

# Lab 9: Lights, Camera, Action!

## Introduction

In this lab you will investigate the marriage of theory and technology. You will study how Faraday's Law is utilized to solve practical problems in circuits. The inner workings of a disposable flash camera will be investigated by dissecting the camera and making some electrical measurements. Voltage and current transients are observed and studied. Energy transfer between battery and flash unit is also considered. By the end of this lab you should:

- Develop basic skills in probing and handling circuit boards safely.
- Understand the application of Faraday's Law to a real-world circuit.



## Safety Concerns

As with many electrical devices, the disposable camera poses a potential shock hazard. Voltages in the flash circuit may approach 330 V and can remain at high voltage even with the battery removed. We ask that you observe the following guidelines:

- 1. Wear safety glasses and gloves!** Both will be made available to you. These are for **your** safety!
2. Treat the flash circuit with the respect it deserves; never intentionally shock yourself or another student.
3. Please remove the battery from the camera as soon as possible during disassembly. Replace it only when the circuit is actively under test.
4. Do not touch the elements on the circuit board with your bare hands. Use gloves, wooden pencils, or plastic rods to contact the switches. If the circuit board must be handled, use only one hand.

5. Use a dc voltmeter to monitor the voltage across the flash capacitor at all times that the circuit board is exposed.

6. Finally, please use a piece of electrical tape (or other mask) to block the bright light emitted by the flash tube, as it can be very annoying!

### **Part 1: Disassembly of Camera**

Disassemble the camera to the point where the battery may be removed. This may be done by removing the rear plastic enclosure by using a small screwdriver to spring or pry open the several small tabs. Take care, in doing this, not to destroy any part of the camera. They need to be re-used in future labs.

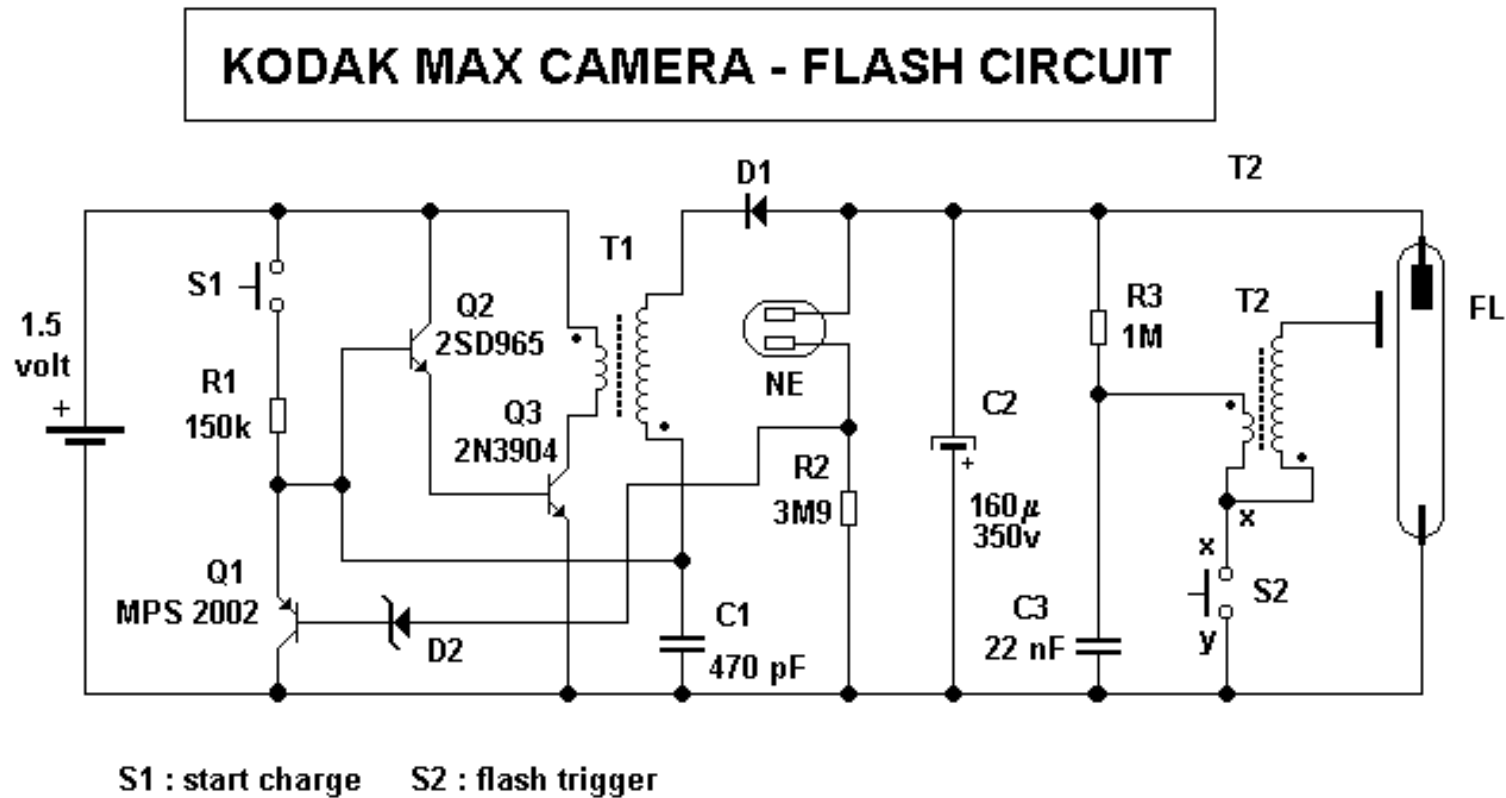
With the rear enclosure removed, you should be able to study and analyze the workings of the shutter switch and film winder mechanisms.

