

CSE-308: Digital System Design

Lecture 1

Introduction

warm-up

quiz...

DLD (also DSD) is basically a design course.
List all the steps involved in capturing a real-world phenomenon and converting it to the simplest digital logic circuit using discrete gates.

Note: You just have to list the steps. Don't write unnecessary details.

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Course Newsgroups:

A: <https://classroom.google.com/c/NzYwMzQwMTY1MDA4>

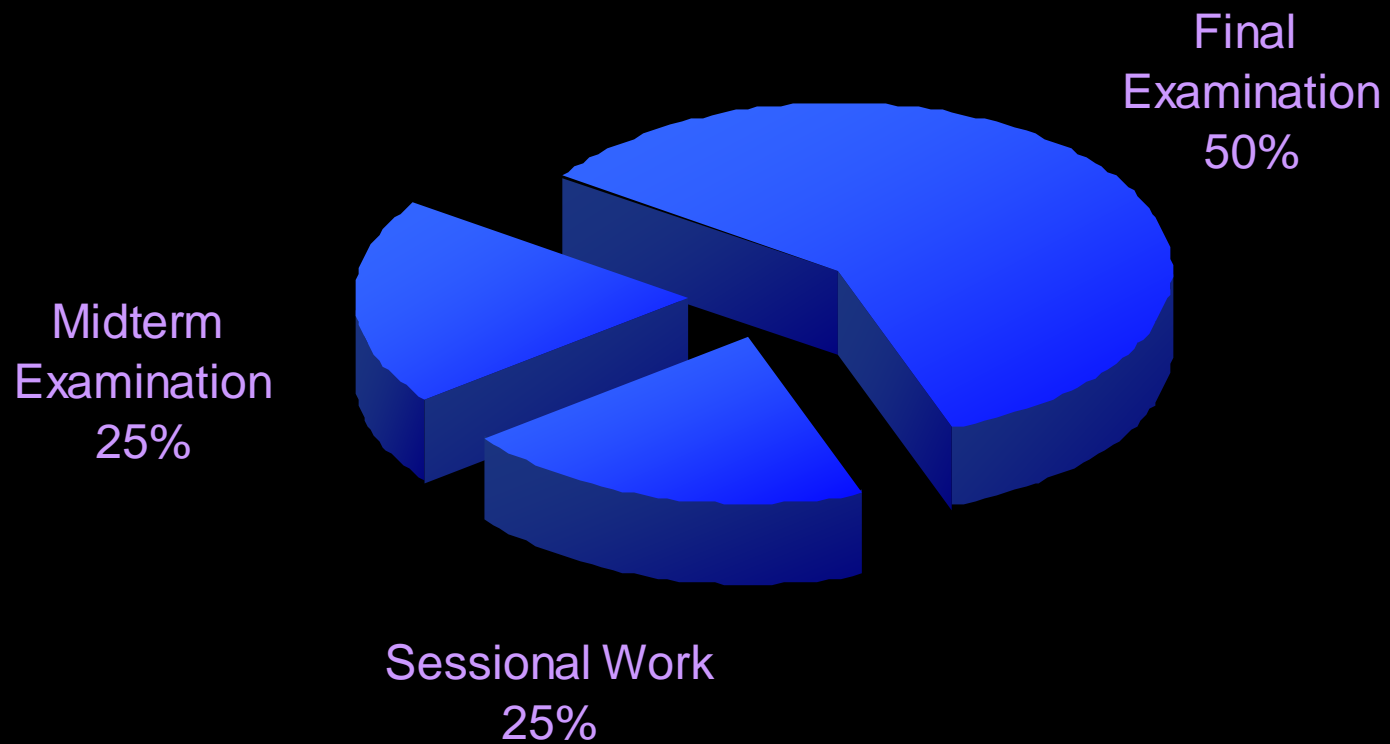
B: <https://classroom.google.com/c/NzUwMDM0NjExNTIy>

C: <https://classroom.google.com/c/NzUwMDM0MjgxOTk5>

Check the **group** often for
announcements related to
the course

marks

distribution...



Sessional Work (25%)

- Homeworks 5%
- Quizzes 15%
 - (50% announced + 50% unannounced)
- Class Participation + Attendance 5%

Homeworks (5%)

- Almost one every two weeks
- **Late homework policy:** Late submission of homeworks will result in "zero" grade

Homeworks (contd...)

- Done on an individual basis
- Collaboration is fine, but it should be you alone who writes up the answers
- Copying of homework is allowed as long as it goes through the head

Midterm Exam (25%)

- During the 7th/8th week
- Duration: Two hours
- Will cover all material covered during the first 7/8 weeks

Final Exam (50%)

- During the 16th/17th week
- Will cover the whole of the course before and after midterm
- Duration: Two hours

What I don't want?

That you fail such an easy course

Essential ingredient to pass is

"HARD WORK"

attendance

policy...

Students with attendance less than 75%
will NOT be allowed to sit in the
"FINAL EXAM"

Course Outline

1. Digital circuit design flow ✓
2. Verilog Hardware Description Language //
3. Logic Synthesis ✓
 - Multilevel logic minimization ✓
 - Technology mapping ✓
 - High-level synthesis ✓
4. Testability Issues //
5. Physical Design Automation //
 - Floorplanning, placement, routing, etc.

