**UNIVERSIDAD DE PUERTO RICO**

**RECINTO UNIVERSITARIO DE MAYAGUEZ**

**FACULTAD DE INGENIERIA**

**DEPARTAMENTO DE INGENIERIA**

Prof. Rodriguez

ICOM4215-080

Hector Hernandez

Pedro Colon

Marie Nazario

Computer Architecture

Report

Contents

[ASMD Diagram 2](#_Toc435652258)

[Block Diagrams 3](#_Toc435652259)

[Data Path 3](#_Toc435652260)

[Control Unit 4](#_Toc435652261)

[Circuit Diagrams 5](#_Toc435652262)

[Data Path 5](#_Toc435652263)

[Control Unit 6](#_Toc435652264)

[Register File 7](#_Toc435652265)

[Microprogram 8](#_Toc435652266)

[Appendices 11](#_Toc435652267)

[Appendix A: Code Implementation 11](#_Toc435652268)

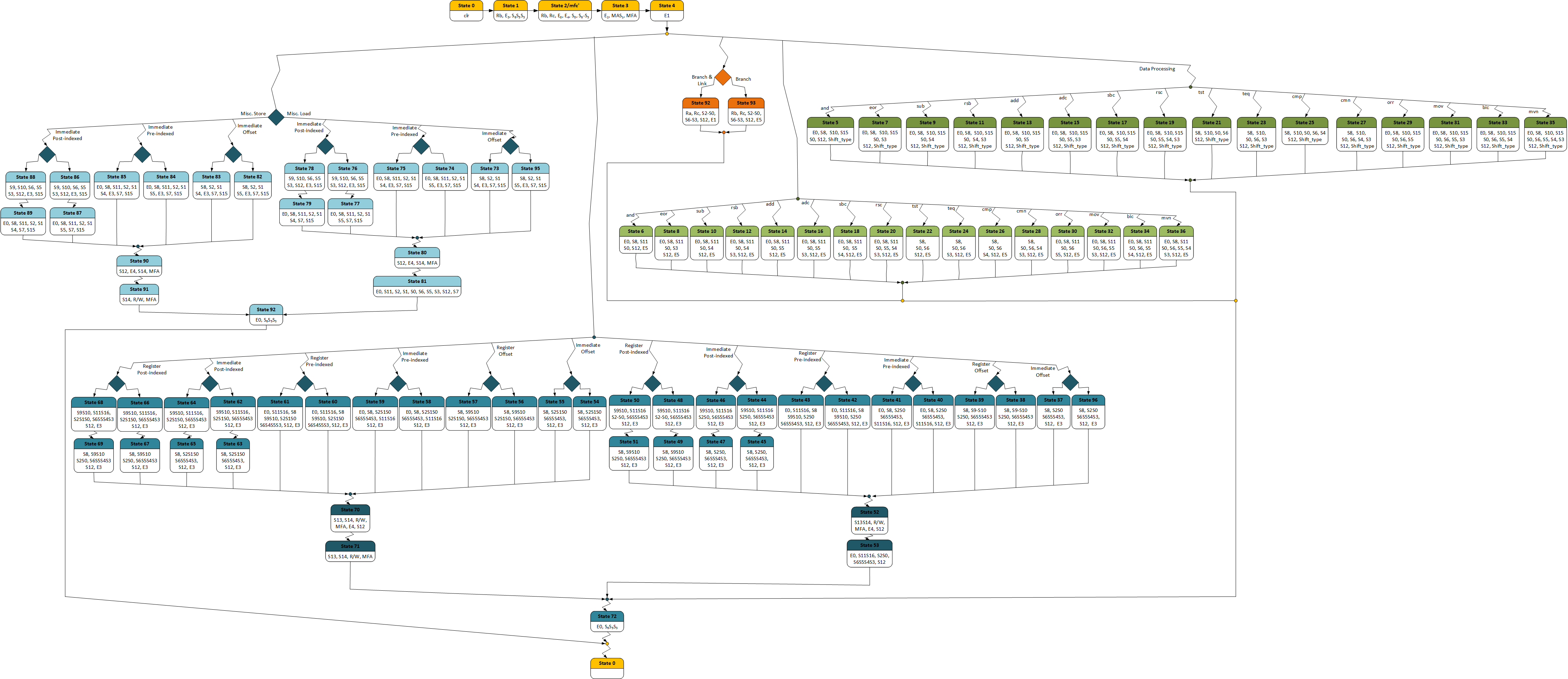
[Appendix B: Simulation Results 57](#_Toc435652269)

[Test A 57](#_Toc435652270)

[Test B 59](#_Toc435652271)

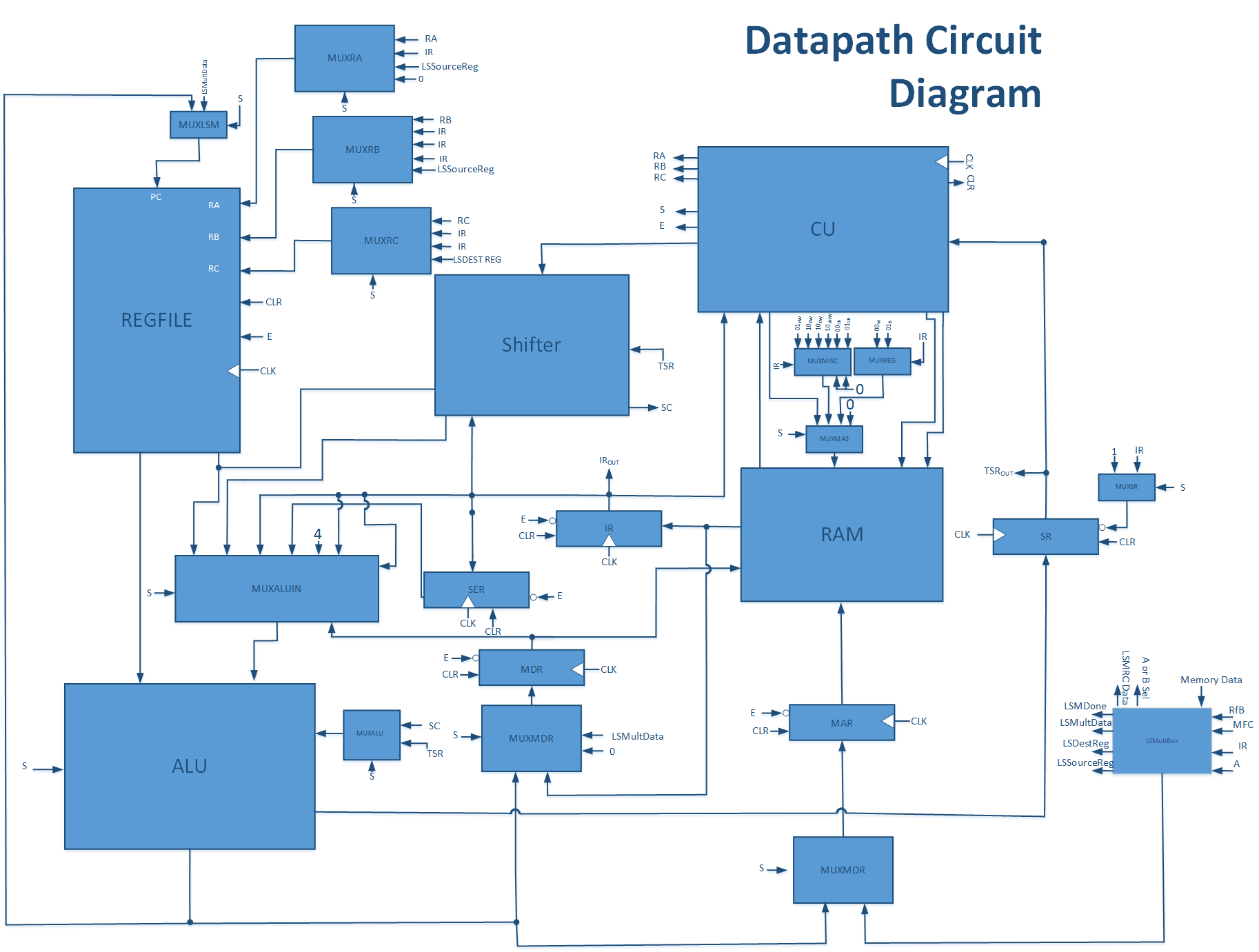
[Test C 65](#_Toc435652272)

