Remember the steps …

- Build the truth table
- Construct the minterm expression
- Convert the minterm expression into circuits

MORE EXAMPLE

XOR

"English"

`f(x,y)` should output 1 when either `x or y is 1, but not both,` otherwise, output 0

1

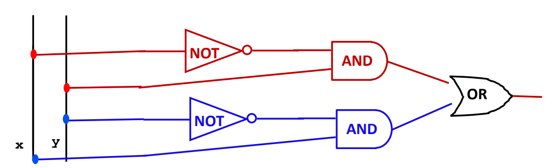
input		output
x	y	XOR(x,y)
0	0	0
0	1	1
1	0	1
1	1	0

2

Formula

$$\overline{x}y + x\overline{y}$$

3



Minterm Expansion Principle – algorithm for building expressions from truth tables

Addition as a circuit

- You (hopefully!) will build a simple adder circuit in lab…

input	Output:

Addition as a circuit

- You (hopefully!) will build a simple adder circuit in lab…

input			output: SUM	
x	y	c_{in}	c_{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

A *full adder* sums three bits.

(A 2-bit adder is a *half adder*)

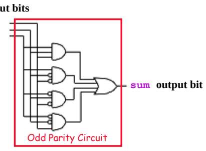
Share the inputs, but **design separate circuits** for each output bit…

Building a Full Adder

Implementing addition in silicon…?

Create a circuit **for each output bit** !

input			output: SUM	
x	y	c_{in}	c_{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

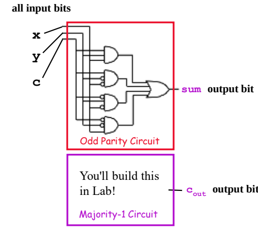


Building a Full Adder

Implementing addition in silicon…?

Create a circuit **for each output bit** !

input			output: SUM	
x	y	c_{in}	c_{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

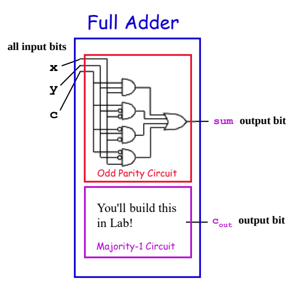


Building a Full Adder

Implementing addition in silicon…?

Create a circuit **for each output bit** !

input			output: SUM	
x	y	c_{in}	c_{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



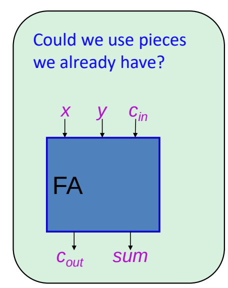
Composing circuits

4-bit Ripple-carry Adder

two 4-bit inputs

```
    0  1  1  1
    1  1  0  1
+
```

How many output bits?



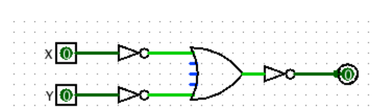
Getting rid of ANDs ?

Can you get rid of the ANDs by using only NOTs and ORs?

input		output
x	y	AND(x,y)
0	0	0
0	1	0
1	0	0
1	1	1

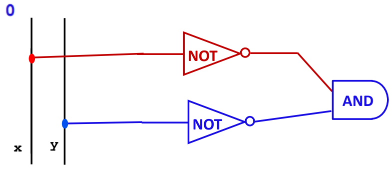
input		output	output	output
x	y	OR(x,y)	NOT(OR(x,y))	NOT(OR(NOT(x),NOT(y)))
0	0	0	1	0
0	1	1	0	0
1	0	1	0	0
1	1	1	0	1

AND… without ANDs



NOR

input		output
x	y	NOR(x,y)
0	0	1
0	1	0
1	0	0
1	1	0

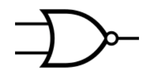


NOR gates

- NOR gates
  –

input		output
x	y	NOR(x,y)
0	0	1
0	1	0
1	0	0
1	1	0

no AND, OR, NOT!



- FACT: ALL gates can be built out of NOR gates…

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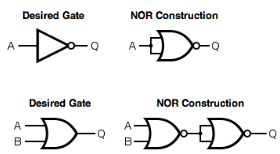
NOR equivalencies



NOT

OR

What about AND?

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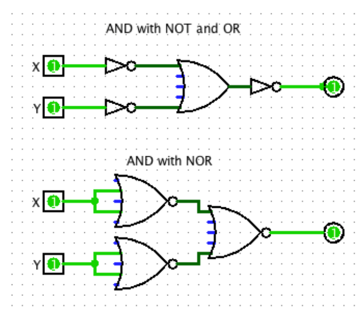
AND… with NORs



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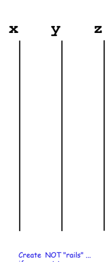
Odd parity circuit

③ Build separate circuits for each output-1 row using ANDs and NOTs
Combine them with an OR.

① Here's the truth table defining a function

input			output
x	y	z	
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	



Let's build an **odd parity** circuit

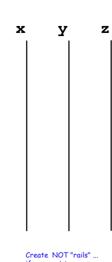
② Write down minterm expansion formula that represents this circuit?

Odd parity circuit

③ Build separate circuits for each output-1 row using ANDs and NOTs
Combine them with an OR.

① Here's the truth table defining a function

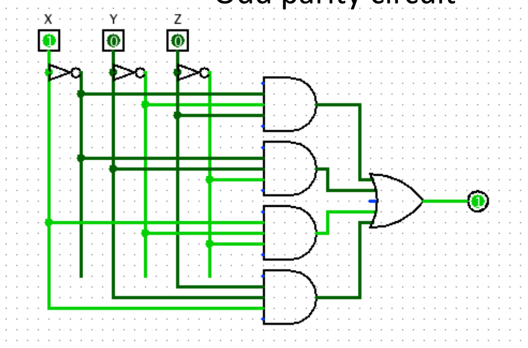
input			output
x	y	z	odd(x,y,z)
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1



Let's build an **odd parity** circuit

② Write down minterm expansion formula that represents this circuit?

Odd parity circuit



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