References

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R.H. Katz, Addison-Wesley Publishing Co., 1993.
2. **Application-specific integrated circuits**
M.J.S. Smith, Addison-Wesley Publishing Co., 1997.
3. **Modern VLSI design: systems on silicon**
W. Wolf, Pearson Education, 1998.
4. **Verilog HDL synthesis: a practical primer**
J. Bhasker, BS Publications, 1998.
5. **High-level synthesis: introduction to chip and system design**
D.D. Gajski, N.D. Dutt, A.C. Wu and A.Y. Yin, Kluwer Academic Publishers, 1992.

6. **Digital systems testing and testable design**
M. Abramovici, M.A. Breuer and A.D. Friedman, IEEE Press, 1994.
7. **Built-in test for VLSI: pseudo-random techniques**
P. Bardell, W.H. McAnney and J. Savir, J. Wiley & Sons, 1987.
8. **An introduction to physical design**
M. Sarrafzadeh and C.K. Wong, McGraw Hill, 1996.
9. **Algorithms for VLSI physical design automation, 3rd Edition**
N.A. Sherwani, Kluwer Academic Publishers, 1999.
10. **VLSI physical design automation: theory and practice**
S.M. Sait and H. Youssef, World Scientific Pub. Co., 1999.

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Digital Circuit Design Flow


Digital Design Process

- Design complexity increasing rapidly
 - Increased size and complexity
 - CAD tools are essential
- The present trend
 - Standardize the design flow

What is design flow?

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- **Standardized design procedure**
 - Starting from the design idea down to the actual implementation
- **Encompasses many steps**
 - Specification //
 - Synthesis //
 - Simulation //
 - Layout //
 - Testability analysis //
 - Many more



ASIC
FPGA
=
=

- **New CAD tools**

- Based on Hardware description language (HDL)
- HDLs provide formats for representing the outputs of various design steps
- An HDL based CAD tool transforms from its HDL input into a HDL output which contains more hardware information.
 - Behavioral level to register transfer level ↙
 - Register transfer level to gate level //
 - Gate level to transistor level //



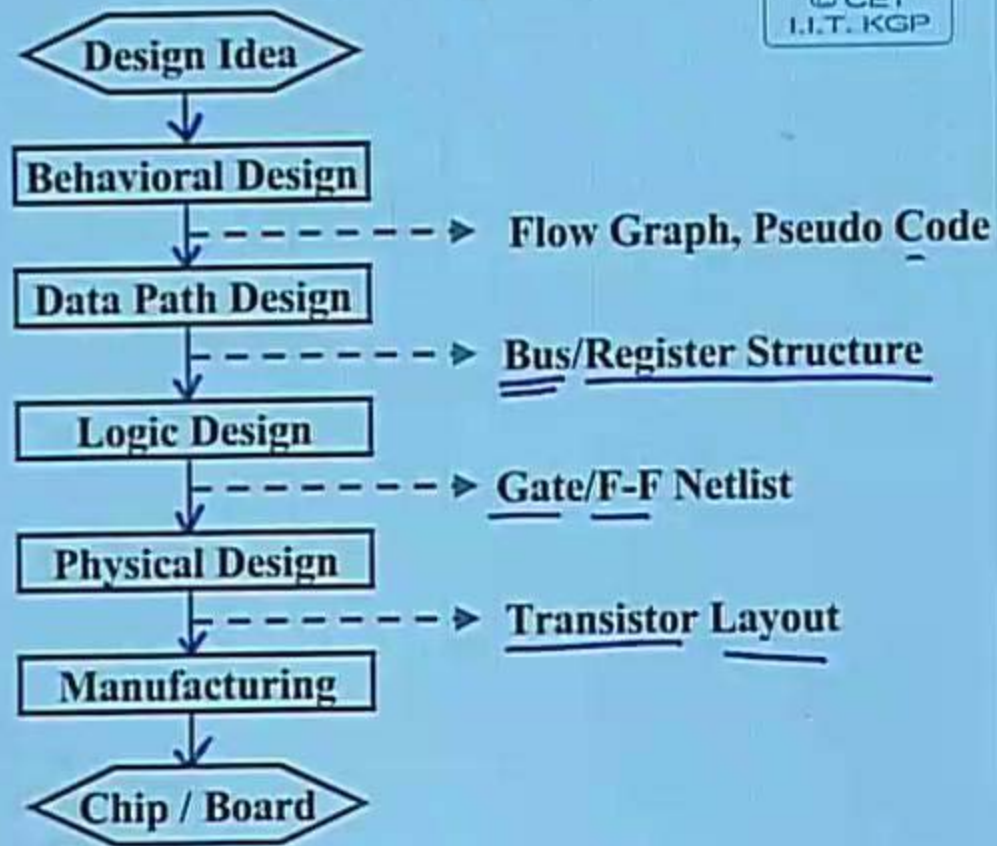
Two Competing HDLs

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1. Verilog
2. VHDL

*In this course we would be
concentrating on Verilog only*

Simplistic View of Design Flow



Design Representation

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- A design can be represented at various levels from three different angles:
 1. Behavioral //
 2. Structural //
 3. Physical //
- Can be represented by Y-diagram

