CSE 260M / ESE 260
Intro. To Digital Logic & Computer Design

Bill Siever
&
Michael Hall

Homework 2

- Posted
  - Due Sunday at 11:59pm
  - Includes JLS part
  - Gradescope dropboxes will be available by Thursday

Review

Last Time

- Binary
- *<u>Unsigned</u>* Integers: Extension of Place-value notation used in decimal
    - Fixed width Binary (e.g., 3-bit; 4-bit; 32-bit) forms a modular ring
    - Addition rules are simple
- 2's Complement

Quiz(ish)

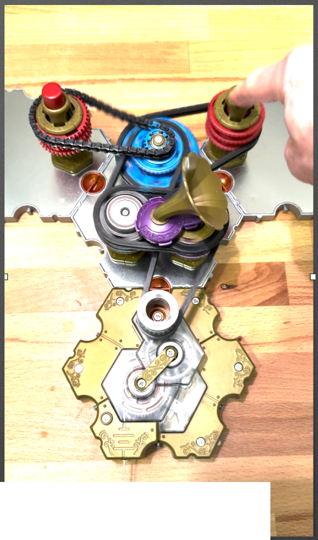
- Consider 5-digit integers
  - Decimal: Max value?
    (I.e., highest decimal number that can be represented)
  - Binary: Max value?
    (I.e., highest binary number that can be represented)

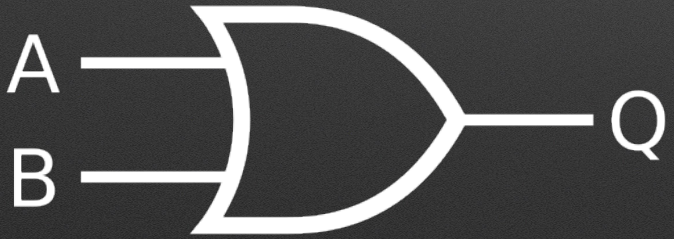
3-bit Number Line: As a Ring

4-bit Number Line: As a Ring

Behavior OVER TIME

- Gate represents a machine of some sort machine
  - in the real world
- They are not instantaneous
  - Real-world outputs and inputs need to be well behaved (noise margin)





Chapter 2: Combinational Logic

1. Intro.
2. Boolean Equations
3. Boolean Algebra
4. From Logic to Gates

2.1 Intro: Combinational Logic

- (Purely) Combine inputs to produce outputs
  - Output depends *only* on current input, not past inputs
- Behavior of all combinational logic can be described with a table

Binary Addition Rules: Fully Elaborated

0+ 0+ 0	=	00
0+ 0+ 1	=	01
0+ 1+ 0	=	01
0+ 1+ 1	=	10
1+ 0+ 0	=	01
1+ 0+ 1	=	10
1+ 1+ 0	=	10
1+ 1+ 1	=	11

Binary Addition Rules: Inputs

Carry	A	B		Sum
0+	0+	0	=	00
0+	0+	1	=	01
0+	1+	0	=	01
0+	1+	1	=	10
1+	0+	0	=	01
1+	0+	1	=	10
1+	1+	0	=	10
1+	1+	1	=	11

Binary Addition Rules: & Outputs

Carry In	A	B		Carry Out	Sum
0+	0+	0	=	0	0
0+	0+	1	=	0	1
0+	1+	0	=	0	1
0+	1+	1	=	1	0
1+	0+	0	=	0	1
1+	0+	1	=	1	0
1+	1+	0	=	1	0
1+	1+	1	=	1	1

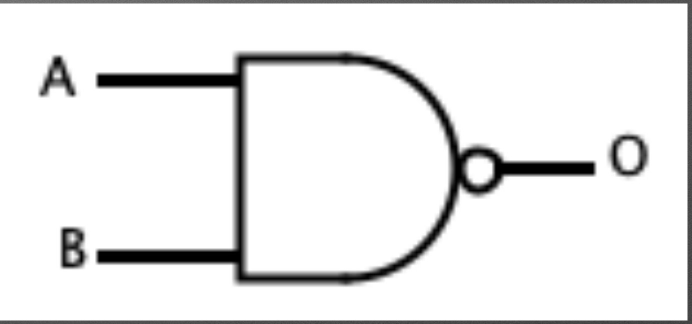
“Tables”

- Consider a function that has n inputs and m, 1-bit outputs
  Describe the shape / size of the complete table?