# ASMD Diagram

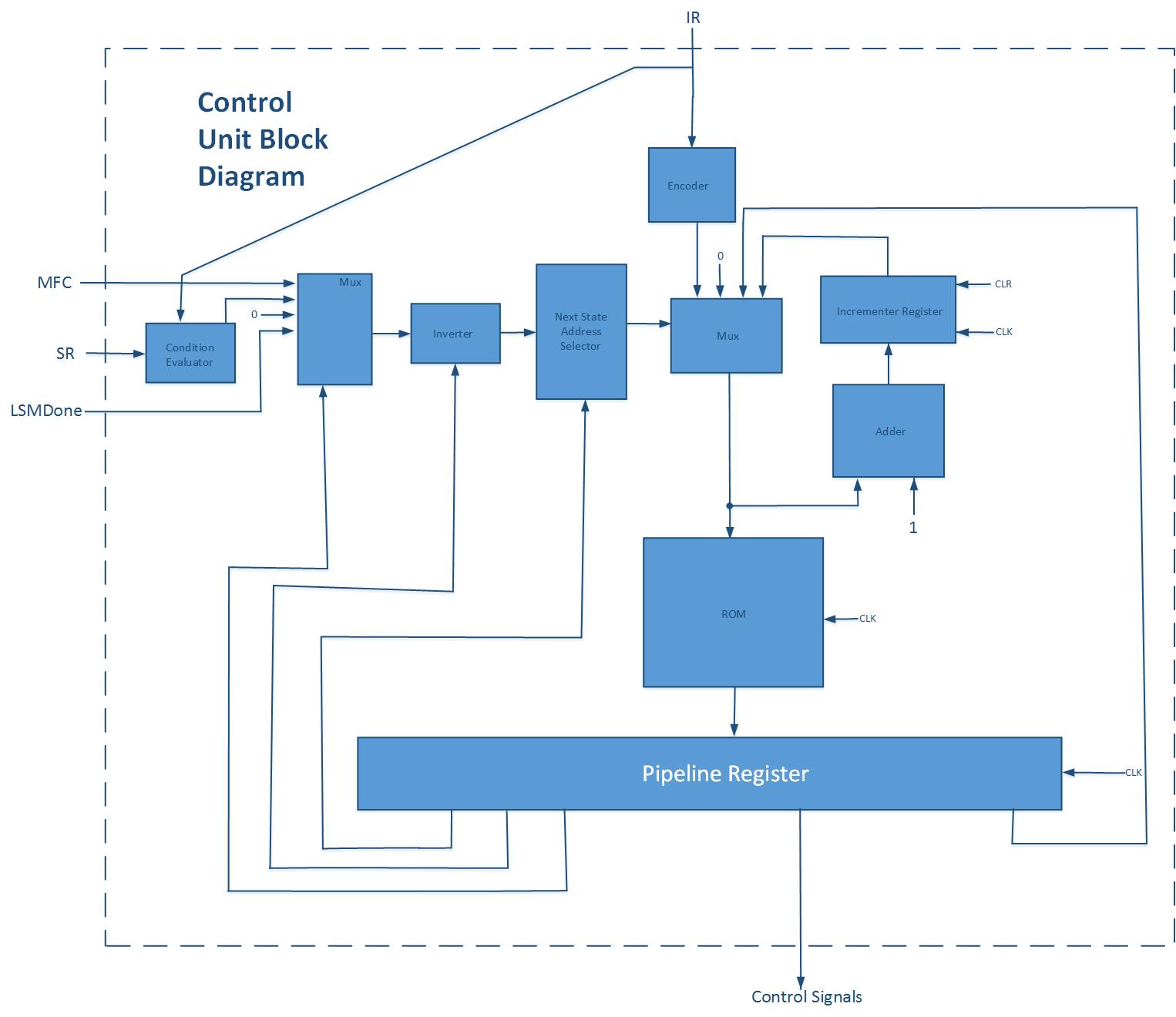


# Block Diagrams

## Data Path

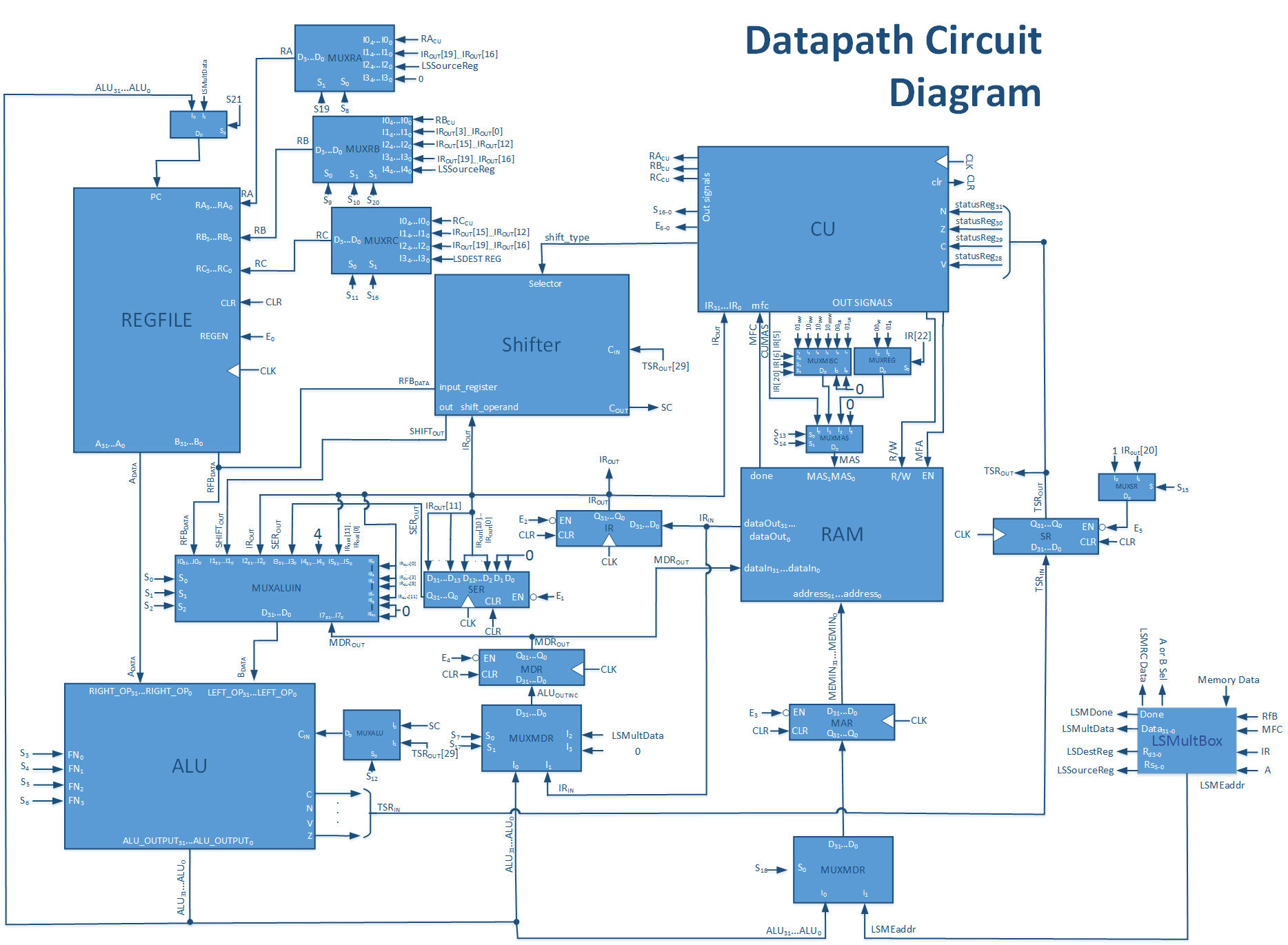


## Control Unit

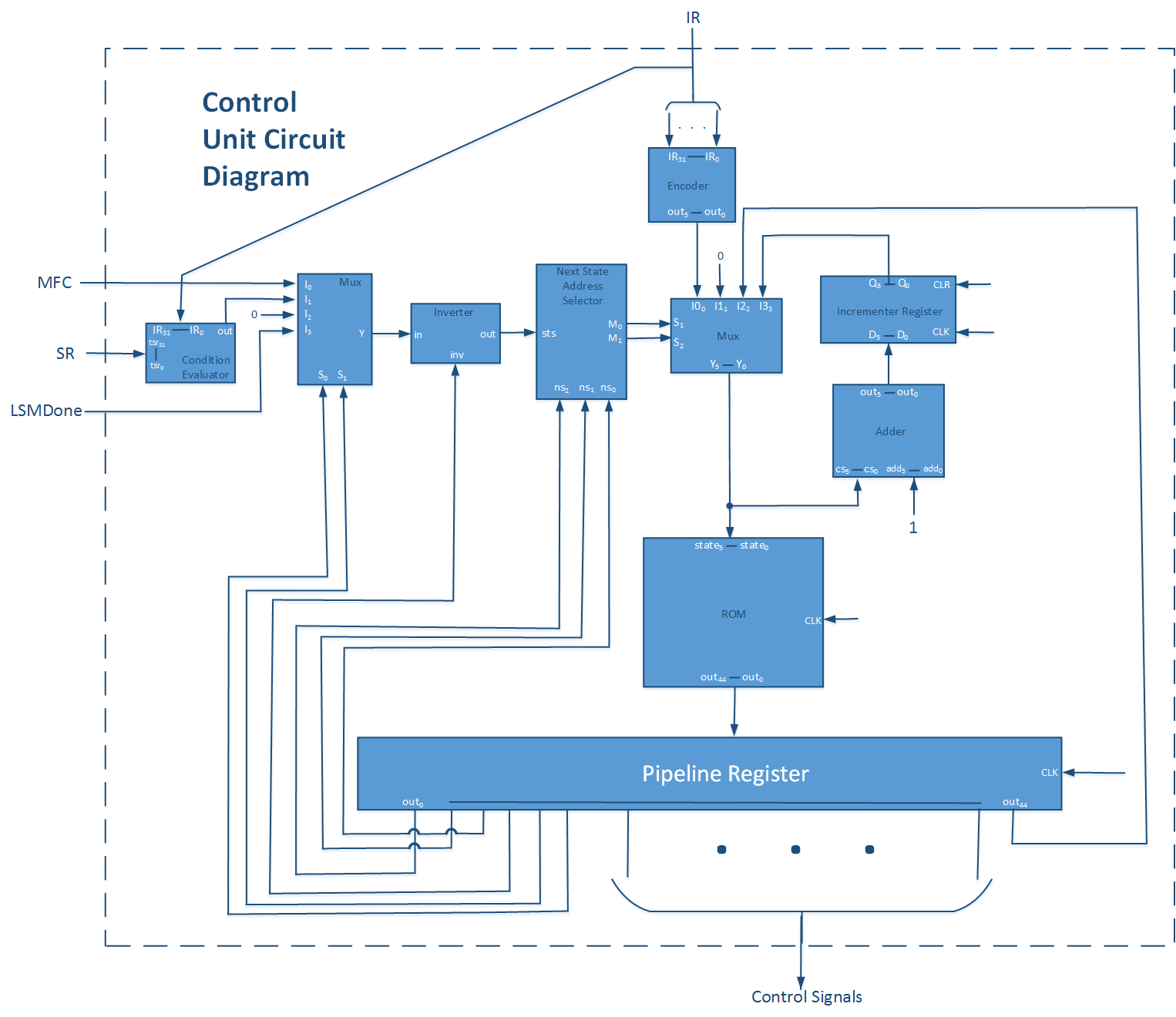


# Circuit Diagrams

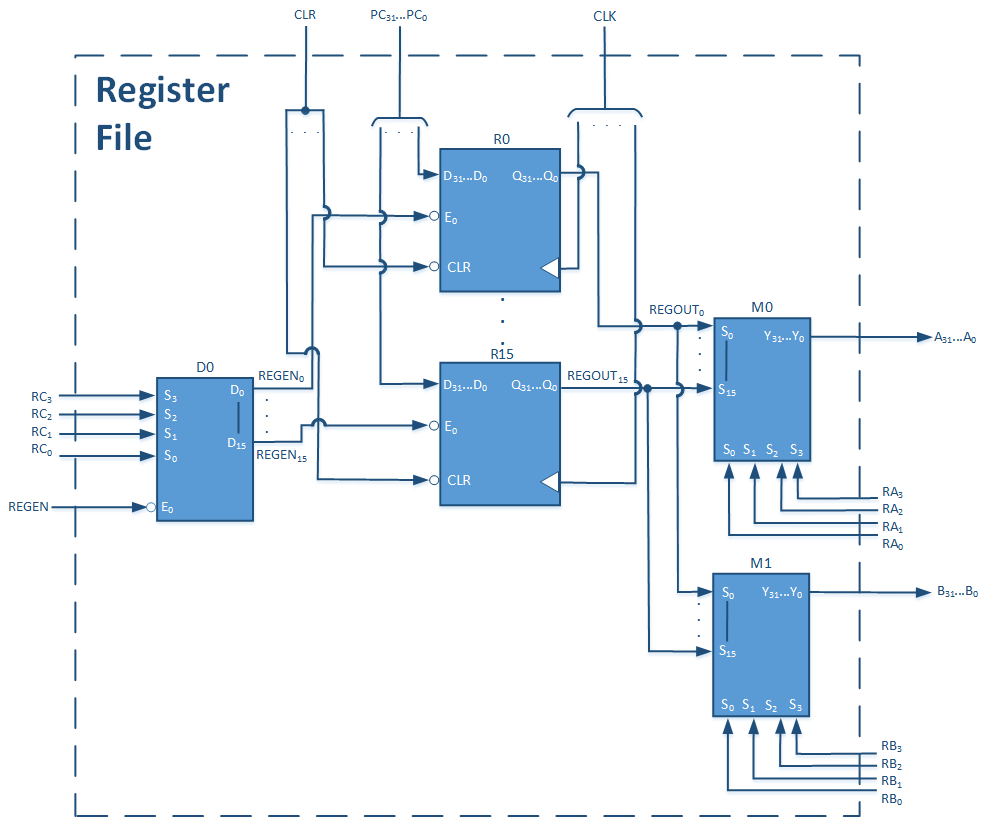
## Data Path



## Control Unit



## Register File



# Microprogram

mem[0][58:0] = 59'b000000000110000000101ZZZZ0ZZZZ00ZZZZ00000000000111100000010;

mem[1][58:0] = 59'b000000000110000000111ZZZZ0111100ZZZZ00000110100110100000010;

mem[2][58:0] = 59'b00000000011000000011011110ZZZZ00111100100010000111100000010;

mem[3][58:0] = 59'b000000001011000001110ZZZZ0ZZZZ00ZZZZ00000000000101100001011;

mem[4][58:0] = 59'b00000001100100000011100000000000ZZZZ00000000000011100000010;

mem[6][58:0] = 59'b00000001010110111001000001000000ZZZZ01001000010111101000010;

mem[5][58:0] = 59'b00000001010110111001000001000001ZZZZ01001000011111101000010;

mem[8][58:0] = 59'b00000001010110111001000001000000000001001000110111101000010;

mem[7][58:0] = 59'b00000001010110111001000001000001000001001000111111101000010;

mem[10][58:0] = 59'b00000001010110111001000001000000000001001001010111101000010;

mem[9][58:0] = 59'b00000001010110111001000001000001000001001001011111101000010;

mem[12][58:0] = 59'b00000001010110111001000001000000000001001001110111101000010;

mem[11][58:0] = 59'b00000001010110111001000001000001000001001001111111101000010;

mem[14][58:0] = 59'b00000001010110111001000001000000000001001010010111101000010;

mem[13][58:0] = 59'b00000001010110111001000001000001000001001010011111101000010;

mem[16][58:0] = 59'b00000001010110111001000001000000000001001010110111101000010;

mem[15][58:0] = 59'b00000001010110111001000001000001000001001010111111101000010;

mem[18][58:0] = 59'b00000001010110111001000001000000000001001011010111101000010;

mem[17][58:0] = 59'b00000001010110111001000001000001000001001011011111101000010;

mem[20][58:0] = 59'b00000001010110111001000001000000000001001011110111101000010;

mem[19][58:0] = 59'b00000001010110111001000001000001000001001011111111101000010;

mem[22][58:0] = 59'b00000001010110111001100001000000000000001100010111101000010;

mem[21][58:0] = 59'b00000001010110111001100001000001000000001100011111101000010;

mem[24][58:0] = 59'b00000001010110111001100001000000000000001100110111101000010;

mem[23][58:0] = 59'b00000001010110111001100001000001000000001100111111101000010;

mem[26][58:0] = 59'b00000001010110111001100001000000000000001101010111101000010;

mem[25][58:0] = 59'b00000001010110111001100001000001000000001101011111101000010;

mem[28][58:0] = 59'b00000001010110111001100001000000000000001101110111101000010;

mem[27][58:0] = 59'b00000001010110111001100001000001000000001101111111101000010;

mem[30][58:0] = 59'b00000001010110111001000001000000000001001110010111101000010;

mem[29][58:0] = 59'b00000001010110111001000001000001000001001110011111101000010;

mem[32][58:0] = 59'b00000001010110111001000001000000000001001110110111101000010;

mem[31][58:0] = 59'b00000001010110111001000001000001000001001110111111101000010;

mem[34][58:0] = 59'b00000001100110111001000001000000000001001111010111101000010;

mem[33][58:0] = 59'b00000001010110111001000001000001000001001111011111101000010;

mem[36][58:0] = 59'b00000001010110111001000001000000000001001111110111101000010;

mem[35][58:0] = 59'b00000001010110111001000001000001000001001111111111101000010;

mem[96][58:0] = 59'b00000001010101101001100001000000000000101010010110100000010;

mem[37][58:0] = 59'b00000001010101101001100001000000000000101001010110100000010;

mem[38][58:0] = 59'b00000001010101101001100001000001000000000010010110100000010;

