/FIFO_coverage		100.0%						
TYPE cvr_grp	FIFO_cover...	100.0%	100	100.0%		✓	auto(1)	
CVP cvr_grp::write_enable	FIFO_cover...	100.0%	100	100.0%		✓		
CVP cvr_grp::read_enable	FIFO_cover...	100.0%	100	100.0%		✓		
CVP cvr_grp::FULL	FIFO_cover...	100.0%	100	100.0%		✓		
CVP cvr_grp::EMPTY	FIFO_cover...	100.0%	100	100.0%		✓		
CVP cvr_grp::ALMOSTFULL	FIFO_cover...	100.0%	100	100.0%		✓		
CVP cvr_grp::ALMOSTEMPTY	FIFO_cover...	100.0%	100	100.0%		✓		
CVP cvr_grp::OVERFLOW	FIFO_cover...	100.0%	100	100.0%		✓		
CVP cvr_grp::UNDERFLOW	FIFO_cover...	100.0%	100	100.0%		✓		
CVP cvr_grp::Write_ack	FIFO_cover...	100.0%	100	100.0%		✓		
CROSS cvr_grp::rd_en_with_wr_enable_full	FIFO_cover...	100.0%	100	100.0%		✓		
CROSS cvr_grp::rd_en_with_wr_enable_empty	FIFO_cover...	100.0%	100	100.0%		✓		
CROSS cvr_grp::rd_en_with_wr_enable_almostfull	FIFO_cover...	100.0%	100	100.0%		✓		
CROSS cvr_grp::rd_en_with_wr_enable_almostempty	FIFO_cover...	100.0%	100	100.0%		✓		
CROSS cvr_grp::rd_en_with_wr_enable_underflow	FIFO_cover...	100.0%	100	100.0%		✓		
CROSS cvr_grp::rd_en_with_wr_enable_overflow	FIFO_cover...	100.0%	100	100.0%		✓		
CROSS cvr_grp::rd_en_with_wr_enable_wr_ack	FIFO_cover...	100.0%	100	100.0%		✓		

Reports:

Code coverage & Assertions:

Statement details:

```
Coverage Report by file with details

================================================================================
=== File: FIFO.sv
================================================================================
Statement Coverage:
    Enabled Coverage            Active      Hits    Misses % Covered
    ----------------            ------      ----    ------ ---------
    Stmts                           38        38         0     100.0

==============================Statement Details==============================

Statement Coverage for file FIFO.sv --

    1                                           module FIFO(fifo_intf.DUT intf);
    2                                           localparam max_fifo_addr = $clog2( intf.FIFO_DEPTH); //ceiling log with base 2
    3                                           //Depth mem word
    4                                           reg [ intf.FIFO_WIDTH-1:0] mem [intf.FIFO_DEPTH-1:0];
    5
    6                                           reg [max_fifo_addr-1:0] wr_ptr, rd_ptr;
    7                                           reg [max_fifo_addr:0] count; //4-bits
    8                                           //WRITE
    9               1                   32613   always @(posedge intf.clk or negedge intf.rst_n) begin
    10                                             if (!intf.rst_n) begin
    11              1                    5522                wr_ptr <= 0;
    12              1                    5522                intf.overflow<=0;
    13              1                    5522                intf.wr_ack<=0;
    14              1                    5522                intf.wr_en<=0;
    15                                             end
    16                                             else if(intf.wr_en && intf.rd_en && intf.empty )begin
    17              1                    1134                mem[wr_ptr] <= intf.data_in;
    18              1                    1134                intf.wr_ack <= 1;
    19              1                    1134                wr_ptr <= wr_ptr + 1;
    20              1                    1134                intf.overflow<=0;
    21
    22                                             end
    23                                             else if (intf.wr_en && !intf.full)
    24                                              begin
    25              1                   14922                mem[wr_ptr] <= intf.data_in;
    26              1                   14922                intf.wr_ack <= 1;
    27              1                   14922                wr_ptr <= (wr_ptr == intf.FIFO_DEPTH-1) ? 0 : wr_ptr + 1;//adding checker to check the wraparound
    28              1                   14922                wr_ptr <= wr_ptr + 1;
    29              1                   14922                intf.overflow<=0;
    30                                             end
    31                                             else begin
    32              1                   11035                intf.wr_ack <= 0;
    33                                                       if (intf.full && intf.wr_en)
    34              1                    1120                       intf.overflow <= 1;
    35                                                       else
    36              1                    9915                       intf.overflow <= 0;
    37                                             end
    38                                          end
    39                                          //READ
    40              1                   32613   always @(posedge intf.clk or negedge intf.rst_n) begin
    41                                             if (!intf.rst_n) begin
    42              1                    5522                rd_ptr <= 0;
    43              1                    5522                intf.underflow<=0;
    44              1                    5522                intf.data_out<=0;
```

```
45          1                   5522                intf.rd_en<=0;
46                                                  end
47                                                  else if (intf.rd_en && (intf.full || !intf.empty))
48                                                  begin //read
49          1                   8208                intf.data_out <= mem[rd_ptr];
50          1                   8208                rd_ptr <= (rd_ptr == intf.FIFO_DEPTH-1) ? 0 : rd_ptr + 1;//adding checker to check the wraparound
51          1                   8208                rd_ptr <= rd_ptr + 1;
52          1                   8208                intf.underflow<=0;
53                                                  end
54                                                  else if (intf.empty && intf.rd_en) //bug==>adding underflow here not below
55          1                   1857                    intf.underflow  <= 1;