- Consider a function that has n inputs and 2, 3-bit output
  Describe the shape / size of the complete table?

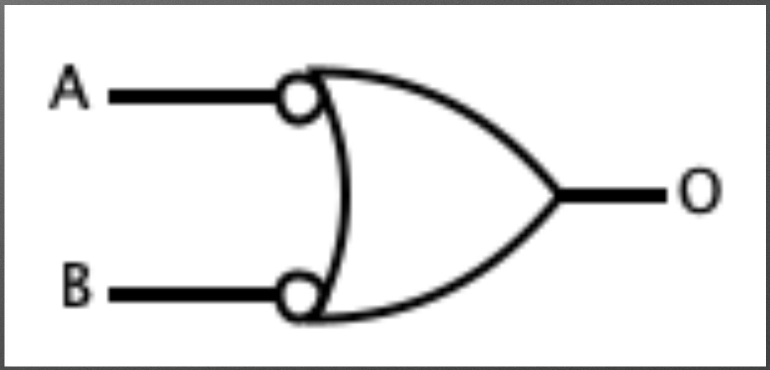
Truth Tables

- Give the truth table for



Truth Tables

- Give the truth table for



2.2 Boolean Equations - History

- George: Mathematical Analysis of Logic
- Formal, algebraic approach to manipulation of binary concepts
- So?
    - Provide formal approach to manipulate concepts

2.4 Gates

- Not just electronics:
  - Scientific American, Vol. 258, No. 4 (APRIL 1988), pp. 118-121 (4 pages)
- Claude: Thesis

Boolean Algebra

Table 2.1 Axioms of Boolean algebra

	Axiom		Dual	Name
A1	$B = 0$ if $B \neq 1$	A1′	$B = 1$ if $B \neq 0$	Binary field
A2	$\overline{0} = 1$	A2′	$\overline{1} = 0$	NOT
A3	$0 \bullet 0 = 0$	A3′	$1 + 1 = 1$	AND/OR
A4	$1 \bullet 1 = 1$	A4′	$0 + 0 = 0$	AND/OR
A5	$0 \bullet 1 = 1 \bullet 0 = 0$	A5′	$1 + 0 = 0 + 1 = 1$	AND/OR

