

Review Problem 9

❖ What does the number 100011_2 represent?

2's comp represents -29

Unsigned 35

S-M -3

MIPS Sub x0,x0,x0
machine
code

ASCII "#"

Debugging Complex Circuits

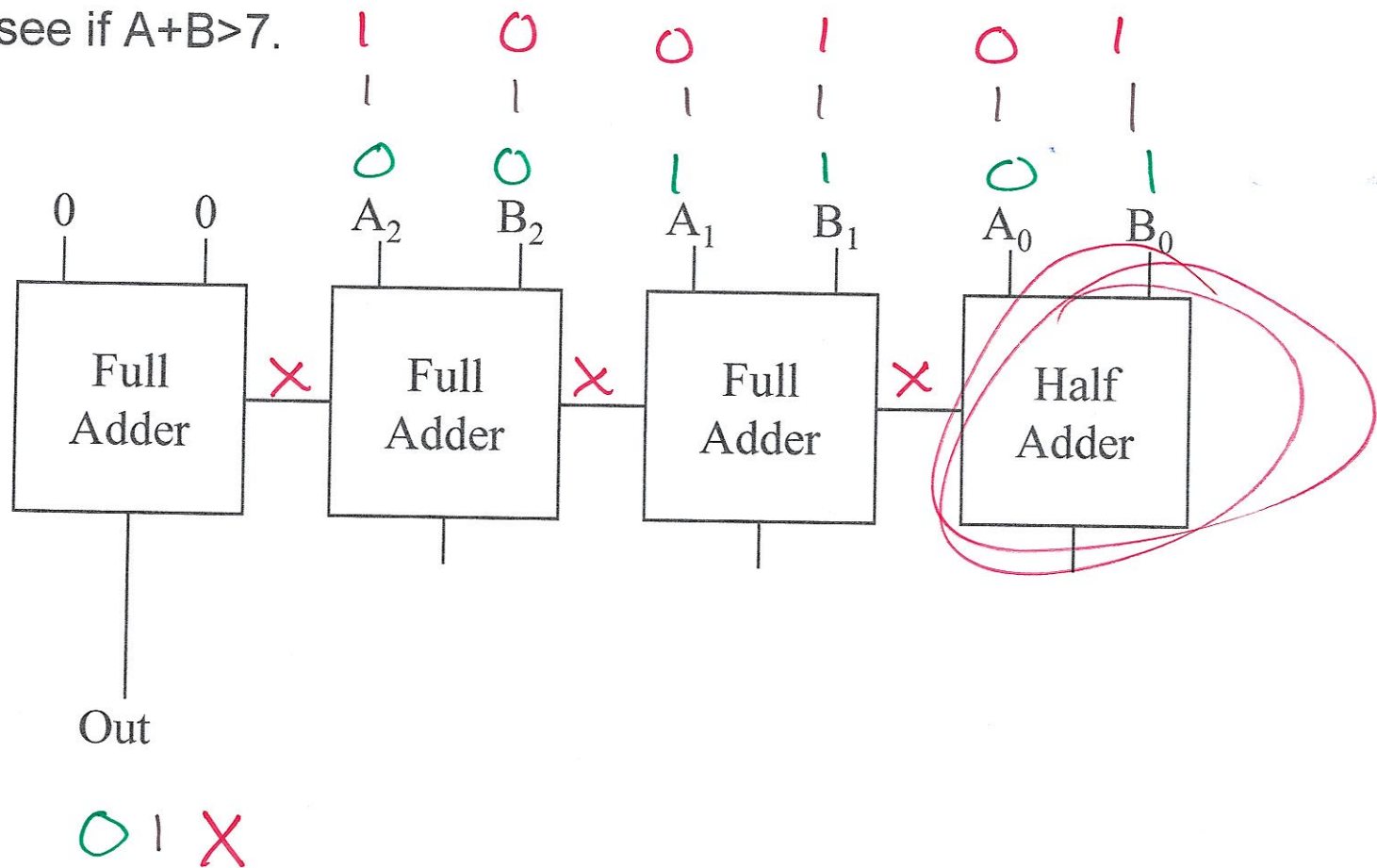
Small : try all combos
big : try all behaviors

Complex circuits require careful debugging

Rip up and retry?

