Part c) After the software has been debugged on the simulator, you will build the hardware on the real board. To build circuits, we'll use a solderless breadboard, also referred to as a protoboard. The holes in the protoboard are internally connected in a systematic manner, as shown in Figure 8.2. The long rows of holes along the outer sides of the protoboard are electrically connected. Some protoboards like the one in Figure 8.2 have four long rows (two on each side), while others have just two long rows (one on each side). We refer to the long rows as power buses. If your protoboard has only two long rows (one on each side, we will connect one row to +3.3V and another row to ground. If your protoboard has two long rows on each side, then two rows will be ground, and one row will be +3.3V. Use a black marker and label the voltage on each row. In the middle of the protoboard, you'll find two groups of holes placed in a 0.1 inch grid. Each adjacent row of five holes is electrically connected. We usually insert components into these holes. IC chips are placed on the protoboard, such that the two rows of pins straddle the center valley. To make connections to the TM4C123 we can run male-male solid wire from the bottom of the microcontroller board to the protoboard. For example, assume we wish to connect TM4C123 PE1 output to the + side of the LED as shown in Figure 8.1. First, cut a 24 gauge solid wire long enough to reach from PE1 and + side of the LED. Next, strip about 0.25 inch off each end. Place one end of the wire in the hole for the PE1 and the other end in one of the four remaining holes in the 5-hole row shared by the + side of the LED.

I like to watch the green power LED when I first power up a new circuit. If the green power LED on the LaunchPad does not illuminate, I quickly disconnect the USB cable.

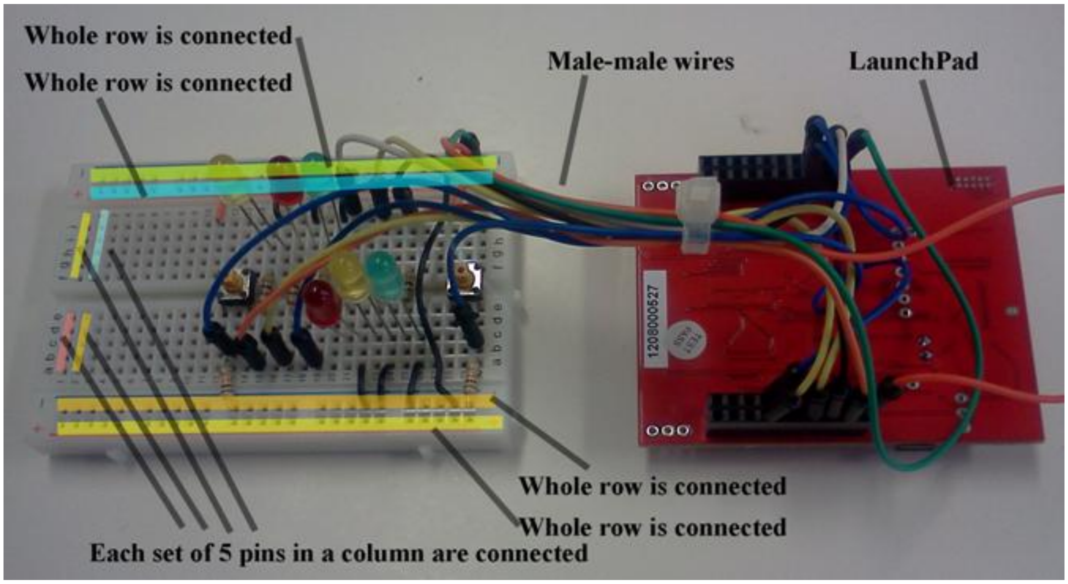

Figure 8.2. All the holes on each of the four long rows are connected. The 5 holes in each short column are connected. Use male-male wires to connect signals on the LaunchPad to devices on the protoboard. Make sure ground wire is connected between the LaunchPad and your circuit. The +3.3V power can be wired from the LaunchPad to your circuit. I like to connect the two dark

blue rows to ground, red rows to +3.3V.