BEHAVIORAL DOMAIN

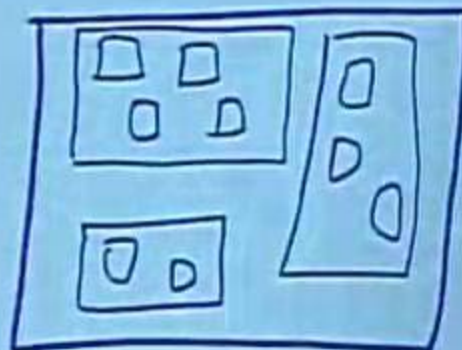
{ Programs
Specifications

STRUCTURAL DOMAIN

Gates
Adders
Registers

Transistors / Layouts
Cells
Chips / Boards

PHYSICAL DOMAIN



Behavioral Representation

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- Specifies how a particular design should respond to a given set of inputs.
- May be specified by
 - Boolean equations ✓
 - Tables of input and output values ✓
 - Algorithms written in standard HLL like C ✓
 - Algorithms written in special HDL like Verilog ✓

An algorithmic level description of Cy

```
module carry (cy, a, b, c);  
  input a, b, c;  
  output cy;  
  assign  
    cy = (a&b) | (b&c) | (c&a);  
endmodule
```

Boolean behavioral specification for Cy

primitive carry (cy, a, b, c);

input a, b, c;

output cy;

table

a	b	c	cy
1	1	?	1;
1	?	1	1;
?	1	1	1;
0	0	?	0;
0	?	0	0;
?	0	0	0;

endtable

endprimitive

comment

000

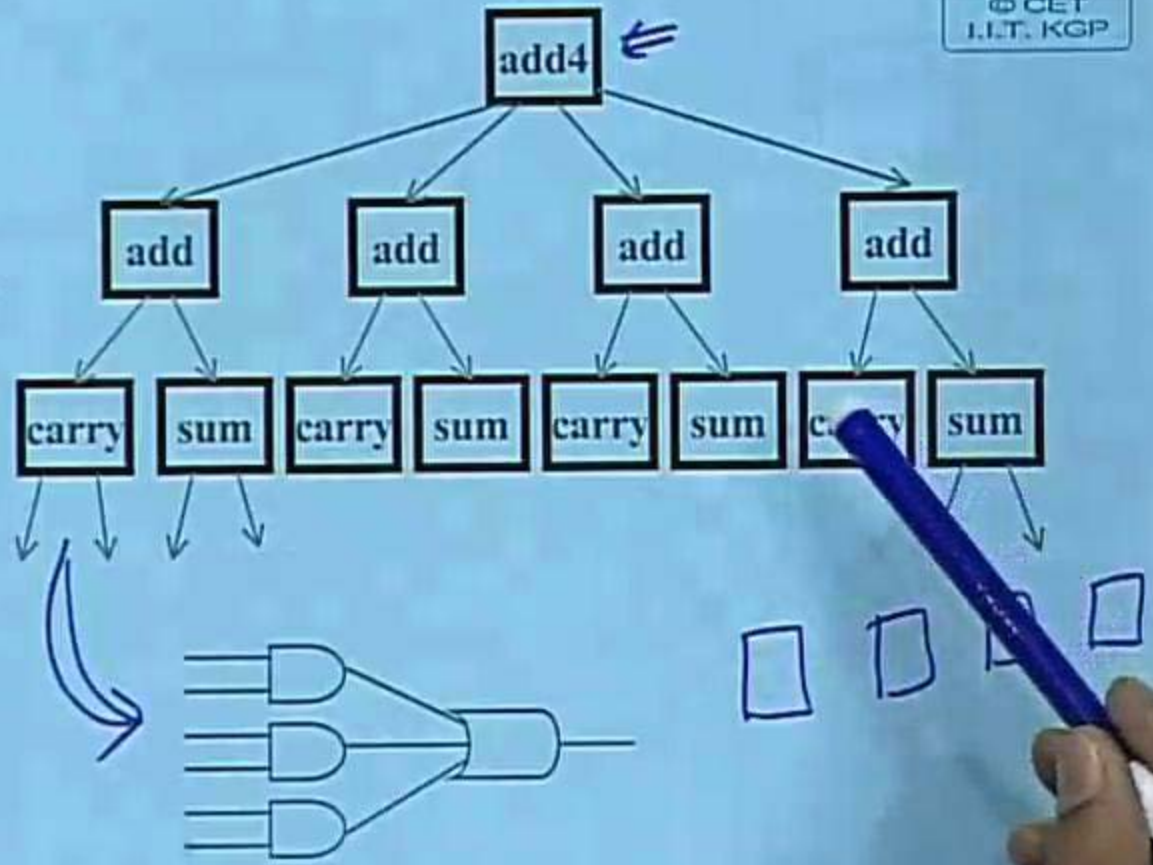
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Structural Representation

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- Specifies how components are interconnected.
- In general, the description is a list of modules and their interconnects.
 - called netlist.
 - can be specified at various levels.

