CSE4117 – Microprocessors

THE DESIGN OF ALU

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INTRODUCTION

In this assignment, we designed an 8-bit ALU that can perform addition, subtraction, and, or, shift-left, shift-right, move and xor operations. As a result of these operations, we obtained the result, and we ensured that the carry, zero, overflow and negative flags were set. On this road, we first needed an eight-by-one multiplexer. Because we had eight operations to perform. The zero and negative flags were determined for all operations, but the carry and overflow flags were just determined at the addition and the substraction operations.

We designed a full subtractor to implement the substraction operation. However, we first built a single-bit full subtractor. Then we were able to obtain a two-bits subtractor using single-bits, four-bits using two-bits, and an eight-bits subtractor using four-bits, respectively.

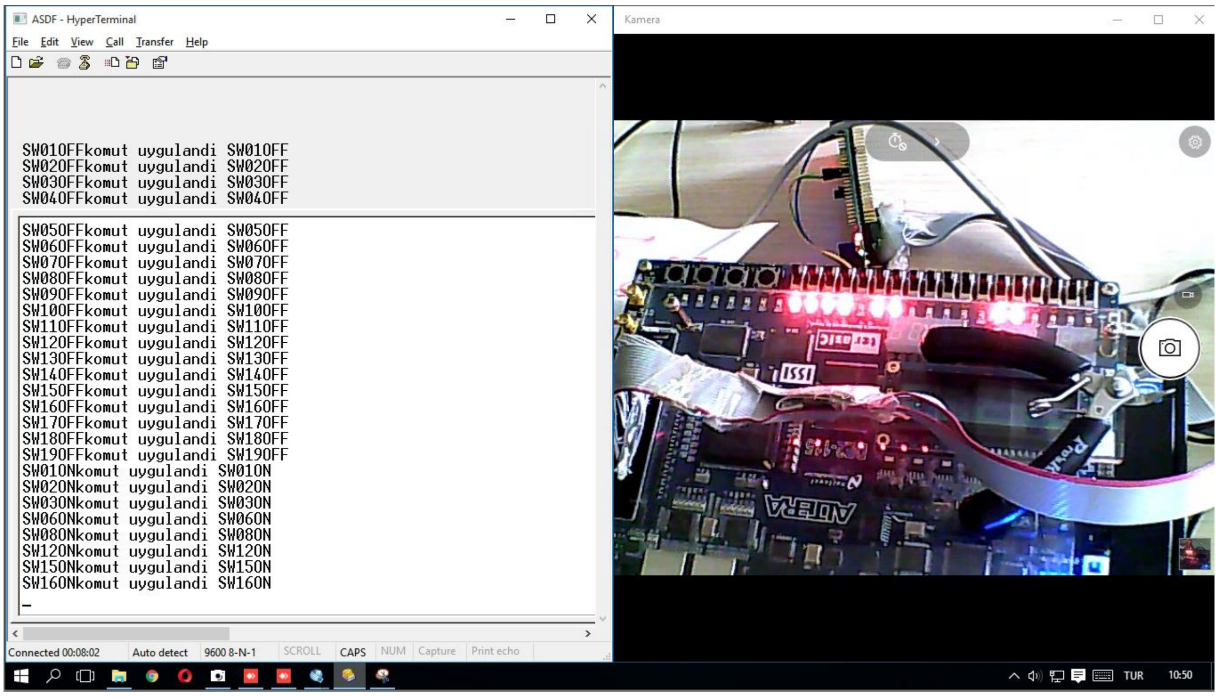
We had to check the most significant bits of the operands and the result in order to detect whether there was an overflow. Because in an addition operation, if the operands are negative and the result is positive, or vice versa, it means overflow. We proceeded in the subtraction process by checking the most important bits in a similar way for overflow detection. We have seen that our design yielded successful results both in our simulations and in our tests on the fpga device. We attach the simulation results and photos of our tests on the fpga device below.

The RTL View was attached as separate from the word document.

1010 0111 (-89) and 1100 1000 (-56) operands were used in the eight operations.

Addition Operation

According to the operands; the result is 0110 1111 (111), the zero, negative, carry and overflow flags were found as 0, 0, 1, 1 respectively.



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SW060FFkomut uygulandi SW060FF
SW070FFkomut uygulandi SW070FF
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SW090FFkomut uygulandi SW090FF
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SW170FFkomut uygulandi SW170FF
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SW010Nkomut uygulandi SW010N
SW020Nkomut uygulandi SW020N
SW030Nkomut uygulandi SW030N
SW060Nkomut uygulandi SW060N
SW080Nkomut uygulandi SW080N
SW120Nkomut uygulandi SW120N
SW150Nkomut uygulandi SW150N
SW160Nkomut uygulandi SW160N
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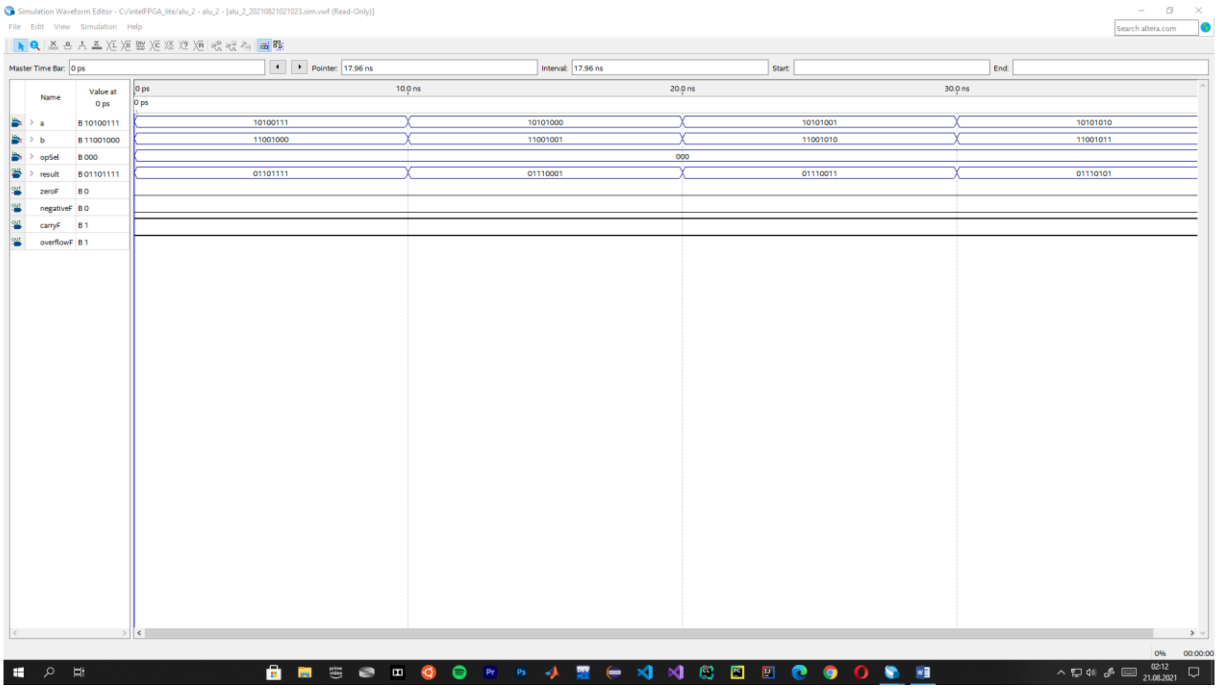
Kamera
TUR 10:50



