CME 341: Logic Mapping for Relational Operators

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Today's agenda

1. Logic Mapping for Relational Operators

Logic Mapping for Relational Operators

Relational operators: review

- As discussed previously, relational operators compare two input vectors and produce a single output bit (1 if the comparison is true, 0 if false)

- List of relational operators:
  - $<$ less than
  - $<=$ less than or equal to
  - $>$ greater than
  - $>=$ greater than or equal to
  - $==$ equal to
  - $!=$ not equal to

- Often used to generate select signals for if-else constructs

- Key question for today: *What type of hardware structure is generated by each*?

Logic for A == B

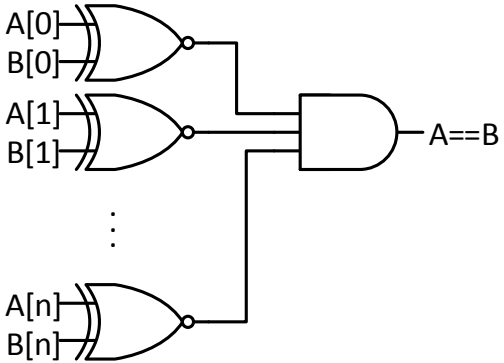
- For two numbers to be equal, all of their individual bits must match (A[0] == B[0], A[1] == B[1], etc.)

- Two bits can be compared using an XNOR gate (XNOR generates 1 if bits match)

A[i]	B[i]	A[i] XNOR B[i]
0	0	1
0	1	0
1	0	0
1	1	1

- Combine results of XNORs together using AND gate to generate final output A == B

Hardware structure for A == B



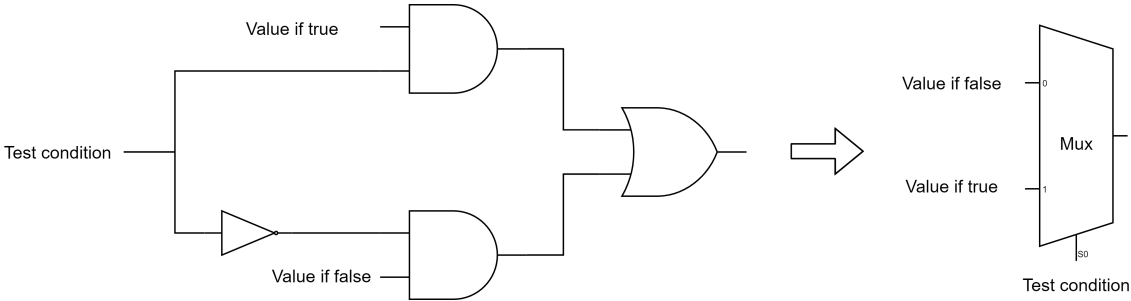
Simple always procedure using ==

Sketch the hardware generated by this code

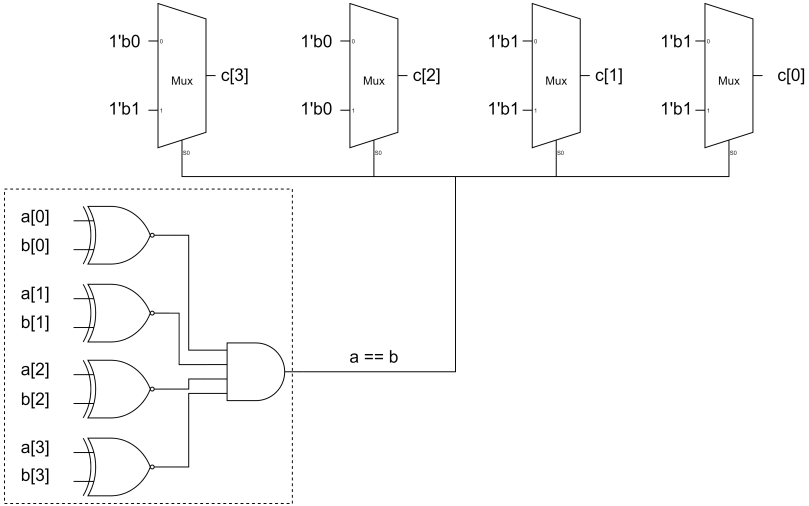
```
input [3:0] a, b;
output [3:0] c;
reg [3:0] c; // The output of a procedure must be declared type reg

always @ (*)
  begin  // begin-end are unnecessary if procedure has a single statement
    if(a == b)
      c = 4'b1011;
    else
      c = 4'b0011;
  end
```