56                                              end
57
58          1                  29495            always @(posedge intf.clk or negedge intf.rst_n) begin
59                                                 if (!intf.rst_n) begin
60          1                   5469                      count <= 0;
61                                                 end
62                                                 else begin
63                                                      if      ( ({intf.wr_en, intf.rd_en} == 2'b10) && !intf.full)
64          1                   9944                        count <= count + 1;
65                                                      else if ( ({intf.wr_en, intf.rd_en} == 2'b01) && !intf.empty)
66          1                   2862                        count <= count - 1; //bug==>adding 2 cases when write and read enable are asserted
67                                                      else if ( ({ intf.wr_en,  intf.rd_en} == 2'b11) && intf.full)
68          1                    368                       count <= count - 1;
69                                                    else if ( ({ intf.wr_en,  intf.rd_en} == 2'b11) && intf.empty)
70          1                   1134                       count <= count + 1;
71
72                                                 end
73                                              end
74
75
76          1                  16634            assign intf.full = (count ==  intf.FIFO_DEPTH)? 1 : 0;
77          1                  16634            assign intf.empty = (count == 0)? 1 : 0;
78          1                  16634            assign intf.almostfull = (count ==  intf.FIFO_DEPTH-1)? 1 : 0; //bug FIFO_DEPTH-2 should be -1
79          1                  16634            assign intf.almostempty = (count == 1)? 1 : 0;
80
81                                               //Add assertions only in simulation, not in synthesis.
82                                               `ifdef SIM
83                                               //ASSERTIONS
84          1                  26964            always_comb begin
85                                               if(!intf.rst_n) begin
86                                               reset: assert final(count == 0 && wr_ptr==0 && rd_ptr==0 );
87                                               cvr_reset:cover final(count == 0 && wr_ptr==0 && rd_ptr==0);
88                                               end
89                                               end
90                                               property p1;
91                                               @(posedge intf.clk) disable iff(!intf.rst_n) (intf.wr_en && !intf.full) |=>(intf.wr_ack)
92                                               endproperty
93                                               wr_ack_assert: assert property(p1);
94                                               wr_ack_cvr: cover property(p1);
95
96                                               property p2;
97                                               @(posedge intf.clk) disable iff(!intf.rst_n) (intf.wr_en && intf.full) |=>(intf.overflow);
98                                               endproperty
99                                               overflow_assert: assert property(p2);
100                                              overflow_cvr: cover property(p2);
101
102                                              property p3;
103                                              @(posedge intf.clk) disable iff(!intf.rst_n) (intf.rd_en && intf.empty) |=>(intf.underflow);
```

```
                                        @(posedge intf.clk) disable iff(!intf.rst_n) (intf.rd_en && intf.empty) |=>(intf.underflow);
                                        endproperty
                                        underflow_assert: assert property(p3);
                                        underflow_cvr: cover property(p3);

                                        property p4;
                                        @(posedge intf.clk) disable iff(!intf.rst_n) (!count) |->(intf.empty);
                                        endproperty
                                        empty_assert: assert property(p4);
                                        empty_cvr: cover property(p4);

                                        property p5;
                                        @(posedge intf.clk) disable iff(!intf.rst_n) (count===intf.FIFO_DEPTH) |->(intf.full);
                                        endproperty
                                        full_assert: assert property(p5);
                                        full_cvr: cover property(p5);

                                        property p6;
                                        @(posedge intf.clk) disable iff(!intf.rst_n) (count===(intf.FIFO_DEPTH-1)) |->(intf.almostfull);
                                        endproperty
                                        almostfull_assert: assert property(p6);
                                        almostfull_cvr: cover property(p6);

                                        property p7;
                                        @(posedge intf.clk) disable iff(!intf.rst_n) (count===1) |->(intf.almostempty);
                                        endproperty
                                        almostempty_assert: assert property(p7);
                                        almostempty_cvr: cover property(p7);

                                        // Write pointer wraparound
                                        property p8;
                                          @(posedge intf.clk) disable iff(!intf.rst_n)
                                             (wr_ptr == intf.FIFO_DEPTH-1 && intf.wr_en && !intf.full) |=> (wr_ptr == 0);
                                        endproperty
                                        pointer_wraparound_assert_write: assert property(p8);
                                        pointer_wraparound_cvr_write:   cover property(p8);

                                        // Read pointer wraparound