Ex. Circuit to see if $A+B > 7$.

+ all combos of sub elements



Debugging Complex Circuits (cont.)

```
module fullAdd (Cout, S, A, B, Cin);  
    output Cout, S; input A, B, Cin;  
  
    assign Cout = (A&B) | (A&Cin) | (B&Cin);  
    assign S = A^B^Cin;  
endmodule
```

```
module halfAdd (Cout, S, A, B);  
    output Cout, S; input A, B;  
  
    fullAdd a1(.Cout, .S, .A, .B, .Cin);  
endmodule
```

Handwritten red annotations: 'X' above Cout, '0 1' above S, and '.Cin(0)' next to the Cin argument in the fullAdd call.

```
module greaterThan7 (Out, A, B);  
    output Out; input [2:0] A, B; wire [3:0] C, S;  
  
    halfAdd pos0(.Cout(C[0]), .S(S[0]), .A(A[0]), .B(B[0]));  
    fullAdd pos1(.Cout(C[1]), .S(S[1]), .A(A[1]), .B(B[1]), .C(C[0]));  
    fullAdd pos2(.Cout(C[2]), .S(S[2]), .A(A[2]), .B(B[2]), .C(C[1]));  
    fullAdd pos3(.Cout(C[3]), .S(Out), .A(0), .B(0), .C(C[2]));  
endmodule
```

Debugging Approach

Test all behaviors.

All combinations of inputs for small circuits, subcircuits.

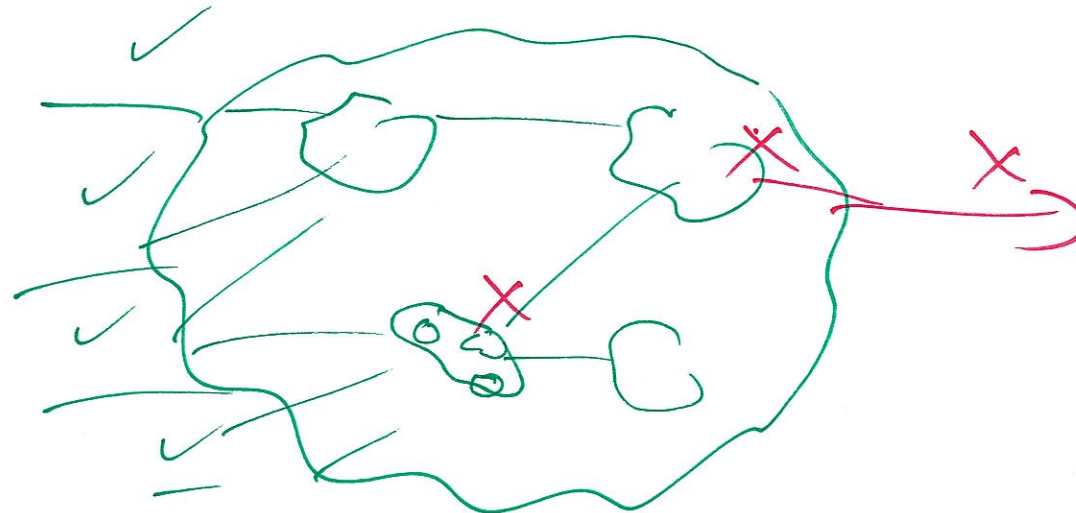
Identify any incorrect behaviors.

Examine inputs and outputs to find earliest place where value is wrong.

Typically, trace backwards from bad outputs, forward from inputs.

Look at values at intermediate points in circuit.

DO NOT RIP UP, DEBUG!