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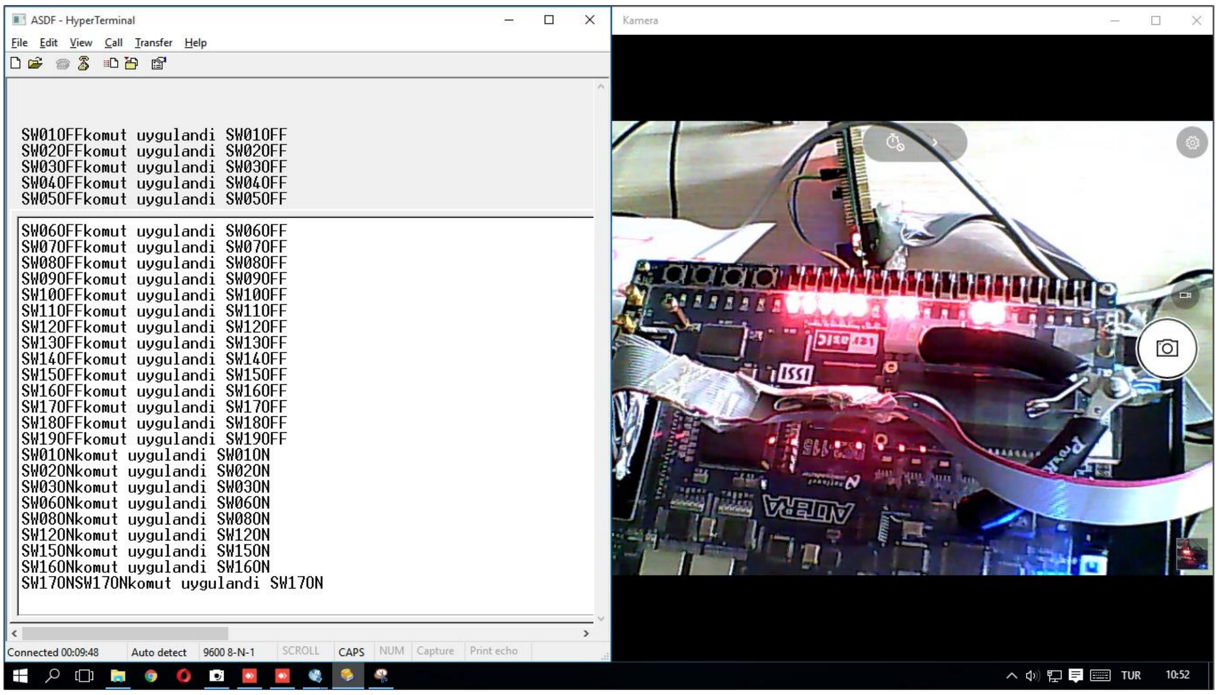
b          B 11001000      11001000    11001001    11001010    11001011
opSel      B 000                             000
result     B 01101111      01101111    01110001    01110011    01110101
zeroF      B 0
negativeF  B 0
carryF     B 1
overflowF  B 1
```

Substraction Operation

According to the operands; the result is 1110 1111 (-17), the zero, negative, carry and overflow flags were found as 0, 1, 1, 0 respectively.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TUR 10:52

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SW080FFkomut uygulandi SW080FF
SW090FFkomut uygulandi SW090FF
SW100FFkomut uygulandi SW100FF
SW110FFkomut uygulandi SW110FF
SW120FFkomut uygulandi SW120FF
SW130FFkomut uygulandi SW130FF
SW140FFkomut uygulandi SW140FF
SW150FFkomut uygulandi SW150FF
SW160FFkomut uygulandi SW160FF
SW170FFkomut uygulandi SW170FF
SW180FFkomut uygulandi SW180FF
SW190FFkomut uygulandi SW190FF
SW010Nkomut uygulandi SW010N
SW020Nkomut uygulandi SW020N
SW030Nkomut uygulandi SW030N
SW060Nkomut uygulandi SW060N
SW080Nkomut uygulandi SW080N
SW120Nkomut uygulandi SW120N
SW150Nkomut uygulandi SW150N
SW160Nkomut uygulandi SW160N
SW170NSW170Nkomut uygulandi SW170N
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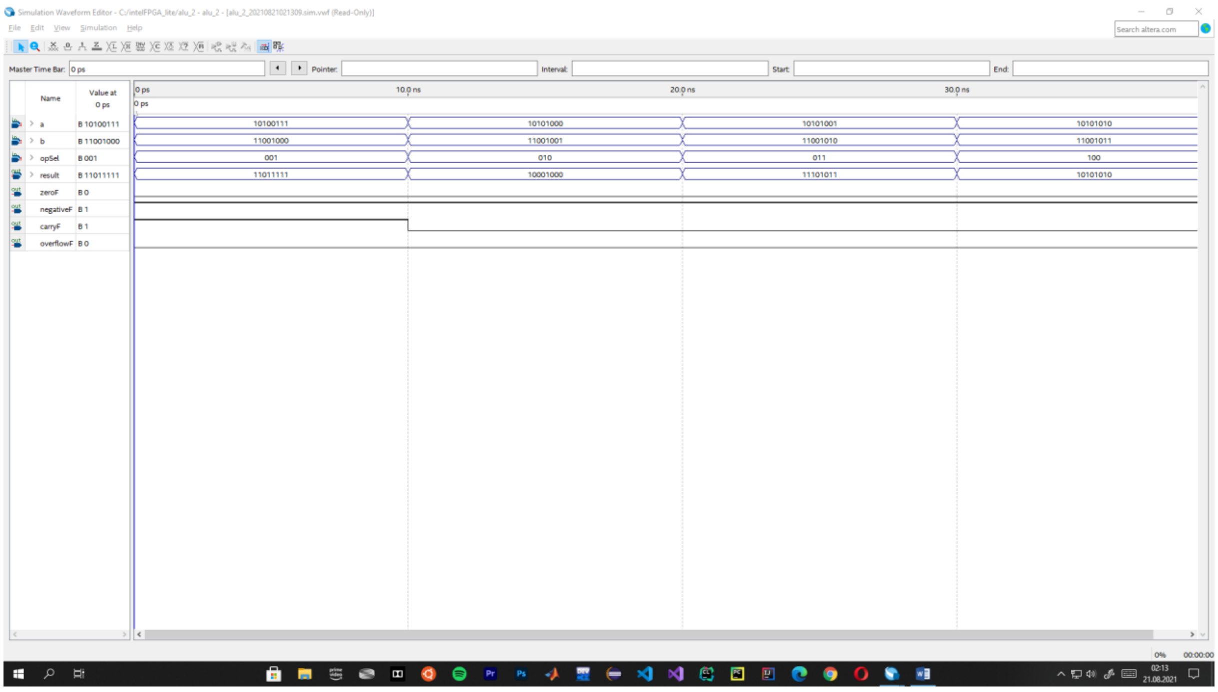
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Search altera.com
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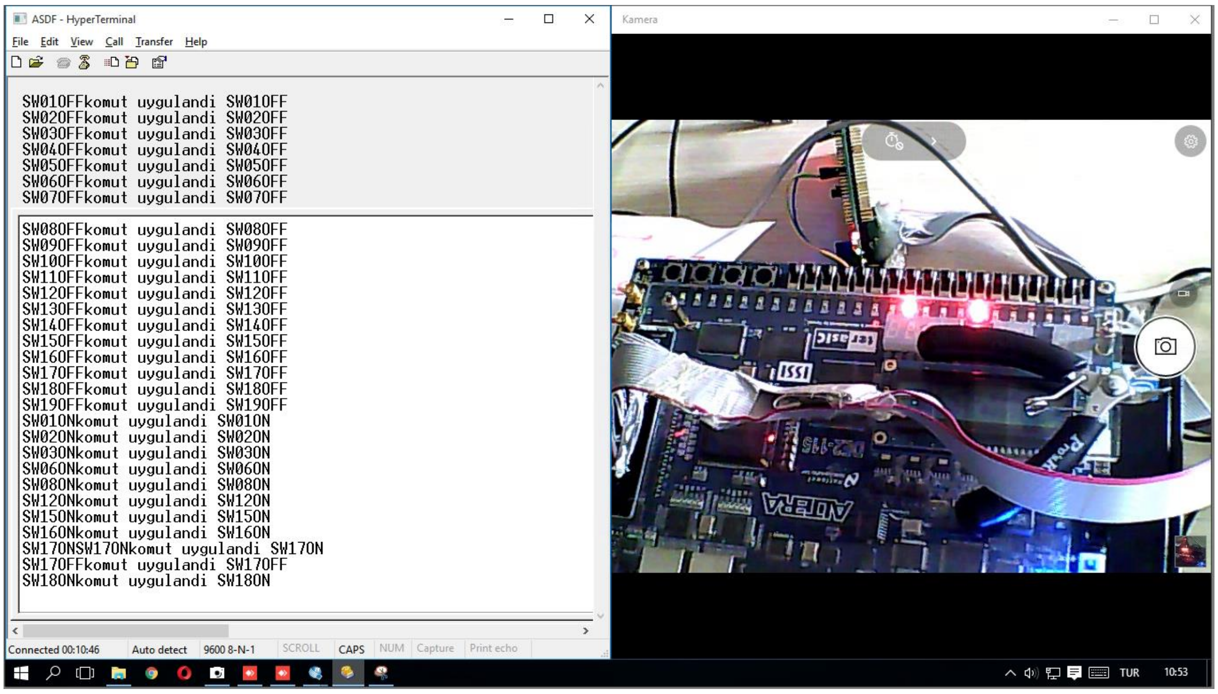
Pointer:
Interval:
Start:
End:
0 ps
10.0 ns
20.0 ns
30.0 ns
02:13 21.08.2021

Name	Value at 0 ps	0 ps	10.0 ns	20.0 ns	30.0 ns
a	B 10100111	10100111	10101000	10101001	10101010
b	B 11001000	11001000	11001001	11001010	11001011
opSel	B 001	001	010	011	100
result	B 11011111	11011111	10001000	11101011	10101010
zeroF	B 0				
negativeF	B 1				
carryF	B 1				
overflowF	B 0				

AND Operation

According to the operands; the result is 1000 0000 (-128), the zero, negative, carry and overflow flags were found as 0, 1, 0, 0 respectively.