                                        property p9;
                                          @(posedge intf.clk) disable iff(!intf.rst_n)
                                             (rd_ptr == intf.FIFO_DEPTH-1 && intf.rd_en && !intf.empty) |=> (rd_ptr == 0);
                                        endproperty
                                        pointer_wraparound_assert_read: assert property(p9);
                                        pointer_wraparound_cvr_read:   cover property(p9);


                                        property p10;
                                        @(posedge intf.clk) disable iff(!intf.rst_n) (wr_ptr<intf.FIFO_DEPTH) && (rd_ptr<intf.FIFO_DEPTH) && (count<=intf.FIFO_DEPTH);
                                        endproperty
                                        threshold_assert: assert property(p10);
                                        threshold_cvr: cover property(p10);

                                        `endif

                                        endmodule

Branch Coverage:
    Enabled Coverage           Active      Hits    Misses % Covered
    ----------------           ------      ----    ------ ---------
    Branches                       31        31         0     100.0
```

Branch details:

```
================================Branch Details================================

Branch Coverage for file FIFO.sv --

------------------------------------IF Branch------------------------------------
    10                                  32613     Count coming in to IF
    10              1                    5522       if (!intf.rst_n) begin
    16              1                    1134       else if(intf.wr_en && intf.rd_en && intf.empty )begin
    23              1                   14922       else if (intf.wr_en && !intf.full)
    31              1                   11035       else begin
Branch totals: 4 hits of 4 branches = 100.0%

------------------------------------IF Branch------------------------------------
    27                                  14922     Count coming in to IF
    27              1                    1041               wr_ptr <= (wr_ptr == intf.FIFO_DEPTH-1) ? 0 : wr_ptr + 1;//adding checker to check the wraparound
    27              2                   13881               wr_ptr <= (wr_ptr == intf.FIFO_DEPTH-1) ? 0 : wr_ptr + 1;//adding checker to check the wraparound
Branch totals: 2 hits of 2 branches = 100.0%

------------------------------------IF Branch------------------------------------
    33                                  11035     Count coming in to IF
    33              1                    1120               if (intf.full && intf.wr_en)
    35              1                    9915               else
Branch totals: 2 hits of 2 branches = 100.0%

------------------------------------IF Branch------------------------------------
    41                                  32613     Count coming in to IF
    41              1                    5522       if (!intf.rst_n) begin
    47              1                    8208       else if (intf.rd_en && (intf.full || !intf.empty))
    54              1                    1857               else if (intf.empty && intf.rd_en) //bug==>adding underflow here not below
                                        17026     All False Count
Branch totals: 4 hits of 4 branches = 100.0%

------------------------------------IF Branch------------------------------------
    50                                   8208     Count coming in to IF
    50              1                     355               rd_ptr <= (rd_ptr == intf.FIFO_DEPTH-1) ? 0 : rd_ptr + 1;//adding checker to check the wraparound
    50              2                    7853               rd_ptr <= (rd_ptr == intf.FIFO_DEPTH-1) ? 0 : rd_ptr + 1;//adding checker to check the wraparound
Branch totals: 2 hits of 2 branches = 100.0%

------------------------------------IF Branch------------------------------------
    59                                  29495     Count coming in to IF
    59              1                    5469       if (!intf.rst_n) begin
    62              1                   24026       else begin
Branch totals: 2 hits of 2 branches = 100.0%

------------------------------------IF Branch------------------------------------
    63                                  24026     Count coming in to IF
    63              1                    9944               if      ( ({intf.wr_en, intf.rd_en} == 2'b10) && !intf.full)
    65              1                    2862               else if ( ({intf.wr_en, intf.rd_en} == 2'b01) && !intf.empty)
    67              1                     368               else if ( ({ intf.wr_en,  intf.rd_en} == 2'b11) && intf.full)
    69              1                    1134             else if ( ({ intf.wr_en,  intf.rd_en} == 2'b11) && intf.empty)
                                         9718     All False Count
Branch totals: 5 hits of 5 branches = 100.0%
```

```
------------------------------------IF Branch------------------------------------
    76                                  16633     Count coming in to IF
    76              1                     745     assign intf.full = (count ==  intf.FIFO_DEPTH)? 1 : 0;
    76              2                   15888     assign intf.full = (count ==  intf.FIFO_DEPTH)? 1 : 0;
Branch totals: 2 hits of 2 branches = 100.0%

------------------------------------IF Branch------------------------------------
    77                                  16633     Count coming in to IF
    77              1                    3119     assign intf.empty = (count == 0)? 1 : 0;
    77              2                   13514     assign intf.empty = (count == 0)? 1 : 0;
Branch totals: 2 hits of 2 branches = 100.0%

------------------------------------IF Branch------------------------------------
    78                                  16633     Count coming in to IF
    78              1                    1139     assign intf.almostfull = (count ==  intf.FIFO_DEPTH-1)? 1 : 0; //bug FIFO_DEPTH-2 should be -1