mem[39][58:0] = 59'b00000001010101101001100001000001000000000001010110100000010;

mem[40][58:0] = 59'b00000001010111000011000001000000000010101010010110100000010;

mem[41][58:0] = 59'b00000001010111000011000001000000000010101001010110100000010;

mem[42][58:0] = 59'b00000001010111000011000001000001000010000010010110100000010;

mem[43][58:0] = 59'b00000001010111000011000001000001000010000001010110100000010;

mem[44][58:0] = 59'b00000001011101011011100000000011000000000110110110100000010;

mem[46][58:0] = 59'b00000001011101011111100000000011000000000110110110100000010;

mem[45][58:0] = 59'b00000001010111000011000001000000000010101010010111100000010;

mem[47][58:0] = 59'b00000001010111000011000001000000000010101001010111100000010;

mem[48][58:0] = 59'b00000001011101100011100000000011000000000110110110100000010;

mem[50][58:0] = 59'b00000001011101100111100000000011000000000110110110100000010;

mem[49][58:0] = 59'b00000001010111000011000001000001000010000010010111100000010;

mem[51][58:0] = 59'b00000001011111000011000001000001000010000001010111100000010;

mem[97][58:0]=59'b000000010101011010010ZZZZXZZZZXXZZZZXX000110111111110000010;

mem[52][58:0] = 59'b00000000101101101001100000000000000000111110110111010100011;

mem[53][58:0] = 59'b00000001010110010001000000000000000001111110111111110000010;

mem[54][58:0] = 59'b00000001010110001101100001000000000000101010010110100000010;

mem[55][58:0] = 59'b00000001010110001101100001000000000000101001010110100000010;

mem[56][58:0] = 59'b00000001010110001101100001000001000000000010010110100000010;

mem[57][58:0] = 59'b00000001010110001101100001000001000000000001010110100000010;

mem[58][58:0] = 59'b00000001010111000101000001000000000010101010010110100000010;

mem[59][58:0] = 59'b00000001010111000101000001000000000010101001010110100000010;

mem[60][58:0] = 59'b00000001010111000101000001000001000010000010010110100000010;

mem[61][58:0] = 59'b00000001010111000101000001000001000010000001010110100000010;

mem[62][58:0] = 59'b00000001011101111111100000000011000000000110110110100000010;

mem[64][58:0] = 59'b00000001011110000011100000000011000000000110110110100000010;

mem[63][58:0] = 59'b00000001010111000101000001000000000010101010010111100000010;

mem[65][58:0] = 59'b00000001010111000101000001000000000010101001010111100000010;

mem[66][58:0] = 59'b00000001011110000111100000000011000000000110110110100000010;

mem[68][58:0] = 59'b00000001011110001011100000000011000000000110110110100000010;

mem[67][58:0] = 59'b00000001010111000101000001000001000010000010010111100000010;

mem[69][58:0] = 59'b00000001011111000101000001000001000010000001010111100000010;

mem[98][58:0] = 59'b000000010101100011010ZZZZXZZZZXXZZZZXX000110111111110000010;

mem[70][58:0] = 59'b00000001011110001111100000000010000000000110110111000100011;

mem[71][58:0] = 59'b00000000101110001111100000000000000000000110110111100100001;

mem[72][58:0] = 59'b000000010101000000110ZZZZXZZZZXXZZZZXX000110111111110000010;

mem[95][58:0] = 59'b00000001010110100001100001000000000000110010010110111000010;

mem[73][58:0] = 59'b00000001010111000111100001000000000000110001010110111000010;

mem[74][58:0] = 59'b00000001010110100001000001000000000010110010010110111000010;

mem[75][58:0] = 59'b00000001010111000111000001000000000010110001010110111000010;

mem[76][58:0] = 59'b00000001011110011011100000000011000000000110110110101000010;

mem[78][58:0] = 59'b00000001011110011111100000000011000000000110110110101000010;

mem[77][58:0] = 59'b00000001010111000111000001000000000010110010000111111000010;

mem[79][58:0] = 59'b00000001011111000111000001000000000010110001000111111000010;

mem[99][58:0] = 59'b000000010101101000010ZZZZXZZZZXXZZZZXX000110111111110000010;

mem[80][58:0] = 59'b00000000101110100001100000000000000000000110110111010010011;

mem[81][58:0] = 59'b00000001010110111001000000000000000001111110110111010010010;

mem[82][58:0] = 59'b00000001010110110101100001000000000000110010000110111000010;

mem[83][58:0] = 59'b00000001010110110101100001000000000000110001000110111000010;

mem[84][58:0] = 59'b00000001010111001001000001000000000010110010000110111000010;

mem[85][58:0] = 59'b00000001010111001001000001000000000010110001000110111000010;

mem[86][58:0] = 59'b00000001011110101111100000000011000000000110110110101000010;

mem[88][58:0] = 59'b00000001011110110011100000000011000000000110110110101000010;

mem[87][58:0] = 59'b00000001010111001001000001000000000010110010000111111000010;

mem[89][58:0] = 59'b00000001011111001001000001000000000010110001000111111000010;

mem[100][58:0]=59'b000000010101101101010ZZZZXZZZZXXZZZZXX000110111111110000010;

mem[90][58:0] = 59'b00000001011110110111100000000010000000000110100111000010001;

mem[91][58:0] = 59'b00000000101110110111100000000000000000000110110111100010011;

mem[92][58:0]=59'b000000010101000000110ZZZZXZZZZXXZZZZXX000110111111110000010;

mem[93][58:0] = 59'b00000000011110111101000000111100111000000110110000000000010;

mem[94][58:0] = 59'b00000000010110111001011110000000111100011010010100000000010;

mem[101][58:0]=59'b111111111011110010110ZZZZ0ZZZZ00ZZZZ11111110110110000001011;

mem[102][58:0]=59'b111111110101000000110ZZZZXZZZZXXZZZZXX111110110111110001010;

mem[105][58:0]=59'b111111110101110011110ZZZZ0ZZZZ00ZZZZ11000110110110000001000;

mem[103][58:0]=59'b111111111011110011110ZZZZ0ZZZZ00ZZZZ11000110110110000001001;

mem[104][58:0]=59’b111111110101000000110ZZZZXZZZZXXZZZZXX000110110111110001000;

# Appendices

## Appendix A: Code Implementation

/\*

Shifter operand === RIGHTOP

0000 AND Logical AND Rd := Rn AND shifteroperand

0001 EOR Logical Exclusive OR Rd := Rn EOR shifteroperand

0010 SUB Subtract Rd := Rn - shifteroperand

0011 RSB Reverse Subtract Rd := shifteroperand - Rn

0100 ADD Add Rd := Rn + shifteroperand

0101 ADC Add with Carry Rd := Rn + shifteroperand + Carry Flag

0110 SBC Subtract with Carry Rd := Rn - shifteroperand - NOT(Carry Flag)

0111 RSC Reverse Subtract with Carry Rd := shifteroperand - Rn - NOT(Carry Flag)

1000 TST Test Update flags after Rn AND shifteroperand

1001 TEQ Test Equivalence Update flags after Rn EOR shifteroperand

1010 CMP Compare Update flags after Rn - shifteroperand

1011 CMN Compare Negated Update flags after Rn + shifteroperand

1100 ORR Logical (inclusive) OR Rd := Rn OR shifteroperand

1101 MOV Move Rd := shifteroperand (no first operand)

1110 BIC Bit Clear Rd := Rn AND NOT(shifteroperand)

1111 MVN Move Not Rd := NOT shifteroperand (no first operand)

\*/

module ALU(output reg [31:0]ALUOUTPUT, output reg Z,N,C, V, input [31:0] LEFTOP,RIGHTOP, input [3:0]FN, input CIN);

reg [31:0] TEMP, TEMP1;

reg CTEMP;

initial begin

N = 0;

C = 0;

V = 0;

Z = 0;

end

always @(LEFTOP, RIGHTOP, FN, CIN) begin

case(FN)

//AND

4'b0000: begin

//Set the output and C flag

{ALUOUTPUT[31:0]} = LEFTOP[31:0] & RIGHTOP[31:0];

C = CIN;

//Set the N flag

N = ALUOUTPUT[31];

//Set the Z flag

if(ALUOUTPUT==0)

Z = 1;

else

Z = 0;

end

// //EOR

4'b0001: begin

{C,ALUOUTPUT[31:0]} = LEFTOP[31:0] ^ RIGHTOP[31:0];

//Set the N flag

N = ALUOUTPUT[31];

//Set the Z flag

if(ALUOUTPUT==0)

Z = 1;

else

Z = 0;

end

// //SUB

4'b0010: begin

{CTEMP,ALUOUTPUT[31:0]} = LEFTOP[31:0] - RIGHTOP[31:0];

C = ~CTEMP;

//Set the N flag

N = ALUOUTPUT[31];

//Set the Z flag

if(ALUOUTPUT==0)

Z = 1;

else

Z = 0;

//Set the overflow flag

//Check for 2's complement overflow

TEMP1 = - RIGHTOP;

if((LEFTOP[31]==TEMP1[31]))

begin

if(LEFTOP[31]!=TEMP[31])

V=1;

else

V=0;

end

else

begin

if((LEFTOP[31]!=TEMP1[31])&&(TEMP[31]==TEMP1))

V=1;

else

V=0;

end

end

// //RSB

4'b0011: begin

{CTEMP,ALUOUTPUT[31:0]} = RIGHTOP[31:0]- LEFTOP[31:0];

C = ~CTEMP;

//Set the N flag

N = ALUOUTPUT[31];

//Set the Z flag

if(ALUOUTPUT==0)

Z = 1;

else

Z = 0;

//Set the overflow flag

//Check for 2's complement overflow

TEMP1 = - LEFTOP;

if((RIGHTOP[31]==TEMP1[31]))

begin

if(RIGHTOP[31]!=TEMP[31])

V=1;

else

V=0;

end

else

begin

if((RIGHTOP[31]!=TEMP1[31])&&(TEMP[31]==TEMP1))

V=1;

else

V=0;

end

end

// //ADD

4'b0100: begin

{C,ALUOUTPUT[31:0]} = LEFTOP[31:0] + RIGHTOP[31:0];

N = ALUOUTPUT[31];

//Set the Z flag

if(ALUOUTPUT==0)

Z = 1;

else

Z = 0;

//Set the overflow flag

//Check for 2's complement overflow

if((LEFTOP[31]==RIGHTOP[31]))

if(LEFTOP[31]!=ALUOUTPUT[31])

V=1;

else

V=0;

else

V=0;

end

// //ADC

4'b0101: begin

{C,ALUOUTPUT[31:0]} = LEFTOP[31:0] + RIGHTOP[31:0] + CIN;

//Set the Z flag

if(ALUOUTPUT==0)

Z = 1;

else

Z = 0;

//Set the overflow flag

//Check for 2's complement overflow

if((LEFTOP[31]==RIGHTOP[31]))

if(LEFTOP[31]!=ALUOUTPUT[31])

V=1;

else

V=0;

else

V=0;

end

// //SBC

4'b0110: begin

{CTEMP,ALUOUTPUT[31:0]} = LEFTOP[31:0] - RIGHTOP[31:0] - ~CIN;

C = ~CTEMP;

//Set the Z flag

if(ALUOUTPUT==0)

Z = 1;

else

Z = 0;

//Set the overflow flag

//Check for 2's complement overflow

if((LEFTOP[31]==RIGHTOP[31]))

if(LEFTOP[31]!=ALUOUTPUT[31])

V=1;

else

V=0;

else

V=0;

end

// //RSC

4'b0111: begin

{CTEMP,ALUOUTPUT[31:0]} = RIGHTOP[31:0] - LEFTOP[31:0] - ~CIN;

C = ~CTEMP;

if(ALUOUTPUT==0)

Z = 1;

else

Z = 0;

//Set the overflow flag

//Check for 2's complement overflow

if((LEFTOP[31]==RIGHTOP[31]))

if(LEFTOP[31]!=ALUOUTPUT[31])

V=1;

else

V=0;

else

V=0;

end

// //TST

4'b1000: begin

{TEMP[31:0]} = LEFTOP[31:0] & RIGHTOP[31:0];

N = TEMP[31];

if(TEMP==0)

Z = 1;

else

Z = 0;

end

// //TEQ

4'b1001: begin

{TEMP[31:0]} = LEFTOP[31:0] ^ RIGHTOP[31:0];

N = TEMP[31];

if(TEMP==0)

Z = 1;

else

Z = 0;

end

// //CMP

4'b1010: begin

{CTEMP,TEMP[31:0]} = LEFTOP[31:0] - RIGHTOP[31:0];

//Set the N flag

C = ~CTEMP;

N = TEMP[31];

//Set the Z flag

if(TEMP==0)

Z = 1;

else

Z = 0;

//Set the overflow flag

//Check for 2's complement overflow

TEMP1 = - RIGHTOP;

if((LEFTOP[31]==TEMP1[31]))

begin

if(LEFTOP[31]!=TEMP[31])

V=1;

else

V=0;

end

else

begin

if((LEFTOP[31]!=TEMP1[31])&&(TEMP[31]==TEMP1))

