

CSE 2600

Intro. To Digital Logic & Computer Design

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This week

- Exam 1 is still being graded.
- Studio 4A: Bring a Micro-USB cable to class. You will need it!

Studio 3B: Space Use

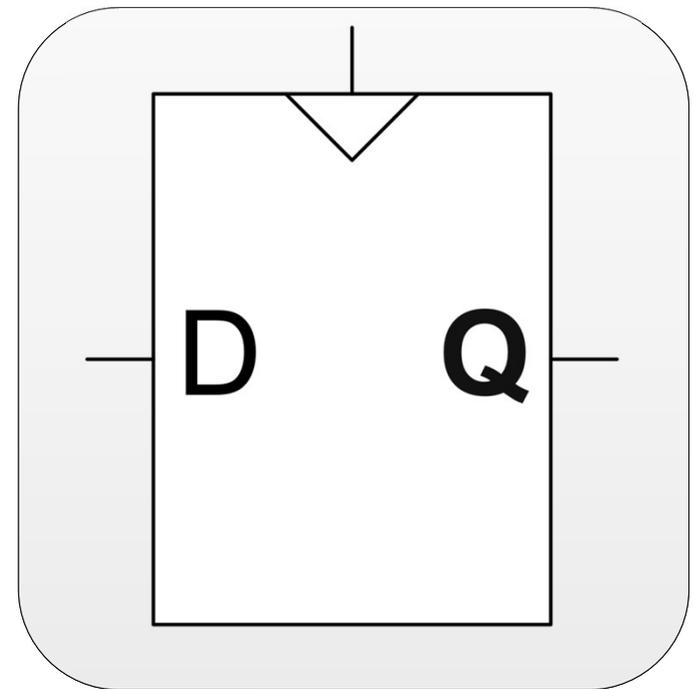
- n states
- ~8 Gates / Flip-flop
(Via in-class approach)
- Assume simple approaches for decoding

ENCODING	GATES FOR STORAGE	GATES FOR DECODING	TOTAL (SPACE) GROWTH
BINARY	$8 \cdot \text{ceil}(\log_2(n))$	Likely n product terms of $\sim \log_2(n)$ variables	$\sim 8 \cdot \log_2(n) + n \cdot \log_2(n) = O(n \log_2(n))$
ONE-HOT	$8 \cdot n$	0	$\sim 8n = O(n)$

