ECE112 - Lab 10

Purpose

- Build a flashlight that runs from ”dead” batteries

Parts/tools needed:

- Flashlight Kit available in lab
- Soldering Iron
- Hand tools
- DMM
- Assembly Instructions: http://www.earstoourworld.org/humanalight

A Flashlight for dead batteries

This lab pulls together lots of the things we’ve been learning and culminates in a fun project: a flashlight that can run from batteries that are too run down to work in most other devices. In fact, this circuit will give useful light when the battery voltage is as low as 0.7V. Normally, a 1.5 volt battery is considered dead when it reaches 1.0V.

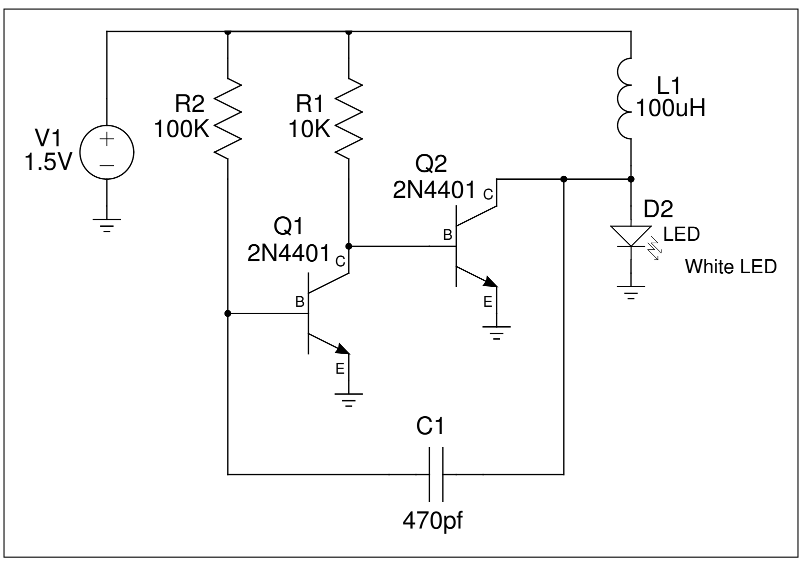

Figure 1: Complete Schematic of Flashlight

In figure 1, we see that the flashlight uses a trick we have seen before; an inductor is used to *boost* the voltage of an existing source. There are two transistors that are connected together to form an amplifier. The second transistor is able to pull the bottom of the inductor to ground to charge its magnetic field up.

A new wrinkle here is the capacitor, C1. It provides a feedback mechanism so that the two transistors plus inductor and capacitor form an oscillator. We saw before that an inductor could flash a white LED when a push-button was released. If we could push the push-button fast enough we could get a nearly continuous light but it would still be flickering.

This circuit provides a mechanism via feedback to flash the light at a much faster rate than we could. Using the feedback path, we actually flash the LED about two hundred thousand times a second, providing a light that is continuous to the eye. We will now break down the circuit into pieces and see how it all works together.

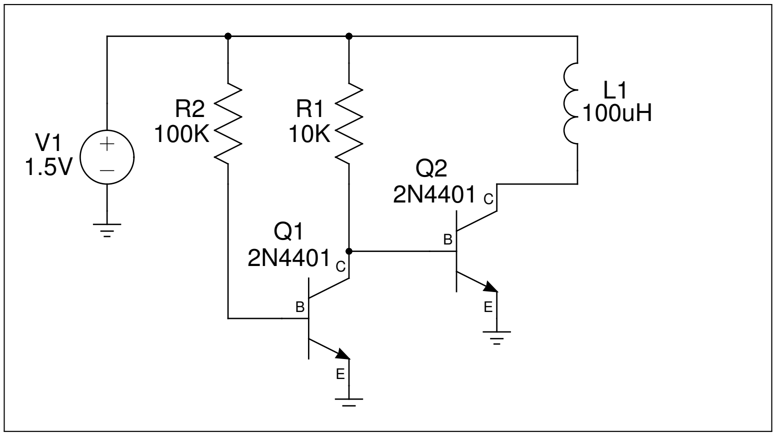

Figure 2: The Amplifier Portion of the Flashlight

Q1 and Q2 form an amplifier that amplifies the pulses that travel round-trip through the circuit. In the most simple scenario, if the base of Q1 is below 0.7 volts, it will be off, and its collector will be at a potential that will allow Q2 to be on. If Q2 is on, then current can flow through the inductor to ground through Q2.

In the opposite case, if Q1's base is at a high voltage (the capacitor will do this for us), then its collector will be near ground. Thus the base of Q2 will be near ground and no current can flow through the inductor to ground. So we see a rule that is if the base of Q1 is high, then Q2 does not allow current to flow through the inductor to ground.

As seen in figure 3, when Q2 is on, current flows through the inductor top to bottom with the positive-most terminal at the top as the passive sign convention would dictate. The LED is off because its threshold voltage or forward voltage V_f is about 3.5 to 4 volts.