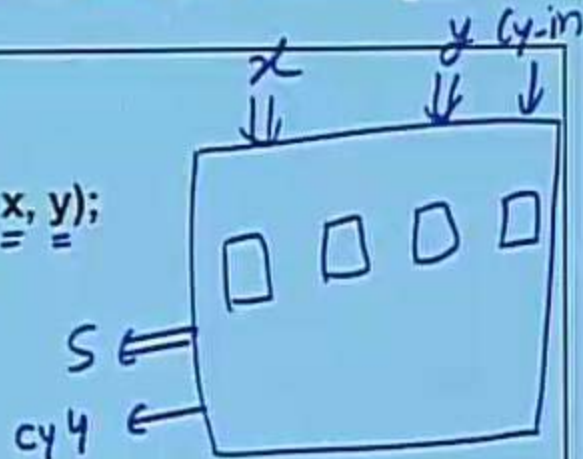
- At the structural level, the levels of abstraction are
 - the module level //
 - the gate level //
 - the switch level // \Rightarrow transistor
 - the circuit level //
- In each level more detail is revealed about the implementation.



Structural representation :: example

4-bit adder

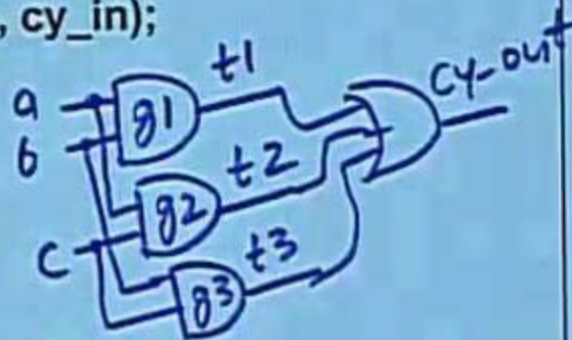
```
module add4 (s, cy4, cy_in, x, y);  
  input [3:0] x, y;  
  input cy_in;  
  output [3:0] s;  
  output cy4;  
  wire [2:0] cy_out;  
  add B0 (cy_out[0], s[0], x[0], y[0], ci);  
  add B1 (cy_out[1], s[1], x[1], y[1], cy_out[0]);  
  add B2 (cy_out[2], s[2], x[2], y[2], cy_out[1]);  
  add B3 (cy4, s[3], x[3], y[3], cy_out[2]);  
endmodule
```



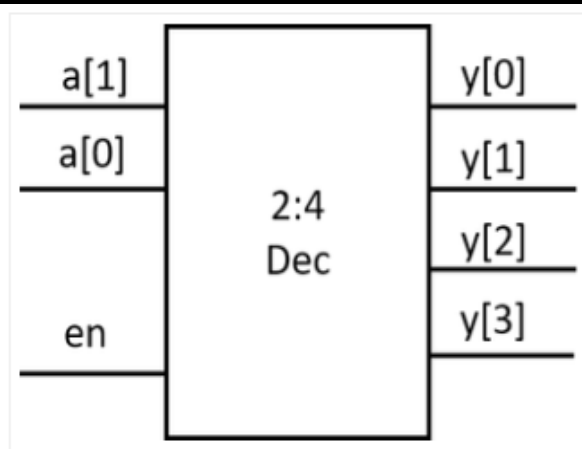
```
module add (cy_out, sum, a, b, cy_in);  
  input a, b, cy_in;  
  output sum, cy_out;  
  sum s1 (sum, a, b, cy_in);  
  carry c1 (cy_out, a, b, cy_in);  
endmodule
```

Instantiate

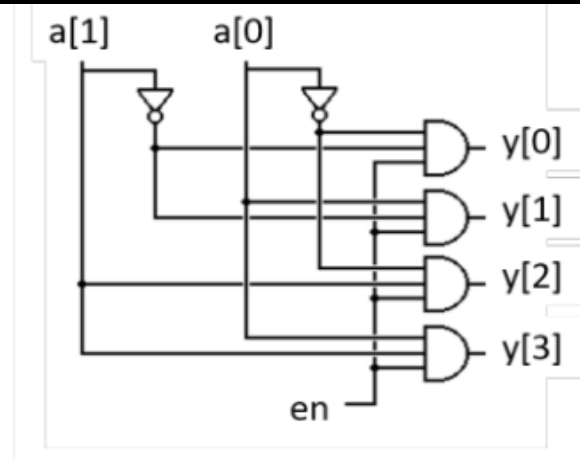
```
module carry (cy_out, a, b, cy_in);  
  input a, b, cy_in;  
  output cy_out;  
  wire t1, t2, t3;  
  and g1 (t1, a, b);  
  and g2 (t2, a, c);  
  and g3 (t3, b, c);  
  or g4 (cy_out, t1, t2, t3);  
endmodule
```