Notice the switch has 4 pins in a rectangular shape, as shown in Figure 8.3. Each button is a single-pole single-throw normally-open switch. All four pins are connected to the switch. Pins 1 and 2 are connected inside the switch; similarly pins 3 and 4 are connected inside the switch. The switch itself is positioned betweens pins 1-2 and 3-4.

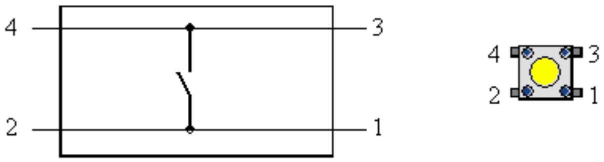

Figure 8.3. Connection diagram for the normally open B3F-style switch.

Do not place or remove wires on the protoboard while the power is on.

The next step is to build the LED output circuit. Using the data sheet, hold an LED and identify which pin is the anode and which is the cathode. LEDs emit light when an electric current passes through them, as shown in Figure 8.4. LEDs have polarity, meaning current must pass from anode to cathode to activate. The anode is labelled **a** or **+** , and cathode is labelled **k** or **-**. The cathode is the short lead and there may be a slight flat spot on the body of round LEDs. Thus, the anode is the longer lead. Furthermore, LEDs will not be damaged if you plug it in backwards. LEDs however won't work plugged in backwards of course.

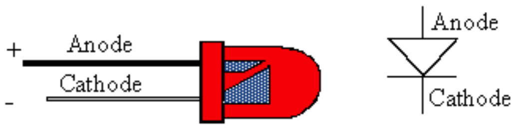

Figure 8.4. A drawing and the circuit symbol for an LED. "Big voltage is on the big wire."

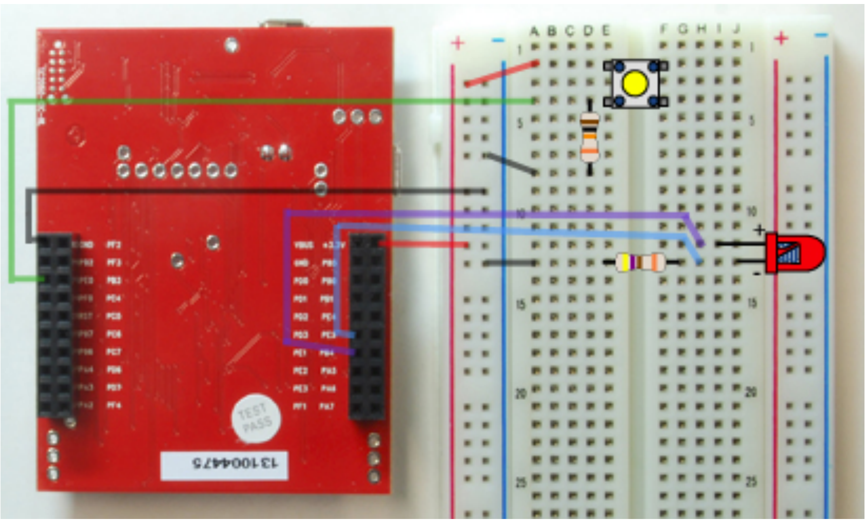

Figure 8.5. A photo showing one possible layout of the circuit. The black wires are ground. The red wires are +3.3V. The purple wire is PE1. The green wire is PE0. The blue wire connects PD3 to the signal between the LED and the resistor; it will be used to measure LED current in Part d). Brown-black-orange resistor is 10kΩ. Yellow-purple-brown resistor is 470Ω. Again, it doesn't matter what color the wires are, the colors are used to identify which wires are which signals.

Part d) Debug your combined hardware/software system on the actual TM4C123 board. First, we will use the debugger to observe the input pin to verify the proper operation of the switch interface. You will have to single step through your code that initializes Port E, and PE0. You then execute the **Peripherals->SystemViewer->GPIO->GPIOE** command. As you single step you should see the actual input as controlled by the switch you have interfaced, see Figure 8.1.

Valvano says 1.1V divided 470 ohms is 4 mA. He should have said 1.1V divided by 470 ohms is about 2 mA. (The LEDs in the kit are 2mA).

