A UVM Reactive Testbench for Jitter Tolerance Measurement of High-Speed Wireline Receivers

Jaeha Kim (jaeha@snu.ac.kr)
Seoul National University, Seoul, Korea

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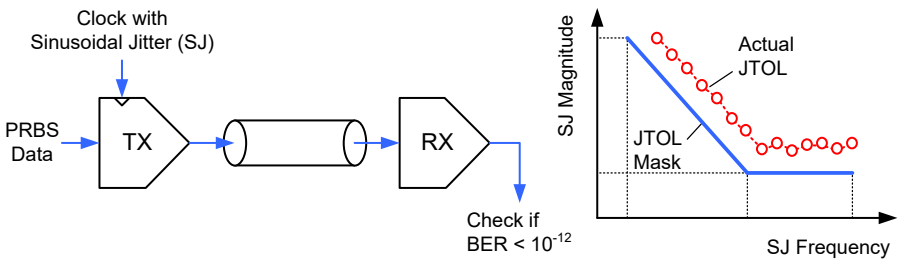
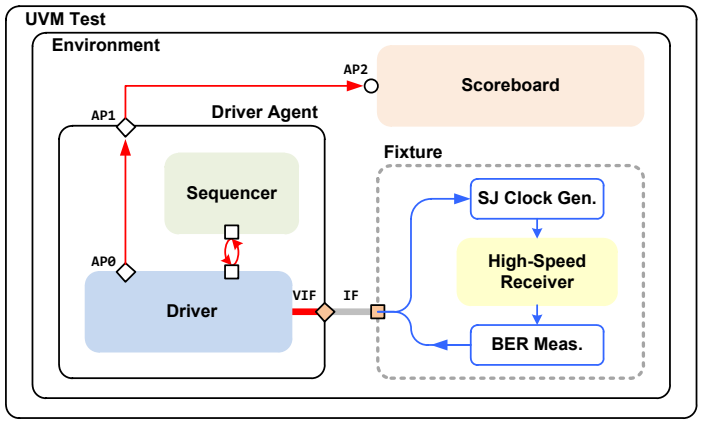
OBJECTIVES

- Jitter tolerance (JTOL) test measures the resilience of a high-speed wireline receiver to the additional sinusoidal jitter (SJ)
- This work demonstrates a UVM testbench performing an iterative search to find the maximum SJ magnitude that can be tolerated for a target BER of 10^{-12} for each SJ frequency



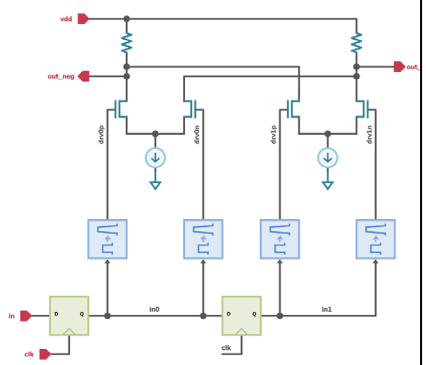
UVM TESTBENCH FOR JTOL MEASUREMENT

- With a well-defined fixture module encapsulating the receiver model and its analog instrumentations, a UVM testbench can be built using standard UVM components



FIXTURE MODULE FOR HIGH-SPEED RECEIVER MODEL

- Using XMODEL primitives, the AMS circuit model and its instrumentations can be described entirely in SystemVerilog
- The XMODEL statistical simulation can simulate BER < 10^{-12}



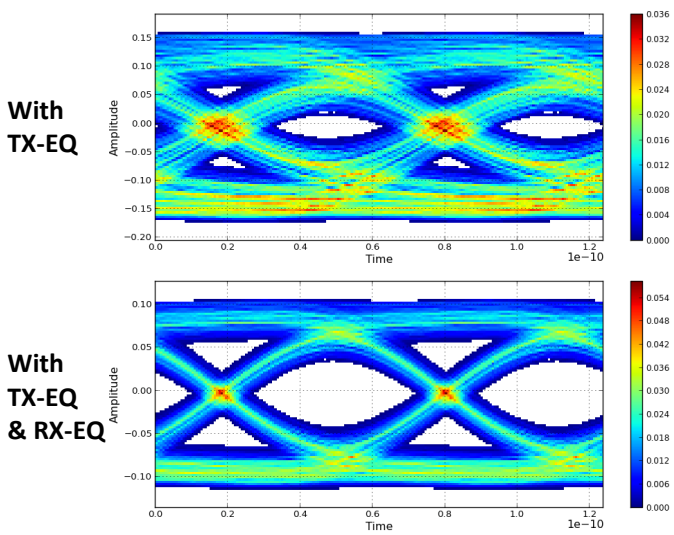

```
module tx_eq (...);

xreal drv0p, drv0n, drv1p, drv1n;
xreal tail0, tail1;
xbit in0, in1;

isource     #(.mode("dc"), .dc(0.00875))
            I0 (.neg(`ground), .pos(tail0), .in(`ground));
isource     #(.mode("dc"), .dc(0.00125))
            I1 (.neg(`ground), .pos(tail1), .in(`ground));
nmosfet     #(.W(2e-05), .L(4e-08), .Kp(2e-05), .Vth(0.5))
            M0 (.g(drv0p), .d(out_neg), .b(`ground), .s(tail0));
nmosfet     #(.W(2e-05), .L(4e-08), .Kp(2e-05), .Vth(0.5))
            M1 (.g(drv0n), .d(out_pos), .b(`ground), .s(tail0));
nmosfet     #(.W(2e-05), .L(4e-08), .Kp(2e-05), .Vth(0.5))
            M2 (.g(drv1p), .d(out_neg), .b(`ground), .s(tail1));
nmosfet     #(.W(2e-05), .L(4e-08), .Kp(2e-05), .Vth(0.5))
            M3 (.g(drv1n), .d(out_pos), .b(`ground), .s(tail1));
resistor    #(.R(50)) R0 (.neg(out_pos), .pos(vdd));
resistor    #(.R(50)) R1 (.neg(out_neg), .pos(vdd));
transition  #(.value0(0.0), .value1(1.0)) XP0 (.out(drv0p), .in(in0));
transition  #(.value0(1.0), .value1(0.0)) XP1 (.out(drv0n), .in(in0));
transition  #(.value0(1.0), .value1(0.0)) XP2 (.out(drv1p), .in(in1));
transition  #(.value0(0.0), .value1(1.0)) XP3 (.out(drv1n), .in(in1));
dff_xbit    XP4 (.clk(clk), .d(in), .q(in0));
dff_xbit    XP5 (.clk(clk), .d(in0), .q(in1));

endmodule   // tx_eq
```