Next remove the front enclosure. Carefully check the voltage across the capacitor, the element located under the camera lens. If it is not fully discharged, use a 1K ohm resistor or larger to dissipate the energy. **Do not simply short the leads!** This can be dangerous, and it can potentially ruin the circuit board.

Before proceeding with any electrical measurements, continue the disassembly of the camera. Pop off the lens assembly and examine the shutter mechanism. Determine how the shutter switch triggers the flash circuit.

## Part 2: Circuit Fundamentals

The following is a circuit diagram of the circuit board that you have in front of you.



Now, let's investigate this circuit:

- How does a flash lamp (FL) work? For a useful description, see the first part of

<http://www.ee.washington.edu/conselec/CE/kuhn/labs/camera/fl.htm>.

- Which capacitor corresponds to the large green one on your own cameras?

- What are the two elements labeled T1 and T2? What is their purpose based on what you read about how a flash lamp works?

- What is a diode? See <http://www.howstuffworks.com/diode3.htm> for more information. D1 and D2 are both diodes that are critical to this circuit. What functions do they provide?

It should be evident by now that this circuit is not a simple RC circuit. We have capacitors, resistors, inductors/transformers, diodes, and transistors. It should also be evident from the following question: how does a capacitor get charged to 350 V from a puny 1.5 V battery?

## Faraday's Law

The way in which this is accomplished is through an ingenious application of Faraday's Law, which has the form  $\mathcal{E} = \frac{-d\Phi_B}{dt}$ .

For a self-induced EMF in an inductor, Faraday's Law has the form  $\mathcal{E}_L = -L \frac{di}{dt}$ .

Initially, when the switch is closed, the current through the inductor/transformer builds up to a constant value. Once this value is reached, then immediately a transistor disconnects the battery and shorts the inductor. With this loss of EMF and being shorted, the flux through the inductor changes extremely rapidly. We know from Faraday's Law that a changing magnetic flux induces an EMF in another coil, say of a transformer. Since the change in flux is so great, a great EMF is induced, and the transformer provides the much higher EMF necessary to bring the capacitor to 330V. This process then repeats itself until the required voltage level is reached across the capacitor.

## The Capacitor

**Remember:** Make sure that you have safety glasses and gloves on! These capacitors hold enough charge to cause serious harm to your body.

The capacitor in this camera is the black cylindrical object located below the lens assembly; it has a value of 160  $\mu\text{F}$ . Put the multimeter into its highest voltage setting and carefully connect alligator clips between the banana plugs and the leads of the capacitor -- the circuit board may need to be lifted slightly to accommodate the connections.

Use an insulated probe (such as the eraser on the end of a pencil) to close the flash charging switch. **Note the ultimate voltage acquired by the capacitor.**

Discharge the capacitor by flashing the lamp. In order to do this, you must complete the trigger circuit. Hold the circuit board so that the capacitor is located down and to the left and with the plastic face of the flash lamp facing up. Directly above the right end of the capacitor is a small, silver square of metal. That patch of metal must be connected to the piece of metal that is protruding from the left edge of the board. Use a small length of insulated wire to connect those two, while guarding your eyes. The flash will be bright! **Note the post-flash voltage of the capacitor.**

The effective time constant of this capacitor is not that of a simple RC circuit, since in these cameras inductors are involved. In reality it more closely resembles an LC time constant. In order to see this, you will need to do the following:

Get an oscilloscope, a scope probe with “minigrabber” leads, two alligator clips, and a battery box with 1 Ohm resistor soldered on. Place the battery in the battery box and attach an alligator clip to the positive end of the box. On the negative end, where the resistor is soldered on, connect the minigrabber lead **between** the box and the actual resistor.

Connect the ground clip of the probe on the opposite side of the resistor. The idea is that you want the scope to be measuring the voltage drop across the resistor. Now, take the other alligator clip and connect the end of the resistor opposite the battery with the negative terminal of the circuit board. Complete the circuit by connecting the “positive” alligator clip to the positive terminal of the circuit board. When you are ready, close the switch that engages the charging circuit, again using an insulating instrument. While charging adjust the oscilloscope until you get a stable trace on the screen. Record the waveform and observe how the trace changes with time. **What is the reason behind the shape of the trace?** Flash the lamp and observe the waveform afterward. (Note: the circuit will automatically begin recharging the capacitor after the flash. To stop this, simply disconnect one of the alligator clips.)

Now, connect a second minigrabber lead to channel two and connect it across the terminals of the capacitor while at its post-flash voltage. Charge the circuit again, this time comparing the traces of both channels. **How do they differ? Explain the waveform of the voltage across the capacitor.**

The capacitor tends to discharge slowly when the flash charging switch is open. **Determine the time constant of this discharge and evaluate the resistance that should be used to model the leakage of the capacitor.**

**What is the frequency of the periodic waveform associated with current flow through the battery? Try to determine the frequency just after the flash is fired as well as the frequency of switching when the capacitor is fully charged. Does it explain the "squeal" that you hear each time the capacitor recharges?**

*Please guarantee that the capacitor is uncharged and reassemble it for later use.*

### ***Follow-up Exercises***

- 1. The energy stored in a capacitor is  $CV^2/2$ . Calculate the energy difference before and after the firing of the flash. How much energy is released by each flash? From what height would a 1.0 kg mass be dropped to achieve kinetic energy of this amount at impact?*
- 2. From the energy capacity of a AAA alkaline cell, estimate the number of these flashes that would be possible from one cell.*

### **Additional Resources**

Online Battery Resources- [http://www.physics.udel.edu/~watson/phys345/frame/index\\_laboratory.html](http://www.physics.udel.edu/~watson/phys345/frame/index_laboratory.html)

<http://members.home.net/andybaird/batteries.html>