

# Computer Science 281

## Lab 4: Creating a Three Bit Adder

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### 1 Design

The goal of this lab is to design and construct on the breadboard a digital circuit that adds two three-bit numbers. The circuit will take two three-bit inputs —  $A = a_2a_1a_0$  and  $B = b_2b_1b_0$  — and output a three-bit sum  $S = s_2s_1s_0$  and a single bit carry,  $c$ . We accomplish this by first designing two variants of a single bit adder, and then chaining these circuits together. The result is a circuit that performs multibit addition in much the same way that we perform multi-position addition by hand with carries from one position to the next.

#### 1.1 Half adder

The first version of a single-bit adder is a circuit known as a *half adder*. This circuit takes two single bit inputs,  $a$  and  $b$ , and yields two outputs, a sum  $s$  and a carry  $c$ .

Perform the following for the single bit half adder:

1. Build the truth table.
2. Generate a K-map for each of the two outputs.
3. Give boolean expressions for each of the outputs.
4. Draw a circuit diagram for the single-bit half adder.

#### 1.2 Full adder

The half-adder is sufficient for the addition of the low-order bits ( $a_0$  and  $b_0$ ), yielding  $s_0$  and  $c_0$  but, to add the remaining bits, we need a digital circuit that can take the carry from an addition in one “column” and add it to the addition carried out in the next “column”. So the more general form of an addition circuit (called a *full adder*) must incorporate a *carry in* input along with the input bits  $a$  and  $b$ . So a full adder has three bits of input —  $a$ ,  $b$ , and  $c_{in}$  — and two bits of output —  $s$  and  $c_{out}$ . The  $s$  bit is the binary addition of the three inputs, and the  $c_{out}$  bit is 1 when the addition of  $a$ ,  $b$ , and  $c_{in}$  yields a carry, and 0 otherwise.

Perform the same four steps as above for the single-bit full adder.

### 2 Realization

Our realization of a three-bit adder circuit uses one half adder and two full adders. The half adder is used to add the low order bits of  $A$  and  $B$ . The  $c$  bit output from the half adder is used as the  $c_{in}$  bit of the first full adder, and the  $a$  and  $b$  of this full adder come from the  $a_1$  and  $b_1$  bits of  $A$  and  $B$ . The  $c_{out}$  bit of this first full adder is routed as the  $c_{in}$  bit of the second full adder along with the high order bits of  $A$  and  $B$ .

Implement the three-bit adder on the breadboard. It is important to keep organized, so use one breadboard column for each of the three subcircuits involved. The goal is to get a logical flow that can allow independent testing of each of the subcircuits.

Demonstrate your completed circuit for your instructor.