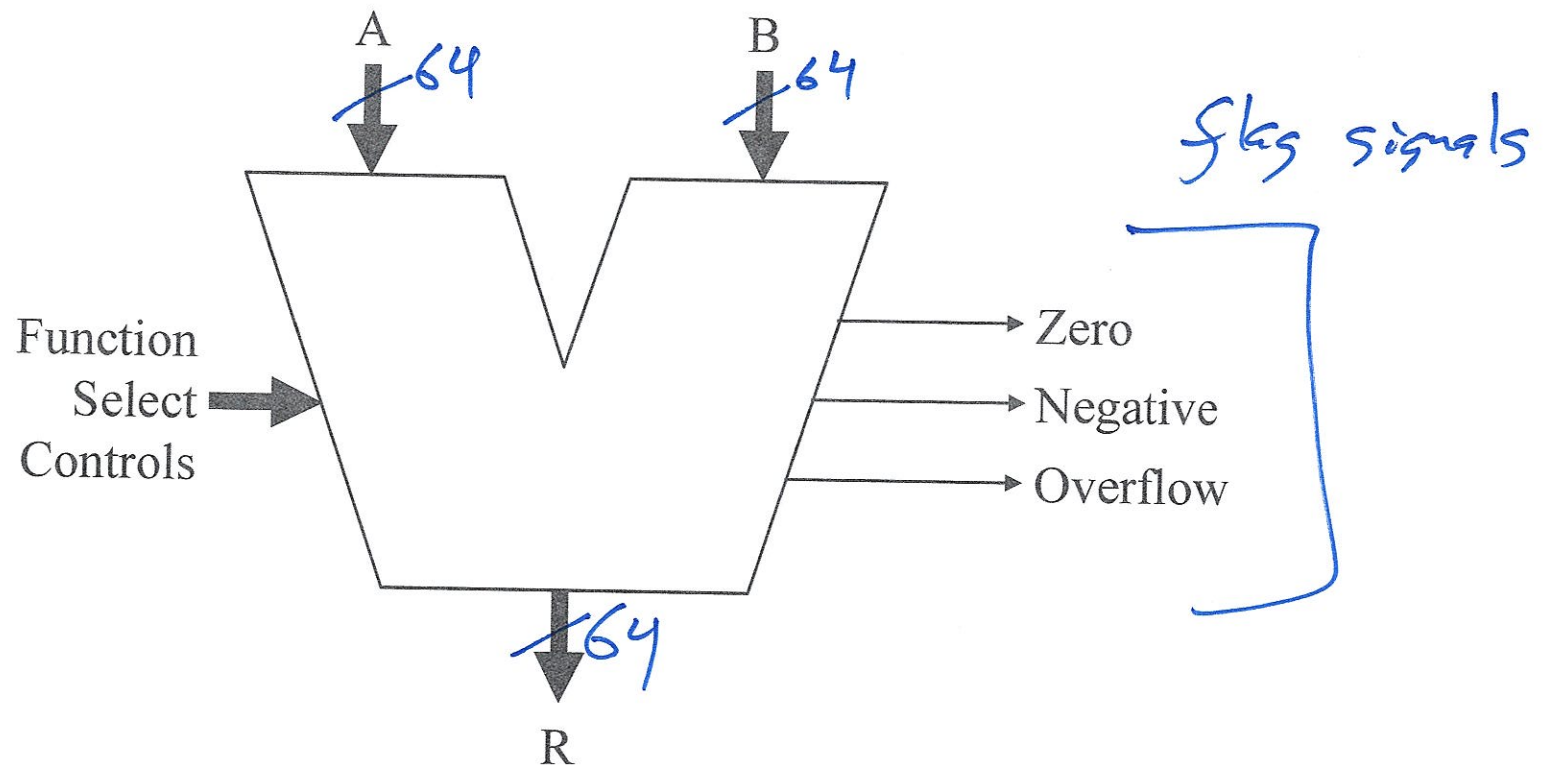
ALU: Arithmetic Logic Unit

Computes arithmetic & logic functions based on controls

Add, subtract

XOR, AND, NAND, OR, NOR