2x4 Decoder



2:4 Decoder Block diagram



2:4 Decoder Schematic Diagram

Inputs			Outputs			
en	$a[1]$	$a[0]$	$y[3]$	$y[2]$	$y[1]$	$y[0]$
0	x	x	0	0	0	0
1	0	0	0	0	0	1
1	0	1	0	0	1	0
1	1	0	0	1	0	0
1	1	1	1	0	0	0

2:4 Decoder Truth Table

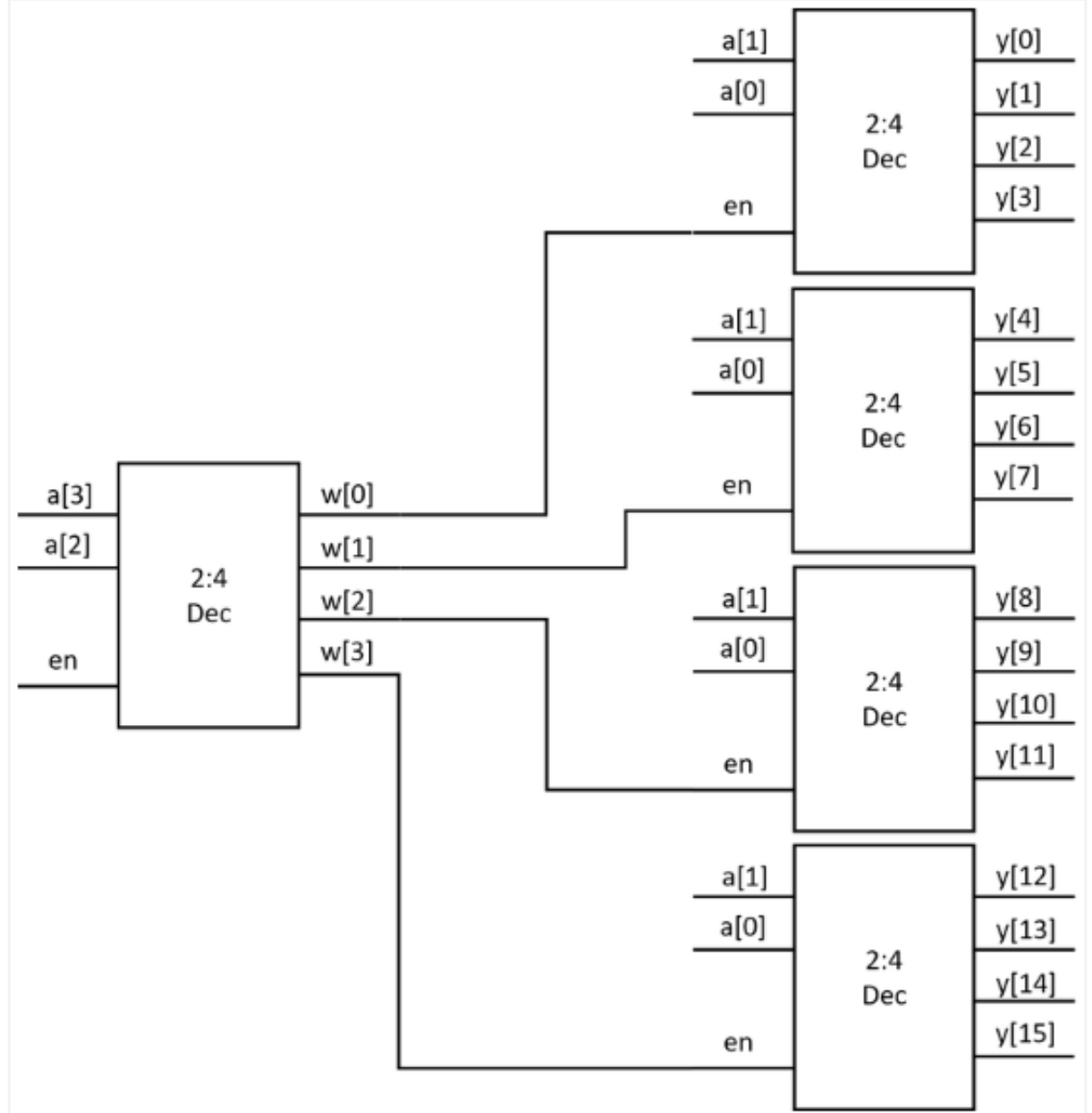
2x4 Decoder Structural/Gate Level Modeling

```
module dec24_str(  
    output [3:0] y,  
    input [1:0] a,  
    input en);  
  
    and (y[0], ~a[1], ~a[0], en); /* 3-input AND gates */  
    and (y[1], ~a[1], a[0], en);  
    and (y[2], a[1], ~a[0], en);  
    and (y[3], a[1], a[0], en);  
  
endmodule
```

2x4 Decoder in Behavioral Modeling using a case statement

```
module dec24_beh(  
    output reg [3:0] y,  
    input [1:0] a,  
    input en);  
    always @(*)  
    if(en) /* only if en = 1, case statement will execute */  
    case(a)  
        0: y = 4'b0001;  
        1: y = 4'b0010;  
        2: y = 4'b0100;  
        3: y = 4'b1000;  
        default: y = 0;  
    endcase  
    else y = 0; /* if en = 0, all bits of y will remain zero */  
endmodule
```