V=1;

else

V=0;

end

end

// //CMN

4'b1011: begin

{C,TEMP[31:0]} = LEFTOP[31:0] + RIGHTOP[31:0];

N = TEMP[31];

//Set the Z flag

if(TEMP==0)

Z = 1;

else

Z = 0;

//Set the overflow flag

//Check for 2's complement overflow

if((LEFTOP[31]==RIGHTOP[31]))

if(LEFTOP[31]!=TEMP[31])

V=1;

else

V=0;

else

V=0;

end

// //ORR

4'b1100: begin

ALUOUTPUT[31:0] = LEFTOP[31:0] | RIGHTOP[31:0];

// $display("Changing");

//Set the N flag

N = ALUOUTPUT[31];

//Set the Z flag

if(ALUOUTPUT==0)

Z = 1;

else

Z = 0;

C = 0;

V = 0;

end

// //MOV

4'b1101: begin

ALUOUTPUT[31:0] = RIGHTOP[31:0];

//Set the N flag

N = ALUOUTPUT[31];

//Set the Z flag

if(ALUOUTPUT==0)

Z = 1;

else

Z = 0;

end

// //BIC

4'b1110: begin

ALUOUTPUT[31:0] = LEFTOP[31:0] & ~RIGHTOP[31:0];

//Set the N flag

N = ALUOUTPUT[31];

//Set the Z flag

if(ALUOUTPUT==0)

Z = 1;

else

Z = 0;

end

// //MVN

4'b1111: begin

ALUOUTPUT[31:0] = ~RIGHTOP[31:0];

//Set the N flag

N = ALUOUTPUT[31];

//Set the Z flag

if(ALUOUTPUT==0)

Z = 1;

else

Z = 0;

end

endcase // FN

end

endmodule

//---------------------------------------------------------------------------------------------------------------------------------------

module mux4x1(output reg[31:0] Y, input [1:0] S, input [31:0] I0, I1, I2, I3);

always @ (S, I0, I1, I2, I3)

case (S)

2'b00: assign Y=I0[31:0];

2'b01: assign Y=I1[31:0];

2'b10: assign Y=I2[31:0];

2'b11: assign Y=I3[31:0];

endcase

endmodule

module mux4x12b(output reg[1:0] Y, input [1:0] S, input [1:0] I0, I1, I2, I3);

always @ (S, I0, I1, I2, I3)

case (S)

2'b00: assign Y=I0[1:0];

2'b01: assign Y=I1[1:0];

2'b10: assign Y=I2[1:0];

2'b11: assign Y=I3[1:0];

default: assign Y= 2'bXX;

endcase

endmodule

module mux4x14b(output reg[3:0] Y, input [1:0] S, input [3:0] I0, I1, I2, I3);

always @ (S, I0, I1, I2, I3)

case (S)

2'b00: assign Y=I0[3:0];

2'b01: assign Y=I1[3:0];

2'b10: assign Y=I2[3:0];

2'b11: assign Y=I3[3:0];

default: assign Y= 4'bXXXX;

endcase

endmodule

//---------------------------------------------------------------------------------------------------------------------------------------

module mux8x1(output reg[31:0] Y, input [2:0] S, input [31:0] I0, I1, I2, I3, I4,I5,I6,I7);

always @ (S, I0, I1, I2, I3, I4,I5,I6,I7)

case (S)

0: assign Y=I0[31:0];

1: assign Y=I1[31:0];

2: assign Y=I2[31:0];

3: assign Y=I3[31:0];

4: assign Y=I4;

5: assign Y=I5;

6: assign Y=I6;

7: assign Y=I7;

endcase

endmodule

module mux8x12b(output reg[1:0] Y, input [2:0] S, input [1:0] I0, I1, I2, I3, I4,I5,I6,I7);

always @ (S, I0, I1, I2, I3, I4,I5,I6,I7)

case (S)

0: assign Y=I0;

1: assign Y=I1;

2: assign Y=I2;

3: assign Y=I3;

4: assign Y=I4;

5: assign Y=I5;

6: assign Y=I6;

7: assign Y=I7;

endcase

endmodule

module mux8x11b(output reg Y, input [2:0] S, input I0, I1, I2, I3, I4,I5,I6,I7);

always @ (S, I0, I1, I2, I3, I4,I5,I6,I7)

case (S)

0: assign Y=I0;

1: assign Y=I1;

2: assign Y=I2;

3: assign Y=I3;

4: assign Y=I4;

5: assign Y=I5;

6: assign Y=I6;

7: assign Y=I7;

endcase

endmodule

module mux8x14b(output reg[3:0] Y, input [2:0] S, input [3:0] I0, I1, I2, I3, I4,I5,I6,I7);

always @ (S, I0, I1, I2, I3, I4,I5,I6,I7)

case (S)

0: assign Y=I0;

1: assign Y=I1;

2: assign Y=I2;

3: assign Y=I3;

4: assign Y=I4;

5: assign Y=I5;

6: assign Y=I6;

7: assign Y=I7;

endcase

endmodule

//---------------------------------------------------------------------------------------------------------------------------------------

module mux2x1(output [31:0] Y, input S, input [31:0] I0, I1);

assign Y=S? I1:I0;

endmodule

//---------------------------------------------------------------------------------------------------------------------------------------

module mux2x11b(output Y, input S, input I0, I1);

assign Y=S? I1:I0;

endmodule

module mux2x12b(output [1:0] Y, input S, input [1:0] I0, I1);

assign Y=S? I1:I0;

endmodule

module mux2x14b(output [3:0] Y, input S, input [3:0] I0, I1);

assign Y=S? I1:I0;

endmodule

//---------------------------------------------------------------------------------------------------------------------------------------

/\*MAS: 00 B // 01 H // 10 w // 11 undefined

1 = read // 0 = write\*/

module ramdummyreadfile (output reg [31:0]dataOut, output reg done, input enable, readWrite, input [7:0]address, input [31:0]dataIn, input [1:0]MAS, input sign);

reg [7:0]mem[0:511];

initial begin

$readmemb("data.bin", mem) ;

done = 0;

end

always @ (enable, readWrite, MAS, dataIn, address, sign) begin

done = 0;

if (enable) begin

done = 0;

if (readWrite) begin

case(MAS)

2'b00: begin

dataOut[7:0] = mem[address][7:0];

if(sign)

dataOut[31:8] = {24{mem[address][7]}};

else

dataOut[31:8] = 24'b000000000000000000000000;

end

2'b01: begin

dataOut[15:8] = mem[address][7:0];

dataOut[7:0] = mem[address + 8'b0000001][7:0];

if(sign)

dataOut[31:16] = {16{mem[address][7]}};

else

dataOut[31:16] = 16'b0000000000000000;

end

2'b10: begin // #30;

dataOut[31:0] = {mem[address][7:0],

mem[address + 8'b0000001][7:0],

mem[address + 8'b0000010][7:0],

mem[address + 8'b0000011][7:0]};

end

default: dataOut = dataOut;

endcase

end

else begin

if(dataIn||!dataIn)

begin

case(MAS)

2'b00: mem[address][7:0] = dataIn[7:0];

2'b01: begin

mem[address][7:0] = dataIn[15:8];

mem[address + 8'b0000001][7:0] = dataIn[7:0] ;

end

2'b10: begin //#60;

mem[address + 8'b00000011][7:0] = dataIn[7:0];

mem[address + 8'b00000010][7:0] = dataIn[15:8];

mem[address + 8'b00000001][7:0] = dataIn[23:16];

mem[address][7:0] = dataIn[31:24];

end

default: dataOut = dataOut;

endcase

end

end

#4 done = 1;

end

else

dataOut = 32'bz;

end

endmodule

//---------------------------------------------------------------------------------------------------------------------------------------

module reg32(output reg [31:0] Q, input [31:0] D, input EN, CLR, CLK);

initial Q = 32'b0000000000000000000000000000000; // Start registers with 0

always @ (negedge CLK, negedge CLR)

if(!EN)

Q <= D; // Enable Sync. Only occurs when Clk is high

else if(!CLR) // clear

Q <= 32'b0000000000000000000000000000000; // Clear Async

else

Q <= Q; // enable off. output what came out before

endmodule

//---------------------------------------------------------------------------------------------------------------------------------------

module dec4x1632b(output reg [15:0] D, input[3:0] A, input EN);

always @(A, EN)

begin

if (!EN)

case(A)

4'b0000: D = 16'b1111111111111110;

4'b0001: D = 16'b1111111111111101;

4'b0010: D = 16'b1111111111111011;

4'b0011: D = 16'b1111111111110111;

4'b0100: D = 16'b1111111111101111;

4'b0101: D = 16'b1111111111011111;

4'b0110: D = 16'b1111111110111111;

4'b0111: D = 16'b1111111101111111;

4'b1000: D = 16'b1111111011111111;

4'b1001: D = 16'b1111110111111111;

4'b1010: D = 16'b1111101111111111;

4'b1011: D = 16'b1111011111111111;

4'b1100: D = 16'b1110111111111111;

4'b1101: D = 16'b1101111111111111;

4'b1110: D = 16'b1011111111111111;

4'b1111: D = 16'b0111111111111111;

default: D = 16'b1111111111111111;

endcase

end

endmodule

//---------------------------------------------------------------------------------------------------------------------------------------

module reg32b(output reg [31:0] Q, input [31:0] D, input EN, CLR, CLK);

initial Q = 32'b0000000000000000000000000000000; // Start registers with 0

always @ (negedge CLK, negedge CLR)

if(!EN)

Q = D; // Enable Sync. Only occurs when Clk is high

else if(!CLR) // clear

Q = 32'b0000000000000000000000000000000; // Clear Async

else

Q <= Q; // enable off. output what came out before

endmodule

//---------------------------------------------------------------------------------------------------------------------------------------

module mux8x132b(output reg [31:0] O, input [31:0] I0, I1, I2, I3, I4, I5, I6, I7, I8, I9, I10, I11, I12, I13, I14, I15, input [3:0] SEL);

always @ (SEL, I0, I1, I2, I3, I4, I5, I6, I7, I8, I9, I10, I11, I12, I13, I14, I15) // if I change the input and enable is high then

case(SEL)

4'b0000: O = I0;

4'b0001: O = I1;

4'b0010: O = I2;

4'b0011: O = I3;

4'b0100: O = I4;

4'b0101: O = I5;

4'b0110: O = I6;

4'b0111: O = I7;

4'b1000: O = I8;

4'b1001: O = I9;

4'b1010: O = I10;

4'b1011: O = I11;

4'b1100: O = I12;

4'b1101: O = I13;

4'b1110: O = I14;

4'b1111: O = I15;

default:O = O;

endcase

endmodule

//---------------------------------------------------------------------------------------------------------------------------------------

module registerFile (output [31:0] A, B, input[31:0] PC, input [3:0] REGEN, input REGCLR, input [3:0] M0SEL, input [3:0] M1SEL, input REGCLK, RFE);

wire [15:0] decoder2RegEnable; // 16 lines of one bit for Register Enables

wire [31:0] reg0ToMux; // 1 line of 32 bits

wire [31:0] reg1ToMux; // 1 line of 32 bits

wire [31:0] reg2ToMux; // 1 line of 32 bits

wire [31:0] reg3ToMux; // 1 line of 32 bits

wire [31:0] reg4ToMux; // 1 line of 32 bits

wire [31:0] reg5ToMux; // 1 line of 32 bits

wire [31:0] reg6ToMux; // 1 line of 32 bits

wire [31:0] reg7ToMux; // 1 line of 32 bits

wire [31:0] reg8ToMux; // 1 line of 32 bits

wire [31:0] reg9ToMux; // 1 line of 32 bits

wire [31:0] reg10ToMux; // 1 line of 32 bits

wire [31:0] reg11ToMux; // 1 line of 32 bits

wire [31:0] reg12ToMux; // 1 line of 32 bits

wire [31:0] reg13ToMux; // 1 line of 32 bits

wire [31:0] reg14ToMux; // 1 line of 32 bits

wire [31:0] reg15ToMux; // 1 line of 32 bits

dec4x1632b D0 (decoder2RegEnable, REGEN, RFE); // Enable selector

reg32b R0 (reg0ToMux, PC, decoder2RegEnable[0], REGCLR, REGCLK);

reg32b R1 (reg1ToMux, PC, decoder2RegEnable[1], REGCLR, REGCLK);

reg32b R2 (reg2ToMux, PC, decoder2RegEnable[2], REGCLR, REGCLK);

reg32b R3 (reg3ToMux, PC, decoder2RegEnable[3], REGCLR, REGCLK);

reg32b R4 (reg4ToMux, PC, decoder2RegEnable[4], REGCLR, REGCLK);

reg32b R5 (reg5ToMux, PC, decoder2RegEnable[5], REGCLR, REGCLK);

reg32b R6 (reg6ToMux, PC, decoder2RegEnable[6], REGCLR, REGCLK);

reg32b R7 (reg7ToMux, PC, decoder2RegEnable[7], REGCLR, REGCLK);

reg32b R8 (reg8ToMux, PC, decoder2RegEnable[8], REGCLR, REGCLK);

reg32b R9 (reg9ToMux, PC, decoder2RegEnable[9], REGCLR, REGCLK);

reg32b R10 (reg10ToMux, PC, decoder2RegEnable[10], REGCLR, REGCLK);

reg32b R11 (reg11ToMux, PC, decoder2RegEnable[11], REGCLR, REGCLK);

reg32b R12 (reg12ToMux, PC, decoder2RegEnable[12], REGCLR, REGCLK);

reg32b R13 (reg13ToMux, PC, decoder2RegEnable[13], REGCLR, REGCLK);

reg32b R14 (reg14ToMux, PC, decoder2RegEnable[14], REGCLR, REGCLK);

reg32b R15 (reg15ToMux, PC, decoder2RegEnable[15], REGCLR, REGCLK);

mux8x132b M0 (A, reg0ToMux, reg1ToMux, reg2ToMux, reg3ToMux, reg4ToMux, reg5ToMux, reg6ToMux, reg7ToMux,

reg8ToMux, reg9ToMux, reg10ToMux, reg11ToMux, reg12ToMux, reg13ToMux, reg14ToMux, reg15ToMux, M0SEL);

mux8x132b M1 (B, reg0ToMux, reg1ToMux, reg2ToMux, reg3ToMux, reg4ToMux, reg5ToMux, reg6ToMux, reg7ToMux,

reg8ToMux, reg9ToMux, reg10ToMux, reg11ToMux, reg12ToMux, reg13ToMux, reg14ToMux, reg15ToMux, M1SEL);

endmodule

//---------------------------------------------------------------------------------------------------------------------------------------

module internalshifter (input [31:0] amount, value, input [1:0] shifttype, output reg [31:0] shiftout);

reg [63:0] temp;

always @(amount, value, shifttype) begin

case(shifttype)

