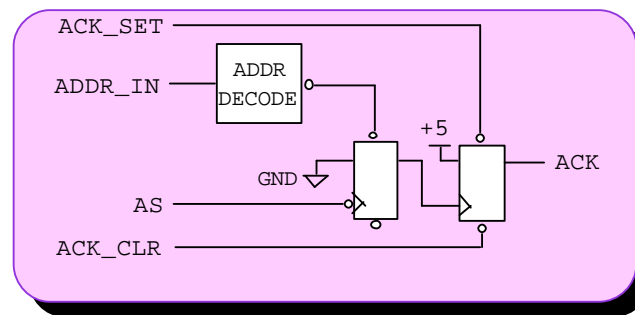


RTL Coding Guidelines

Think Synchronous

- *Synchronous* designs run smoothly through synthesis, simulation and place-and-route
- Isolate necessary *Asynchronous* logic into separate blocks



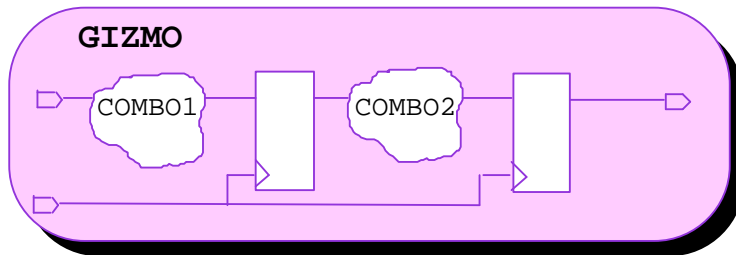
← *Asynchronous*
Address Decoder

How am I going to
synthesize this?

RTL Coding Guidelines

Think RTL

- Describe the circuits in terms of its registers and the combinational logic between them



```
module GIZMO (A, CLK, Z);  
  ...  
  always @(A) begin : COMBO1...  
  always @(posedge CLK)...  
  always @(B) begin : COMBO2...  
  always @(posedge CLK) ...  
end module;
```



RTL Coding Guidelines

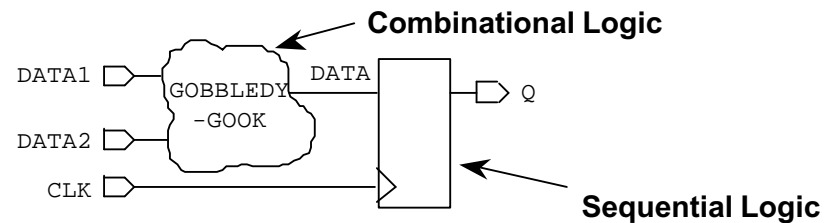
Separate Combinational from Sequential

- Follows RTL coding style
- Easy to read and self-documenting

```
module EXAMPLE (DATA1,DATA2,CLK,Q)
input DATA1,DATA2,CLK;
output Q;

reg DATA, Q;
always @(DATA1 or DATA2)
begin: COMBO
DATA <= GOBBLEDYGOOK(DATA1,DATA2);
end

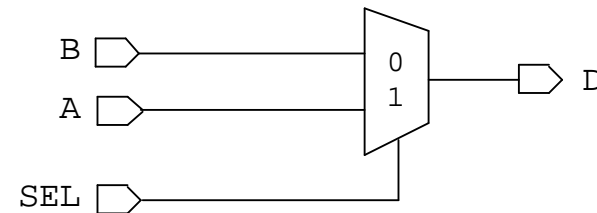
always @(posedge CLK)
begin: SEQUENTIAL
Q <= DATA;
end
endmodule
```



IF Statements

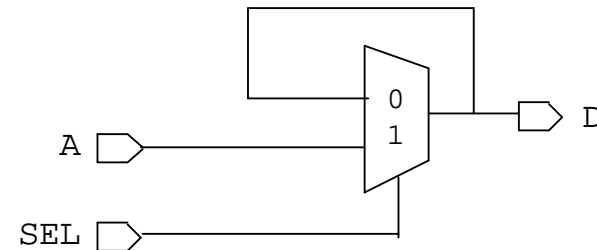
- IF statements infer multiplexer logic

```
always @(SEL or A or B)
  if (SEL)
    D <= A;
  else
    D <= B;
```