ASDF - HyperTerminal

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SW030FFkomut uygulandi SW030FF
SW040FFkomut uygulandi SW040FF
SW050FFkomut uygulandi SW050FF
SW060FFkomut uygulandi SW060FF
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SW080FFkomut uygulandi SW080FF
SW090FFkomut uygulandi SW090FF
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SW120FFkomut uygulandi SW120FF
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SW140FFkomut uygulandi SW140FF
SW150FFkomut uygulandi SW150FF
SW160FFkomut uygulandi SW160FF
SW170FFkomut uygulandi SW170FF
SW180FFkomut uygulandi SW180FF
SW190FFkomut uygulandi SW190FF
SW010Nkomut uygulandi SW010N
SW020Nkomut uygulandi SW020N
SW030Nkomut uygulandi SW030N
SW060Nkomut uygulandi SW060N
SW080Nkomut uygulandi SW080N
SW120Nkomut uygulandi SW120N
SW150Nkomut uygulandi SW150N
SW160Nkomut uygulandi SW160N
SW170NSW170Nkomut uygulandi SW170N
SW170FFkomut uygulandi SW170FF
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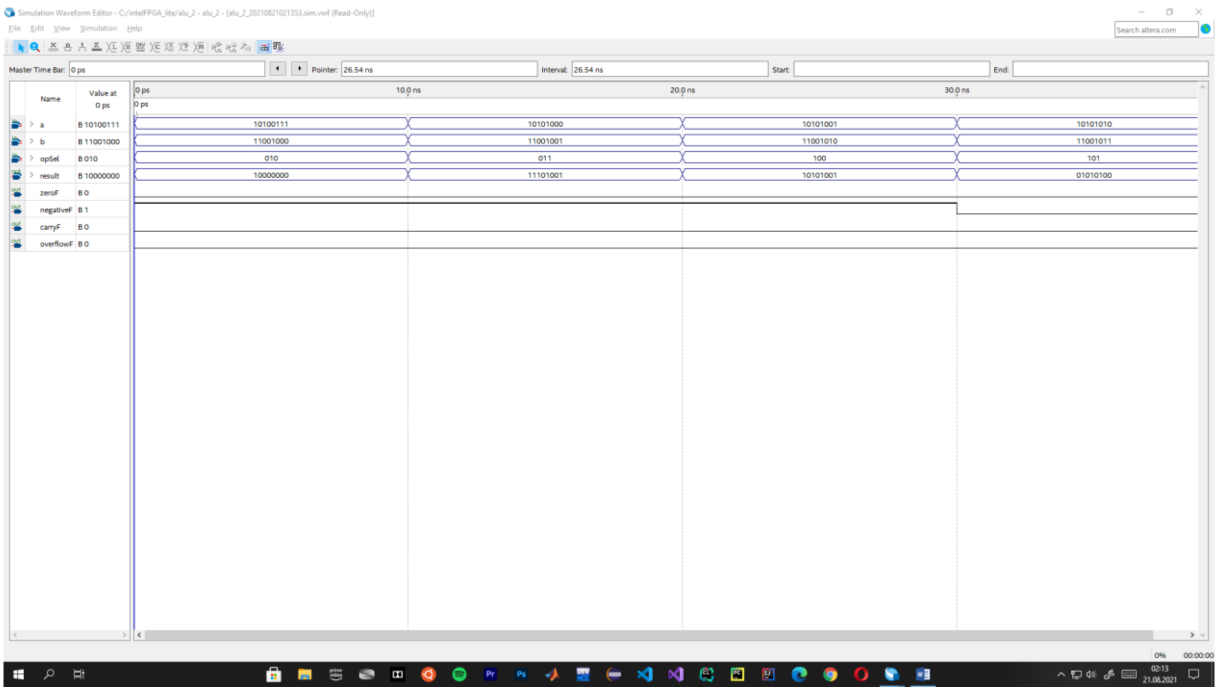

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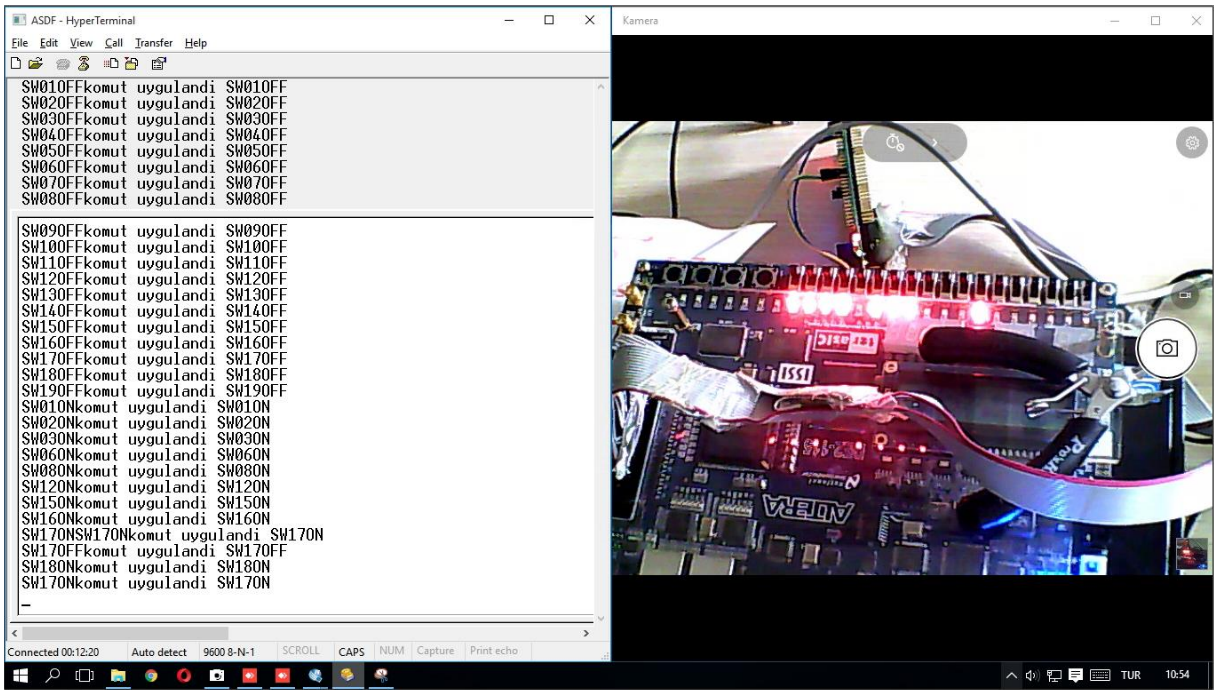
Name	Value at 0 ps	0 ps	10.0 ns	20.0 ns	30.0 ns
a	B 10100111	10100111	10101000	10101001	10101010
b	B 11001000	11001000	11001001	11001010	11001011
opSel	B 010	010	011	100	101
result	B 10000000	10000000	11101001	10101001	01010100
zeroF	B 0				
negativeF	B 1				
carryF	B 0				
overflowF	B 0				

OR Operation

According to the operands; the result is 1110 1111 (-17), the zero, negative, carry and overflow flags were found as 0, 1, 0, 0 respectively.



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SW060FFkomut uygulandi SW060FF
SW070FFkomut uygulandi SW070FF
SW080FFkomut uygulandi SW080FF

SW090FFkomut uygulandi SW090FF
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SW110FFkomut uygulandi SW110FF
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SW150FFkomut uygulandi SW150FF
SW160FFkomut uygulandi SW160FF
SW170FFkomut uygulandi SW170FF
SW180FFkomut uygulandi SW180FF
