cs281: Introduction to Computer Systems

Lab 4: Creating a Two Bit Adder

1 Design

The goal of this lab is to design and construct on the breadboard a digital circuit that adds two two-bit numbers. The circuit will take two two-bit inputs, $A = a_1a_0$ and $B = b_1b_0$ and output is a two-bit sum $S = s_1s_0$ and a single bit carry, c. We accomplish this by first designing two variants of a single bit adder, and then chaining these two circuits together. The result is a circuit that performs multi-bit addition in much the same way that we perform multi-position addition by hand with carries from one position to the next, and can easily be extended to longer inputs.

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. You can use a single truth table and include an additional column for the second output.
2. Generate a K-map for each of the two outputs (one for s and one for c).
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 two-bit adder circuit uses one half adder and one full-adder. 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 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 full adder adder becomes the carry from the aggregate circuit. Implement the two-bit adder on the breadboard. It is important to keep organized, so use one breadboard column for each of the two subcircuits involved. The goal is to get a logical flow that can allow independent testing of each of the subcircuits. A and B should come from the switches, and the two-bits of output should get wired appropriately to the hex display, with the carry-out going to a monitor LED. Demonstrate the completed circuit for your instructor.