

# Warm-Up: Adders

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## Instructor's Handout

This handout contains solutions and notes.

Recompile without solutions before distributing.

### Problem 1:

Fill the following binary addition table.

*Hint:*  $s$  is “sum,”  $c$  is “carry”

$a$	$b$	$s$	$c$
0	0	?	?
0	1	?	?
1	0	?	?
1	1	?	?

### Problem 2:

Draw a logic circuit that satisfies the above table.

This is called a *half adder*.

*Hint:* You should need exactly two gates.

#### Solution:

$$s = a \text{ xor } b$$

$$c = a \text{ and } b$$

### Definition 3:

A *full adder* is similar to a half adder, but it has an extra input:

a full adder takes  $a$ ,  $b$ , and  $c_{\text{in}}$ , and produces  $s$  and  $c_{\text{out}}$ .

*Hint:*  $c_{\text{in}}$  is “carry in”

### Problem 4:

Use two half adders to construct a full adder.

#### Solution:

$$s_1, c_1 = \text{HA}(a, b)$$

$$s_2, c_2 = \text{HA}(s_1, c_{\text{in}})$$

$$s_{\text{out}} = s_2$$

$$c_{\text{out}} = \text{OR}(c_1, c_2)$$

Of course, the class should just draw the circuit.

**Problem 5:**

How can we add two four-bit binary numbers using the full adder?

We want a four-bit output sum and a one-bit  $c_{\text{out}}$ .

**Problem 6:**

Say that all basic logic gates need  $1u$  of time to fully switch states.

*Note:* This is called *gate delay*

How much time does a full adder need to fully switch states?

How about your circuit from Problem 5?

**Problem 7: Bonus**

Design a faster solution to Problem 5.