SW190FFkomut uygulandi SW190FF
SW010Nkomut uygulandi SW010N
SW020Nkomut uygulandi SW020N
SW030Nkomut uygulandi SW030N
SW060Nkomut uygulandi SW060N
SW080Nkomut uygulandi SW080N
SW120Nkomut uygulandi SW120N
SW150Nkomut uygulandi SW150N
SW160Nkomut uygulandi SW160N
SW170NSW170Nkomut uygulandi SW170N
SW170FFkomut uygulandi SW170FF
SW180Nkomut uygulandi SW180N
SW170Nkomut uygulandi SW170N
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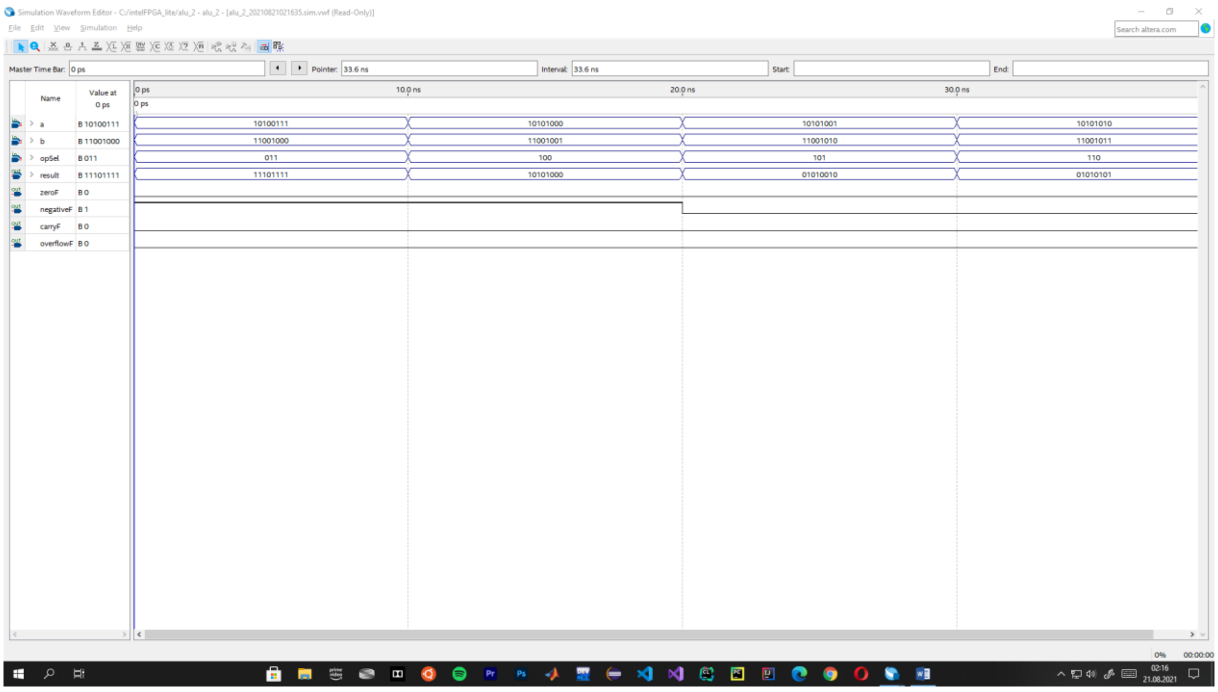
Kamera
TUR 10:54



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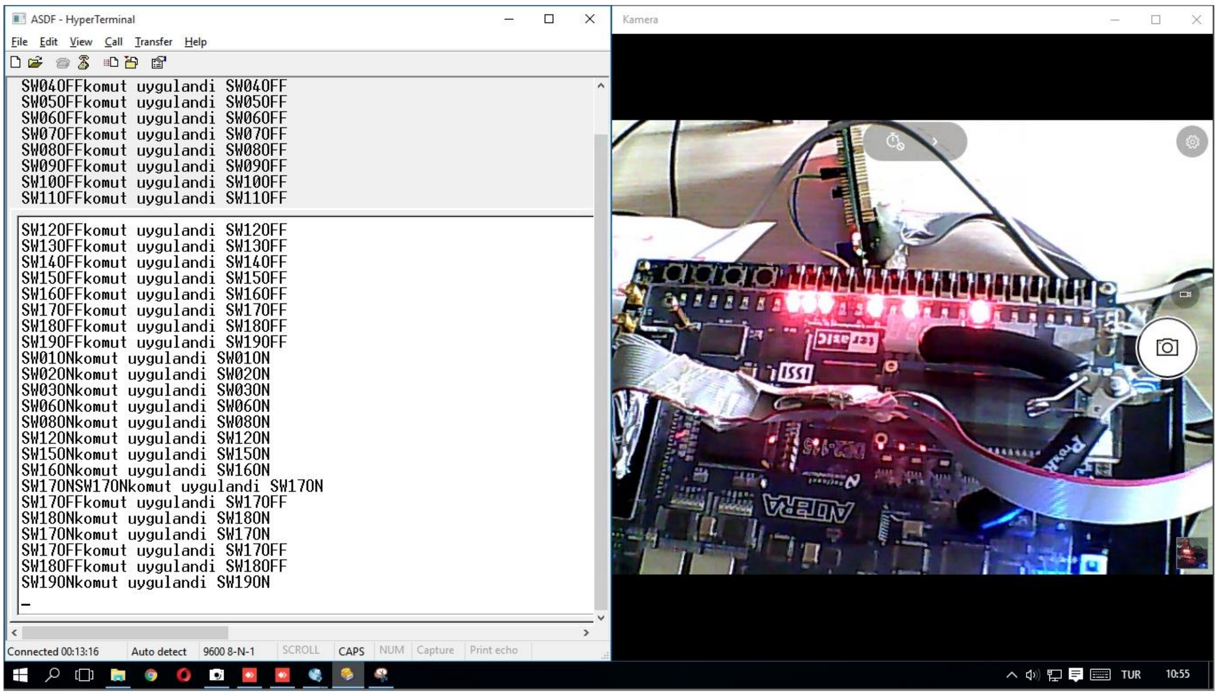
b	B 11001000	11001000	11001001	11001010	11001011
opSel	B 011	011	100	101	110
result	B 11101111	11101111	10101000	01010010	01010101
zeroF	B 0				
negativeF	B 1				
carryF	B 0				
overflowF	B 0				

Mov A Operation

According to the operands; the result is 1010 0111 (-89), the zero, negative, carry and overflow flags were found as 0, 1, 0, 0 respectively.



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SW090FFkomut uygulandi SW090FF
SW100FFkomut uygulandi SW100FF
SW110FFkomut uygulandi SW110FF

SW120FFkomut uygulandi SW120FF
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SW140FFkomut uygulandi SW140FF
SW150FFkomut uygulandi SW150FF
SW160FFkomut uygulandi SW160FF
SW170FFkomut uygulandi SW170FF
SW180FFkomut uygulandi SW180FF
SW190FFkomut uygulandi SW190FF
SW010Nkomut uygulandi SW010N
SW020Nkomut uygulandi SW020N
SW030Nkomut uygulandi SW030N
SW060Nkomut uygulandi SW060N
SW080Nkomut uygulandi SW080N
SW120Nkomut uygulandi SW120N
SW150Nkomut uygulandi SW150N
SW160Nkomut uygulandi SW160N
SW170NSW170Nkomut uygulandi SW170N
SW170FFkomut uygulandi SW170FF
SW180Nkomut uygulandi SW180N
SW170Nkomut uygulandi SW170N
SW170FFkomut uygulandi SW170FF
SW180FFkomut uygulandi SW180FF
SW190Nkomut uygulandi SW190N
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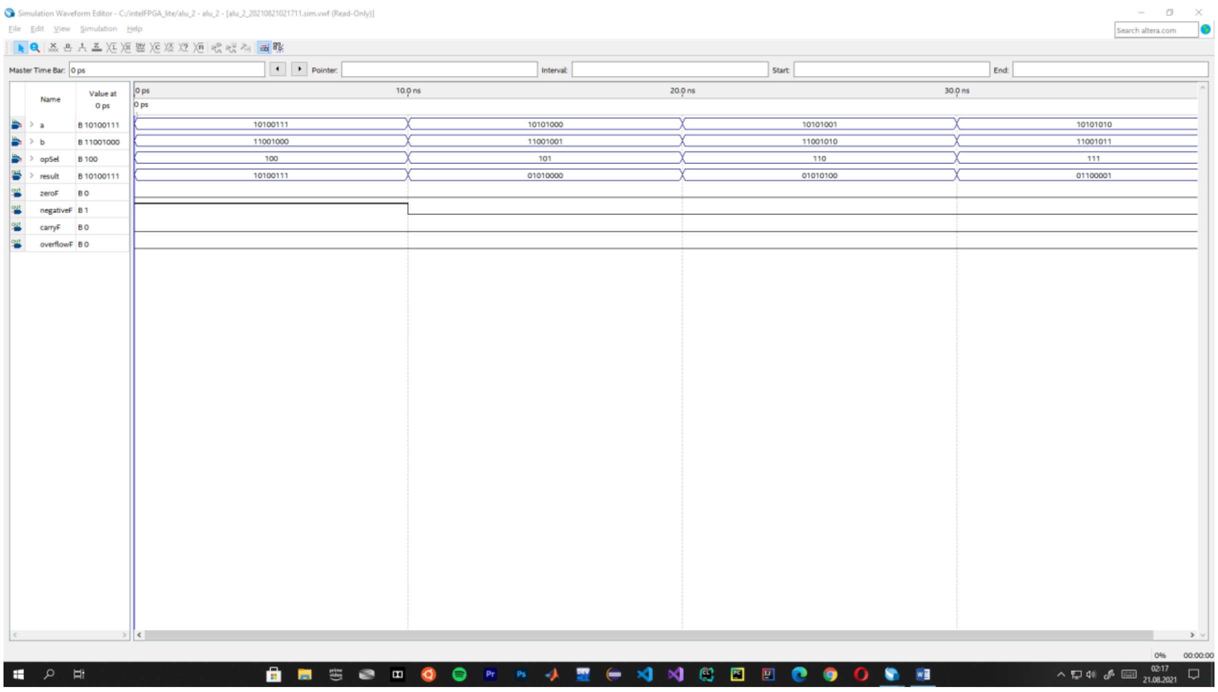
Connected 00:13:16 | Auto detect | 9600 8-N-1 | SCROLL | CAPS | NUM | Capture | Print echo



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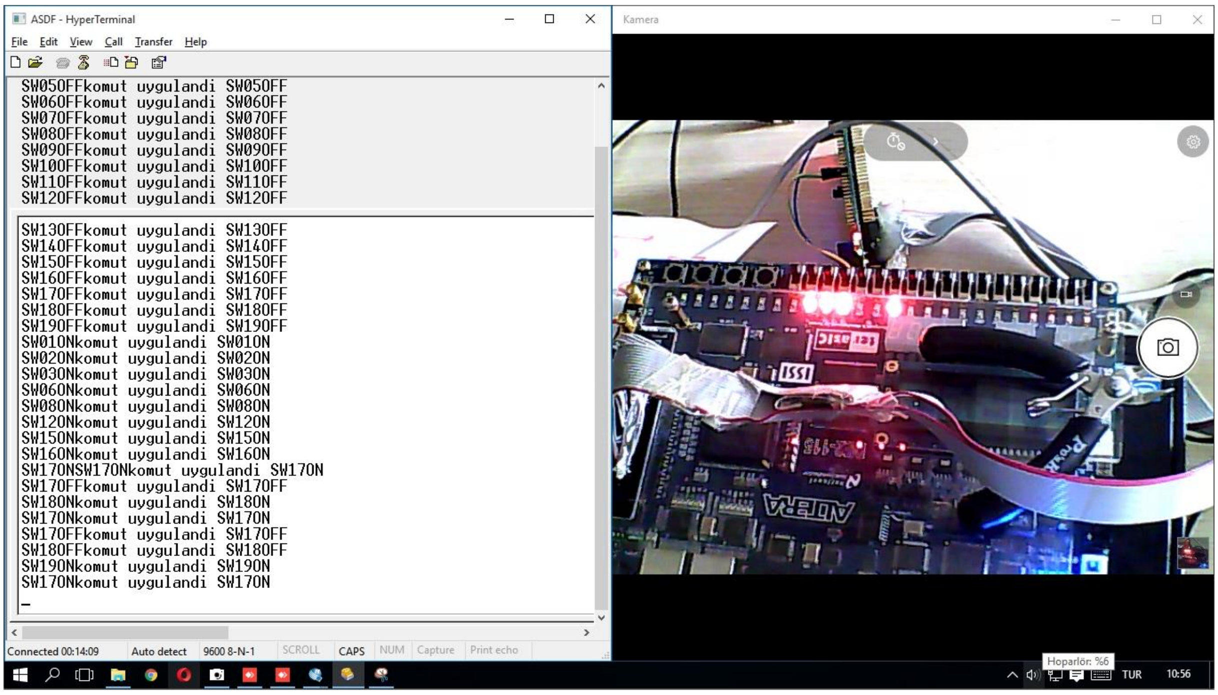