- Latches are inferred unless all variables are assigned in all branches

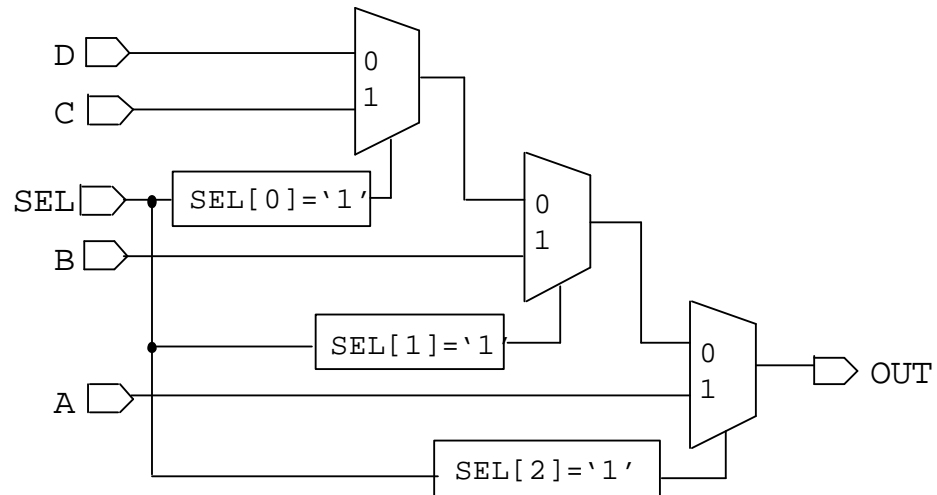
```
always @(SEL or A)
  if (SEL)
    D <= A;
```



IF Statements (cont.)

- IF-ELSE-IF statements infer priority-encoded multiplexers

```
always @(SEL or A or B or C or D)
  if (SEL[2] == 1'b1)
    OUT <= A;
  else if (SEL[1] == 1'b1)
    OUT <= B;
  else if (SEL[0] == 1'b1)
    OUT <= C;
  else
    OUT <= D;
```



Long delay from D to OUT

IF Statements (cont.)

- **Remove redundant conditions**
- **Use CASE statements if conditions are mutually exclusive**

Don't

```
always @(A or B or C or D or E)
  if (A < B)
    OUT <= C;
  else if (A > B)
    OUT <= D;
  else if (A == B)
    OUT <= E;
```

Do

```
always @(A or B or C or D or E)
  if (A < B)
    OUT <= C;
  else if (A > B)
    OUT <= D;
  else
    OUT <= E;
```

CASE Statements

Verilog Directives

- **full_case** indicates that all *user-desired* cases have been specified
- Do not use *default* for one-hot encoding

one hot →

```
always @(SEL or A or B or C)
begin
  case (SEL) //synopsys full_case
    3'b001 : OUT <= A;
    3'b010 : OUT <= B;
    3'b100 : OUT <= C;
  endcase
end
```

Does not infer latches

```
always @(SEL or A or B)
begin
  case (SEL)
    3'b001 : OUT <= A;
    3'b010 : OUT <= B;
    3'b100 : OUT <= C;
  endcase
end
```

**Infers latches for OUT
because not all cases
are specified**

CASE Statements

Verilog Directives (cont.)

- **parallel_case** indicates that all cases listed are mutually exclusive to prevent priority-encoded logic

```
always @(SEL or A or B or C)
begin
  case (SEL) //synopsys parallel_case
    A : OUT <= 3'b001;
    B : OUT <= 3'b010;
    C : OUT <= 3'b100;
  endcase
end
```

Infers a multiplexer

CASE Statements

“CASE” vs. “IF-ELSE IF”

- Use IF-ELSE for 2-to-1 multiplexers
- Use CASE for n-to-1 multiplexers where $n > 2$
- Use IF-ELSE IF for priority encoders
- Use CASE with `//synopsys parallel_case` when conditions are mutually exclusive
- Use CASE with `//synopsys full_case` when not all conditions are specified
- Use CASE with `//synopsys full_case parallel_case` for one-hot Finite State Machines (FSMs)

CASE Statements

FSM Encoding

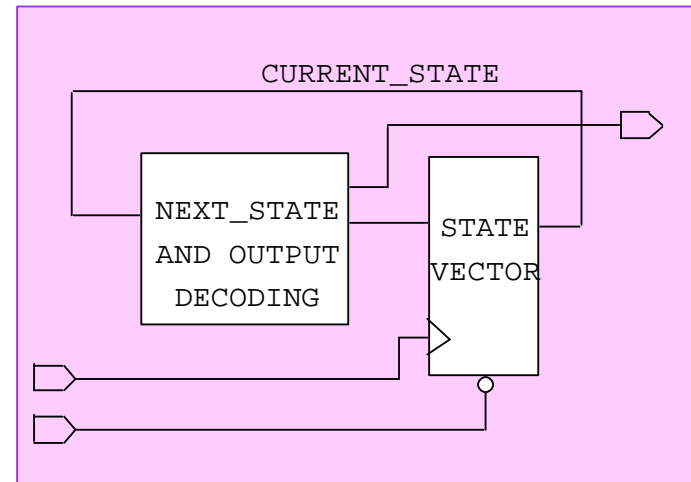
- Use **CASE** statements to describe FSMs
- Use `//synopsys parallel_case` to indicate mutual exclusivity
- Use `//synopsys full_case` when not all possible states are covered (one-hot)
- Do not use *default* unless recovery state is desired