    78              2                   15494     assign intf.almostfull = (count ==  intf.FIFO_DEPTH-1)? 1 : 0; //bug FIFO_DEPTH-2 should be -1
Branch totals: 2 hits of 2 branches = 100.0%

------------------------------------IF Branch------------------------------------
    79                                  16633     Count coming in to IF
    79              1                    3669     assign intf.almostempty = (count == 1)? 1 : 0;
    79              2                   12964     assign intf.almostempty = (count == 1)? 1 : 0;
Branch totals: 2 hits of 2 branches = 100.0%

------------------------------------IF Branch------------------------------------
    85                                  26964     Count coming in to IF
    85              1                    5067     if(!intf.rst_n) begin
                                        21897     All False Count
Branch totals: 2 hits of 2 branches = 100.0%


Condition Coverage:
    Enabled Coverage            Active   Covered    Misses % Covered
    ----------------            ------   -------    ------ ---------
    FEC Condition Terms              24        24         0     100.0
```

Condition details:

```
================================Condition Details================================

Condition Coverage for file FIFO.sv --

----------------Focused Condition View-------------------
Line       16 Item    1  ((intf.wr_en && intf.rd_en) && intf.empty)
Condition totals: 3 of 3 input terms covered = 100.0%

  Input Term   Covered  Reason for no coverage   Hint
 -----------  --------  ----------------------  --------------
  intf.wr_en         Y
  intf.rd_en         Y
  intf.empty         Y

     Rows:       Hits  FEC Target            Non-masking condition(s)
 ---------  ---------  --------------------  -------------------------
  Row   1:          1  intf.wr_en_0          -
  Row   2:          1  intf.wr_en_1          (intf.empty && intf.rd_en)
  Row   3:          1  intf.rd_en_0          intf.wr_en
  Row   4:          1  intf.rd_en_1          (intf.empty && intf.wr_en)
  Row   5:          1  intf.empty_0          (intf.wr_en && intf.rd_en)
  Row   6:          1  intf.empty_1          (intf.wr_en && intf.rd_en)

----------------Focused Condition View-------------------
Line       23 Item    1  (intf.wr_en && ~intf.full)
Condition totals: 2 of 2 input terms covered = 100.0%

  Input Term   Covered  Reason for no coverage   Hint
 -----------  --------  ----------------------  --------------
  intf.wr_en         Y
   intf.full         Y

     Rows:       Hits  FEC Target            Non-masking condition(s)
 ---------  ---------  --------------------  -------------------------
  Row   1:          1  intf.wr_en_0          -
  Row   2:          1  intf.wr_en_1          ~intf.full
  Row   3:          1  intf.full_0           intf.wr_en
  Row   4:          1  intf.full_1           intf.wr_en
```

```
----------------Focused Condition View-------------------
Line       33 Item    1  (intf.full && intf.wr_en)
Condition totals: 2 of 2 input terms covered = 100.0%

  Input Term   Covered  Reason for no coverage   Hint
 -----------  --------  ----------------------  --------------
   intf.full         Y
  intf.wr_en         Y

     Rows:       Hits  FEC Target            Non-masking condition(s)
 ---------  ---------  --------------------  -------------------------
  Row   1:          1  intf.full_0           -
  Row   2:          1  intf.full_1           intf.wr_en
  Row   3:          1  intf.wr_en_0          intf.full
  Row   4:          1  intf.wr_en_1          intf.full

----------------Focused Condition View-------------------
Line       47 Item    1  (intf.rd_en && (intf.full || ~intf.empty))
Condition totals: 3 of 3 input terms covered = 100.0%

  Input Term   Covered  Reason for no coverage   Hint
 -----------  --------  ----------------------  --------------
  intf.rd_en         Y
   intf.full         Y
  intf.empty         Y

     Rows:       Hits  FEC Target            Non-masking condition(s)
 ---------  ---------  --------------------  -------------------------
  Row   1:          1  intf.rd_en_0          -
  Row   2:          1  intf.rd_en_1          (intf.full || ~intf.empty)
  Row   3:          1  intf.full_0           (intf.rd_en && intf.empty)
  Row   4:          1  intf.full_1           intf.rd_en
  Row   5:          1  intf.empty_0          (intf.rd_en && ~intf.full)
  Row   6:          1  intf.empty_1          (intf.rd_en && ~intf.full)
```

```
----------------Focused Condition View-------------------
Line       54 Item    1  (intf.empty && intf.rd_en)
Condition totals: 2 of 2 input terms covered = 100.0%

  Input Term   Covered  Reason for no coverage   Hint
 -----------  --------  ----------------------  --------------
  intf.empty         Y
  intf.rd_en         Y

     Rows:       Hits  FEC Target            Non-masking condition(s)
 ---------  ---------  --------------------  -------------------------
  Row   1:          1  intf.empty_0          -
  Row   2:          1  intf.empty_1          intf.rd_en
  Row   3:          1  intf.rd_en_0          intf.empty
  Row   4:          1  intf.rd_en_1          intf.empty

----------------Focused Condition View-------------------
Line       63 Item    1  ((~intf.rd_en && intf.wr_en) && ~intf.full)
Condition totals: 3 of 3 input terms covered = 100.0%

  Input Term   Covered  Reason for no coverage   Hint
 -----------  --------  ----------------------  --------------
  intf.rd_en         Y
  intf.wr_en         Y
   intf.full         Y

     Rows:       Hits  FEC Target            Non-masking condition(s)
 ---------  ---------  --------------------  -------------------------
  Row   1:          1  intf.rd_en_0          (~intf.full && intf.wr_en)
  Row   2:          1  intf.rd_en_1          -
  Row   3:          1  intf.wr_en_0          ~intf.rd_en
  Row   4:          1  intf.wr_en_1          (~intf.full && ~intf.rd_en)
  Row   5:          1  intf.full_0           (~intf.rd_en && intf.wr_en)
  Row   6:          1  intf.full_1           (~intf.rd_en && intf.wr_en)
```

```
----------------Focused Condition View-------------------