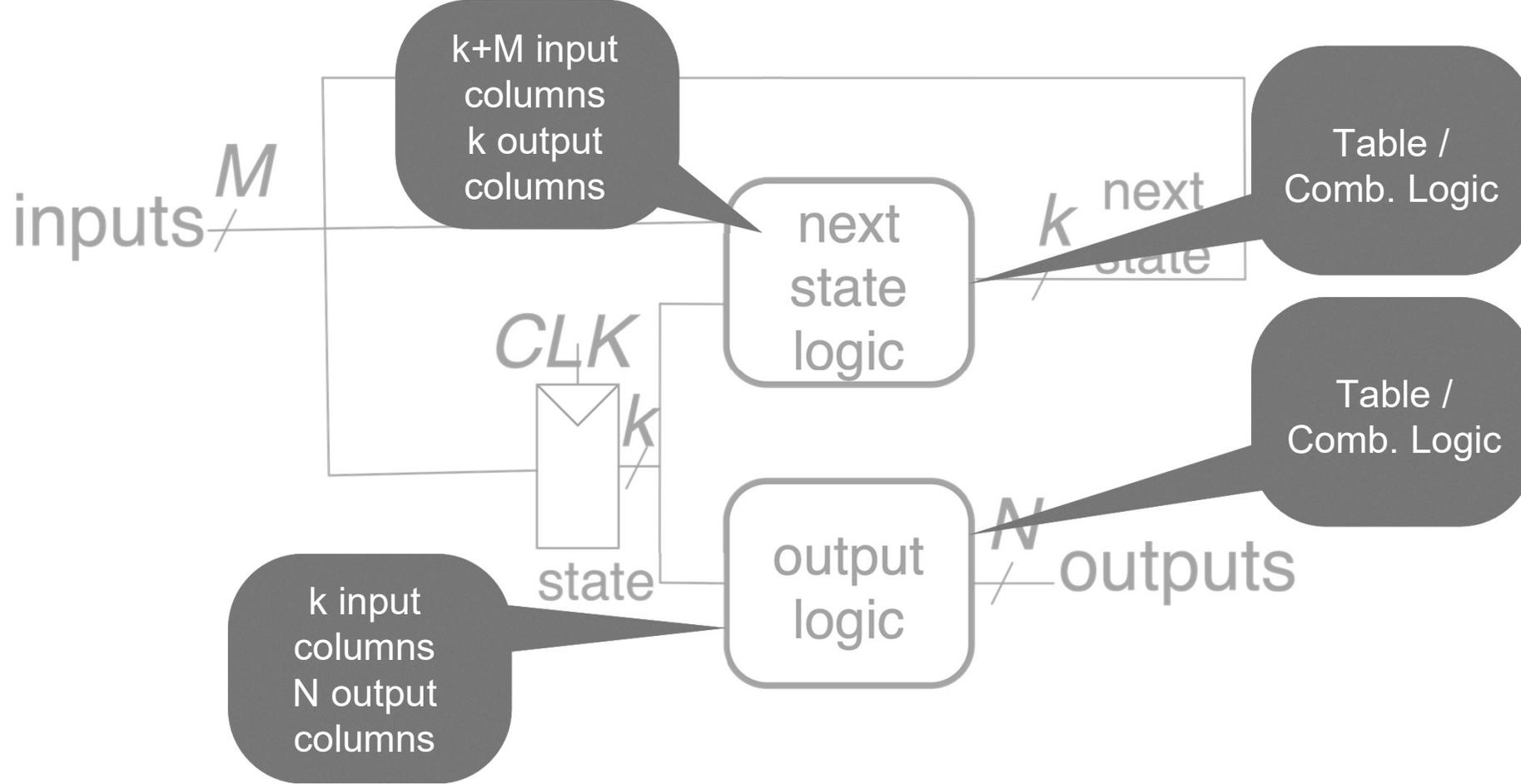
Rough Graph

D-flip flop Time Parameters

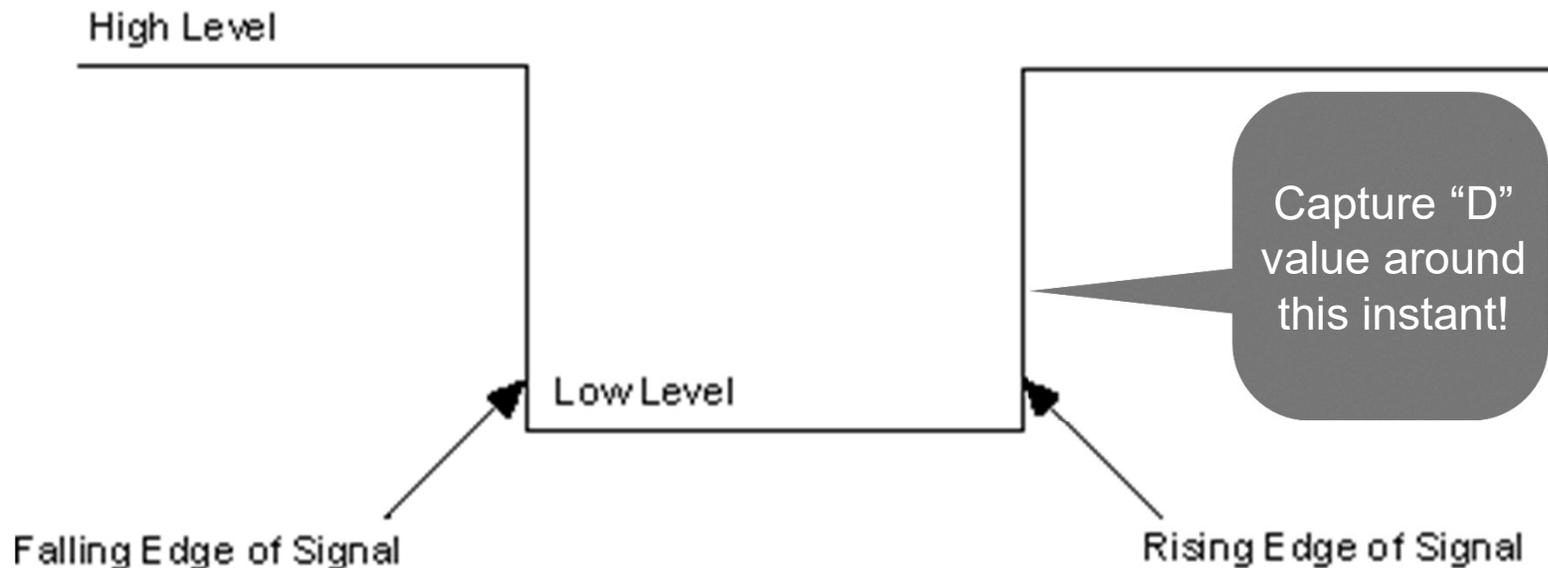
- t_{pcq} : Propagation delay from Clock to Q (pcq)
- t_{ccq} : Contamination delay from C to Q (ccq)
- t_{setup} : Setup time (for d before clock)
- t_{hold} : Hold time (for d after clock)