CASE Statements

FSM Encoding (cont.)

```
module EXAMPLE (RESET, CLK, OUT);
input  RESET, CLK;
output [1:0] OUT;
parameter IDLE=4'b0001, GO=4'b0010, YIELD=4'b0100,
STOP=4'b1000;
reg [3:0] CURRENT_STATE, NEXT_STATE;
always @(CURRENT_STATE)
begin: COMBO
  case (CURRENT_STATE) // synopsys full_case parallel_case
    IDLE: begin NEXT_STATE = GO; OUT <= 2'b01; end
    GO: begin NEXT_STATE = YIELD; OUT <= 2'b11; end
    YIELD: begin NEXT_STATE = STOP; OUT <= 2'b10; end
    STOP: begin NEXT_STATE = IDLE; OUT <= 2'b00; end
  endcase
end
always @(posedge CLK or negedge RESET)
begin: SEQUENTIAL
  if (~RESET)
    CURRENT_STATE <= IDLE;
  else
    CURRENT_STATE <= NEXT_STATE
  end
end
endmodule
```

- Use parameter statements to define state values
- Use CASE statements and // synopsys parallel_case full_case to describe FSM

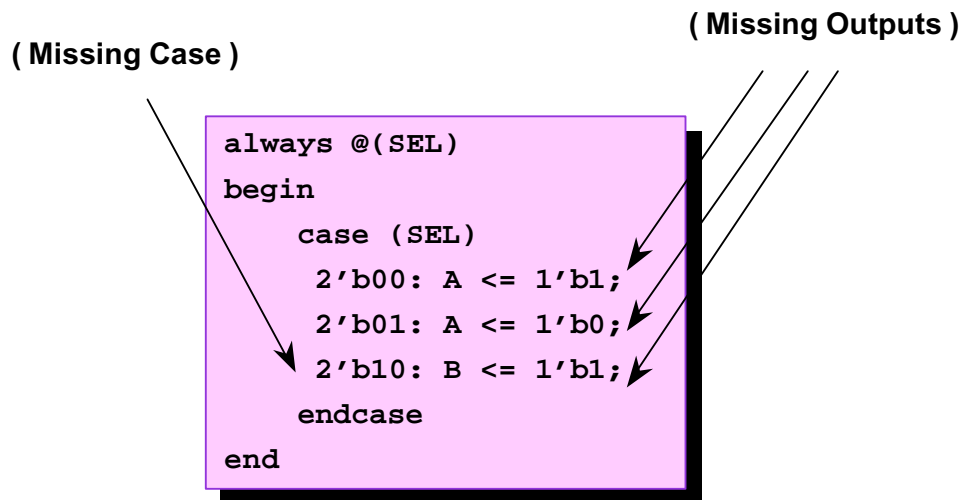


CASE Statements

Watch for Unintentional Latches

- Completely specify all branches for every case and if statement
- Completely specify all outputs for every case and if statement
- Use `//synopsys full_case` if all desired cases have been specified

What's wrong with this example?



CASE Statements

Cascade Chain Inference

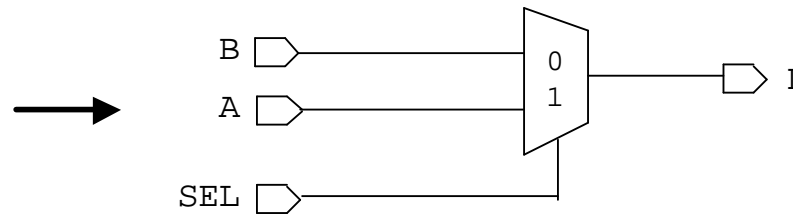
- Using cascade chains improves QoR significantly for multiplexers
- Completely specify all possible cases for cascade chains to be inferred

```
always @(SEL)
begin
  case (SEL)
    3'b000: OUT <= A;
    3'b001: OUT <= B;
    3'b010: OUT <= C;
    3'b011: OUT <= D;
    3'b100: OUT <= E;
    3'b101: OUT <= F;
    3'b110: OUT <= G;
    3'b111: OUT <= H;
  endcase
end
```