Line       65 Item    1  ((intf.rd_en && ~intf.wr_en) && ~intf.empty)
Condition totals: 3 of 3 input terms covered = 100.0%

  Input Term   Covered  Reason for no coverage   Hint
 -----------  --------  ----------------------  --------------
  intf.rd_en         Y
  intf.wr_en         Y
  intf.empty         Y

     Rows:       Hits  FEC Target            Non-masking condition(s)
 ---------  ---------  --------------------  -------------------------
  Row   1:          1  intf.rd_en_0          -
  Row   2:          1  intf.rd_en_1          (~intf.empty && ~intf.wr_en)
  Row   3:          1  intf.wr_en_0          (~intf.empty && intf.rd_en)
  Row   4:          1  intf.wr_en_1          intf.rd_en
  Row   5:          1  intf.empty_0          (intf.rd_en && ~intf.wr_en)
  Row   6:          1  intf.empty_1          (intf.rd_en && ~intf.wr_en)

----------------Focused Condition View-------------------
Line       67 Item    1  ((intf.rd_en && intf.wr_en) && intf.full)
Condition totals: 3 of 3 input terms covered = 100.0%

  Input Term   Covered  Reason for no coverage   Hint
 -----------  --------  ----------------------  --------------
  intf.rd_en         Y
  intf.wr_en         Y
   intf.full         Y

     Rows:       Hits  FEC Target            Non-masking condition(s)
 ---------  ---------  --------------------  -------------------------
  Row   1:          1  intf.rd_en_0          -
  Row   2:          1  intf.rd_en_1          (intf.full && intf.wr_en)
  Row   3:          1  intf.wr_en_0          intf.rd_en
  Row   4:          1  intf.wr_en_1          (intf.full && intf.rd_en)
  Row   5:          1  intf.full_0           (intf.rd_en && intf.wr_en)
  Row   6:          1  intf.full_1           (intf.rd_en && intf.wr_en)

----------------Focused Condition View-------------------
Line       69 Item    1  ((intf.rd_en && intf.wr_en) && intf.empty)
Condition totals: 3 of 3 input terms covered = 100.0%

  Input Term   Covered  Reason for no coverage   Hint
 -----------  --------  ----------------------  --------------
  intf.rd_en         Y
  intf.wr_en         Y
  intf.empty         Y

     Rows:       Hits  FEC Target            Non-masking condition(s)
 ---------  ---------  --------------------  -------------------------
  Row   1:          1  intf.rd_en_0          -
  Row   2:          1  intf.rd_en_1          (intf.empty && intf.wr_en)
  Row   3:          1  intf.wr_en_0          intf.rd_en
  Row   4:          1  intf.wr_en_1          (intf.empty && intf.rd_en)
  Row   5:          1  intf.empty_0          (intf.rd_en && intf.wr_en)
  Row   6:          1  intf.empty_1          (intf.rd_en && intf.wr_en)


Expression Coverage:
    Enabled Coverage            Active   Covered    Misses % Covered
    ----------------            ------   -------    ------ ---------
    FEC Expression Terms             0         0         0     100.0
FSM Coverage:
    Enabled Coverage            Active      Hits    Misses % Covered
    ----------------            ------      ----    ------ ---------
    FSMs                                                        100.0
        States                       0         0         0     100.0
        Transitions                  0         0         0     100.0
Toggle Coverage:
    Enabled Coverage            Active      Hits    Misses % Covered
    ----------------            ------      ----    ------ ---------
    Toggle Bins                    20        20         0     100.0
```

Toggle details:

```
================================Toggle Details================================

Toggle Coverage for File FIFO.sv --

      Line                                  Node      1H->0L      0L->1H  "Coverage"
--------------------------------------------------------------------------------------
         6                             wr_ptr[2]           1           1      100.00
         6                             wr_ptr[1]           1           1      100.00
         6                             wr_ptr[0]           1           1      100.00
         6                             rd_ptr[2]           1           1      100.00
         6                             rd_ptr[1]           1           1      100.00
         6                             rd_ptr[0]           1           1      100.00
         7                              count[3]           1           1      100.00
         7                              count[2]           1           1      100.00
         7                              count[1]           1           1      100.00
         7                              count[0]           1           1      100.00

Total Node Count     =         10
Toggled Node Count   =         10
Untoggled Node Count =          0

Toggle Coverage      =      100.0% (20 of 20 bins)
```

Assertions:

```
DIRECTIVE COVERAGE:
--------------------------------------------------------------------------------------------
Name                                    Design Design   Lang File(Line)      Count Status
                                        Unit   UnitType
--------------------------------------------------------------------------------------------
/\top#DUT /cvr_reset                    FIFO   Verilog  SVA  FIFO.sv(94)       870 Covered
/\top#DUT /wr_ack_cvr                   FIFO   Verilog  SVA  FIFO.sv(101)     5077 Covered
/\top#DUT /overflow_cvr                 FIFO   Verilog  SVA  FIFO.sv(107)      684 Covered
/\top#DUT /underflow_cvr                FIFO   Verilog  SVA  FIFO.sv(113)      406 Covered
/\top#DUT /empty_cvr                    FIFO   Verilog  SVA  FIFO.sv(119)     1398 Covered
/\top#DUT /full_cvr                     FIFO   Verilog  SVA  FIFO.sv(125)     1051 Covered
/\top#DUT /almostfull_cvr               FIFO   Verilog  SVA  FIFO.sv(131)      862 Covered
/\top#DUT /almostempty_cvr              FIFO   Verilog  SVA  FIFO.sv(137)     1554 Covered
/\top#DUT /pointer_wraparound_cvr_write FIFO   Verilog  SVA  FIFO.sv(145)      347 Covered
/\top#DUT /pointer_wraparound_cvr_read  FIFO   Verilog  SVA  FIFO.sv(153)       76 Covered
/\top#DUT /threshold_cvr                FIFO   Verilog  SVA  FIFO.sv(160)     5077 Covered