0: shiftout[31:0] = value[31:0]<<amount; //Logical Shift Left

1: shiftout[31:0] = value[31:0]>>amount; //Logical Shift Right

2: shiftout[31:0] = $signed(value[31:0])>>>amount; //right arithmetic

3: begin

temp = {value, value} >> amount; //rotate right

shiftout[31:0] = temp[31:0];

end

endcase //shifttype

end

endmodule

//---------------------------------------------------------------------------------------------------------------------------------------

module shifter(input[31:0] inputregister, input[11:0] shifteroperand, input selector, output [31:0] out);

wire[31:0] amounttointernal,valuetointernal;

wire[1:0] shifttypetointernal;

mux2x1 amountmux(amounttointernal,selector,{27'b000000000000000000000000000,shifteroperand[11:8],1'b0}, {27'b000000000000000000000000000,shifteroperand[11:7]});

mux2x1 valuemux(valuetointernal,selector,{24'b000000000000000000000000,shifteroperand[7:0]},inputregister[31:0]);

mux2x12b shifttypemux(shifttypetointernal,selector,2'b01,shifteroperand[6:5]);

internalshifter intsh(amounttointernal,valuetointernal,shifttypetointernal,out);

endmodule

//---------------------------------------------------------------------------------------------------------------------------------------

module adder(input [31:0] pc, right, output reg [31:0] out);

always @(pc, right)

out = pc+right;

endmodule

//---------------------------------------------------------------------------------------------------------------------------------------

// Control unit

// IR condition evaluator

module condEval(output reg out, input [31:0] IR, input [31:0] str);

always @ (IR, str)

case(IR[31:28])

4'b0000: begin if (str[30]) out = 1; // Z=1

else out = 0; end

4'b0001: begin if (str[30] == 0) out = 1; // Z=0

else out = 0; end

4'b0010: begin if (str[29]) out = 1; // C=1

else out = 0; end

4'b0011: begin if (str[29]== 0) out = 1; // C=0

else out = 0; end

4'b0100: begin if (str[31]) out = 1; // N=1

else out = 0; end

4'b0101: begin if (str[31] == 0) out = 1; // N=0

else out = 0; end

4'b0110: begin if (str[28]) out = 1; // V=1

else out = 0; end

4'b0111: begin if (str[28]==0) out = 1; // V=0

else out = 0; end

4'b1000: begin if (str[29] == 1 && str[30] == 0) out = 1; // C=1 & Z=0

else out = 0; end

4'b1001: begin if (str[29] == 0 || str[30] == 1) out = 1; // C=0 or Z=1

else out = 0; end

4'b1010: begin if (str[31] == str[28]) out = 1; // N=Z

else out = 0; end

4'b1011: begin if (str[31] != str[28]) out = 1; // N!=V

else out = 0; end

4'b1100: begin if (str[30] == 0 && str[31] == str[28]) out = 1; // Z=0 & N=V

else out = 0; end

4'b1101: begin if (str[30] == 1 || (str[31] != str[28])) out = 1; //Z=1 or N!=V

else out = 0; end

4'b1110: out = 1;

4'b1111: out = 0;

default: out = 1;

endcase

endmodule

//-------------------------------------------------------------------------------

// mux to inverter with inputs if 1 bit

module mux4x11b(output reg Y, input [1:0] S, input I0, I1, I2, I3);

always @ (S, I0, I1, I2, I3)

case (S)

2'b00: assign Y=I0;

2'b01: assign Y=I1;

2'b10: assign Y=I2;

2'b11: assign Y=I3;

default: Y=I1;

endcase

endmodule

//-------------------------------------------------------------------------------

//inverter

module inverter(output reg out, input in, inv);

always @ (in, inv)

if(inv)

out = ~in;

else

out = in;

endmodule

//-------------------------------------------------------------------------------

// 4bit mux selector upon conditions

module NSASel(output reg [1:0] M, input [2:0] ns, input sts);

always @ (ns, sts)

case(ns)

3'b000: M = 2'b00; //encoder

3'b001: M = 2'b01; //0

3'b010: M = 2'b10; //pipeline

3'b011: M = 2'b11; //incrementer

3'b100:

case(sts)

0: M = 2'b00; //encoder

1: M = 2'b10; //pipeline

endcase

3'b101:

case(sts)

0: M = 2'b11; //incrementer

1: M = 2'b10; //pipeline

endcase

3'b110:

case(sts)

0: M = 2'b11; //incrementer

1: M = 2'b00; //encoder

endcase

3'b111: M = 2'b01; //0

endcase

endmodule

//-------------------------------------------------------------------------------

// IR encoder for next state

module encoder(output reg [6:0] out, input [31:0] IR);

always @(IR)

case(IR[27:25])

3'b000: begin

if (IR[4]) begin

if (IR[7]) begin //multiplies & extra load/stores

if(IR[20]) begin //load

if(IR[23]) begin //add

if(IR[24]) begin //offset or pre-indexed (P)

if(IR[21]) out = 74; //pre-indexed (W)

else out = 95; //offset addresing

end

else begin //post-indexed

if(IR[21]) out = 1; //unpredictable

else out = 76; //normal

end

end

else begin //sub

if(IR[24]) begin //offset or pre-indexed (P)

if(IR[21]) out = 75; //pre-indexed (W)

else out = 73; //offset addresing

end

else begin //post-indexed

if(IR[21]) out = 1; //unpredictable

else out = 78; //normal

end

end

end

else begin //store

if(IR[23]) begin //add

if(IR[24]) begin //offset or pre-indexed (P)

if(IR[21]) out = 84; //pre-indexed (W)

else out = 82; //offset addresing

end

else begin //post-indexed

if(IR[21]) out = 1; //unpredictable

else out = 86; //normal

end

end

else begin //sub

if(IR[24]) begin //offset or pre-indexed (P)

if(IR[21]) out = 85; //pre-indexed (W)

else out = 83; //offset addresing

end

else begin //post-indexed

if(IR[21]) out = 1; //unpredictable

else out = 88; //normal

end

end

end

end

else out = 1;

end

else begin

if (IR[20]) begin //data processing immediate shift

case (IR[24:21])

0: out = 5; //and

1: out = 7; //eor

2: out = 9; //sub

3: out = 11; //rsb

4: out = 13; //add

5: out = 15; //adc

6: out = 17; //sbc

7: out = 19; //rsc

8: out = 21; //tst

9: out = 23; //teq

10: out = 25; //cmp

11: out = 27; //cmn

12: out = 29; //orr

13: out = 31; //mov

14: out = 33; //bic

15: out = 35; //mvn

endcase

end

else begin

if (IR[24:23] == 2'b10) out = 1 ;//; //miscellaneous instructions

else begin //data processing immediate shift

case (IR[24:21])

0: out = 5; //and

1: out = 7; //eor

2: out = 9; //sub

3: out = 11; //rsb

4: out = 13; //add

5: out = 15; //adc

6: out = 17; //sbc

7: out = 19; //rsc

8: out = 21; //tst

9: out = 23; //teq

10: out = 25; //cmp

11: out = 27; //cmn

12: out = 29; //orr

13: out = 31; //mov

14: out = 33; //bic

15: out = 35; //mvn

endcase

end

end

end

end //done

3'b001: begin

if (IR[20]) begin //data processing immediate (32-bit)

case (IR[24:21])

0: out = 6; //and

1: out = 8; //eor

2: out = 10; //sub

3: out = 12; //rsb

4: out = 14; //add

5: out = 16; //adc

6: out = 18; //sbc

7: out = 20; //rsc

8: out = 22; //tst

9: out = 24; //teq

10: out = 26; //cmp

11: out = 28; //cmn

12: out = 30; //orr

13: out = 32; //mov

14: out = 34; //bic

15: out = 36; //mvn

endcase

end

else begin

if (IR[24:23] == 2'b10 && IR[21:20] == 2'b00) out = 1; //undefined instruction

else if (IR[24:23] == 2'b10 && IR[21:20] == 2'b10) out = 1; //move immediate to status register

else begin //data processing immediate (32-bit)

case (IR[24:21])

0: out = 6; //and

1: out = 8; //eor

2: out = 10; //sub

3: out = 12; //rsb

4: out = 14; //add

5: out = 16; //adc

6: out = 18; //sbc

7: out = 20; //rsc

8: out = 22; //tst

9: out = 24; //teq

10: out = 26; //cmp

11: out = 28; //cmn

12: out = 30; //orr

13: out = 32; //mov

14: out = 34; //bic

15: out = 36; //mvn

endcase

end

end

end //done

3'b010: begin //load/store immediate offset

if(IR[20]) begin //load

if(IR[23]) begin //add

if(IR[24]) begin //offset or pre-indexed (P)

if(IR[21]) out = 40; //pre-indexed (W)

else out = 96; //offset addresing

end

else begin //post-indexed

if(IR[21]) out = 1; //privilage loads/store

else out = 44; //normal

end

end

else begin //sub

if(IR[24]) begin //offset or pre-indexed (P)

if(IR[21]) out = 41; //pre-indexed (W)

else out = 37; //offset addresing

end

else begin //post-indexed

if(IR[21]) out = 1; //privilage loads/store

else out = 46; //normal

end

end

end

else begin //store

if(IR[23]) begin //add

if(IR[24]) begin //offset or pre-indexed (P)

if(IR[21]) out = 58; //pre-indexed (W)

else out = 54; //offset addresing

end

else begin //post-indexed

if(IR[21]) out = 1; //privilage loads/store

else out = 62; //normal

end

end

else begin //sub

if(IR[24]) begin //offset or pre-indexed (P)

if(IR[21]) out = 59; //pre-indexed (W)

else out = 55; //offset addresing

end

else begin //post-indexed

if(IR[21]) out = 1; //privilage loads/store

else out = 64; //normal

end

end

end

end //done

3'b011: begin

if(IR[4]) out = 1; //arquitecturally undefined & media instructions

else begin //load/store register offset

if(IR[20]) begin //load

if(IR[23]) begin //add

if(IR[24]) begin //offset or pre-indexed (P)

if(IR[21]) out = 42; //pre-indexed (W)

else out = 38; //offset addresing

end

else begin //post-indexed

if(IR[21]) out = 1; //privilage loads/store

else out = 48; //normal

end

end

else begin //sub

if(IR[24]) begin //offset or pre-indexed (P)

if(IR[21]) out = 43; //pre-indexed (W)

else out = 39; //offset addresing

end

else begin //post-indexed

if(IR[21]) out = 1; //privilage loads/store

else out = 50; //normal

end

end

end

else begin //store

if(IR[23]) begin //add

if(IR[24]) begin //offset or pre-indexed (P)

if(IR[21]) out = 60; //pre-indexed (W)

else out = 56; //offset addresing

end

else begin //post-indexed

if(IR[21]) out = 1; //privilage loads/store

else out = 66; //normal

end

end

else begin //sub

if(IR[24]) begin //offset or pre-indexed (P)

if(IR[21]) out = 61; //pre-indexed (W)

else out = 57; //offset addresing

end

else begin //post-indexed

if(IR[21]) out = 1; //privilage loads/store

else out = 68; //normal

end

end

end

end

end //done

3'b100: begin //load/store multiples

if(IR[20]==1)//LOAD

out = 101;

else //Store

out = 105;

end

3'b101: begin

if (IR[24]) out = 93; //branch with link

else out = 94; //branch

end //done

3'b110: out = 1; //does not apply

3'b111: out = 1; //does not apply

endcase

endmodule

//-------------------------------------------------------------------------------

