ES 4 Lab 1: Blinky lights
Lab report due Mon, Feb 10

1 Introduction

The aim of this lab is for you to get comfortable using the lab equipment and building circuits on a breadboard. These will be essential skills for the remainder of the labs this semester.

After successfully completing this lab, you should be able to:

- Use a power supply to provide a constant voltage to a circuit
- Use a digital multimeter to measure voltages
- Use a breadboard to make circuit connections
- Wire up LEDs with current-limiting resistors
- Translate a circuit schematic into a physical implementation on a breadboard
- Connect circuits to your UPduino FPGA board

2 Lab tools

L1: Follow the video tutorial posted on the course website to get started with the digital multimeter (DMM) and DC power supply (DCPS, or just "power supply").

3 Building circuits

Our primary tool for prototyping circuits is a "breadboard". This is a plastic board with hundreds of holes and embedded metal strips which can be used to make electrical connections. The figure below shows which holes (called "tie points") are electrically connected inside the breadboard:
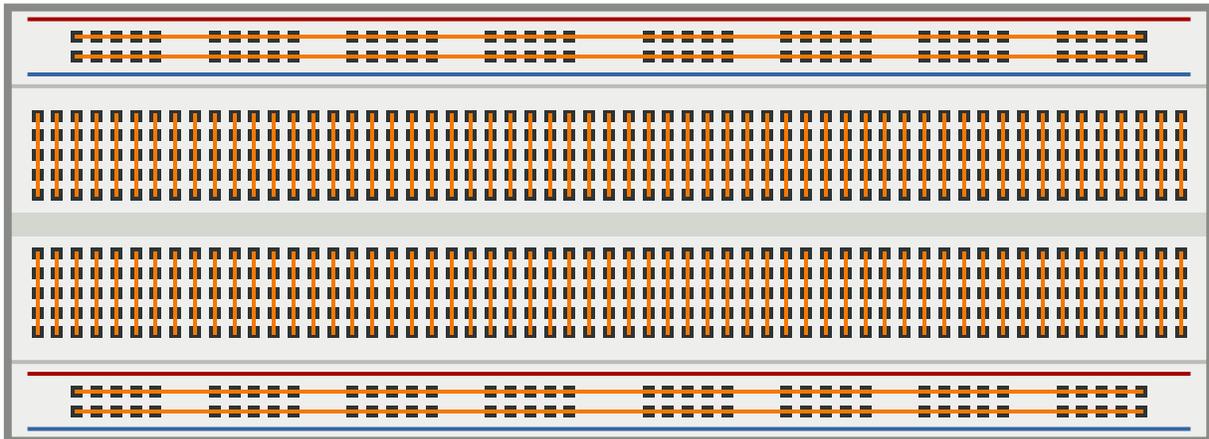

Each side of the breadboard also has two "rails" which run the full length of the breadboard.[1] By convention, we use the blue rails for the negative power supply (aka "ground") and the red rails for the positive power supply (aka "power", "5 V", or "V_{cc}").

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[1]Sometimes these rails are split in the middle – it's always wise to check this with a meter first!

A schematic is an idealized representation of a circuit. If you don't have much experience with circuit schematics, watch the video tutorial posted on the course website about how schematics work, and how to translate them into a physical breadboard implementation.

L2: Build this circuit on your breadboard. When you press the switch, the LED should light up.
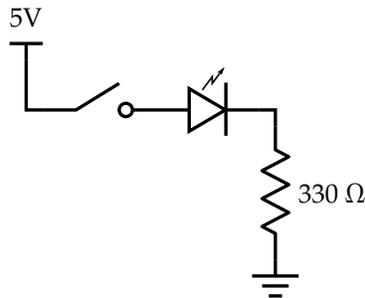

L3: What happens if you turn the LED around? (i.e., put the long lead on the ground side?)

L4: What happens if you swap the positions of the LED and the switch? (i.e., put the switch between the LED and ground?) What about the resistor? Draw schematics of what you tried and make notes about the outcome.

4   Connecting to your FPGA

L5: Connect an LED to pin 2 of your UPduino according to the schematic below, and connect the UPduino to a USB port on a computer. The LED should blink at 1 Hz.

WARNING: Make sure to disconnect the benchtop power supply from your breadboard before plugging in the UPduino. The UPduino will draw current from the USB port port to power the circuit, and external power is unnecessary. There are relatively few things that will destroy the UPduino, but incorrectly connecting it to an external power source is one of them.
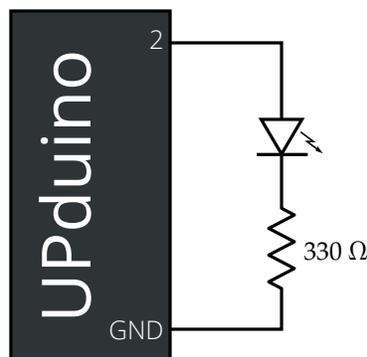
5   Analyzing circuit behavior with an oscilloscope

L6: Connect an LED to pin 47 of your UPduino. The LED should be flickering.

Obviously the LED is turning off and on, but exactly how fast is that happening? We're going to need a tool that can measure voltages at higher speeds than our eyeballs can see. Not coincidentally, we have tools in the lab to do that! In fact, we have *two* tools, *oscilloscopes* and *logic analyzers*. These have different strengths, summarized below:

	Oscilloscope (Tek TDS 2012)	**Logic analyzer (Digital Discovery)**
Measures	Analog voltages (0-200V)	Digital voltage levels (low/high) up to 5V
Simultaneous signals	2	40
Capture speed	Fast (25MHz)	Wicked fast (800MHz)
Interface	A bazillion buttons and knobs	Complicated PC program with a bazillion settings

For now we'll be using the oscilloscope, but we'll start using the logic analyzer later in the course when we need to monitor many signals at once. Watch the video on the course website about how to use the oscilloscope.

L7: How fast is the LED blinking? Draw the waveform (i.e., the voltage vs time graph), making sure to label the relevant units.

L8: Now connect an LED to pin 48 of your UPduino. The light should be on (and not blinking), but you might notice the light is dimmer than when you used the switch. Examine the voltage on the diode using the oscilloscope, and document what you see.

L9: Connect an LED to pin 4 of your UPduino. It should be on, but dimmer than the previous one. Record a hypothesis about what is happening, and then test it with the oscilloscope. Make some notes about what you discover.

L10: Connect an LED to pin 6 of your UPduino. It should be on (and not blinking). Examine it with the oscilloscope, and make notes about what you find.

L11: Connect an LED to pin 11 of your UPduino, and observe the blinking behavior of the LED for a few seconds. Again, write down a hypothesis about what is happening, and then examine what is really going on using the oscilloscope. Record your observations.

L12: (Optional) If you'd like more practice, you can test the following pins:

Pin	Expected signal
28	500 Hz
42	1 kHz, 80% duty cycle
43	10 kHz, 2% duty cycle
37	2MHz

6   What to turn in

There is no formal lab report to turn in, just submit the notes you took along the way.