MEASUREMENT OF LED VOLTAGE AND CURRENT

Help

0:00 / 3:18 1.0x

JONATHAN VALVANO: Hi.

Jon Valvano here.

Let me show you how to measure the voltage and current across the LED.

We have lab eight running, and we can see here that the LED is on.

But we've added this special wire here to PD3,

and that's going to be your voltmeter.

And over on the screen right here, we can see what the voltage is.

I've got it tied to ground, and so we can see that it's 0.0 volts.

All right.

Next, I'll move it over to the other end of the 470-ohm resistor.

There's the resistor.

And now, we can see that we're measuring here at 1.1 volts.

If I were to move it to the other side of the LED,

it wouldn't work because it's beyond the range of this voltmeter.

This voltmeter goes from 0 to 3 volts.

And this voltage here is above 3 volts, but it's about 3 volts.

So you'll have to take my word for it that somewhere around 3 volts

is the other end of the diode.

All right.

What just happened?

We have PE1, which is the output of the microcontroller, tied

to one end of the diode.

And then, we have the 470-ohm resistor here tied to ground.

This was 0.0 volts.

This is 1.1 volts.

And this is about 3 volts.

It may be a little higher, but it's about 3 volts.

OK.

So we can calculate the voltage across the diode as 3.0 minus 1.1,

which you can see is 1.9 volts.

But more interestingly, we can measure the current.

Because this current equals that current,

we can measure the current across the diode

by actually measuring the current across the resistor-- which

is 1.1 volts minus 0 over 470, and this is going to be,

for this situation, about 4 milliamps [VALVANO MADE A MATH ERROR.

CORRECT ANSWER IS 2 mA].

Now, when you do your measurement, these numbers may be different,

but this current will be somewhere in the 2 to 4 milliamp range.

Now, it wasn't a requirement for you to own a voltmeter to do this class.

But if you have one, you might as well use it.

And so here is my voltmeter, and I'm going to attach my ground.

Because you always have to attach a ground to use the meter.

And we'll do the same three measurements.

We'll first measure ground here, which is 0 volts.

And then, we'll measure the voltage across the resistor, which we can see is actually 1.2 volts.

And we can also properly measure the voltage on the other side of the diode

right here, which we can see is about 3 volts.

And so if you do the math on this, it comes out

a little bit different, but approximately, the same.

So in summary, what we did is we verified

the circuit works by measuring the voltage and current

across the LED and the resistor.

OK.

Now you try it.

Help

Next, we will debug the output and the LED. PD3 is a debugging probe. You can use it to measure any voltage between 0 and 3.0V. With the power off connect a wire between PD3 and the LED cathode (-) (which is also connected to one end of the 470 resistor), as shown in Figure 8.1. This PD3-LED connection is illustrated as the blue wire in Figure 8.5. Define V_{PD3} as the voltage on PD3. Power it back up, start the debugger, run your program and do not press the switch. The LED should be on. We can verify all aspects of the LED interface are proper by beginning in the **Peripherals->SystemViewer->GPIO->PORTE** debugger window. In the debugging window you should see bit 1 of Port E is 1. In the Grader window (with your program running) you can observe the voltage seen at the PD3-probe. You can calculate the current across the LED using Ohm's Law. The LED current will equal the current in the resistor, which is

$$I_d = V_{PD3}/470\Omega$$

Assuming the port output voltage, V_{OH}, on PE1 is 3.0V, the voltage across the LED is about

$$V_d = (3.0-V_{PD3})$$

The LED voltage is only an approximation because we are guessing what the voltage on PE1 will be.

GRADING ON THE REAL BOARD

DR. JONATHAN VALVANO: Let's walk through the steps

of getting a grade for the Lab 8 Real Board.

We take the number from edX, Copy, and we go over to Keil.

This is the real board so we make sure the debugger is set up

for the real board.

We compile or build.

We download the code to the real board, and we debug on the real board.

This window over here is where we interact.

We have to be running in order to be grading, so I push the Run button here.

	0:00 / 1:38	1.0x				

Help