ECE112 - Lab 9

Purpose

- Observe inductor behavior

Tools needed:

- Blue protoboard
- DMM

Background of Inductor Behavior

The defining relationship for an inductor:

$$v_L = L\frac{di}{dt} \tag{1}$$

tells us that an instantaneous (or mathematically discontinuous) change in inductor current requires an infinite voltage to be generated across the inductor terminals. However, in our universe, infinite voltages are physically impossible. Thus, we can infer that an instantaneous change in an inductor's current is impossible.

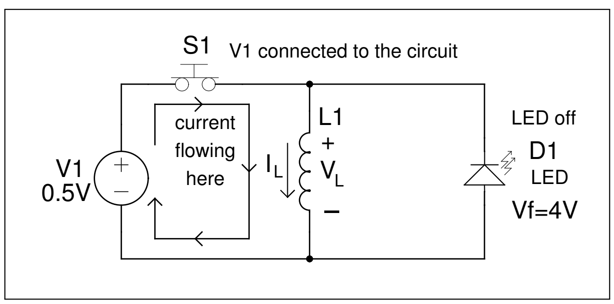

Figure 1: Voltage Source Delivers Energy to the Inductor

In figure 1, when S1 is depressed, an instantaneous change of voltage occurs across the terminals of L1 and D1. Since the LED's threshold voltage is 4 volts, and it's reverse biased, no current flows through it. However, just prior and just after S1 is depressed, zero current flows through L1. Otherwise, we would have an instantaneous change in L1's current. Having the same current flowing in the infinitesimally small time interval before and after the switch closure keeps consistency with the requirement of mathematical continuity.

Note that regardless of the voltage source's value, the current begins to ramp up in the inductor. A higher voltage increases the current more quickly. A smaller inductor ramps up current faster as well. But given enough time, the current in the inductor increases to any arbitrarily large value.

Now, what happens when S1 is opened? We know that the inductor current cannot change instantaneously. At the moment just before and just after S1 opens, the current must be the same. This indicates that two things must occur. See figure 2.

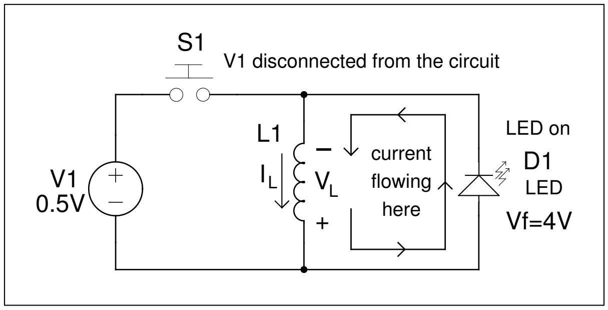

Figure 2: Inductor Supplies Energy to the LED

First, the polarity of v_L must change. V1 is no longer in the circuit, so it is not forcing current to flow through L1. Rather, L1 is supplying current by virtue of its now collapsing magnetic field. We know that when an element is supplying current, the current flows from the positive terminal. Thus, we have a new picture with i_L still oriented as before, but with v_L oriented in the opposite direction.

Secondly, to keep the current flowing through L1 the same just after S1 opens again, the voltage must rise at the terminals of L1 until that level of current flows. In this case, v_L will rise until it reaches 4 volts, the threshold voltage of the LED, then continuing upwards until the current flowing through the LED is the same as the current that was flowing through the inductor just before S1 was opened. The voltage simply increases, riding up the IV curve of the LED until the current through the LED matches the current through the inductor just before the switch was opened.

At that point, the mathematical continuity is satisfied and the energy in the inductor will be delivered to the LED. As it does so, the current delivered to the LED decreases as the magnetic field decreases.

Lighting two, 4 volt white LEDs from a 1.5 volt battery

Now we will utilize the inductor's current to voltage transformation behavior to light two white LEDs using a power supply that does not have enough voltage to light them by itself. Typically, white LEDs are have their brightness specified at a voltage of about 3.5-4 volts. Using two of them in series would normally require a supply voltage of 7 to 8 volts. However, by using an inductor to boost our supply voltage, we can make the LEDs flash from a 1.5 volt battery.

Referring to figure 3, when the push button is depressed, the PNP BJT allows current to flow into the inductor. While the inductor is building up its magnetic field (which happens as quickly as 5ms) the LEDs will remain off. Once the push button is released, the inductor will create a reverse polarity voltage limited only by the combined V_f of the two white LEDs. Once the current through the LEDs is equal to the current previously going through the inductor, the voltage and current begins decrease. The result is that we see the stored energy in the inductor briefly flash both LEDs.

Build the circuit in figure 3 on your blue protoboard. View the video to see how to wind a *pot core*. You need 5-6 ft of enameled wire to wind the pot core. Also, be sure to use the correct sides of the push button switch to make your connections. It's easy to use the wrong terminals.