TOTAL DIRECTIVE COVERAGE: 100.0%  COVERS: 11

ASSERTION RESULTS:
-----------------------------------------------------
Name                File(Line)          Failure Pass
                                        Count   Count
-----------------------------------------------------
/\top#DUT /reset    FIFO.sv(93)             0     1
/\top#DUT /wr_ack_assert
                    FIFO.sv(100)            0     1
/\top#DUT /overflow_assert
                    FIFO.sv(106)            0     1
/\top#DUT /underflow_assert
                    FIFO.sv(112)            0     1
/\top#DUT /empty_assert
                    FIFO.sv(118)            0     1
/\top#DUT /full_assert
                    FIFO.sv(124)            0     1
/\top#DUT /almostfull_assert
                    FIFO.sv(130)            0     1
/\top#DUT /almostempty_assert
                    FIFO.sv(136)            0     1
/\top#DUT /pointer_wraparound_assert_write
                    FIFO.sv(144)            0     1
/\top#DUT /pointer_wraparound_assert_read
                    FIFO.sv(152)            0     1
/\top#DUT /threshold_assert
                    FIFO.sv(159)            0     1

Total Coverage By File (code coverage only, filtered view): 100.0%
```

Functional & Directive Coverage:

```
COVERGROUP COVERAGE:
----------------------------------------------------------------------------
--------------------
Covergroup                                                 Metric       Goal
Status

----------------------------------------------------------------------------
--------------------
 TYPE /func_pkg/FIFO_coverage/cvr_grp                     100.0%        100
Covered
    covered/total bins:                                      64         64
    missing/total bins:                                       0         64
    % Hit:                                                100.0%        100
    Coverpoint cvr_grp::write_enable                      100.0%        100
Covered
        covered/total bins:                                   2          2
        missing/total bins:                                   0          2
        % Hit:                                            100.0%        100
        bin wr_enable_low                                 12826          1
Covered
        bin wr_enable_high                                17176          1
Covered
    Coverpoint cvr_grp::read_enable                       100.0%        100
Covered
        covered/total bins:                                   2          2
        missing/total bins:                                   0          2
        % Hit:                                            100.0%        100
        bin rd_enable_low                                 19937          1
Covered
        bin rd_enable_high                                10065          1
Covered
    Coverpoint cvr_grp::FULL                              100.0%        100
Covered
        covered/total bins:                                   2          2
        missing/total bins:                                   0          2
        % Hit:                                            100.0%        100
        bin Full_low                                      28105          1
Covered
        bin Full_high                                      1897          1
Covered
    Coverpoint cvr_grp::EMPTY                             100.0%        100
Covered
        covered/total bins:                                   2          2
        missing/total bins:                                   0          2
        % Hit:                                            100.0%        100
        bin Empty_low                                     24387          1
Covered
        bin Empty_high                                     5615          1
Covered
    Coverpoint cvr_grp::ALMOSTFULL                        100.0%        100
Covered
        covered/total bins:                                   2          2
```

```
        missing/total bins:                                 0          2
        % Hit:                                          100.0%        100
        bin Almostfull_low                               27992          1
Covered
        bin Almostfull_high                               2010          1
Covered
    Coverpoint cvr_grp::ALMOSTEMPTY                     100.0%        100
Covered
        covered/total bins:                                 2          2
        missing/total bins:                                 0          2
        % Hit:                                          100.0%        100
        bin Almostempty_low                              23463          1
Covered
        bin Almostempty_high                              6539          1
Covered
    Coverpoint cvr_grp::OVERFLOW                        100.0%        100
Covered
        covered/total bins:                                 2          2
        missing/total bins:                                 0          2
        % Hit:                                          100.0%        100
        bin Overflow_low                                 28882          1
Covered
        bin Overflow_high                                 1120          1
Covered
    Coverpoint cvr_grp::UNDERFLOW                       100.0%        100
Covered
        covered/total bins:                                 2          2
        missing/total bins:                                 0          2
        % Hit:                                          100.0%        100
        bin Underflow_low                                25757          1
Covered
        bin Underflow_high                                4245          1
Covered
    Coverpoint cvr_grp::Write_ack                       100.0%        100
Covered
        covered/total bins:                                 2          2
        missing/total bins:                                 0          2
        % Hit:                                          100.0%        100
        bin write_acknowledge_low                        13946          1
Covered
        bin write_acknowledge_high                       16056          1
