Main module

```
`timescale 1ns / 1ps
//////////////////////////////////////////////////////////////////////////////////
// Company:
// Engineer:
//
// Create Date: 04.03.2024 00:16:07
// Design Name:
// Module Name: C_rot
// Project Name:
// Target Devices:
// Tool Versions:
// Description:
//
// Dependencies:
//
// Revision:
// Revision 0.01 - File Created
// Additional Comments:
//
//////////////////////////////////////////////////////////////////////////////////


`timescale 1ns / 1ps

//#(parameter N = 15)

module doubly_pipeline #(parameter N = 31) (

        input signed [N:0] a,
        input signed [N:0] b,
        input signed [N:0] p,
        input signed [N:0] q,
        //input [15:0] inangle,
        input clk,
        input rst,
//        output reg  signed  [N:0] af,
        output  reg signed  [N:0] qf,
//        output reg  signed  [N:0] bf,
        output  reg signed  [N:0] pf,
        //output  signed [N:0] afcal,
        //output  signed [N:0] bfcal,
        output reg [15:0]  output_angle

    );
    wire  [3:0] shift;
    wire  [15:0] microangle;
    wire  signed [N:0] a0,ax1,ax2,ax3,ax4,ax5,ax6,ax7,ax8,ax9,ax10,ax11,ax12 ;
    wire  signed [N:0] b0,by1,by2,by3,by4,by5,by6,by7,by8,by9,by10,by11,by12 ;
    wire  signed [N:0] p0,px1,px2,px3,px4,px5,px6,px7,px8,px9,px10,px11,px12 ;
    wire  signed [N:0] q0,qy1,qy2,qy3,qy4,qy5,qy6,qy7,qy8,qy9,qy10,qy11,qy12 ;
    wire  [15:0] outangle0 ,outangle1 ,outangle2 ,outangle3 ,outangle4 ,outangle5
,outangle6 ,outangle7, outangle8,outangle9,outangle10,outangle11;
    wire  [15:0] outangle12 ;
    wire  [15:0] dec_angle;
    reg  [15:0] output_angle_it=0;



    iteration Rot0( .a(a) , .b(b) , .p(p) , .q(q)      ,.shift(4'd0),
 .dec_angle(16'h0)     , .microangle(16'h2d00),   .clk(clk), .ax(a0),.by(b0),
.px(p0),.qy(q0), .outangle(outangle0) );



    iteration Rot1( .a(a0), .b(b0),   .p(p0) , .q(q0) , .shift(4'd1),
 .dec_angle(outangle0) , .microangle( 16'h1a_92 ), .clk(clk), .ax(ax1),.by(by1),
.px(px1),.qy(qy1), .outangle(outangle1));

    iteration Rot2( .a(ax1), .b(by1), .p(px1) , .q(qy1) , .shift(4'd2),
 .dec_angle(outangle1) , .microangle( 16'h0e_0a ), .clk(clk),
.ax(ax2),.by(by2),.px(px2),.qy(qy2), .outangle(outangle2));

    iteration Rot3( .a(ax2) ,.b(by2), .p(px2) , .q(qy2) , .shift(4'd3),
 .dec_angle(outangle2) , .microangle(16'h07_21 ),  .clk(clk),
.ax(ax3),.by(by3),.px(px3),.qy(qy3), .outangle(outangle3));

    iteration Rot4( .a(ax3), .b(by3), .p(px3) , .q(qy3) , .shift(4'd4),
 .dec_angle(outangle3) , .microangle( 16'h03_94 ), .clk(clk),
.ax(ax4),.by(by4),.px(px4),.qy(qy4), .outangle(outangle4));

    iteration Rot5( .a(ax4), .b(by4), .p(px4) , .q(qy4) , .shift(4'd5),
.dec_angle(outangle4) , .microangle( 16'h01_ca ), .clk(clk),
.ax(ax5),.by(by5),.px(px5),.qy(qy5), .outangle(outangle5));

    iteration Rot6( .a(ax5), .b(by5), .p(px5) , .q(qy5) , .shift(4'd6),
 .dec_angle(outangle5) , .microangle( 16'h00_e4 ), .clk(clk),
.ax(ax6),.by(by6),.px(px6),.qy(qy6), .outangle(outangle6));

    iteration Rot7( .a(ax6), .b(by6), .p(px6) , .q(qy6) , .shift(4'd7),
.dec_angle(outangle6) , .microangle( 16'h00_71 ), .clk(clk),
.ax(ax7),.by(by7),.px(px7),.qy(qy7),.outangle(outangle7));
```