Multiplexers

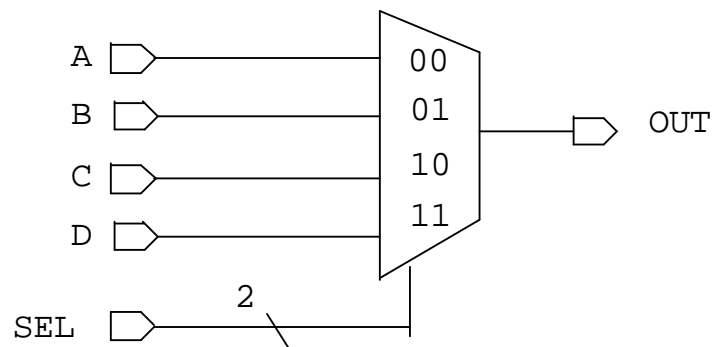
- Use IF or continuous assignment when select is a single-bit signal

```
always @(SEL or A or B)
  if (SEL)
    D <= A;
  else
    D <= B;
-----
assign D = SEL ? A : B;
```



- Use CASE statements when select is a multi-bit bus

```
always @(SEL or A or B
or C or D)
begin
  case (SEL)
    2'b00 : OUT <= A;
    2'b01 : OUT <= B;
    2'b10 : OUT <= C;
    2'b11 : OUT <= D;
  endcase
end
```



Operators

- **Operators inferred from HDL**

- Adder, Subtractor, AddSub (+, -), Multiplier (*)
- Comparators (>, >=, <, <=, ==, !=)
- Incrementer, Decrementer, IncDec (+1, -1)

- **Example**

```
module add (sum, a, b);  
output [15:0] sum;  
input [15:0] a, b;  
  
assign sum = a + b + 1'b1;  
  
endmodule
```

Design indicates two adders.

```
module add (sum, a, b);  
output [15:0] sum;  
input [15:0] a, b;  
wire temp;  
  
assign {sum, temp} = {a, 1'b1} + {b, 1'b1};  
  
endmodule
```

FE infers one adder with carry chain.

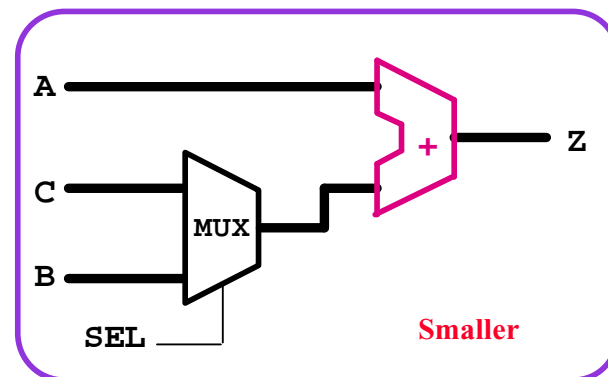
Operators

Operator Sharing

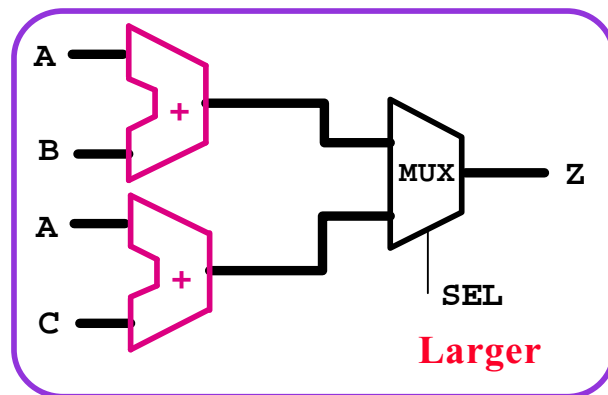
- Operators can be shared within an *always* block by default
- Users can disable sharing

```
always @(SEL or A or  
B or C)  
begin  
  if (SEL)  
    Z = A+B;  
  else  
    Z = A+C;  
end
```

With Sharing



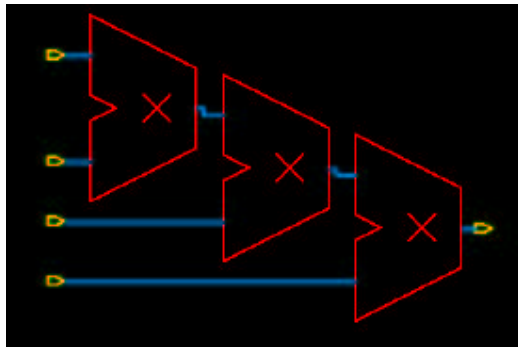
Without Sharing



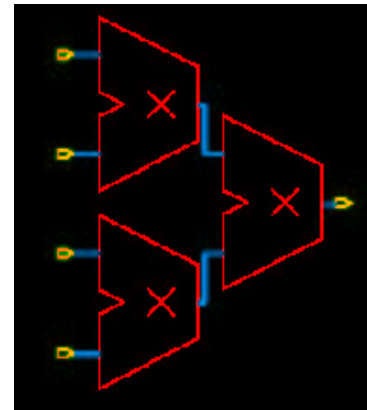
Operators

Operator Balancing

- Use parenthesis to guide synthesis



$A*B*C*D$



$(A*B)*(C*D)$