//6bit mux selector for state choosing (may increase depending on final states quantity)

module mux4x16b(output reg [6:0] Y, input [1:0] S, input [6:0] I0, I1, I2, I3);

always @ (S, I0, I1, I2, I3)

case (S)

2'b00: assign Y=I0[6:0];

2'b01: assign Y=I1[6:0];

2'b10: assign Y=I2[6:0];

2'b11: assign Y=I3[6:0];

default: Y=I1;

endcase

endmodule

//-------------------------------------------------------------------------------

//state adder

module cuAdder(output reg [6:0] out, input [6:0] cs, input [3:0] add);

initial out = 7'b0000000;

always @ (cs)

out = cs + add;

endmodule

//-------------------------------------------------------------------------------

//state adder register

module IncReg(output reg [6:0] Q, input [6:0] D, input EN, CLR, CLK);

initial Q = 6'b000000; //Start registers with 0

always @ (posedge CLK, negedge CLR)

if(!EN)

Q = D; //Enable Sync. Only occurs when Clk is high

else if(!CLR) //clear

Q = 6'b000000; //Clear Async

else

Q <= Q; //enable off. output what came out before

endmodule

//-------------------------------------------------------------------------------

//ROM (output may increce, depending on signals requiered, 1bit per signal)

module ROM (output reg [61:0] out, input [6:0] state, input clk);

reg [61:0]mem[105:0];

initial begin

// 61 59 58 57 56 55 54 53 |52 50 47 46 |39 38 37 33 32 28 26 22 20 17 13 12 11 10 9 8 7 6 5 3 1 0

// S22 sign ENM S19 S20 S21 S18 S17|s0s1 NS Inv pl |clr E0 RA S8 RB S9S10 RC S11S16 S2-S0 S6-S3 S12 Sel E1 E2 E3 E4 S7 S15 S13S14 MAS R/W MFA

mem[0][61:0] = 62'b000000000000110000000101ZZZZ0ZZZZ00ZZZZ00000000000111100000010;

mem[1][61:0] = 62'b000000000000110000000111ZZZZ0111100ZZZZ00000110100110100000010;

mem[2][61:0] = 62'b00000000000011000000011011110ZZZZ00111100100010000111100000010;

mem[3][61:0] = 62'b000000000001011000001110ZZZZ0ZZZZ00ZZZZ00000000000101100001011;

mem[4][61:0] = 62'b00000000001100100000011100000000000ZZZZ00000000000011100000010;

mem[6][61:0] = 62'b00000000001010110111001000001000000ZZZZ01001000010111101000010;

mem[5][61:0] = 62'b00000000001010110111001000001000001ZZZZ01001000011111101000010;

mem[8][61:0] = 62'b00000000001010110111001000001000000000001001000110111101000010;

mem[7][61:0] = 62'b00000000001010110111001000001000001000001001000111111101000010;

mem[10][61:0] = 62'b00000000001010110111001000001000000000001001001010111101000010;

mem[9][61:0] = 62'b00000000001010110111001000001000001000001001001011111101000010;

mem[12][61:0] = 62'b00000000001010110111001000001000000000001001001110111101000010;

mem[11][61:0] = 62'b00000000001010110111001000001000001000001001001111111101000010;

mem[14][61:0] = 62'b00000000001010110111001000001000000000001001010010111101000010;

mem[13][61:0] = 62'b00000000001010110111001000001000001000001001010011111101000010;

mem[16][61:0] = 62'b00000000001010110111001000001000000000001001010110111101000010;

mem[15][61:0] = 62'b00000000001010110111001000001000001000001001010111111101000010;

mem[18][61:0] = 62'b00000000001010110111001000001000000000001001011010111101000010;

mem[17][61:0] = 62'b00000000001010110111001000001000001000001001011011111101000010;

mem[20][61:0] = 62'b00000000001010110111001000001000000000001001011110111101000010;

mem[19][61:0] = 62'b00000000001010110111001000001000001000001001011111111101000010;

mem[22][61:0] = 62'b00000000001010110111001100001000000000000001100010111101000010;

mem[21][61:0] = 62'b00000000001010110111001100001000001000000001100011111101000010;

mem[24][61:0] = 62'b00000000001010110111001100001000000000000001100110111101000010;

mem[23][61:0] = 62'b00000000001010110111001100001000001000000001100111111101000010;

mem[26][61:0] = 62'b00000000001010110111001100001000000000000001101010111101000010;

mem[25][61:0] = 62'b00000000001010110111001100001000001000000001101011111101000010;

mem[28][61:0] = 62'b00000000001010110111001100001000000000000001101110111101000010;

mem[27][61:0] = 62'b00000000001010110111001100001000001000000001101111111101000010;

mem[30][61:0] = 62'b00000000001010110111001000001000000000001001110010111101000010;

mem[29][61:0] = 62'b00000000001010110111001000001000001000001001110011111101000010;

mem[32][61:0] = 62'b00000000001010110111001000001000000000001001110110111101000010;

mem[31][61:0] = 62'b00000000001010110111001000001000001000001001110111111101000010;

mem[34][61:0] = 62'b00000000001100110111001000001000000000001001111010111101000010;

mem[33][61:0] = 62'b00000000001010110111001000001000001000001001111011111101000010;

mem[36][61:0] = 62'b00000000001010110111001000001000000000001001111110111101000010;

mem[35][61:0] = 62'b00000000001010110111001000001000001000001001111111111101000010;

mem[96][61:0] = 62'b00000000001010101101001100001000000000000101010010110100000010;

mem[37][61:0] = 62'b00000000001010101101001100001000000000000101001010110100000010;

mem[38][61:0] = 62'b00000000001010101101001100001000001000000000010010110100000010;

mem[39][61:0] = 62'b00000000001010101101001100001000001000000000001010110100000010;

mem[40][61:0] = 62'b00000000001010111000011000001000000000010101010010110100000010;

mem[41][61:0] = 62'b00000000001010111000011000001000000000010101001010110100000010;

mem[42][61:0] = 62'b00000000001010111000011000001000001000010000010010110100000010;

mem[43][61:0] = 62'b00000000001010111000011000001000001000010000001010110100000010;

mem[44][61:0] = 62'b00000000001011101011011100000000011000000000110110110100000010;

mem[46][61:0] = 62'b00000000001011101011111100000000011000000000110110110100000010;

mem[45][61:0] = 62'b00000000001010111000011000001000000000010101010010111100000010;

mem[47][61:0] = 62'b00000000001010111000011000001000000000010101001010111100000010;

mem[48][61:0] = 62'b00000000001011101100011100000000011000000000110110110100000010;

mem[50][61:0] = 62'b00000000001011101100111100000000011000000000110110110100000010;

mem[49][61:0] = 62'b00000000001010111000011000001000001000010000010010111100000010;

mem[51][61:0] = 62'b00000000001011111000011000001000001000010000001010111100000010;

mem[97][61:0] = 62'b000000000010101011010010ZZZZXZZZZXXZZZZXX000110111111110000010;

mem[52][61:0] = 62'b10000000000101101101001100000000000000000111110110111010100011;

mem[53][61:0] = 62'b00000000001010110010001000000000000000001111110111111110000010;

mem[54][61:0] = 62'b00000000001010110001101100001000000000000101010010110100000010;

mem[55][61:0] = 62'b00000000001010110001101100001000000000000101001010110100000010;

mem[56][61:0] = 62'b00000000001010110001101100001000001000000000010010110100000010;

mem[57][61:0] = 62'b00000000001010110001101100001000001000000000001010110100000010;

mem[58][61:0] = 62'b00000000001010111000101000001000000000010101010010110100000010;

mem[59][61:0] = 62'b00000000001010111000101000001000000000010101001010110100000010;

mem[60][61:0] = 62'b00000000001010111000101000001000001000010000010010110100000010;

mem[61][61:0] = 62'b00000000001010111000101000001000001000010000001010110100000010;

mem[62][61:0] = 62'b00000000001011101111111100000000011000000000110110110100000010;

mem[64][61:0] = 62'b00000000001011110000011100000000011000000000110110110100000010;

mem[63][61:0] = 62'b00000000001010111000101000001000000000010101010010111100000010;

mem[65][61:0] = 62'b00000000001010111000101000001000000000010101001010111100000010;

mem[66][61:0] = 62'b00000000001011110000111100000000011000000000110110110100000010;

mem[68][61:0] = 62'b00000000001011110001011100000000011000000000110110110100000010;

mem[67][61:0] = 62'b00000000001010111000101000001000001000010000010010111100000010;

mem[69][61:0] = 62'b00000000001011111000101000001000001000010000001010111100000010;

mem[98][61:0] = 62'b000000000010101100011010ZZZZXZZZZXXZZZZXX000110111111110000010;

mem[70][61:0] = 62'b10000000001011110001111100000000010000000000110110111000100010;

mem[71][61:0] = 62'b10000000000101110001111100000000010000000000110110111100100001;

mem[72][61:0] = 62'b000000000010101000000110ZZZZXZZZZXXZZZZXX000110111111110000010;

mem[95][61:0] = 62'b00000000001010110100001100001000000000000110010010110111000010;

mem[73][61:0] = 62'b00000000001010111000111100001000000000000110001010110111000010;

mem[74][61:0] = 62'b00000000001010110100001000001000000000010110010010110111000010;

mem[75][61:0] = 62'b00000000001010111000111000001000000000010110001010110111000010;

mem[76][61:0] = 62'b00000000001011110011011100000000011000000000110110110101000010;

mem[78][61:0] = 62'b00000000001011110011111100000000011000000000110110110101000010;

mem[77][61:0] = 62'b00000000001010111000111000001000000000010110010000111111000010;

mem[79][61:0] = 62'b00000000001011111000111000001000000000010110001000111111000010;

mem[99][61:0] = 62'b000000000010101101000010ZZZZXZZZZXXZZZZXX000110111111110000010;

mem[80][61:0] = 62'b01000000000101110100001100000000000000000000110110111010010011;

mem[81][61:0] = 62'b01000000001010110111001000000000000000001111110110111010010010;

mem[82][61:0] = 62'b00000000001010110110101100001000000000000110010000110111000010;

mem[83][61:0] = 62'b00000000001010110110101100001000000000000110001000110111000010;

mem[84][61:0] = 62'b00000000001010111001001000001000000000010110010000110111000010;

mem[85][61:0] = 62'b00000000001010111001001000001000000000010110001000110111000010;

mem[86][61:0] = 62'b00000000001011110101111100000000011000000000110110110101000010;

mem[88][61:0] = 62'b00000000001011110110011100000000011000000000110110110101000010;

mem[87][61:0] = 62'b00000000001010111001001000001000000000010110010000111111000010;

mem[89][61:0] = 62'b00000000001011111001001000001000000000010110001000111111000010;

mem[100][61:0]= 62'b000000000010101101101010ZZZZXZZZZXXZZZZXX000110111111110000010;

mem[90][61:0] = 62'b01000000001011110110111100000000010000000000110100111000010001;

mem[91][61:0] = 62'b01000000000101110110111100000000000000000000110110111100010011;

mem[92][61:0] = 62'b000000000010101000000110ZZZZXZZZZXXZZZZXX000110111111110000010;

mem[93][61:0] = 62'b00000000000011110111101000000111100111000000110110000000000010;

mem[94][61:0] = 62'b00000000000010110111001011110000000111100011010010100000000010;

mem[101][61:0]= 62'b000111111111011110010110ZZZZ0ZZZZ00ZZZZ11111110110110000001011;

mem[102][61:0]= 62'b000111111110101000000111ZZZZXZZZZXXZZZZXX111110110111110001010;

mem[105][61:0]= 62'b000111111110101110011110ZZZZ0ZZZZ00ZZZZ11000110110110000001000;

mem[103][61:0]= 62'b000111111111011110011110ZZZZ0ZZZZ00ZZZZ11000110110110000001001;

mem[104][61:0]= 62'b000111111110101000000110ZZZZXZZZZXXZZZZXX000110110111110001000;

end

always @ (posedge clk)

out = mem[state][58:0];

endmodule

//-------------------------------------------------------------------------------

//control unit box (output depends on ROM output)

module ControlUnit (output reg [48:0] out, input clk, mfc, lsmDone, input [31:0] IR, statusReg);

wire [6:0] state, stateSel0, stateSel3, addToR;

wire [1:0] ms;

wire invIn, invOut, condOut;

wire [61:0] innerOut;

condEval condEv (condOut, IR, statusReg);//Sirve

mux4x11b mux1b (invIn, innerOut[52:51], mfc, condOut, 1'b0, lsmDone);

inverter inv (invOut, invIn, innerOut[47]);

NSASel stateSel (ms, innerOut[50:48], invOut);

encoder iREnc (stateSel0, IR);//Sirve

mux4x16b mux6b (state, ms, stateSel0, 7'b0000000, innerOut[46:40], stateSel3);

cuAdder adderAlu (addToR, state, 4'b0001);

IncReg incR (stateSel3, addToR, 1'b0, innerOut[39], clk);

ROM rom (innerOut, state, clk);

// always @(posedge clk)

// out = innerOut[39:0];

// always @ (state)