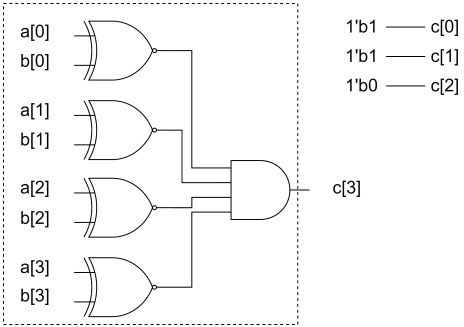
Recall: if-else template



Template applied to procedure:



Quartus optimizer removes unnecessary logic... final circuit built in FPGA



Not equal to operator (!=)

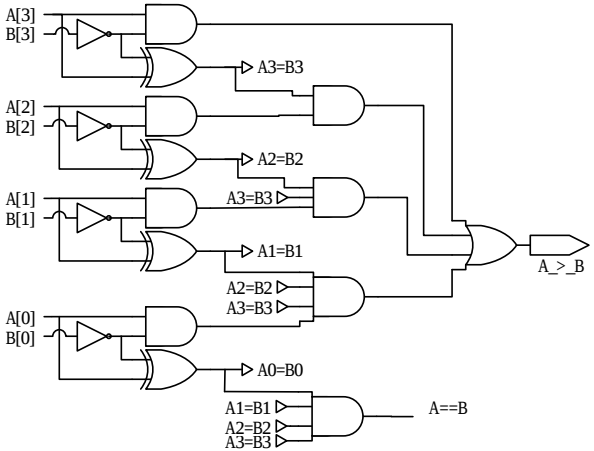
- This is trivial once we know how to do the equal to operator
- Just build the equal to logic, then invert the result
- Nothing more to be said...

Greater than operator ($>$)

(For unsigned numbers, different for signed case)

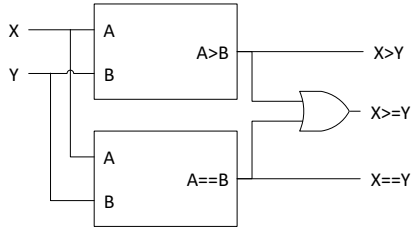
- Algorithm to check if A $>$ B
  - ▷ Compare MSBs of A and B
    - If MSB of A $= 1$ and MSB of B $= 0$, A $>$ B is true ... stop!
    - If MSBs are the same, continue...
  - ▷ MSBs are same, so compare 2nd MSB of A and B
    - If 2nd MSB of A $= 1$ and 2nd MSB of B $= 0$, A $>$ B is true ... stop!
    - If 2nd MSBs are the same, continue...
  - ▷ First 2 MSBs are same, so compare 3rd MSB of A and B
  - ▷ Etc...
  - ▷ All but LSBs are same, so compare LSB of A and B
    - If LSB of A $= 1$ and LSB of B $= 0$, A $>$ B is true ... stop!
    - Otherwise, A $>$ B is false!
    - Note that if we reached this point and LSBs are the same, A == B
- (Not complicated... this is just how we compare numbers in our everyday lives!)

Hardware for $>$ operator



Remaining relational operators are simple!

- A >= B ... just OR the A > B and A == B outputs from the previous slide
- A < B : equivalent to B > A ... just switch the places of A and B in previous slide
- A <= B ... just OR A < B with A == B
- Template for all relational operators:



Thank you!
Have a great day!