4x16 Decoder using five 2x4 Decoders

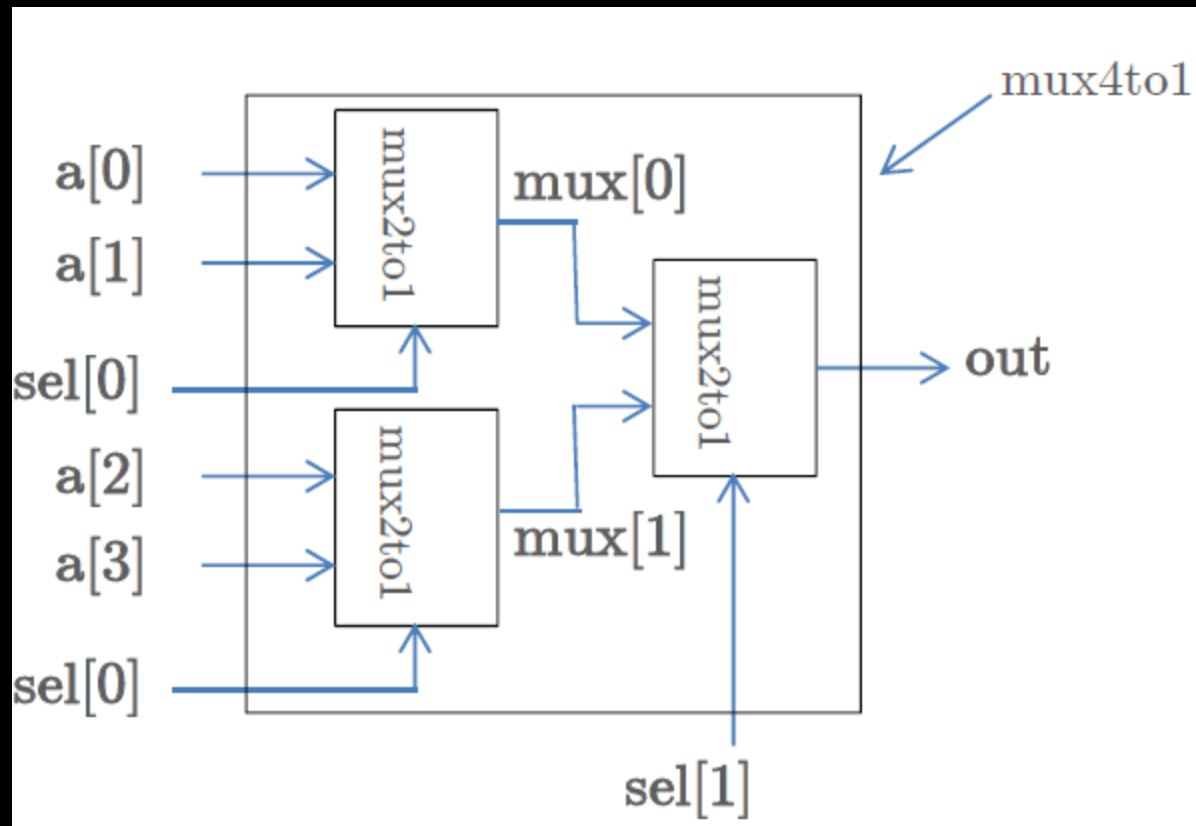


Schematic of 4:16 decoder using five 2:4 decoders

4x16 Decoder using five 2x4 Decoders

```
module dec4x16_str(  
    output [15:0] y,  
    input [3:0] a,  
    input en  
);  
    wire [3:0] w;  
    dec2x4_str u0(w, a[3:2], en);  
    dec2x4_str u1(y[3:0], a[1:0], w[0]);  
    dec2x4_str u2(y[7:4], a[1:0], w[1]);  
    dec2x4_str u3(y[11:8], a[1:0], w[2]);  
    dec2x4_str u4(y[15:12], a[1:0], w[3]);  
endmodule
```