Covered
    Cross cvr_grp::rd_en_with_wr_enable_full            100.0%        100
Covered
        covered/total bins:                                 6          6
        missing/total bins:                                 0          6
        % Hit:                                          100.0%        100
        bin <rd_enable_low,wr_enable_low,Full_low>        8841          1
Covered
        bin <rd_enable_high,wr_enable_low,Full_low>
                                                          3585          1
Covered
        bin <rd_enable_low,wr_enable_high,Full_low>
```

```
                                                          9199          1
Covered
        bin <rd_enable_high,wr_enable_high,Full_low>
                                                          6480          1
Covered
        bin <rd_enable_low,wr_enable_low,Full_high>
                                                           400          1
Covered
        bin <rd_enable_low,wr_enable_high,Full_high>
                                                          1497          1
Covered
        ignore_bin read_enable_with_full_high                0
ZERO
    Cross cvr_grp::rd_en_with_wr_enable_empty          100.0%        100
Covered
        covered/total bins:                                  6          6
        missing/total bins:                                  0          6
        % Hit:                                         100.0%        100
        bin <rd_enable_low,wr_enable_low,Empty_low>
                                                          5143          1
Covered
        bin <rd_enable_low,wr_enable_high,Empty_low>
                                                         10696          1
Covered
        bin <rd_enable_high,wr_enable_low,Empty_low>
                                                          2068          1
Covered
        bin <rd_enable_high,wr_enable_high,Empty_low>
                                                          6480          1
Covered
        bin <rd_enable_low,wr_enable_low,Empty_high>
                                                          4098          1
Covered
        bin <rd_enable_high,wr_enable_low,Empty_high>
                                                          1517          1
Covered
        ignore_bin write_enable_with_empty_high              0
ZERO
    Cross cvr_grp::rd_en_with_wr_enable_almostfull     100.0%        100
Covered
        covered/total bins:                                  8          8
        missing/total bins:                                  0          8
        % Hit:                                         100.0%        100
        bin <rd_enable_low,wr_enable_low,Almostfull_low>
                                                          8804          1
Covered
        bin <rd_enable_high,wr_enable_low,Almostfull_low>
                                                          3386          1
Covered
        bin <rd_enable_low,wr_enable_high,Almostfull_low>
                                                         10124          1
Covered
        bin <rd_enable_high,wr_enable_high,Almostfull_low>
```

```
                                                          5678          1
Covered
        bin <rd_enable_low,wr_enable_low,Almostfull_high>
                                                           437          1
Covered
        bin <rd_enable_high,wr_enable_low,Almostfull_high>
                                                           199          1
Covered
        bin <rd_enable_low,wr_enable_high,Almostfull_high>
                                                           572          1
Covered
        bin <rd_enable_high,wr_enable_high,Almostfull_high>
                                                           802          1
Covered
    Cross cvr_grp::rd_en_with_wr_enable_almostempty
                                                       100.0%         100
Covered
        covered/total bins:                                  8           8
        missing/total bins:                                  0           8
        % Hit:                                         100.0%         100
        bin <rd_enable_low,wr_enable_low,Almostempty_low>
                                                          7836          1
Covered
        bin <rd_enable_high,wr_enable_low,Almostempty_low>
                                                          3035          1
Covered
        bin <rd_enable_low,wr_enable_high,Almostempty_low>
                                                          8711          1
Covered
        bin <rd_enable_high,wr_enable_high,Almostempty_low>
                                                          3881          1
Covered
        bin <rd_enable_low,wr_enable_low,Almostempty_high>
                                                          1405          1
Covered
        bin <rd_enable_high,wr_enable_low,Almostempty_high>
                                                           550          1
Covered
        bin <rd_enable_low,wr_enable_high,Almostempty_high>
                                                          1985          1
Covered
        bin <rd_enable_high,wr_enable_high,Almostempty_high>
                                                          2599          1
Covered
    Cross cvr_grp::rd_en_with_wr_enable_underflow      100.0%         100
Covered
        covered/total bins:                                  6           6
        missing/total bins:                                  0           6
        % Hit:                                         100.0%         100
        bin <rd_enable_low,wr_enable_low,Underflow_low>
                                                          8304          1
Covered
        bin <rd_enable_high,wr_enable_low,Underflow_low>
```

```
                                                          2862          1
Covered
        bin <rd_enable_low,wr_enable_high,Underflow_low>
                                                          9245          1
Covered
        bin <rd_enable_high,wr_enable_high,Underflow_low>
                                                          5346          1
Covered