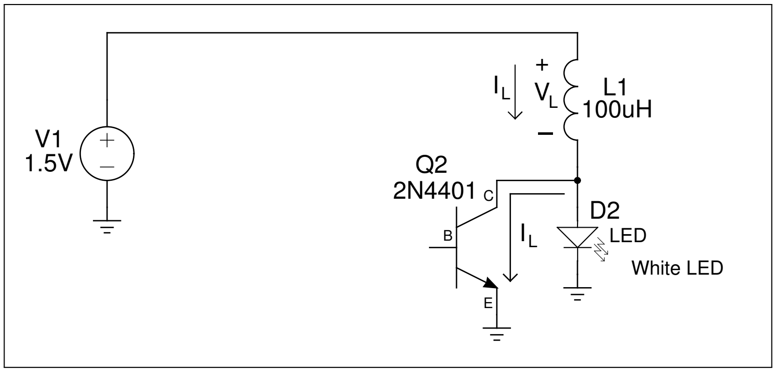

Figure 3: The Inductor During Charging

Figure 4 shows what happens when Q2 turns off. The inductor L1 attempts to maintain the current flow through itself. To do so, the voltage across its terminals must reverse. In doing so, the voltage now seen at the LED is the battery voltage (1.5V) plus the inductor voltage V_L. During this brief interval the LED will be illuminated.

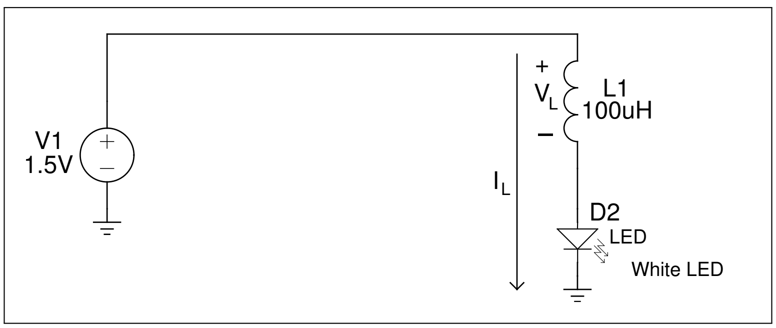

Figure 4: The Inductor Delivers its Stored Energy, Lighting the LED

Now we we add the feedback element C1, back and we have the full schematic again. See figure 5. C1 provides a signal back to Q1 from Q2 to create an oscillator, essentially an automatic way to pulse the inductor with charge at a rapid rate to keep the LED continuously illuminated at least to our eyes.

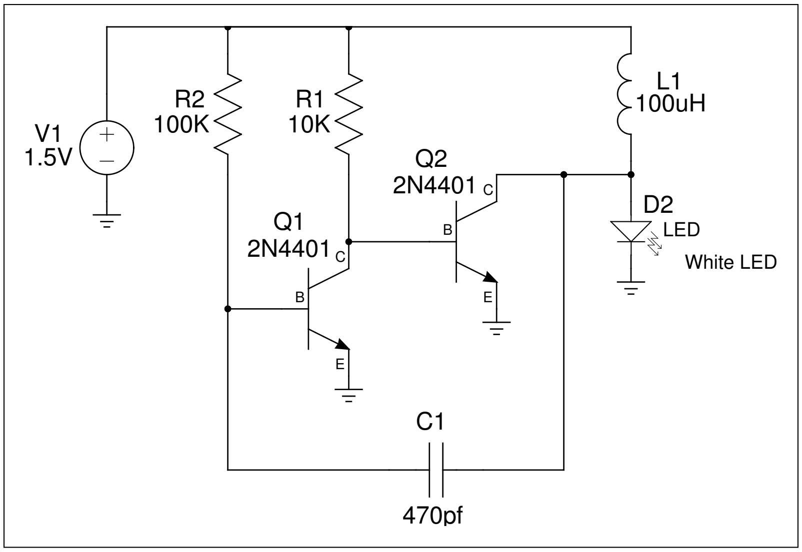

Figure 5: Complete Schematic of Flashlight with C1

To understand how the whole circuit operates, let's take a look at what happens right after the power is applied. When V1 is first energized, Q2 is immediately turned on, receiving current through R1. This brings Q2's collector to ground and begins to charge the magnetic field of L1. Since C1's right side is connected to Q2's collector, which is at ground, Q1 cannot turn on immediately. This confirms that Q2 is indeed on.

So, for a while we stay in this state. L1 is building up its magnetic field with Q2 on and Q1 off. During this time, C1 is being charged through R2 and is approaching the 0.7V it takes to turn on Q1.

When V1 is first energized, L1 will not allow any current to begin to flow instantaneously, but 1.5 volts will appear across L1 immediately. This lifts the right side of C1 to 1.5V relative to the left side, C1 begins to charge, but slowly. Meanwhile, Q2 receives current immediately from V1, turning on Q2 and beginning to charge the magnetic field of L1.

When the voltage at the left side of C1 reaches 0.7V, Q1 turns on, bringing its collector to ground. This in turn, turns Q2 off. The magnetic field in L1 begins to collapse and delivers its energy to the LED bringing its anode up to about 4 volts. Since the capacitor was connected to Q2's collector, the voltage now at the base of Q1 goes negative, cutting it off very hard. As the voltage at the right side of C1 drops and C1 is charged from R1, Q1's base will again reach 0.7V and Q1 turns on again. This begins second cycle of the oscillation.

For another explanation of this circuit, see: https://www.youtube.com/watch?v=qfgX93o8HzY

Conclusion

Your flashlight should be able to run from fresh or quite depleted AA cells for a long time. The circuit is very efficient and is very clever. In addition, it helps a worthy cause to help others.

In this project we see every circuit element we have used in our class. We use resistors and capacitors for timing. The inductor is used for energy storage and conversion. The transistors are used as both amplifiers and switches. Enjoy your flashlight!

Can you guess what would happen if you tried to power your flashlight from a 5 volt supply? Look at the schematic for a hint.

Show your working flashlight to your TA.