UVM SEQUENCE FOR ITERATIVE SEARCH

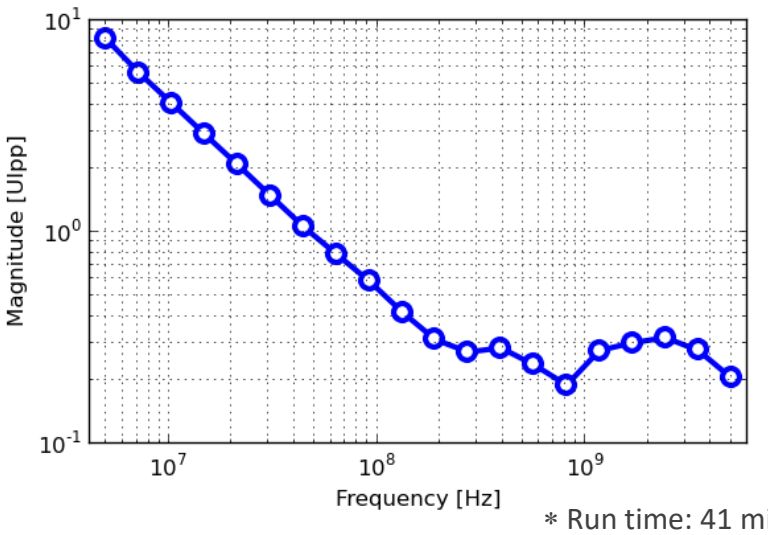
```
class SEQ_JTOL extends uvm_sequence #(PACKET);
    // some details are omitted for brevity ...
    task body();
        PKT = PACKET::type_id::create("PKT");
        for (int i=0; i<freq_numpt; i++) begin:LOOP
            PKT.SJ_freq = (i == 0) ? freq_max : PKT.SJ_freq/freq_ratio;
            PKT.SJ_mag = (i == 0) ? 0.5 : PKT.SJ_mag;
            flag = 0;

            // phase 1: linear search to find the first failing point
            while (1) begin
                start_item(PKT);
                finish_item(PKT);
                get_response(RSP);
                if (RSP.BER < RSP.BER_tol) begin
                    mag_min = PKT.SJ_mag;
                    PKT.SJ_mag += mag_inc;
                    if (flag == -1) break; else flag = 1;
                end
                else begin
                    mag_max = PKT.SJ_mag;
                    PKT.SJ_mag -= mag_inc;
                    if (flag == 1) break; else flag = -1;
                end
            end

            // phase 2: binary search to find the pass/fail boundary
            while (mag_max/mag_min > 1.05) begin
                PKT.SJ_mag = $sqrt(mag_max * mag_min);
                start_item(PKT);
                finish_item(PKT);
                get_response(RSP);
                if (RSP.BER < RSP.BER_tol) mag_min = PKT.SJ_mag;
                else mag_max = PKT.SJ_mag;
            end
        end: LOOP
    endtask: body
endclass: SEQ_JTOL
```

- Sequence component can use **get_response()** method to retrieve the BER result for tried SJ frequency & magnitude
- It finds the maximum SJ meeting BER < 10^{-12} using a combination of linear & binary search

SIMULATED STATISTICAL EYE DIAGRAMS



SIMULATED JITTER TOLERANCE CURVE




```
JITTER TOLERANCE (JTOL)
INDEX     FREQUENCY(Hz)     MAGNITUDE(UIpp)
1         5.0000e+06        8.1488
2         7.1922e+06        5.6295
3         1.0346e+07        4.0418
4         1.4882e+07        2.8870
5         2.1407e+07        2.0728
6         3.0792e+07        1.4806
7         4.4293e+07        1.0576
8         6.3714e+07        0.7851
9         9.1649e+07        0.5858
10        1.3183e+08        0.4184
11        1.8963e+08        0.3106
12        2.7278e+08        0.2709
13        3.9238e+08        0.2834
14        5.6442e+08        0.2362
15        8.1189e+08        0.1894
16        1.1679e+09        0.2756
17        1.6799e+09        0.2996
18        2.4165e+09        0.3168
19        3.4760e+09        0.2763
20        5.0000e+09        0.2051
TOTAL NUMBER OF TRIALS: 106
```

∗ Run time: 41 minutes with 106 BER trials

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