        bin <rd_enable_high,wr_enable_low,Underflow_high>
                                                           723          1
Covered
        bin <rd_enable_high,wr_enable_high,Underflow_high>
                                                          1134          1
Covered
        ignore_bin read_with_underflow                    2388
Occurred
    Cross cvr_grp::rd_en_with_wr_enable_overflow       100.0%         100
Covered
        covered/total bins:                                  6           6
        missing/total bins:                                  0           6
        % Hit:                                         100.0%         100
        bin <rd_enable_low,wr_enable_low,Overflow_low>
                                                          9241          1
Covered
        bin <rd_enable_low,wr_enable_high,Overflow_low>
                                                          9944          1
Covered
        bin <rd_enable_high,wr_enable_low,Overflow_low>
                                                          3585          1
Covered
        bin <rd_enable_high,wr_enable_high,Overflow_low>
                                                          6112          1
Covered
        bin <rd_enable_low,wr_enable_high,Overflow_high>
                                                           752          1
Covered
        bin <rd_enable_high,wr_enable_high,Overflow_high>
                                                           368          1
Covered
        ignore_bin write_with_overflow                       0
ZERO
    Cross cvr_grp::rd_en_with_wr_enable_wr_ack         100.0%         100
Covered
        covered/total bins:                                  6           6
        missing/total bins:                                  0           6
        % Hit:                                         100.0%         100
        bin <rd_enable_low,wr_enable_low,write_acknowledge_low>
                                                          9241          1
Covered
        bin <rd_enable_low,wr_enable_high,write_acknowledge_low>
                                                           752          1
Covered
        bin <rd_enable_high,wr_enable_low,write_acknowledge_low>
```

```
                                                          3585          1
Covered
        bin <rd_enable_high,wr_enable_high,write_acknowledge_low>
                                                           368          1
Covered
        bin <rd_enable_low,wr_enable_high,write_acknowledge_high>
                                                          9944          1
Covered
        bin <rd_enable_high,wr_enable_high,write_acknowledge_high>
                                                          6112          1
Covered
        ignore_bin write_with_wr_ack                         0
ZERO
 CLASS FIFO_coverage

TOTAL COVERGROUP COVERAGE: 100.0%  COVERGROUP TYPES: 1

DIRECTIVE COVERAGE:
--------------------------------------------------------------------------------
-------------------
Name                                     Design Design   Lang File(Line)
Count Status
                                         Unit   UnitType
--------------------------------------------------------------------------------
-------------------
/top/DUT/cvr_reset                       FIFO   Verilog  SVA  FIFO.sv(95)
2611 Covered
/top/DUT/wr_ack_cvr                      FIFO   Verilog  SVA  FIFO.sv(102)
14571 Covered
/top/DUT/overflow_cvr                    FIFO   Verilog  SVA  FIFO.sv(108)
1017 Covered
/top/DUT/underflow_cvr                   FIFO   Verilog  SVA  FIFO.sv(114)
1682 Covered
/top/DUT/empty_cvr                       FIFO   Verilog  SVA  FIFO.sv(120)
5029 Covered
/top/DUT/full_cvr                        FIFO   Verilog  SVA  FIFO.sv(126)
1719 Covered
/top/DUT/almostfull_cvr                  FIFO   Verilog  SVA  FIFO.sv(132)
1838 Covered
/top/DUT/almostempty_cvr                 FIFO   Verilog  SVA  FIFO.sv(138)
5894 Covered
/top/DUT/pointer_wraparound_cvr_write    FIFO   Verilog  SVA  FIFO.sv(146)
953 Covered
/top/DUT/pointer_wraparound_cvr_read     FIFO   Verilog  SVA  FIFO.sv(154)
331 Covered
/top/DUT/threshold_cvr                   FIFO   Verilog  SVA  FIFO.sv(161)
27091 Covered

TOTAL DIRECTIVE COVERAGE: 100.0%  COVERS: 11
```

Verification Plan:

Label	Description	Stimulus Generation	Functional Coverage	Functionality Check
FIFO_1	If rst_n high therefore all FIFO locations will be reseted & the output signals should be zero	we make directed testing for the reset signal at the beginning of testbench initialize the FIFO & then randomize it inside loops by constraining it to be active less often	No Functional Coverage for reset signal	Output Checked against zero in check_data function
FIFO_2	If write enable asserted and read enable deasserted we check the FIFO if it is not full so we will write data_in inside the FIFO	Randomization under constraints on the data_in & write enable	we include cover point for the wr_en signal & for full signal	Output Checked against check_data function
FIFO_3	If write enable deasserted and active read asserted we check the FIFO if it is not empty so we will read from the FIFO & get the value to be stored in data_out signal	Randomization under constraints for read enable signal	we include cover point for the rd_en signal & for empty signal	Output Checked against check_data function
FIFO_4	When read_enable and write_enable are asserted together, the outcome is determined by the status flags. If the full flag is asserted, the design gives priority to the read operation. If the empty flag is asserted, the design instead gives priority to the write operation. In cases where neither flag is asserted, the read and write operations are carried out concurrently.	NO Randomization occur for the output flags	We defined nine coverpoints to monitor the activity of read_enable, write_enable, and each of the output flags. In addition, we introduced seven cross coverage points to capture specific combinations (bins) that occur between the read and write enables and the output flags.	Output Checked against check_data function