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    iteration Rot8( .a(ax7),  .b(by7),  .p(px7) , .q(qy7) , .shift(4'd8),
 .dec_angle(outangle7)  , .microangle( 16'h00_38 ), .clk(clk), .ax(ax8), .by(by8),
.px(px8),.qy(qy8),  .outangle(outangle8));

    iteration Rot9( .a(ax8),  .b(by8),  .p(px8) , .q(qy8) , .shift(4'd9),
 .dec_angle(outangle8)  , .microangle( 16'h00_1c ), .clk(clk), .ax(ax9), .by(by9),
.px(px9),.qy(qy9),  .outangle(outangle9));

    iteration Rot10( .a(ax9),  .b(by9),  .p(px9) , .q(qy9) , .shift(4'd10),
.dec_angle(outangle9)  , .microangle( 16'h00_0d ), .clk(clk), .ax(ax10),
.by(by10), .px(px10),.qy(qy10), .outangle(outangle10));

   iteration Rot11( .a(ax10), .b(by10), .p(px10) , .q(qy10) , .shift(4'd11),
 .dec_angle(outangle10) , .microangle( 16'h00_05 ), .clk(clk), .ax(ax11),
.by(by11), .px(px11),.qy(qy11), .outangle(outangle11));

   iteration Rot12( .a(ax11), .b(by11), .p(px11) , .q(qy11) , .shift(4'd12),
 .dec_angle(outangle11) , .microangle( 16'h00_03 ), .clk(clk), .ax(ax12),
.by(by12), .px(px12),.qy(qy12), .outangle(outangle12));

//   assign output_angle = outangle12;
//  assign af = (0.607)*ax12;
//  assign bf = (0.607)*by12;
//  assign pf = (0.607)*px12;
//  assign qf = (0.607)*qy12;


 always @(clk) begin
     if (!rst ) begin // Reset outputs to zero until ready
//         af <= 0;
//         bf <= 0;
         pf <= 0;
         qf <= 0;
         output_angle <= 0;
     end
     else if (a== 0 || b ==0) begin
        pf <= p;
        qf <= q;
     end

     else
     begin // Output valid results when ready
//         af <= (ax12 >>> 1) + (ax12 >>> 3) + (ax12 >>> 6) - (ax12 >>> 5) - (ax12
>>> 9);
//         bf <= (by12 >>>1) +  (by12 >>> 3) +  (by12 >>> 6) -  (by12 >>> 5) -
(by12 >>>9);
         pf <= (px12 >>> 1) + (px12 >>> 3) +  (px12 >>> 6) - (px12 >>> 5) - (px12
>>> 9);
```

```
        qf <= (qy12 >>>1) +  (qy12 >>> 3) +  (qy12 >>> 6) -  (qy12 >>> 5) - (qy12
>>>9);
        output_angle <= outangle12;
    end
end


//   assign af = (ax12 >>> 1) + (ax12 >>> 3) + (ax12 >>> 6) - (ax12 >>> 5) - (ax12
>>> 9);


//   assign bf = (by12 >>>1) +  (by12 >>>3) +  (by12 >>>6) -  (by12 >>> 5) - (by12
>>>9);

//assign af = afr;
//assign bf = bfr;
//assign output_angle = outangle12;

endmodule
```

iteration Code

```
`timescale 1ns / 1ps
//////////////////////////////////////////////////////////////////////////////////
////
// Company:
// Engineer:
//
// Create Date: 04.03.2024 00:14:28
// Design Name:
// Module Name: iteration
// Project Name:
// Target Devices:
// Tool Versions:
// Description:
//
// Dependencies:
//
// Revision:
// Revision 0.01 - File Created
// Additional Comments:
//
//////////////////////////////////////////////////////////////////////////////////
////


`timescale 1ns / 1ps
```

```
module iteration #(parameter N = 31) (
input signed [N:0] a,p,
input signed [N:0] b,q,

input  [3:0]shift,
//input [15:0] inangle,
input [15:0] microangle,
input [15:0] dec_angle ,
input clk,
output  reg signed [N:0] ax,px,
output  reg signed [N:0] by,qy,
output reg [15:0] outangle
) ;
// reg  signed [N:0] ox_shift;
// reg  signed [N:0] oy_shift;

always @ (posedge clk)

 begin

  if ( b  >= 0  )
   begin
    ax <= a + (b >>> shift);
    by <= b - (a >>> shift);
    outangle <= dec_angle + microangle;

    px <= p + (q >>> shift);
    qy <= q - (p >>> shift);


  end
  else begin
    ax <= a - (b >>> shift);
    by <= b + (a >>> shift);
    outangle <= dec_angle - microangle;
    px <= p - (q >>> shift);
    qy <= q + (p >>> shift);