Master Time Bar: 0 ps
Pointer:
Interval:
Start:
End:
0 ps
10.0 ns
20.0 ns
30.0 ns

Name	Value at 0 ps	0 ps	10.0 ns	20.0 ns	30.0 ns
a	B 10100111	10100111	10101000	10101001	10101010
b	B 11001000	11001000	11001001	11001010	11001011
opSel	B 100	100	101	110	111
result	B 10100111	10100111	01010000	01010100	01100001
zeroF	B 0				
negativeF	B 1				
carryF	B 0				
overflowF	B 0				

Shift Left Operation

According to the operands; the result is 0100 1110 (78), the zero, negative, carry and overflow flags were found as 0, 0, 0, 0 respectively.



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SW090FFkomut uygulandi SW090FF
SW100FFkomut uygulandi SW100FF
SW110FFkomut uygulandi SW110FF
SW120FFkomut uygulandi SW120FF

SW130FFkomut uygulandi SW130FF
SW140FFkomut uygulandi SW140FF
SW150FFkomut uygulandi SW150FF
SW160FFkomut uygulandi SW160FF
SW170FFkomut uygulandi SW170FF
SW180FFkomut uygulandi SW180FF
SW190FFkomut uygulandi SW190FF
SW010Nkomut uygulandi SW010N
SW020Nkomut uygulandi SW020N
SW030Nkomut uygulandi SW030N
SW060Nkomut uygulandi SW060N
SW080Nkomut uygulandi SW080N
SW120Nkomut uygulandi SW120N
SW150Nkomut uygulandi SW150N
SW160Nkomut uygulandi SW160N
SW170NSW170Nkomut uygulandi SW170N
SW170FFkomut uygulandi SW170FF
SW180Nkomut uygulandi SW180N
SW170Nkomut uygulandi SW170N
SW170FFkomut uygulandi SW170FF
SW180FFkomut uygulandi SW180FF
SW190Nkomut uygulandi SW190N
SW170Nkomut uygulandi SW170N
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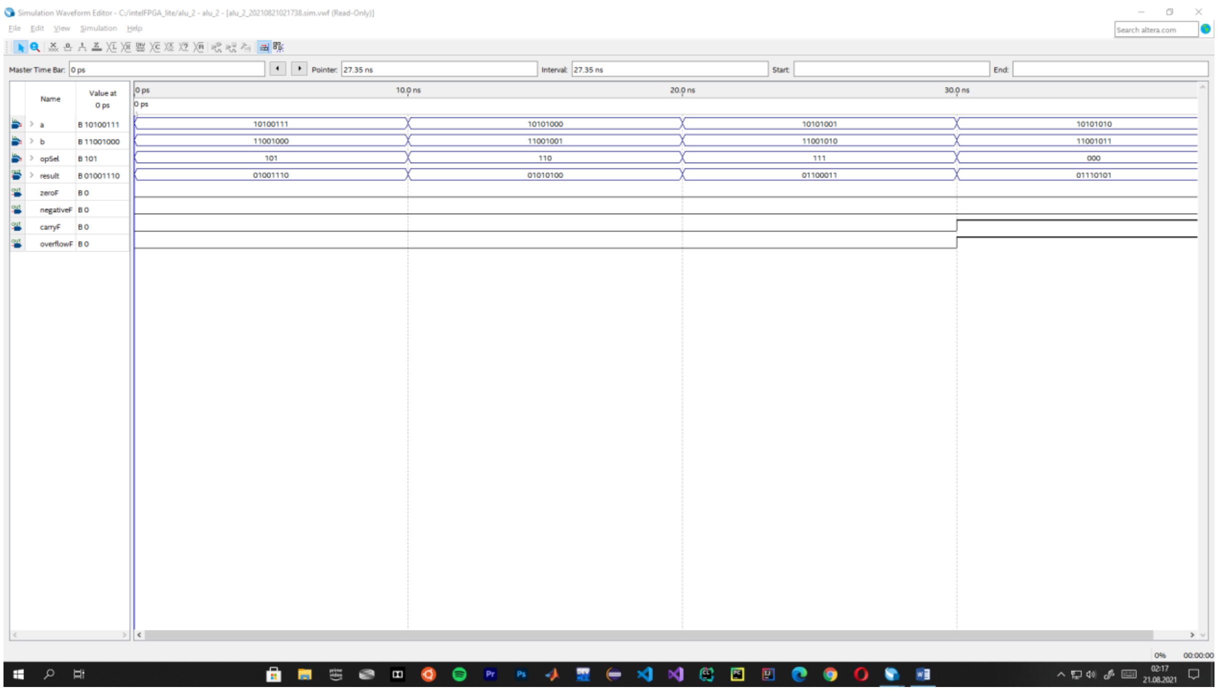

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```
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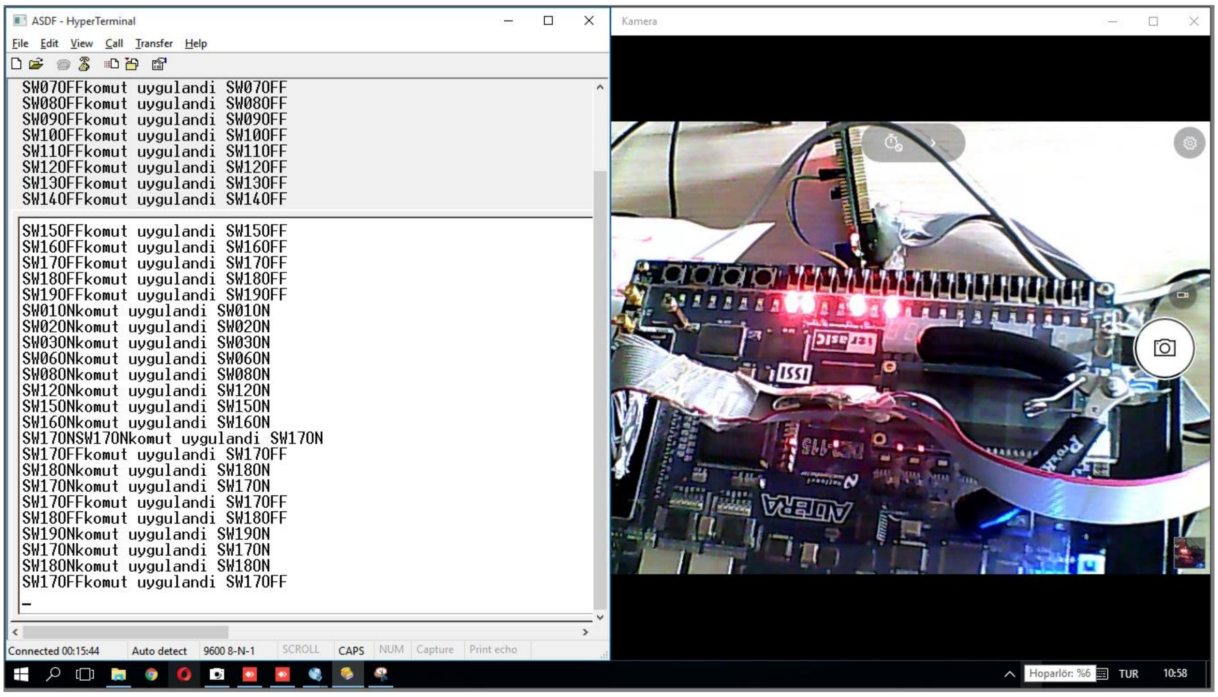
a           B 10100111     10100111    10101000    10101001    10101010
b           B 11001000     11001000    11001001    11001010    11001011
opSel       B 101          101         110         111         000
result      B 01001110     01001110    01010100    01100011    01110101
zeroF       B 0
negativeF   B 0
carryF      B 0
overflowF   B 0
```