Boolean Algebra

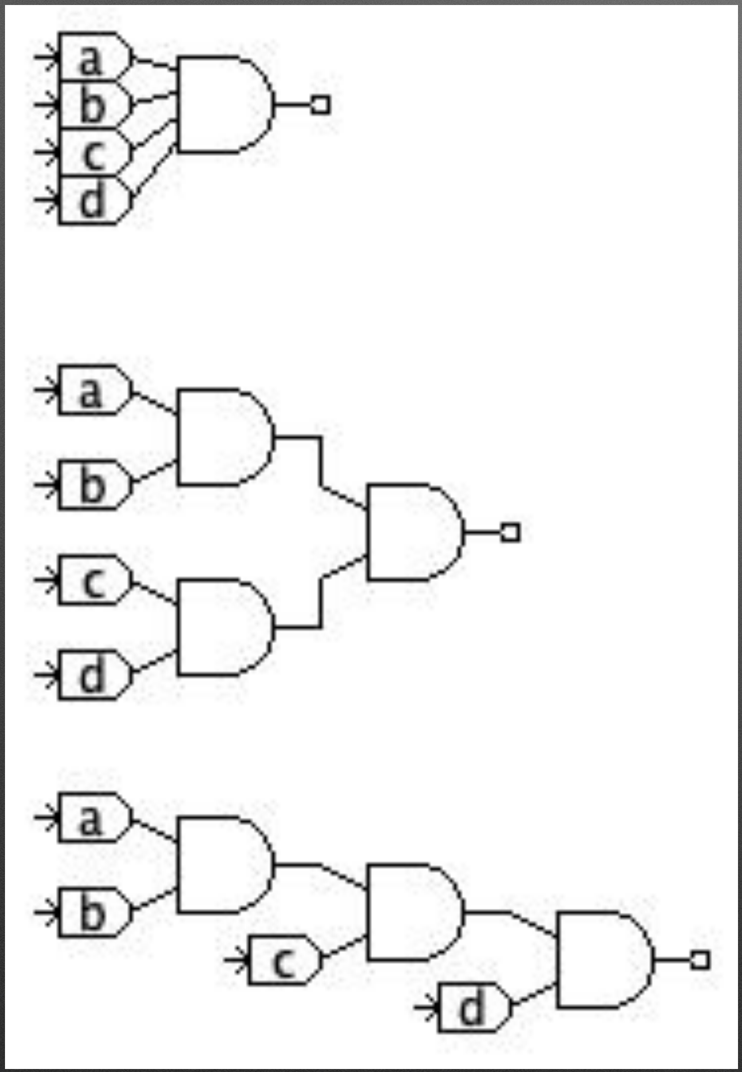
Table 2.2 Boolean theorems of one variable

	Theorem		Dual	Name
T1	$B \bullet 1 = B$	T1′	$B + 0 = B$	Identity
T2	$B \bullet 0 = 0$	T2′	$B + 1 = 1$	Null Element
T3	$B \bullet B = B$	T3′	$B + B = B$	Idempotency
T4		$\overline{\overline{B}} = B$		Involution
T5	$B \bullet \overline{B} = 0$	T5′	$B + \overline{B} = 1$	Complements

Boolean Algebra

Table 2.3 Boolean theorems of several variables

	Theorem		Dual	Name
T6	$B \bullet C = C \bullet B$	T6′	$B + C = C + B$	Commutativity
T7	$(B \bullet C) \bullet D = B \bullet (C \bullet D)$	T7′	$(B + C) + D = B + (C + D)$	Associativity
T8	$(B \bullet C) + (B \bullet D) = B \bullet (C + D)$	T8′	$(B + C) \bullet (B + D) = B + (C \bullet D)$	Distributivity
T9	$B \bullet (B + C) = B$	T9′	$B + (B \bullet C) = B$	Covering
T10	$(B \bullet C) + (B \bullet \overline{C}) = B$	T10′	$(B + C) \bullet (B + \overline{C}) = B$	Combining
T11	$(B \bullet C) + (\overline{B} \bullet D) + (C \bullet D)$ $= (B \bullet C) + (\overline{B} \bullet D)$	T11′	$(B + C) \bullet (\overline{B} + D) \bullet (C + D)$ $= (B + C) \bullet (\overline{B} + D)$	Consensus
T12	$\overline{B_0 \bullet B_1 \bullet B_2 \ldots}$ $= (\overline{B}_0 + \overline{B}_1 + \overline{B}_2 \ldots)$	T12′	$\overline{B_0 + B_1 + B_2 \ldots}$ $= (\overline{B}_0 \bullet \overline{B}_1 \bullet \overline{B}_2 \ldots)$	De Morgan's Theorem



Compare / Contrast

Combinational Logic vs. Sequential Logic

- Output of Sequential Logic
  - Depends on current inputs <u>and</u> *sequence* of past inputs (values and order)
  - Requires concept of memory

Demos of Circuits in JLS

- Overview of parts / ideas
  - Equation: D = A*B*C
    - Realization A & Testing
    - Realization B B & Testing
  - Bubble Pushing
  - DeMorgan's Laws?

Timing & Simulation

Next Time

- Studio
    - Prep work will be posted
        - Install JLS
        - Check Email for attendance code