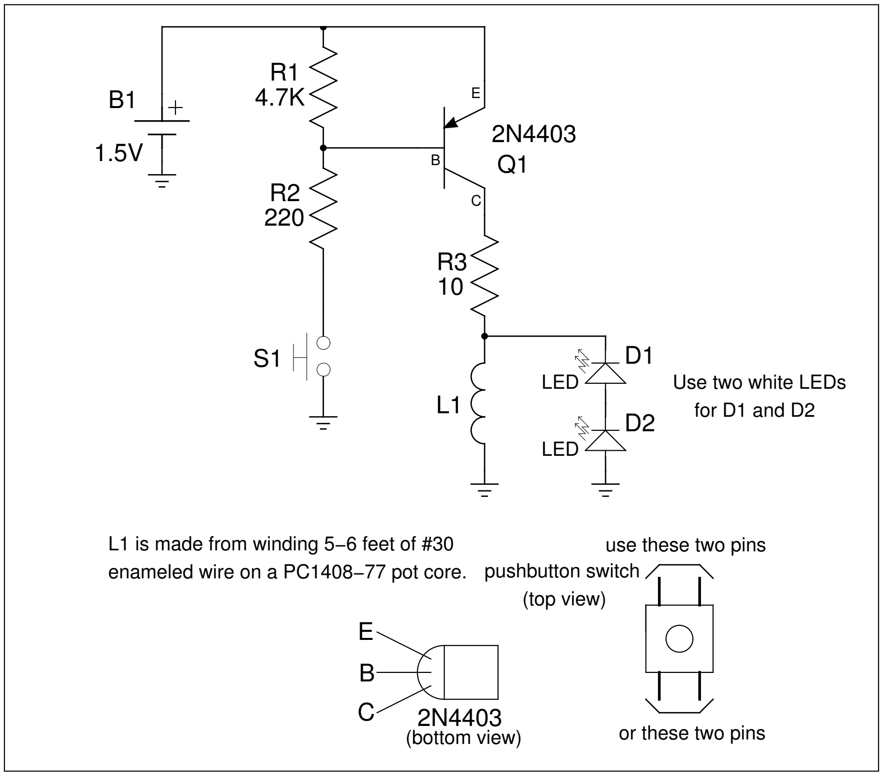

Figure 3: Inductive Kickback schematic

Once your circuit is complete, briefly push the push button switch, then release it. The LEDs should flash. If the LEDs light up as the button is being pressed, you have them both in backwards. If either one is backwards, you will never see a flash. Assuming your circuit is correct, when does the LED flash; when the button is pushed or when it is released?

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Looking at figure 4, complete drawing the dotted current arrows (6 places) and the voltage polarities for the inductor (4 places).

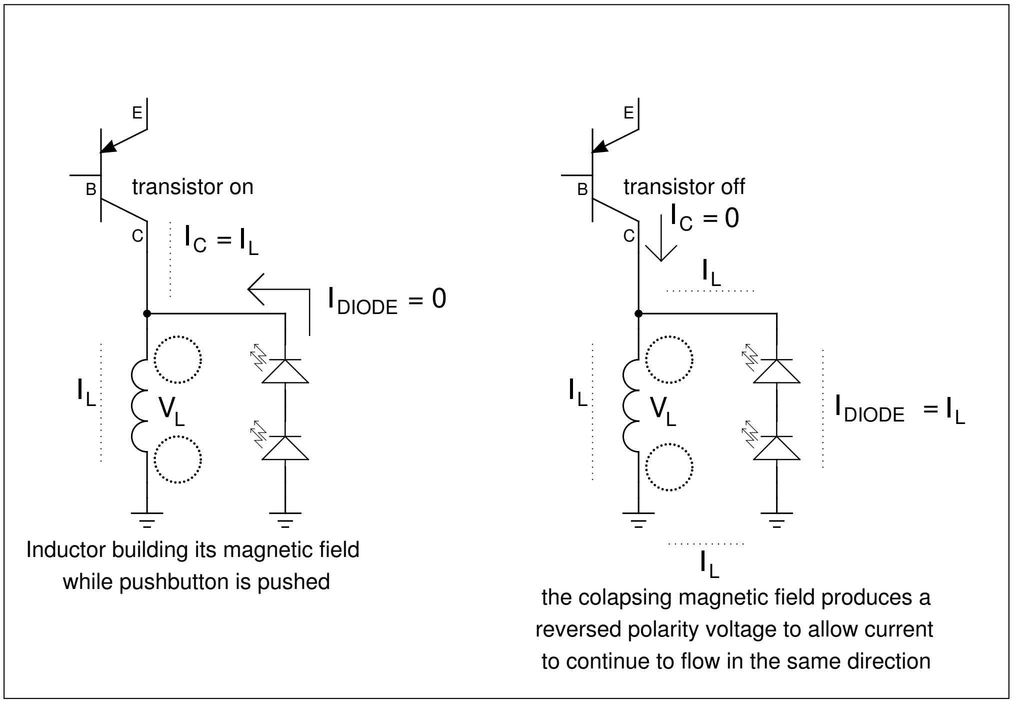

Figure 4: Current Flow Diagrams to Complete

Now, explain why you think the LEDs flash when they do.

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When the switch is closed, name three things that limit the current through the inductor.

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Suppose that the BJT in figure 4 has a $V_{ce(sat)}$ of -0.2V, and that the resistance in the inductor is 70 ohms. What would be the current through the LEDs at the moment the switch is released? Do any calculations in the box below.

If we were to double the inductance of L1, how much would the peak current increase through the LEDs?

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Show your working circuit to your TA.

Circuit works? _______________