Review: Moore Machine Structure



D-Flip-Flop Clock

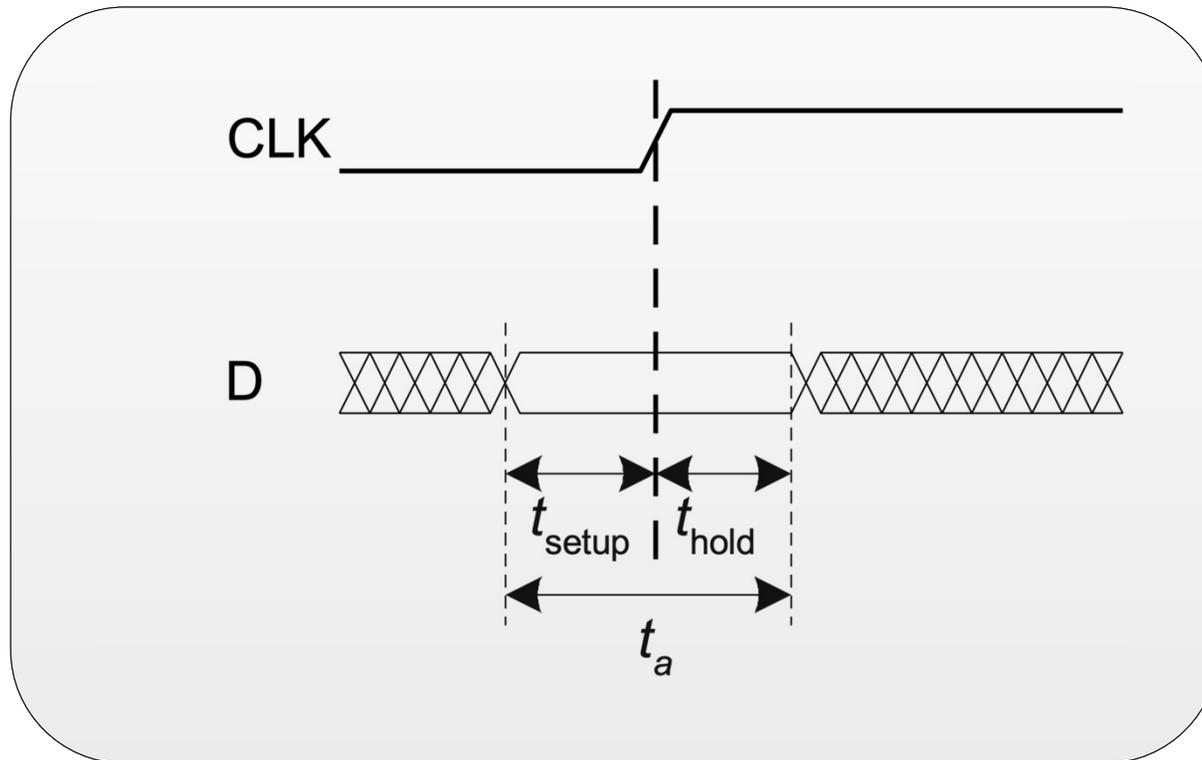


https://www.ni.com/docs/en-US/bundle/ni-hsdio/page/hsdio/fedge_trigger.html

Studio 3B Review

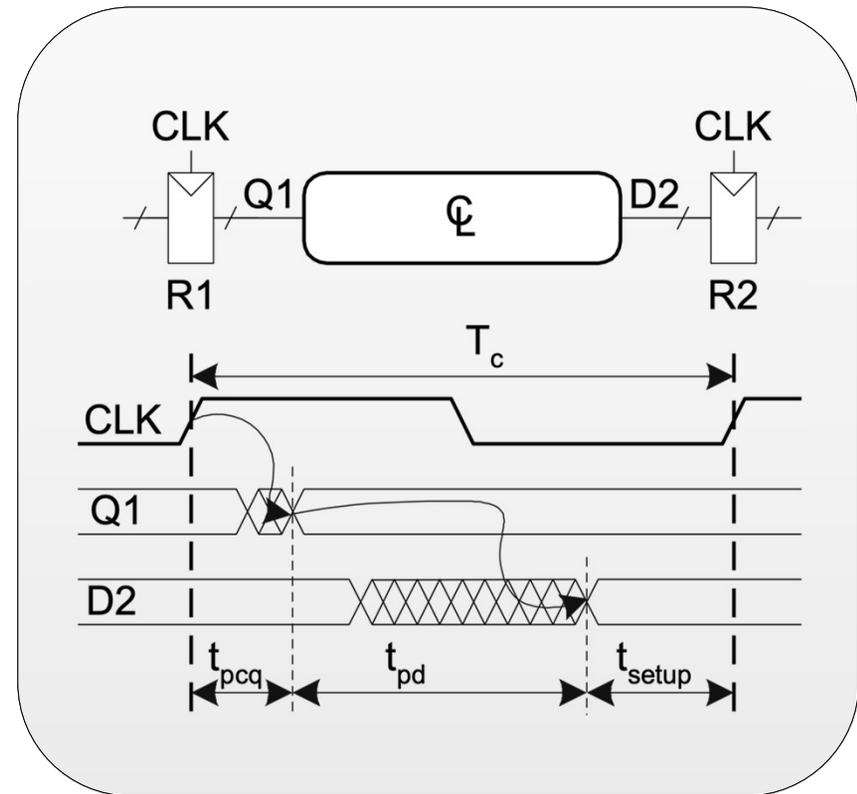
- D-FF Model
 - NOR oscillation - Why?
 - *Important*: Circuits are composed of continually, concurrently executing elements!
- D-Latch Setup / Hold: Shaping waveforms and measuring around clock
 - Demonstrates concept, but shouldn't be measured empirically in practice!
(Rely on data sheets in this class)