4x1 Multiplexer using 2x1 Multiplexers

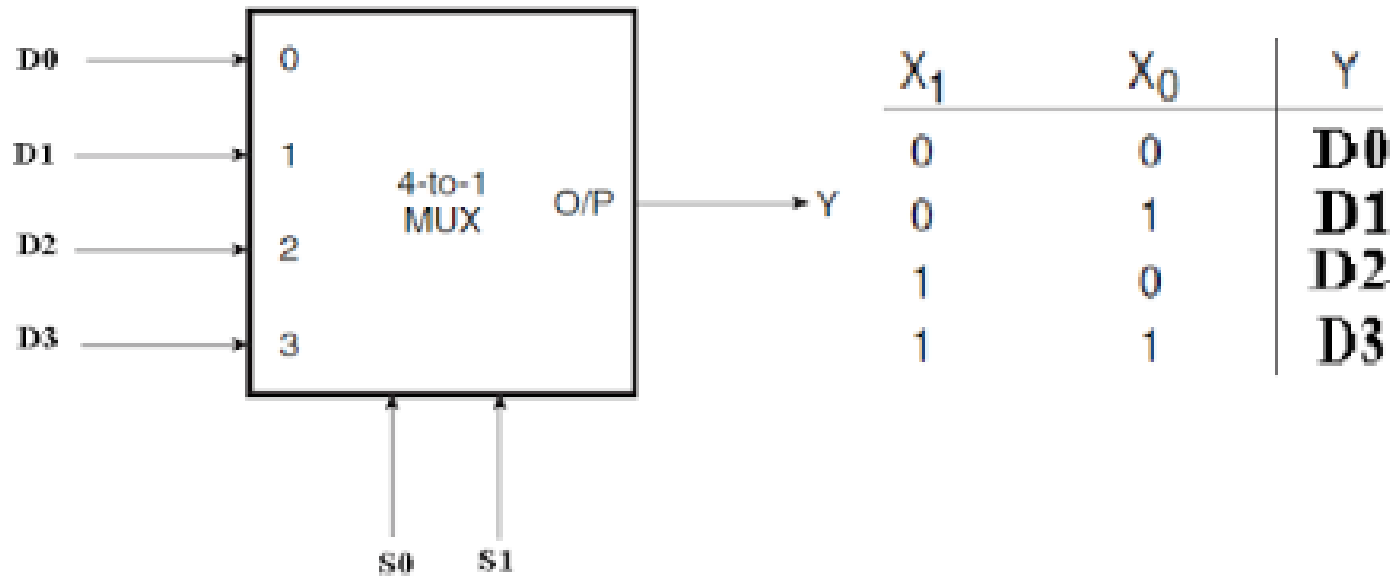


4x1 Multiplexer using 2x1 Multiplexers

```
module mux2to1(a,b,sel,out);  
    input a,b,sel;  
    output out;  
    assign out = sel?b:a;  
endmodule
```

```
module mux4to1(a,sel,out);  
    input [3:0] a;  
    input [1:0] sel;  
    output out;  
    wire mux[1:0];  
  
    mux2to1 m1 (a[0],a[1],sel[0],mux[0]),  
              m2 (a[2],a[3],sel[0],mux[1]),  
              m3 (mux[0],mux[1],sel[1],out);  
endmodule
```

4x1 Multiplexer



And the equation is

$$Y = D0 \bar{S1} \bar{S0} + D1 \bar{S1} S0 + D2 S1 \bar{S0} + D3 S1 S0$$

Gate Level Modeling

```
module gatelevel(i0,i1,i2,i3,s0,s1,y);  
  
input i0,i1,i2,i3,s0,s1;  
  
output y;  
  
wire a,b,c,d,e,f;    // for partial outputs  
  
not (a,s0);           // a=~s0  
  
not (b,s1);  
  
and (c,i0,a,b);       // c=i0&&a&&b  
  
and (d,i1,s0,b);  
  
and (e,i2,a,s1);  
  
and (f,i3,s0,s1);  
  
or (y,c,d,e,f);      // y=c||d||e||f  
  
endmodule
```

Behavioral Modeling

```
module behavioral(  
  
    input i0,i1,i2,i3,  
  
    output reg y,  
  
    input[1:0] sel  
  
);  
  
    always @ (i0,i1,i2,i3,sel) // Mention all the inputs inside the always block  
  
    case(sel)  
  
        2'b00: y=i0;        // Follow the truth table  
  
        2'b01: y=i1;  
  
        2'b10: y=i2;  
  
        2'b11: y=i3;  
  
    endcase  
  
endmodule
```

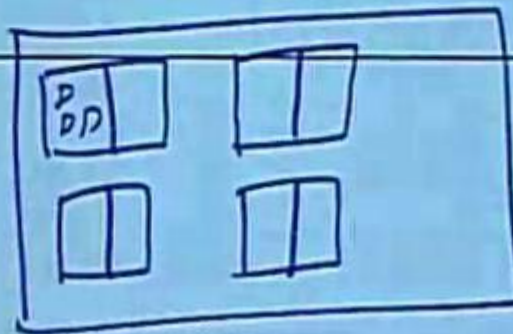
Data Flow Modeling

```
module dataflow(i0,i1,i2,i3,s0,s1,y);  
  
input i0,i1,i2,i3,s0,s1;  
  
output y;  
  
assign y=(!s0&&!s1&&i0)||(s0&&!s1&&i0)||(!s0&&s1&&i2)||(s0&&s1&&i3);  
  
endmodule
```

Physical Representation

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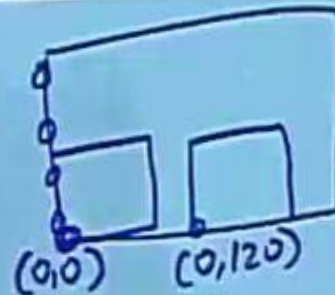
- The lowest level of physical specification.
 - Photo-mask information required by the various processing steps in the fabrication process.
- At the module level, the physical layout for the 4-bit adder may be defined by a rectangle or polygon, and a collection of ports.



