CS1800
9/15 Tues.

Admin

- say your name
- recitations start this week
- ps1 due 9/18 11:59pm
  - ↳ gradescope
  - handwritten

Agenda

1. Logic gate problem solving
2. circuits
3. more gates
4. truth tables *

0. Review

What is the gate?

A	B	out
0	0	0
0	1	1
1	0	1
1	1	1

or

A	out
0	1
1	0

not

A	B	output
0	0	0
0	1	0
1	0	0
1	1	1

and

review - adding

```
  3        4
+ 6      + 6
---      ---
  9        10
```

Sum = 9, Carry = 0

Sum = 0, Carry = 1

preview - counting in binary

00	0
01	1
10	2
11	3
100	4
101	5

1. Solving problems with logic gates

goal add numbers (integers) (unsigned)

to start: adding bits

```
  0      0      1      1
+ 0    + 1    + 0    + 1
----   ----   ----   ----
 00     01     01     10
```

carry, sum

operations: and, or, not

boolean values: 0, 1

a + b = ? ↳ need gates to do this!

two inputs: a, b

two outputs: S, C

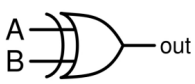
Addition

↳ truth table

A	B	C	S
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

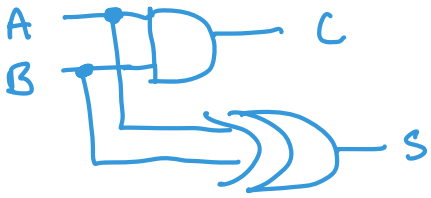
carry = and

sum = xor



Addition circuit

add with logic

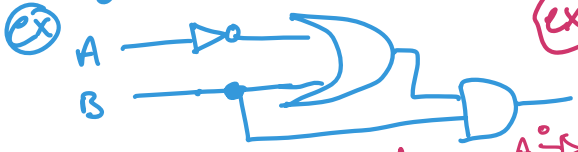


2 gates
2 inputs
2 outputs

2. circuits → use logic gates to perform operations on boolean inputs. multiple gates strung together

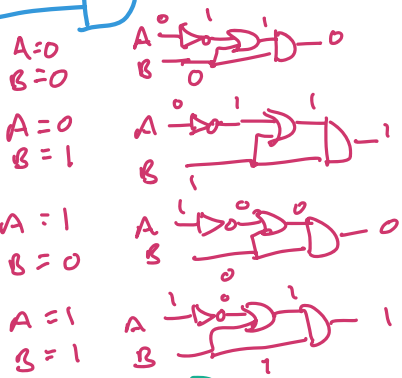
- read from left to right
- output from any gate is also a boolean
  ↳ can also be input to the next gate

what is truth table?



execute each row

A	B	output
0	0	0
0	1	1
1	0	0
1	1	1



ex) what gates?

A	B	output
0	0	1
0	1	1
1	0	1
1	1	0

→ opp of and



3. more gates

and  or  not 

xor 

and/or/not do everything!

but, logic of convenience :) to help

addition

A	B	C	S
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0

new ones...

nand looks like  does 

A	B	A NAND B
0	0	1
0	1	1
1	0	1
1	1	0

nor looks like  does 

A	B	A NOR B
0	0	1
0	1	0
1	0	0
1	1	0

xnor looks like does

A	B	A XNOR B

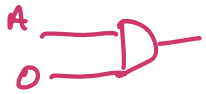


0 0	1
0 1	0
1 0	0
1 1	1

What other outputs?
What circuits can we build to produce them?

A	B	01	02	03	04	05	...
0	0	0	0	1	0	1	
0	1	0	0	1	0	1	
1	0	1	0	1	1	0	
1	1	1	0	1	0	0	
						(not A)	

02, 03 can use literal 0, 1 as inputs



gate: all zeroes

0 AND anything = 0

01 gate: output same as A



0 or A is A



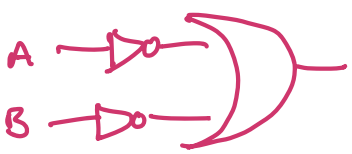
gate: all ones

1 or anything = 1

4. circuits and truth tables

nand gate  (shortcut)

and, not gate 

ex circuit 

- left to right
- one operation at a time

A	B	NOT A	NOT B	(NOT A) OR (NOT B)
0	0	1	1	1
0	1	1	0	1
1	0	0	1	1
1	1	0	0	0

↳ nand gate!

Which is better? Blue!
- shorter, cheaper, etc.
- simpler circuit is better

How did we know they're equivalent?
- two circuits are equivalent when truth table has same output for all inputs
- truth table - proof technique
- one step at a time, easy to follow :)

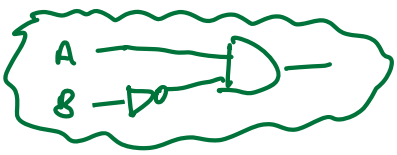
desired output:

A	B	out
0	0	0
0	1	0
1	0	1
1	1	0

Circuit to represent this?

when is it 1

when A = 1 and B = 0



A	B	NOT B	A AND NOT B
0	0	1	0
0	1	0	0
1	0	1	1
1	1	0	0

Equivalent:

NOT (A AND B)	(NOT A) OR (NOT B)
B	B OR 0
1	(any) OR 1
0	(any) and 0