// $display("Next State %d",state);

always @(innerOut)

out = {innerOut[61:53], innerOut[39:0]};

endmodule

//---------------------------------------------------------------------------------------------------------------------------------------

module LSMBlackBox(output reg [31:0] registerDataOut, memoryDataOut, effectiveAddress, output reg [3:0] sourceRegisterA, sourceRegisterB, destinationRegister ,output reg done ,input [31:0] ir, memoryDataIn, a,b, input clk, mfc, enable);

reg inc;

reg [4:0] j;

reg [4:0] cnt;

reg [31:0] startaddress;

reg [31:0] currAddress = 0;

reg [12:0] i;

always @(enable) begin

if(enable) begin

done = 0;

cnt = 0;

sourceRegisterA = ir[19:16];

#8

begin

#4 ;//$display("SRA %d RA %d",sourceRegisterA, a);

for(j = 0; j<16;j=j+1) begin

if(ir[j]==1)

cnt = cnt+1;

end

//Calculate effective address

//01 increment after

// startaddress = Rn

// endaddress = Rn + (NumberOfSetBitsIn(registerlist) \* 4) - 4

// if W == 1 then

// Rn = Rn + (NumberOfSetBitsIn(registerlist) \* 4)

if(ir[24:23]==2'b01) begin

inc = 1;

#4 begin

startaddress = a;

if(ir[21]==1) begin

destinationRegister = ir[19:16];

registerDataOut = startaddress + (cnt\*4);

#3; //$display("Waiting to store");

end

end

end

//11 increment before

// startaddress = Rn + 4

// endaddress = Rn + (NumberOfSetBitsIn(registerlist) \* 4)

// if W == 1 then

// Rn = Rn + (NumberOfSetBitsIn(registerlist) \* 4)

else if(ir[24:23]==2'b11) begin

// $display("IB");

inc = 1;

#4 begin

startaddress = a+4;

if(ir[21]==1) begin

destinationRegister = ir[19:16];

registerDataOut = startaddress + (cnt\*4);

#3;// $display("Waiting to store");

end

end

end

//00 decrement after

// startaddress = Rn - (NumberOfSetBitsIn(registerlist) \* 4) + 4

// endaddress = Rn

// if W == 1 then

// Rn = Rn - (NumberOfSetBitsIn(registerlist) \* 4)

else if(ir[24:23]==2'b00) begin

inc = 0;

// $display("DA");

#4 begin

startaddress = a-(cnt\*4)+4;

if(ir[21]==1) begin

destinationRegister = ir[19:16];

registerDataOut = startaddress - (cnt\*4);

#3; //$display("tato");

end

end

end

//10 decrement before

// startaddress = Rn - (NumberOfSetBitsIn(registerlist) \* 4)

// endaddress = Rn - 4

// if W == 1 then

// Rn = Rn - (NumberOfSetBitsIn(registerlist) \* 4)

else begin

inc = 0;

// $display("DB");

#4 begin

startaddress = a-(cnt\*4);

if(ir[21]==1) begin

destinationRegister = ir[19:16];

registerDataOut = startaddress - (cnt\*4);

#3 ;//$display("pot");

end

end

end

currAddress = startaddress;

// $display("Start addr %d", startaddress);

for(j=0;j<16;j=j+1) begin

if(ir[j]==1) begin

if(ir[20]==1) begin //load

// $display("lOADING");

effectiveAddress = currAddress;

// $display("Eff addr %d", effectiveAddress);

//Set RC

destinationRegister = j[4:0];

//Get the data to load.

while(!mfc) begin

#4 ;//$display("Waiting for memory");

end

#4 ;//$display("");

//Pipe the data out

registerDataOut = memoryDataIn;

//Wait a while

#4 ;//$display("Wait complete");

destinationRegister = 4'bX;

end

else begin //store

//$display("Storing");

//Set effective Address

effectiveAddress = currAddress;

//$display("Eaddr %d",effectiveAddress);

//Get data

sourceRegisterA = j[4:0];

//Wait a bit

#4;// $display("Done waiting");

//Ouput data

memoryDataOut = a;

//$display("Memory data out %d",memoryDataOut);

//Get the data to load.

while(!mfc) begin

#4;// $display("Waiting for memory");

end

//$display("Printing Memory:");

// for (i = 0; i < 512; i = i +1) begin

// $display ("Memory location %d content: %b", i, ram.mem[i]);

// end

#4;

// $display("Done storing");

end

if(inc)

currAddress = currAddress + 4;

else

currAddress = currAddress - 4;

end

end

registerDataOut = 32'bX;

memoryDataOut = 32'bX;

effectiveAddress = 32'bX;

sourceRegisterA = 4'bX;

sourceRegisterB = 4'bX;

destinationRegister = 4'bX;

//mark done

done = 1;

end

end

end

endmodule

//---------------------------------------------------------------------------------------------------------------------------------------

module datapath;

wire E5;

wire [3:0] RA; // Selector of A Mux is 3 bits

wire [3:0] RB; // Selector of B Mux is 3 bits

wire [3:0] RC; // Register Enable Selectors (Input to Decoders 0 and 1)

wire [1:0]MAS;

wire MFC;

//Flags

wire N, COUT, V, ZERO;//ALU Flags

//Clock

reg CLK; // Register Clock Enable (All Clocks of Registers are Shared)

//General wires

wire CIN;

wire [31:0] PC, LEFTOP, B,TSROUT;

wire [31:0] aluinselmuxtoalu;

wire [31:0] martoram;

wire [1:0] muxregoutput, muxmiscout;

wire [31:0] memdata;

wire [31:0] irout, mdrout, mdrin;

wire [31:0] shifteroutput;

wire [31:0] serout;

wire SC;

wire [48:0] cuSignals;

wire [31:0] LSMultData,LSMEaddr,LSMultRegData;

wire [3:0] LSMSourceRegA,LSMSourceRegB, LSMDestReg;

wire LSMDone, miscout, regout, SIGN;

wire [31:0] rfmuxtorf, marmuxtoram;

ControlUnit cu (cuSignals, CLK, MFC, LSMDone, irout, TSROUT);

//Register file muxes

mux4x14b ramux(RA, {cuSignals[44],cuSignals[33]}, cuSignals[37:34], irout[19:16],LSMSourceRegA,4'b0000);

mux8x14b rbmux(RB, {cuSignals[43],cuSignals[28:27]}, cuSignals[32:29], irout[3:0], irout[15:12], irout[19:16],LSMSourceRegB,4'b0000,4'b0000,4'b0000);

mux4x14b rcmux(RC, cuSignals[22:21], cuSignals[26:23], irout[15:12], irout[19:16],LSMDestReg);

//Register file

mux2x1 rfmux(rfmuxtorf,cuSignals[42],PC,LSMultRegData);

registerFile registerFile (LEFTOP, B, rfmuxtorf, RC, cuSignals[39], RA, RB, CLK, cuSignals[38]);

//Input mux

mux8x1 aluinputselectmux(aluinselmuxtoalu, cuSignals[20:18],

B, shifteroutput, irout, serout,4,{{20{1'b0}},irout[11:0]},{{24{1'b0}},irout[11:8],irout[3:0]},mdrout);

//Alu

mux2x11b alucinmux(CIN, cuSignals[13], SC, TSROUT[29]);

ALU alu1(PC, ZERO, N, COUT, V, LEFTOP, aluinselmuxtoalu, cuSignals[17:14], CIN);

//Status register

mux2x11b srmux(E5, cuSignals[6], 1'b1, ~irout[20]);

reg32 statusregister(TSROUT, {N,ZERO,COUT,V,28'b0000000000000000000000000000}, E5, cuSignals[39], CLK);

//Right side

mux4x1 mdrmux(mdrin, {cuSignals[40],cuSignals[7]}, PC, memdata,LSMultData

,0);

reg32 mdr(mdrout, mdrin, cuSignals[8], cuSignals[39], CLK);

mux2x1 marmux(marmuxtoram, cuSignals[41], PC, LSMEaddr);

reg32 mar(martoram, marmuxtoram, cuSignals[9], cuSignals[39], CLK);

mux8x12b miscmux(muxmiscout, {irout[20],irout[6],irout[5]}, 2'b00 ,2'b01, 2'b10, 2'b10, 2'b10, 2'b00, 2'b00, 2'b01);

mux2x12b regmux(muxregoutput, irout[22], 2'b10, 2'b00);

mux4x12b masmux(MAS, cuSignals[5:4], cuSignals[3:2], muxmiscout, muxregoutput, 2'b00);

mux8x11b miscsigmux(miscout, {irout[20],irout[6],irout[5]}, 1'b0, 1'b0, 1'b0, 1'b0, 1'b0, 1'b0, 1'b1, 1'b1);

mux2x11b regsigmux(regout, irout[22], 1'b0, 1'b0);

mux4x11b signedmux(SIGN, cuSignals[61:60], cuSignals[59], miscout, regout, 1'b0);

// Enable Read/Write Input Address Input Data Datasize

ramdummyreadfile ram(memdata, MFC, cuSignals[0], cuSignals[1], martoram[7:0], mdrout, MAS, SIGN);

reg32 ir(irout, memdata, cuSignals[10], cuSignals[39], CLK);

shifter sh(B, irout[11:0], cuSignals[12], shifteroutput);

reg32 ser(serout, {{18{irout[11]}},irout[11:0],2'b00}, cuSignals[11], cuSignals[39], CLK);

LSMBlackBox lsm(LSMultRegData, LSMultData, LSMEaddr, LSMSourceRegA, LSMSourceRegB, LSMDestReg ,LSMDone ,irout, memdata, LEFTOP,B, CLK, MFC, cuSignals[45]);

//Vamos a probar

parameter simtime = 5000;

initial begin CLK = 1; end

initial forever #2 CLK = ~CLK; // Change Clock Every Time Unit

always @(martoram)

if(martoram||!martoram)

$display("Memory Access: %b (%0d)",martoram,martoram);

reg [12:0] i;

initial #simtime begin

$display("Printing Memory:");

for (i = 0; i < 512; i = i +1) begin

$display ("Memory location %d content: %b", i, ram.mem[i]);

end

end

initial #simtime $finish;

endmodule

## Appendix B: Simulation Results

## Test A

Memory Access: 00000000000000000000000000000000 (0)

Memory Access: 00000000000000000000000000000100 (4)

Memory Access: 00000000000000000000000000001000 (8)

Memory Access: 00000000000000000000000000101000 (40)

Memory Access: 00000000000000000000000000001100 (12)

Memory Access: 00000000000000000000000000101010 (42)

Memory Access: 00000000000000000000000000010000 (16)

Memory Access: 00000000000000000000000000010100 (20)

Memory Access: 00000000000000000000000000011000 (24)

Memory Access: 00000000000000000000000000011100 (28)

Memory Access: 00000000000000000000000000010100 (20)

Memory Access: 00000000000000000000000000011000 (24)

Memory Access: 00000000000000000000000000011100 (28)

Memory Access: 00000000000000000000000000010100 (20)

Memory Access: 00000000000000000000000000011000 (24)

Memory Access: 00000000000000000000000000011100 (28)

Memory Access: 00000000000000000000000000010100 (20)

Memory Access: 00000000000000000000000000011000 (24)

Memory Access: 00000000000000000000000000011100 (28)

Memory Access: 00000000000000000000000000010100 (20)

Memory Access: 00000000000000000000000000011000 (24)

Memory Access: 00000000000000000000000000011100 (28)

Memory Access: 00000000000000000000000000010100 (20)

Memory Access: 00000000000000000000000000011000 (24)

Memory Access: 00000000000000000000000000011100 (28)

Memory Access: 00000000000000000000000000010100 (20)

Memory Access: 00000000000000000000000000011000 (24)

Memory Access: 00000000000000000000000000011100 (28)

Memory Access: 00000000000000000000000000100000 (32)

Memory Access: 00000000000000000000000000101011 (43)

Memory Access: 00000000000000000000000000100100 (36)

Memory Access: 00000000000000000000000000101100 (44)

Printing Memory:

Memory location 0 content: 11100010

Memory location 1 content: 00000001

Memory location 2 content: 00000000

Memory location 3 content: 00000000

Memory location 4 content: 11100011

Memory location 5 content: 10000000

Memory location 6 content: 00010000

Memory location 7 content: 00101000

Memory location 8 content: 11100111

Memory location 9 content: 11010001

Memory location 10 content: 00100000

Memory location 11 content: 00000000

Memory location 12 content: 11100101

Memory location 13 content: 11010001

Memory location 14 content: 00110000

Memory location 15 content: 00000010

Memory location 16 content: 11100000

Memory location 17 content: 10000000

Memory location 18 content: 01010000

Memory location 19 content: 00000000

Memory location 20 content: 11100000

Memory location 21 content: 10000010

Memory location 22 content: 01010000

Memory location 23 content: 00000101

Memory location 24 content: 11100010

Memory location 25 content: 01010011

Memory location 26 content: 00110000

Memory location 27 content: 00000001

Memory location 28 content: 00011010

Memory location 29 content: 11111111

Memory location 30 content: 11111111

Memory location 31 content: 11111101

Memory location 32 content: 11100101

Memory location 33 content: 11000001

Memory location 34 content: 01010000

Memory location 35 content: 00000011

Memory location 36 content: 11101010

Memory location 37 content: 00000000

Memory location 38 content: 00000000

Memory location 39 content: 00000001

Memory location 40 content: 00001011

Memory location 41 content: 00000101

Memory location 42 content: 00000111

Memory location 43 content: 01001101

Memory location 44 content: 11101010

Memory location 45 content: 11111111

Memory location 46 content: 11111111

Memory location 47 content: 11111111

## Test B

Memory Access: 00000000000000000000000000000000 (0)