Shift Right Operation

According to the operands; the result is 0101 0011 (83), the zero, negative, carry and overflow flags were found as 0, 0, 0, 0 respectively.



ASDF - HyperTerminal

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SW110FFkomut uygulandi SW110FF
SW120FFkomut uygulandi SW120FF
SW130FFkomut uygulandi SW130FF
SW140FFkomut uygulandi SW140FF

SW150FFkomut uygulandi SW150FF
SW160FFkomut uygulandi SW160FF
SW170FFkomut uygulandi SW170FF
SW180FFkomut uygulandi SW180FF
SW190FFkomut uygulandi SW190FF
SW010Nkomut uygulandi SW010N
SW020Nkomut uygulandi SW020N
SW030Nkomut uygulandi SW030N
SW060Nkomut uygulandi SW060N
SW080Nkomut uygulandi SW080N
SW120Nkomut uygulandi SW120N
SW150Nkomut uygulandi SW150N
SW160Nkomut uygulandi SW160N
SW170NSW170Nkomut uygulandi SW170N
SW170FFkomut uygulandi SW170FF
SW180Nkomut uygulandi SW180N
SW170Nkomut uygulandi SW170N
SW170FFkomut uygulandi SW170FF
SW180FFkomut uygulandi SW180FF
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SW180Nkomut uygulandi SW180N
SW170FFkomut uygulandi SW170FF
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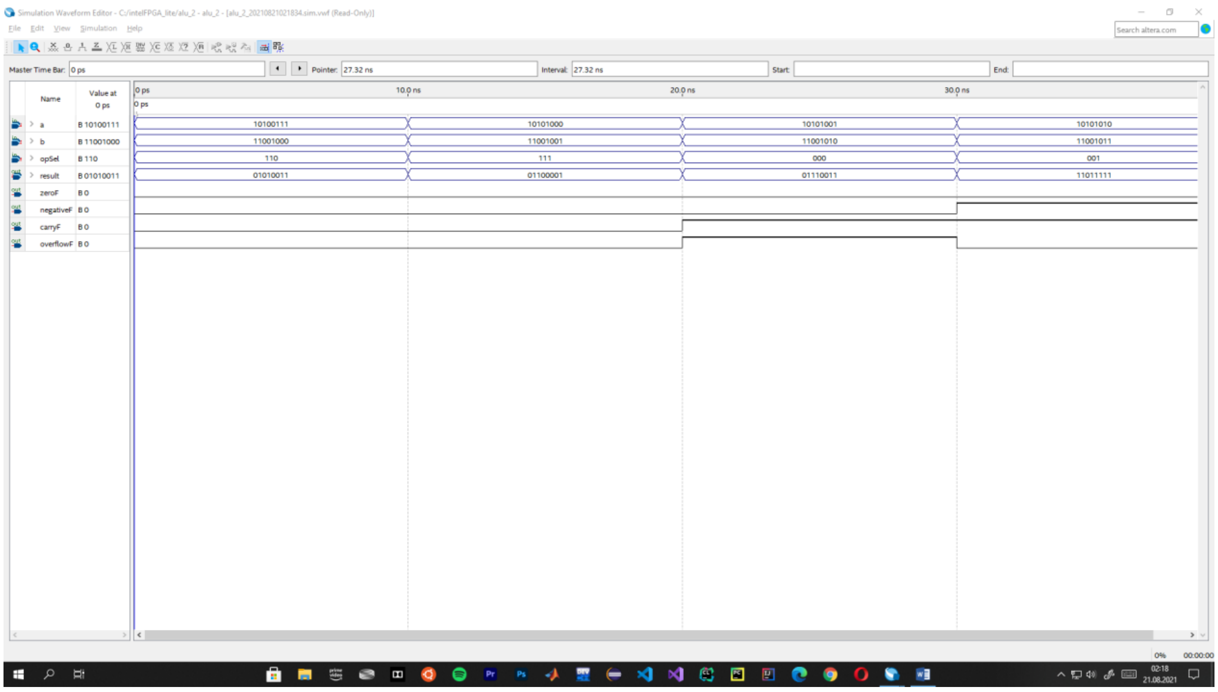