D flip flop: Setup & Hold Time

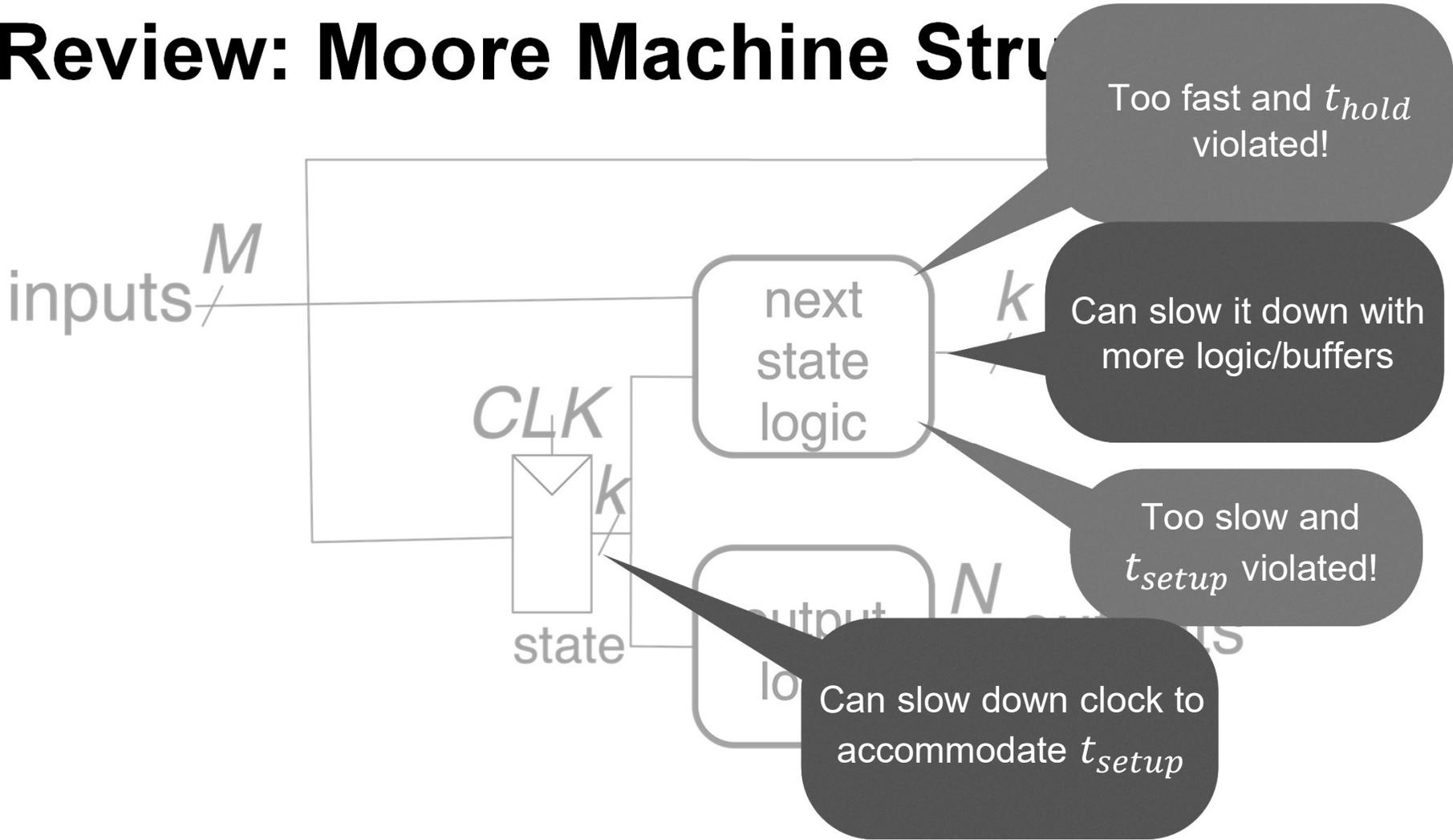


Setup Time Constraint

- Max time from R1 through CL
- R2's input needs to be stable t_{setup} before clock



Review: Moore Machine Structure



Chapter 4

Hardware Description Languages (HDLs)

- Specifies logic function only
- Computer-aided design (CAD) tool produces or synthesizes the optimized gates
- Most commercial designs built using HDLs

VHDL

- VHDL 2008
- Developed in 1981 by the Department of Defense
- IEEE standard (1076) in 1987
- Updated in 2008 (IEEE STD 1076-2008)

Questions this week:

Verilog?