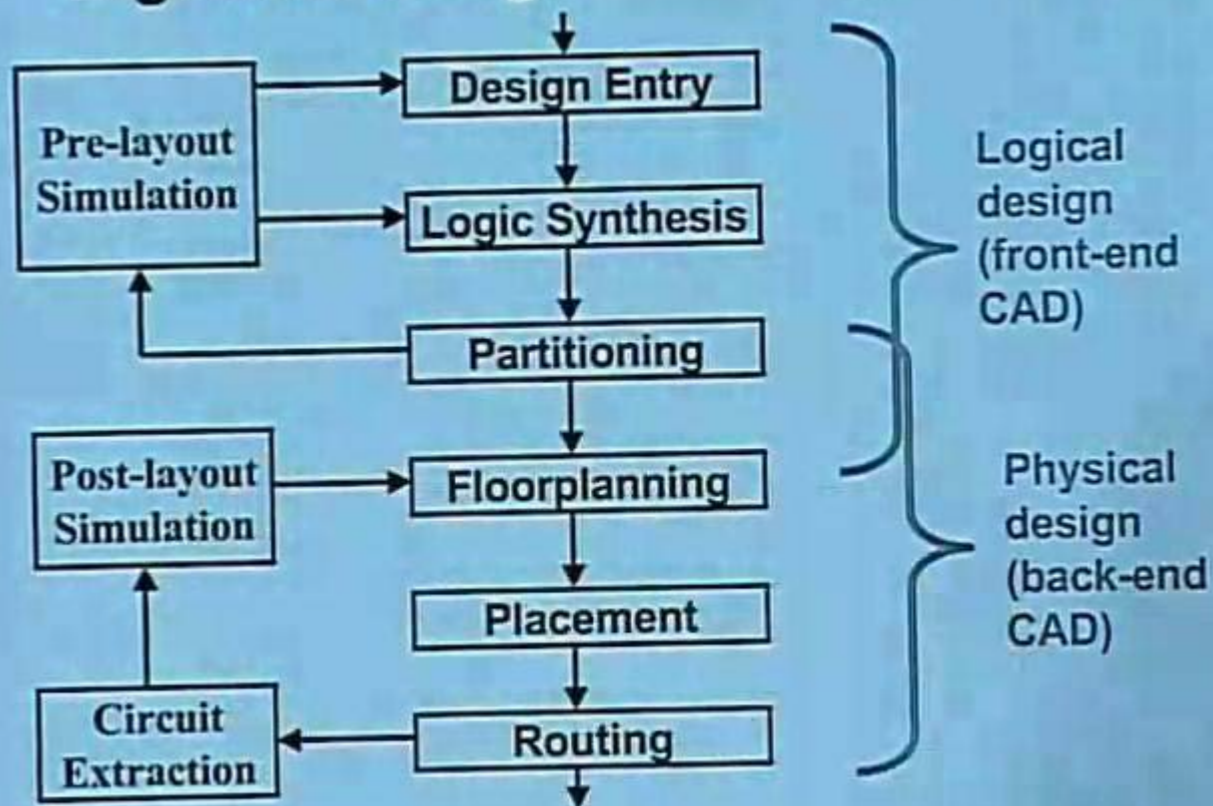
Physical representation -- example

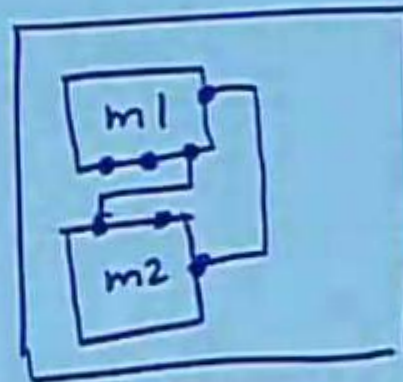
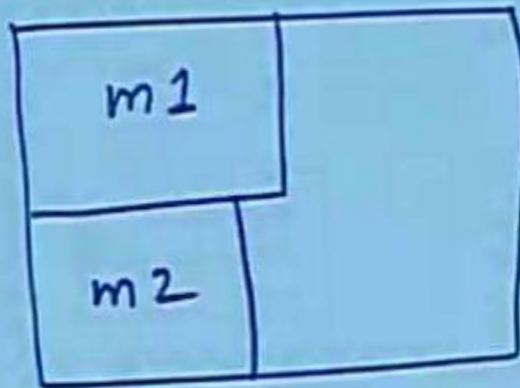
Imaginary physical description for 4-bit adder

```
module add4( --- )  
  input x[3:0], y[3:0];  
  input cy_in;  
  output s[3:0];  
  output cy4;  
  boundary [0, 0, 130, 500];  
  port x[0]    aluminum width = 1 origin = [0, 35];  
  port y[0]    aluminum width = 1 origin = [0, 85];  
  port cy_in   polysilicon width = 2 origin = [70, 0];  
  port s[0]    aluminum width = 1 origin = [120, 65];  
  
  (add a0) origin = [0, 0];  
  (add a1) origin = [0, 120];  
  
endmodule
```



look





Logical
design
(front-end
CAD)

Physical
design
(back-end
CAD)