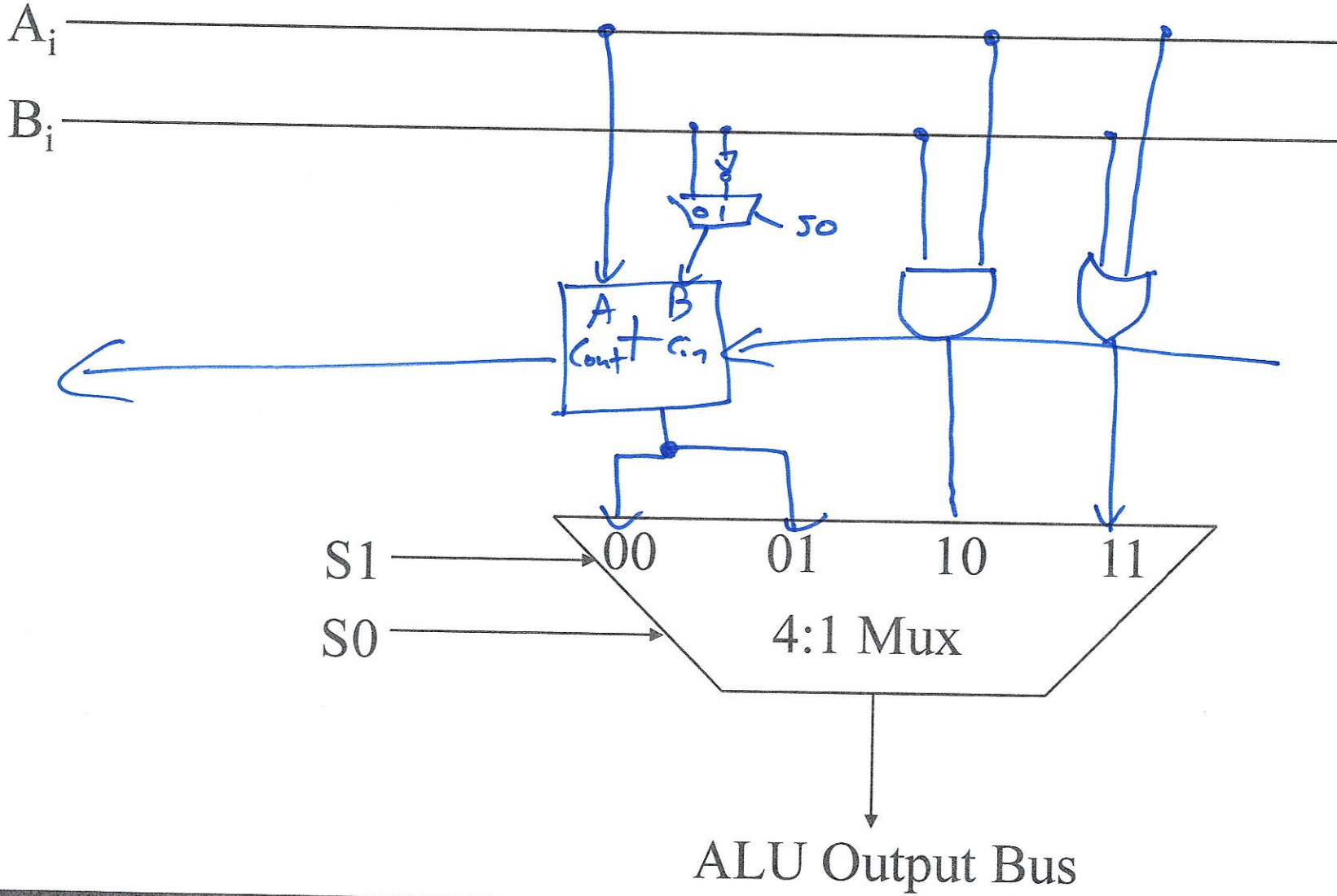
==, <, overflow, ...



172 bit

Bit Slice ALU Design

⁰⁰ Add, ⁰¹ Subtract, ¹⁰ AND, ¹¹ OR



Bit Slice ALU Design (cont.)

Route Carries

Overflow, zero, negative