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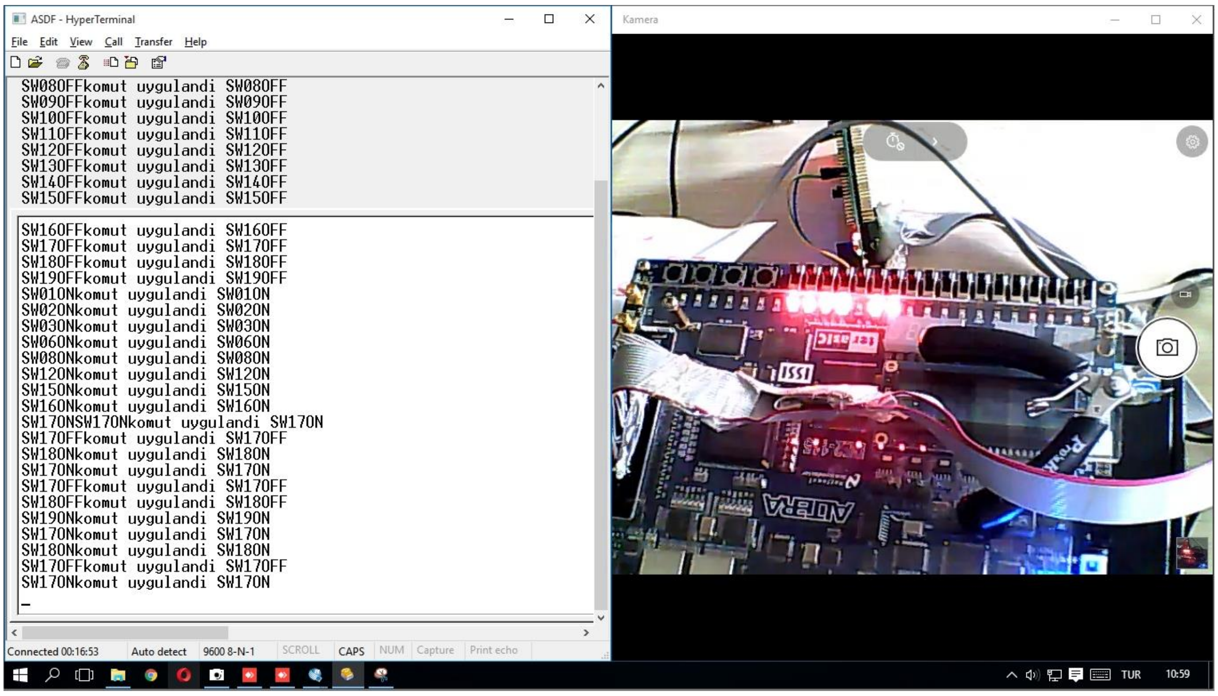
Master Time Bar: 0 ps Pointer: 27.32 ns Interval: 27.32 ns Start: End:

```
Name        Value at 0 ps   0 ps        10.0 ns     20.0 ns     30.0 ns
a           B 10100111      10100111    10101000    10101001    10101010
b           B 11001000      11001000    11001001    11001010    11001011
opSel       B 110           110         111         000         001
result      B 01010011      01010011    01100001    01110011    11011111
zeroF       B 0
negativeF   B 0
carryF      B 0
overflowF   B 0
```

XOR Operation

According to the operands; the result is 0110 1111 (111), the zero, negative, carry and overflow flags were found as 0, 0, 0, 0 respectively.



ASDF - HyperTerminal
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TUR 10:59

```
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SW150FFkomut uygulandi SW150FF
SW160FFkomut uygulandi SW160FF
SW170FFkomut uygulandi SW170FF
SW180FFkomut uygulandi SW180FF
SW190FFkomut uygulandi SW190FF
SW010Nkomut uygulandi SW010N
SW020Nkomut uygulandi SW020N
SW030Nkomut uygulandi SW030N
SW060Nkomut uygulandi SW060N
SW080Nkomut uygulandi SW080N
SW120Nkomut uygulandi SW120N
SW150Nkomut uygulandi SW150N
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SW170NSW170Nkomut uygulandi SW170N
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SW180Nkomut uygulandi SW180N
SW170Nkomut uygulandi SW170N
SW170FFkomut uygulandi SW170FF
SW180FFkomut uygulandi SW180FF
SW190Nkomut uygulandi SW190N
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SW170FFkomut uygulandi SW170FF
SW170Nkomut uygulandi SW170N
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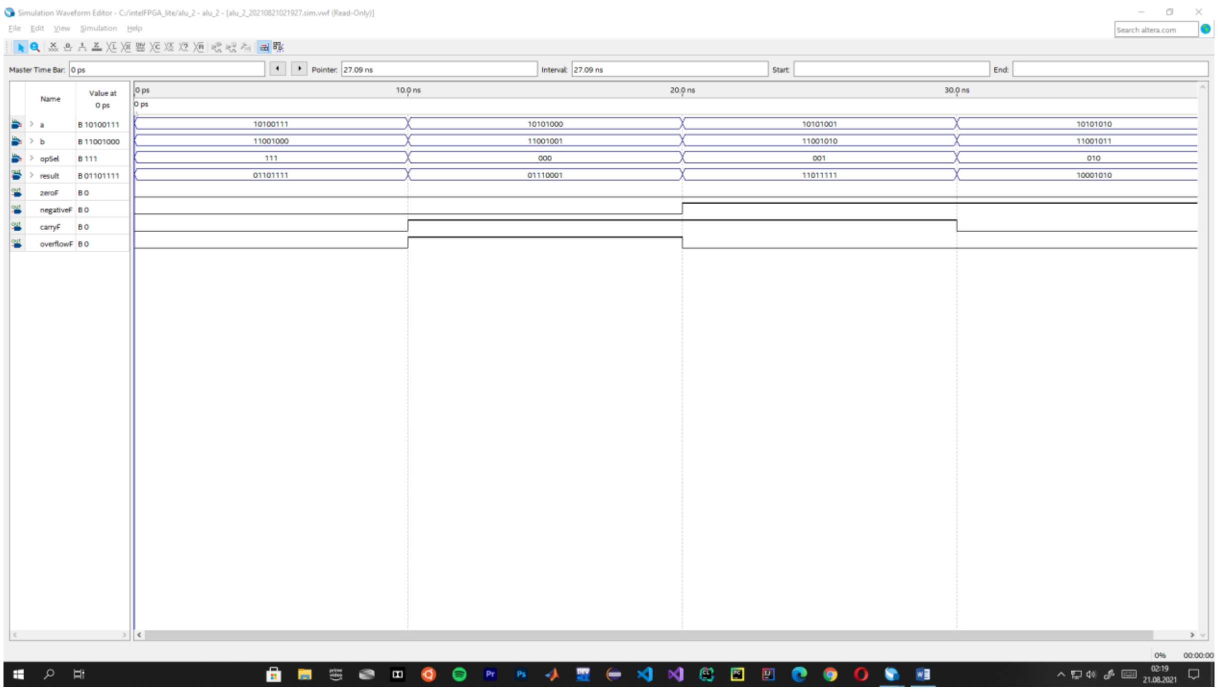

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File Edit View Simulation Help
Search altera.com
Master Time Bar: 0 ps
Pointer: 27.09 ns
Interval: 27.09 ns
Start:
End:
0 ps
10.0 ns
20.0 ns
30.0 ns

Name	Value at 0 ps	0 ps	10.0 ns	20.0 ns	30.0 ns
a	B 10100111	10100111	10101000	10101001	10101010
b	B 11001000	11001000	11001001	11001010	11001011
opSel	B 111	111	000	001	010
result	B 01101111	01101111	01110001	11011111	10001010
zeroF	B 0				
negativeF	B 0				
carryF	B 0				
overflowF	B 0				

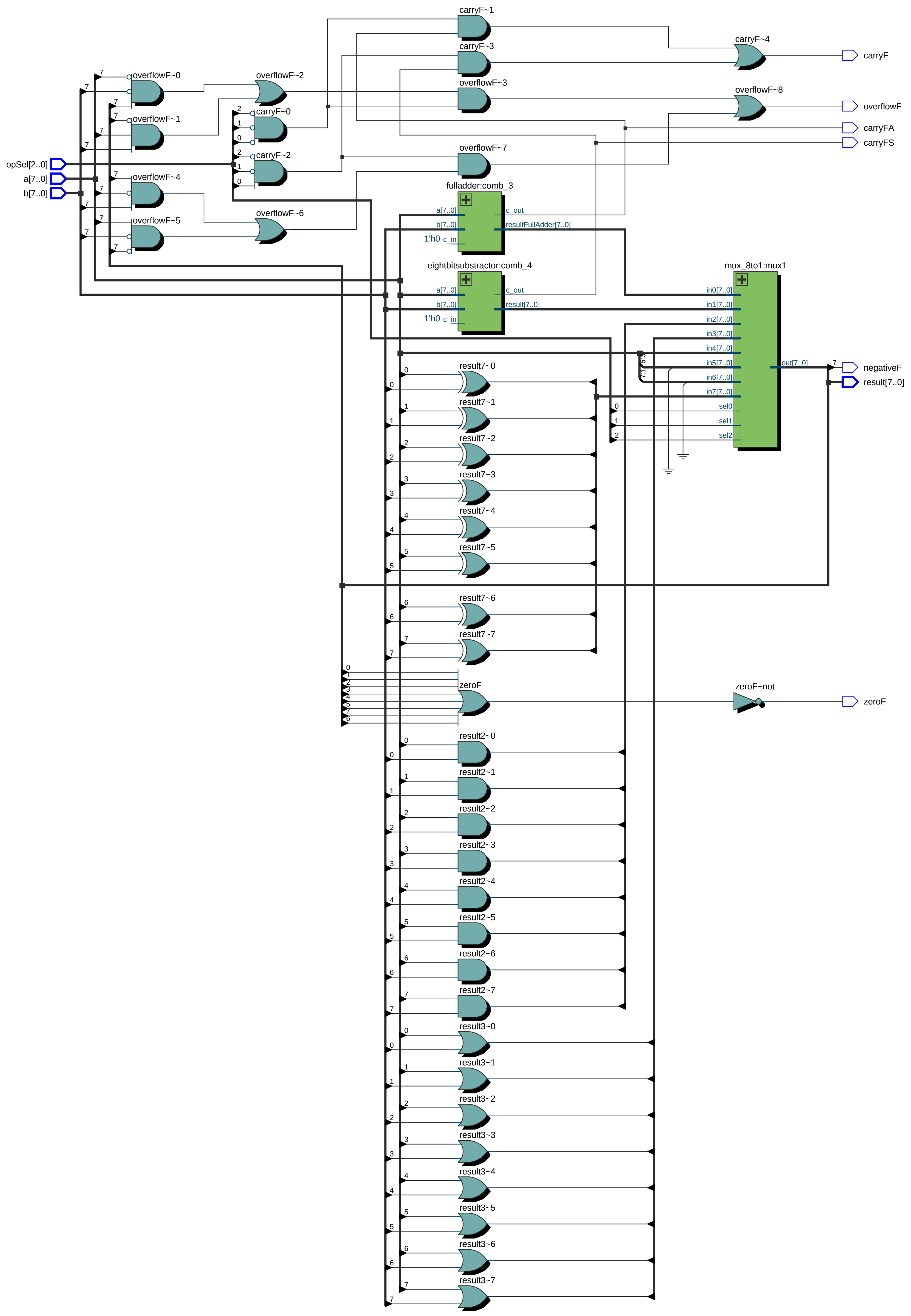
Source Code