VHDL?

Both?

**Questions this week:
Verilog?**

Both?

We will use Verilog

Not VHDL

(System) Verilog

- Developed in 1984 by Gateway Design Automation
- IEEE standard (1364) in 1995
- Extended in 2005 (IEEE STD 1800-2009)

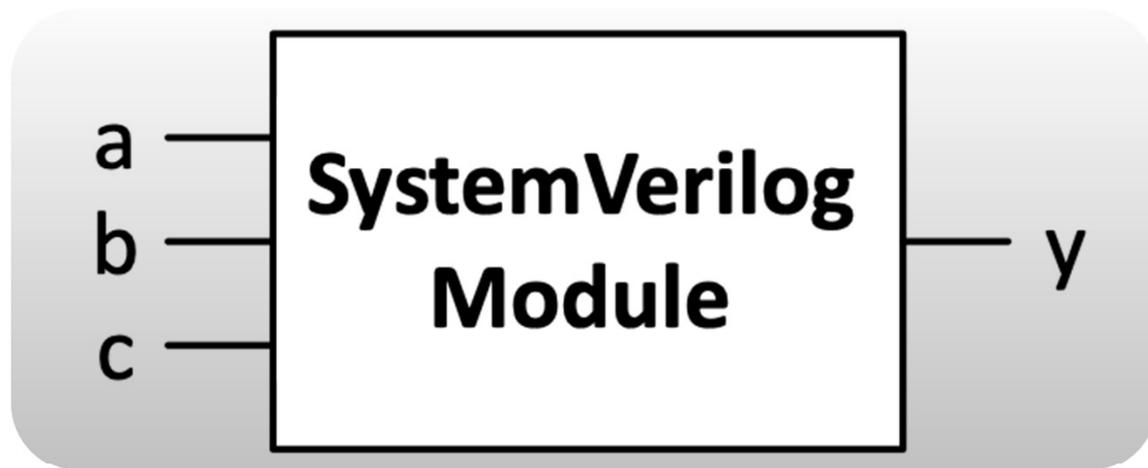
HDL

- A HDL is not a computer program.
- A HDL is not a computer program!
- A HDL is *not* a computer program!
- A HDL is not a computer program!
- A HDL is **NOT** a computer program!

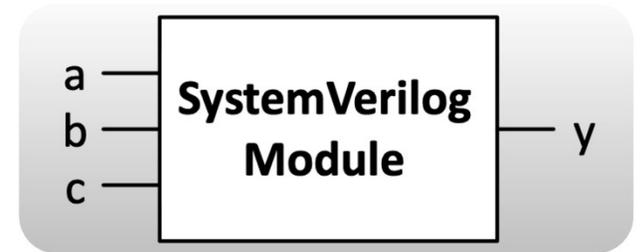
HDL

- HDL is a way to describe hardware
- HDLs typically can describe hardware in different ways
- HDLs describe hardware in modules

(System) Verilog Module Example

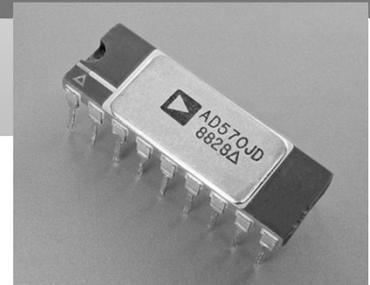


(System) Verilog Module Example

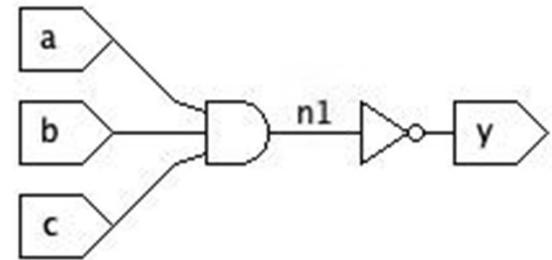


```
module example(input logic a, b, c,  
               output logic y);  
    // module body goes here  
endmodule
```