Memory Access: 00000000000000000000000000000100 (4)

Memory Access: 00000000000000000000000000001000 (8)

Memory Access: 00000000000000000000000000001100 (12)

Memory Access: 00000000000000000000000000010000 (16)

Memory Access: 00000000000000000000000010011000 (152)

Memory Access: 00000000000000000000000000010100 (20)

Memory Access: 00000000000000000000000000011000 (24)

Memory Access: 00000000000000000000000000011100 (28)

Memory Access: 00000000000000000000000010011100 (156)

Memory Access: 00000000000000000000000000100000 (32)

Memory Access: 00000000000000000000000000100100 (36)

Memory Access: 00000000000000000000000010100000 (160)

Memory Access: 00000000000000000000000000101000 (40)

Memory Access: 00000000000000000000000000101100 (44)

Memory Access: 00000000000000000000000010100100 (164)

Memory Access: 00000000000000000000000000110000 (48)

Memory Access: 00000000000000000000000000110100 (52)

Memory Access: 00000000000000000000000010101000 (168)

Memory Access: 00000000000000000000000000111000 (56)

Memory Access: 00000000000000000000000000111100 (60)

Memory Access: 00000000000000000000000010101100 (172)

Memory Access: 00000000000000000000000001000000 (64)

Memory Access: 00000000000000000000000001000100 (68)

Memory Access: 00000000000000000000000010110000 (176)

Memory Access: 00000000000000000000000001001000 (72)

Memory Access: 00000000000000000000000001001100 (76)

Memory Access: 00000000000000000000000001010000 (80)

Memory Access: 00000000000000000000000001010100 (84)

Memory Access: 00000000000000000000000010110100 (180)

Memory Access: 00000000000000000000000001011000 (88)

Memory Access: 00000000000000000000000010010100 (148)

Memory Access: 00000000000000000000000001011100 (92)

Memory Access: 00000000000000000000000010010000 (144)

Memory Access: 00000000000000000000000001100000 (96)

Memory Access: 00000000000000000000000001100100 (100)

Memory Access: 00000000000000000000000001101100 (108)

Memory Access: 00000000000000000000000010111000 (184)

Memory Access: 00000000000000000000000001110000 (112)

Memory Access: 00000000000000000000000001110100 (116)

Memory Access: 00000000000000000000000001111100 (124)

Memory Access: 00000000000000000000000010111100 (188)

Memory Access: 00000000000000000000000010000000 (128)

Memory Access: 00000000000000000000000010000100 (132)

Memory Access: 00000000000000000000000010111100 (188)

Memory Access: 00000000000000000000000010001000 (136)

Memory Access: 00000000000000000000000011000000 (192)

Memory Access: 00000000000000000000000010001100 (140)

Printing Memory:

Memory location 0 content: 11100010

Memory location 1 content: 00000001

Memory location 2 content: 00000000

Memory location 3 content: 00000000

Memory location 4 content: 11100011

Memory location 5 content: 10000000

Memory location 6 content: 00010000

Memory location 7 content: 00100010

Memory location 8 content: 11100011

Memory location 9 content: 10000000

Memory location 10 content: 01000000

Memory location 11 content: 10011000

Memory location 12 content: 11100001

Memory location 13 content: 10100000

Memory location 14 content: 10100000

Memory location 15 content: 00000100

Memory location 16 content: 11100100

Memory location 17 content: 10011010

Memory location 18 content: 00110000

Memory location 19 content: 00000100

Memory location 20 content: 11100000

Memory location 21 content: 10000001

Memory location 22 content: 00100000

Memory location 23 content: 00000011

Memory location 24 content: 11100001

Memory location 25 content: 10100000

Memory location 26 content: 01010000

Memory location 27 content: 00000010

Memory location 28 content: 11100100

Memory location 29 content: 10001010

Memory location 30 content: 01010000

Memory location 31 content: 00000100

Memory location 32 content: 11100000

Memory location 33 content: 01000001

Memory location 34 content: 01010000

Memory location 35 content: 00000010

Memory location 36 content: 11100100

Memory location 37 content: 10001010

Memory location 38 content: 01010000

Memory location 39 content: 00000100

Memory location 40 content: 11100000

Memory location 41 content: 01100001

Memory location 42 content: 01010000

Memory location 43 content: 00000010

Memory location 44 content: 11100100

Memory location 45 content: 10001010

Memory location 46 content: 01010000

Memory location 47 content: 00000100

Memory location 48 content: 11100000

Memory location 49 content: 10000000

Memory location 50 content: 01010001

Memory location 51 content: 11000011

Memory location 52 content: 11100100

Memory location 53 content: 10001010

Memory location 54 content: 01010000

Memory location 55 content: 00000100

Memory location 56 content: 11100000

Memory location 57 content: 10000000

Memory location 58 content: 01010001

Memory location 59 content: 10000011

Memory location 60 content: 11100100

Memory location 61 content: 10001010

Memory location 62 content: 01010000

Memory location 63 content: 00000100

Memory location 64 content: 11100000

Memory location 65 content: 10000000

Memory location 66 content: 01010101

Memory location 67 content: 01100011

Memory location 68 content: 11100100

Memory location 69 content: 10001010

Memory location 70 content: 01010000

Memory location 71 content: 00000100

Memory location 72 content: 11100001

Memory location 73 content: 01010010

Memory location 74 content: 00000000

Memory location 75 content: 00000001

Memory location 76 content: 11011011

Memory location 77 content: 00000000

Memory location 78 content: 00000000

Memory location 79 content: 00000001

Memory location 80 content: 11100010

Memory location 81 content: 00000001

Memory location 82 content: 11100000

Memory location 83 content: 00000000

Memory location 84 content: 11100100

Memory location 85 content: 10001010

Memory location 86 content: 11100000

Memory location 87 content: 00000100

Memory location 88 content: 11100101

Memory location 89 content: 00110100

Memory location 90 content: 11000000

Memory location 91 content: 00000100

Memory location 92 content: 11100101

Memory location 93 content: 00110100

Memory location 94 content: 10110000

Memory location 95 content: 00000100

Memory location 96 content: 11100001

Memory location 97 content: 01111100

Memory location 98 content: 00000000

Memory location 99 content: 00001011

Memory location 100 content: 01101010

Memory location 101 content: 00000000

Memory location 102 content: 00000000

Memory location 103 content: 00000001

Memory location 104 content: 11100010

Memory location 105 content: 00000001

Memory location 106 content: 01010000

Memory location 107 content: 00000000

Memory location 108 content: 11100100

Memory location 109 content: 10001010

Memory location 110 content: 01010000

Memory location 111 content: 00000100

Memory location 112 content: 11100000

Memory location 113 content: 10000001

Memory location 114 content: 01010000

Memory location 115 content: 00001011

Memory location 116 content: 01101010

Memory location 117 content: 00000000

Memory location 118 content: 00000000

Memory location 119 content: 00000001

Memory location 120 content: 11100010

Memory location 121 content: 00000001

Memory location 122 content: 01010000

Memory location 123 content: 00000000

Memory location 124 content: 11100100

Memory location 125 content: 10001010

Memory location 126 content: 01010000

Memory location 127 content: 00000100

Memory location 128 content: 11100011

Memory location 129 content: 10000000

Memory location 130 content: 00010000

Memory location 131 content: 00000100

Memory location 132 content: 11100111

Memory location 133 content: 00111010

Memory location 134 content: 11000000

Memory location 135 content: 00000001

Memory location 136 content: 11100111

Memory location 137 content: 10101010

Memory location 138 content: 11000000

Memory location 139 content: 00000001

Memory location 140 content: 11101010

Memory location 141 content: 11111111

Memory location 142 content: 11111111

Memory location 143 content: 11111111

Memory location 144 content: 10100000

Memory location 145 content: 00000000

Memory location 146 content: 00000000

Memory location 147 content: 00000000

Memory location 148 content: 11000000

Memory location 149 content: 00000000

Memory location 150 content: 00000000

Memory location 151 content: 00000000

Memory location 152 content: 11111111

Memory location 153 content: 11111111

Memory location 154 content: 11111111

Memory location 155 content: 11110101

Memory location 156 content: 00000000

Memory location 157 content: 00000000

Memory location 158 content: 00000000

Memory location 159 content: 00010111

Memory location 160 content: 00000000

Memory location 161 content: 00000000

Memory location 162 content: 00000000

Memory location 163 content: 00001011

Memory location 164 content: 11111111

Memory location 165 content: 11111111

Memory location 166 content: 11111111

Memory location 167 content: 11110101

Memory location 168 content: 11111111

Memory location 169 content: 11111111

Memory location 170 content: 11111111

Memory location 171 content: 11111110

Memory location 172 content: 11111111

Memory location 173 content: 11111111

Memory location 174 content: 11111111

Memory location 175 content: 10101000

Memory location 176 content: 11111101

Memory location 177 content: 01111111

Memory location 178 content: 11111111

Memory location 179 content: 11111111

Memory location 180 content: 00000000

Memory location 181 content: 00000000

Memory location 182 content: 00000000

Memory location 183 content: 01010000

Memory location 184 content: 11111101

Memory location 185 content: 01111111

Memory location 186 content: 11111111

Memory location 187 content: 11111111

Memory location 188 content: 10100000

Memory location 189 content: 00000000

Memory location 190 content: 00000000

Memory location 191 content: 00100010

Memory location 192 content: 10100000

Memory location 193 content: 00000000

Memory location 194 content: 00000000

Memory location 195 content: 00100010

## Test C

Memory Access: 00000000000000000000000000000000 (0)

Memory Access: 00000000000000000000000000000100 (4)

Memory Access: 00000000000000000000000000001000 (8)

Memory Access: 00000000000000000000000000001100 (12)

Memory Access: 00000000000000000000000000011000 (24)

Memory Access: 00000000000000000000000000011100 (28)

Memory Access: 00000000000000000000000000100000 (32)

Memory Access: 00000000000000000000000000100100 (36)

Memory Access: 00000000000000000000000000010000 (16)

Memory Access: 00000000000000000000000000101000 (40)

Memory Access: 00000000000000000000000000101100 (44)

Memory Access: 00000000000000000000000000110000 (48)

Memory Access: 00000000000000000000000000110100 (52)

Memory Access: 00000000000000000000000000010100 (20)

Memory Access: 00000000000000000000000000011000 (24)

Memory Access: 00000000000000000000000000011100 (28)

Memory Access: 00000000000000000000000000100010 (34)

Memory Access: 00000000000000000000000000100000 (32)

Memory Access: 00000000000000000000000000111000 (56)

Memory Access: 00000000000000000000000000100100 (36)

Printing Memory:

Memory location 0 content: 11100010

Memory location 1 content: 00000001

Memory location 2 content: 00000000

Memory location 3 content: 00000000

Memory location 4 content: 11100011

Memory location 5 content: 10000000

Memory location 6 content: 10100000

Memory location 7 content: 00011000

Memory location 8 content: 11100011

Memory location 9 content: 10010000

Memory location 10 content: 01000000

Memory location 11 content: 00101000

Memory location 12 content: 11101000

Memory location 13 content: 10111010

Memory location 14 content: 00100000

Memory location 15 content: 10100100

Memory location 16 content: 11101000

Memory location 17 content: 10101010

Memory location 18 content: 00100000

Memory location 19 content: 10100100

Memory location 20 content: 00000100

Memory location 21 content: 10001010

Memory location 22 content: 01000000

Memory location 23 content: 00000100

Memory location 24 content: 11100011

Memory location 25 content: 10000000

Memory location 26 content: 00010000

Memory location 27 content: 00000100

Memory location 28 content: 11100001

Memory location 29 content: 01010100

Memory location 30 content: 11000000

Memory location 31 content: 11110110

Memory location 32 content: 11100100

Memory location 33 content: 10001010

Memory location 34 content: 11000000

Memory location 35 content: 00000100

Memory location 36 content: 11101010

Memory location 37 content: 11111111

Memory location 38 content: 11111111

Memory location 39 content: 11111111

Memory location 40 content: 11100011

Memory location 41 content: 10000000

Memory location 42 content: 00010000

Memory location 43 content: 00000100

Memory location 44 content: 11100001

Memory location 45 content: 01010100

Memory location 46 content: 11000000

Memory location 47 content: 11110110

Memory location 48 content: 11100100

Memory location 49 content: 10001010

Memory location 50 content: 11000000

Memory location 51 content: 00000100

Memory location 52 content: 11101010

Memory location 53 content: 11111111

Memory location 54 content: 11111111

Memory location 55 content: 11111111

Memory location 56 content: 11111111

Memory location 57 content: 11111111

Memory location 58 content: 11000000

Memory location 59 content: 00000100