```
module onebitsubstractor(input a, input b, input c_in, output c_out, output result);

assign c_out = (~a&b)|(b&c_in)|(~a&c_in);
assign result = (a ^ b) ^ c_in;

endmodule

//-------------------------------------------------------------------
module twobitsubstractor(input [1:0]a,input [1:0]b, input c_in, output c_out, output  [1:0] result);

wire cout;
onebitsubstractor s0(a[0],b[0],c_in,cout,result[0]);
onebitsubstractor s1(a[1],b[1],cout,c_out,result[1]);

endmodule

//-------------------------------------------------------------------
module fourbitsubstractor(input [3:0]a,input [3:0]b, input c_in, output c_out, output  [3:0] result);

wire cout;
twobitsubstractor s0(a[1:0],b[1:0],c_in,cout,result[1:0]);
twobitsubstractor s1(a[3:2],b[3:2],cout,c_out,result[3:2]);

endmodule

//-------------------------------------------------------------------
module eightbitsubstractor(input [7:0]a,input [7:0]b, input c_in, output c_out, output  [7:0] result);

wire cout;
fourbitsubstractor s0(a[3:0],b[3:0],c_in,cout,result[3:0]);
fourbitsubstractor s1(a[7:4],b[7:4],cout,c_out,result[7:4]);

endmodule

module fulladder(
input [7:0] a,
input [7:0] b,
input c_in,
output reg c_out,
output reg [7:0] resultFullAdder);

always @(a or b or c_in)
begin
{c_out, resultFullAdder} = a+b+c_in;
end

endmodule

//-------------------------------------------------------------------
module mux2to1(in0,in1,sel0,out);

input[7:0] in0,in1;
input sel0;
output[7:0] out;
```

```
assign out[7] =  (in0[7] & ~sel0)|(in1[7] & sel0);
assign out[6] =  (in0[6] & ~sel0)|(in1[6] & sel0);
assign out[5] =  (in0[5] & ~sel0)|(in1[5] & sel0);
assign out[4] =  (in0[4] & ~sel0)|(in1[4] & sel0);
assign out[3] =  (in0[3] & ~sel0)|(in1[3] & sel0);
assign out[2] =  (in0[2] & ~sel0)|(in1[2] & sel0);
assign out[1] =  (in0[1] & ~sel0)|(in1[1] & sel0);
assign out[0] =  (in0[0] & ~sel0)|(in1[0] & sel0);

endmodule

//-----------------------------------------------------------------
module mux4to1(in0,in1,in2,in3,sel0,sel1,out);

input[7:0] in0,in1,in2,in3;
input sel0,sel1;
output[7:0] out;
wire[7:0] w1,w2;

mux2to1 m1(in0,in1,sel0,w1);
mux2to1 m2(in2,in3,sel0,w2);
mux2to1 m3(w1,w2,sel1,out);

endmodule

//-----------------------------------------------------------------
module mux_8to1(in0,in1,in2,in3,in4,in5,in6,in7,sel0,sel1,sel2,out);

input[7:0] in0,in1,in2,in3,in4,in5,in6,in7;
input sel0,sel1,sel2;
output[7:0] out;
wire[7:0] w1,w2;

mux4to1 m1(in0,in1,in2,in3,sel0,sel1,w1);
mux4to1 m2(in4,in5,in6,in7,sel0,sel1,w2);
mux2to1 m3(w1,w2,sel2,out);

endmodule

//-----------------------------------------------------------------
module alu_2(a, b, opSel, zeroF, carryF, negativeF, overflowF, carryFS, carryFA, result);

input [7:0] a, b;
input [2:0] opSel;
output zeroF, negativeF, carryF, overflowF, carryFS, carryFA;
output [7:0] result;
wire [7:0] result0, result1, result2, result3, result4, result5, result6, result7;

fulladder(a, b, 0, carryFA, result0);
eightbitsubstractor(a, b, 0, carryFS, result1);
assign result2 = a & b;
assign result3 = a | b;
assign result4 = a;
assign result5 = a << 1;
assign result6 = a >> 1;
assign result7 = a ^ b;
```

```
mux_8to1 mux1(result0, result1,result2, result3, result4, result5, result6, result7, opSel[0], opSel[1],
opSel[2], result);


assign zeroF = ~(result[7] | result[6] | result[5] | result[4] | result[3] | result[2] | result[1] | result[0]);
assign negativeF = result[7] ;


assign overflowF = (((~a[7] & ~b[7] & result[7]) | (a[7] & b[7] & ~result[7]))
& (~opSel[0] & ~opSel[1] & ~opSel[2])) | (((~a[7] & b[7] & result[7]) | (a[7] & ~b[7] & ~result[7]))
& (opSel[0] & ~opSel[1] & ~opSel[2]));

assign carryF = (~opSel[0] & ~opSel[1] & ~opSel[2] & carryFA) | (opSel[0] & ~opSel[1] & ~opSel[2] & carryFS);

endmodule

//------------------------------------------------------------------
```

The RTL View


carryF~1
carryF~3
carryF~4
carryF
overflowF~3
overflowF~8
overflowF
carryFA
carryFS
overflowF~0
overflowF~2
overflowF~1
carryF~0
carryF~2
overflowF~7
opSel[2..0]
a[7..0]
b[7..0]
overflowF~4
overflowF~5
overflowF~6
fulladder:comb_3
a[7..0]
b[7..0]
1'h0 c_in
c_out
resultFullAdder[7..0]
eightbitsubstractor:comb_4
a[7..0]
b[7..0]
1'h0 c_in
c_out
result[7..0]
mux_8to1:mux1
in0[7..0]
in1[7..0]
in2[7..0]
in3[7..0]
in4[7..0]
in5[7..0]
in6[7..0]
in7[7..0]
sel0
sel1
sel2
out[7..0]
negativeF
result[7..0]
result7~0
result7~1
result7~2
result7~3
result7~4
result7~5
result7~6
result7~7
zeroF
zeroF~not
zeroF
result2~0
result2~1
result2~2
result2~3
result2~4
result2~5
result2~6
result2~7
result3~0
result3~1
result3~2
result3~3
result3~4
result3~5
result3~6
result3~7