Input & Output
are like the Pins
On chips or in
JLS



HDL: Structural (Verilog)



```
module nand3(input  logic a, b, c
             output logic y);
    logic n1;           // internal signal

    and  my_and(n1, a, b, c); // instance of and3
    not  my_inverter(y,n1);  // instance of inv
endmodule
```

Example & Tour of Environment

(System) Verilog

- Case sensitive
- Identifiers follow rules like in programming languages
 - Ex: 2inputGate not allowed, but gateWithTwoInputs is.
- Whitespace ignored
- C/Java Style comments:
 - `// Comment to end of line`
 - `/*`
Block Comment
`*/`

(System) Verilog

- Basic logic operators
 - Binary: $\&$, $|$, \wedge
 - Unary: \sim

HDL: Structural (Verilog)

```
module nand3(input  logic a, b, c
             output logic y);
    logic n1;           // internal signal

    and  my_and(n1, a, b, c); // instance of and3
    not  my_inverter(y,n1);   // instance of inv
endmodule
```

HDL: Structural (Verilog) (Without named instances)

```
module nand3(input  logic a, b, c
             output logic y);
    logic n1;           // internal signal

    and(n1, a, b, c);  // instance of and3
    not(y,n1);        // instance of inv
endmodule
```

HDL: Behavioral (Verilog)

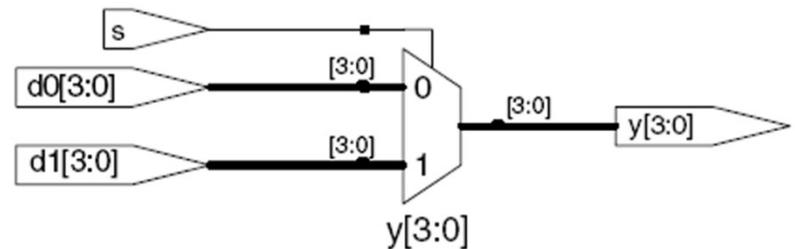
```
module nand3(input  logic a, b, c
             output logic y);
    assign y = ~(a & b & c);
endmodule
```

(System) Verilog

- Multi-bit values: Array-like notation with bit ordering:
`logic [7:0] a;`
- Multi-bit reductions by pre-fix notation on multi-bit values
`assign y = &a;`

(System) Verilog

- Conditionals via Ternary operator (? :)



```
module mux2(input logic [3:0] d0, d1,  
            input logic s,  
            output logic [3:0] y);  
    assign y = s ? d1 : d0;  
endmodule
```

Example

Operator Precedence

~	NOT
*, /, %	mult, div, mod
+, -	add, sub
<<, >>	shift
<<<, >>>	arithmetic shift
<, <=, >, >=	comparison
==, !=	equal, not equal
&, ~&	AND, NAND
^, ~^	XOR, XNOR
, ~	OR, NOR
?:	ternary operator

Number Formats

Number	# Bits	Base	Decimal Equivalent	Stored
3'b101	3	binary	5	101
'b11	unsized	binary	3	00...0011
8'b11	8	binary	3	00000011
8'b1010_1011	8	binary	171	10101011
3'd6	3	decimal	6	110
6'o42	6	octal	34	100010
8'hAB	8	hexadecimal	171	10101011
42	Unsized	decimal	42	00...0101010

Verilog Bit Manipulations

- Subscripting and grouping

```
assign y = {a[2:1], {3{b[0]}}, a[0], 6'b100_010};
```

- Underscores can be used for clarity