  end

end

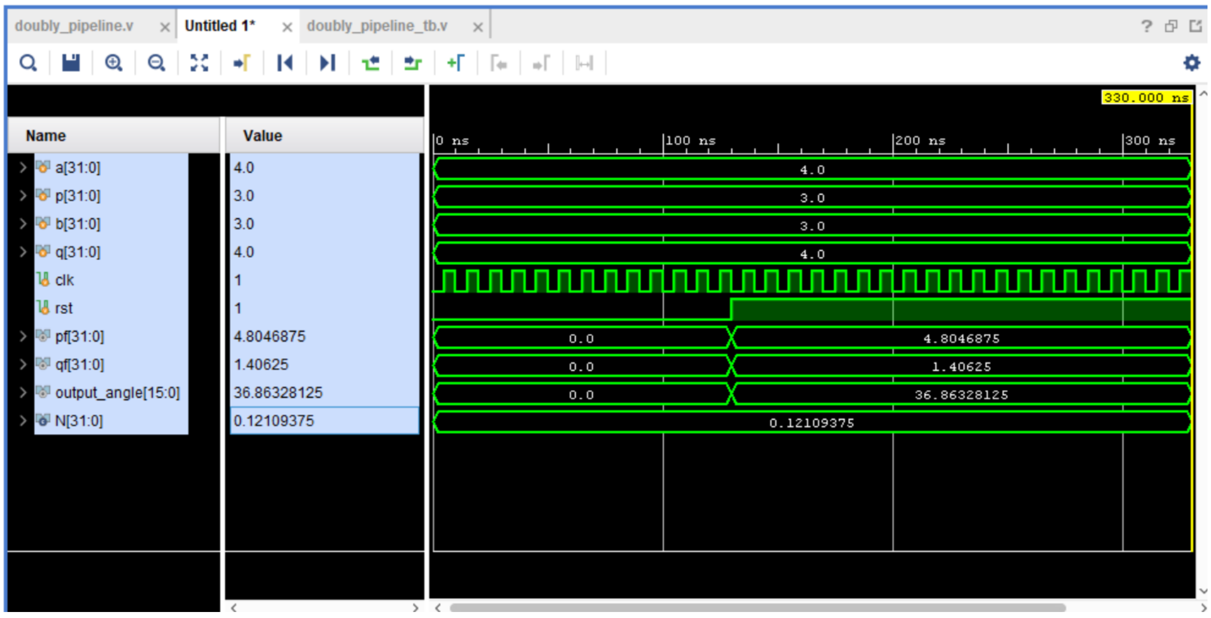
//assign ox= (ox_shift >>>(0*(shift)));
//assign oy= (oy_shift >>>(0*(shift)));


endmodule
```

Testbench

```verilog
`timescale 1ns / 1ps
//////////////////////////////////////////////////////////////////////////////
////
// Company:
// Engineer:
//
// Create Date: 04.03.2024 00:18:50
// Design Name:
// Module Name: Cordic_rotation_tb
// Project Name:
// Target Devices:
// Tool Versions:
// Description:
//
// Dependencies:
//
// Revision:
// Revision 0.01 - File Created
// Additional Comments:
//
//////////////////////////////////////////////////////////////////////////////
////


`timescale 1ns / 1ps

module doubly_pipeline_tb;
 parameter N =31;
  reg  signed [N :0] a,p;
  reg  signed [N :0] b,q;
  reg clk;
  reg rst;
//  wire signed [N:0] af;
  wire signed [N:0] pf;
//  wire signed [N:0] bf;
  wire signed [N:0] qf;
  wire [15:0] output_angle;

  // Instantiate the Cordic_rotation module
  doubly_pipeline uut(
    .a(a),
    .b(b),
    .p(p),
    .q(q),

    .clk(clk),
    .rst(rst),
//    .af(af),
//    .bf(bf),
    .pf(pf),
    .qf(qf),

    .output_angle(output_angle)

  );

  // Clock generation
  initial begin
    clk = 0;
    forever #5 clk = ~clk;
  end

  // Apply stimulus
  initial begin
  rst =0 ;
    // Initialize inputs
    a = 32'h00000400;
    b = 32'h00000300;

    p = 32'h00000300;
    q = 32'h00000400;
    //inangle = 16'd70_95;
    #130      // set clock

   rst =1;


    #200;
    $finish;
  end


endmodule
```

Result



Name	Value
a[31:0]	4.0
p[31:0]	3.0
b[31:0]	3.0
q[31:0]	4.0
clk	1
rst	1
pf[31:0]	4.8046875
qf[31:0]	1.40625
output_angle[15:0]	36.86328125
N[31:0]	0.12109375