



## Class #17: Project Pulsing Circuits

**Purpose:** The objective of this project is to use what has been learned so far to build some electronic projects found on the internet by modifying the designs to match available components.

Background: Before doing this experiment, students should be able to

- Build simple circuits on protoboards
- Build an astable multivibrator circuit using a 555 timer chip.
- Know the resistance of and how to connect to a standard set of earbuds.
- Analyze simple circuits consisting of combinations of resistors, especially voltage dividers.
- Do a transient (time dependent) simulation of circuits using LTspice
- Select an appropriate resistor for an LED based on the available supply voltage.
- Use and properly orient an LED in a circuit.
- Measure voltages in a circuit using Analog Discovery
- Identify the frequency and duty cycle of pulsed voltages.
- Review the background for the previous experiments.

Learning Outcomes: Students will be able to

- Build projects found on the internet requiring some modification to match available components
- Use an NPN transistor in a simple circuit
- Use a photocell (LDR) in a circuit.
- Power a circuit using the +5V output (red wire) from Analog Discovery

Resources Required:

- Analog Discovery
- LTspice
- Matlab
- Parts Kit and a few additional parts

Helpful links for this experiment can be found on the course website under Class #17.

### Pre-Lab

*Required Reading:* Before beginning the lab, at least one team member must read over and be generally acquainted with this document and the other **required reading** materials.

*Hand-Drawn Circuit Diagrams:* Before beginning the lab, hand-drawn circuit diagrams must be prepared for all circuits either to be analyzed using LTspice or physically built and characterized using Analog Discovery.

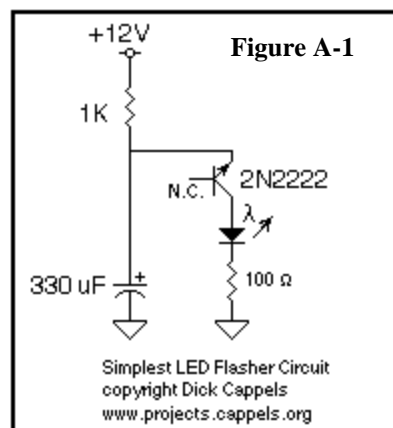
**Due:** At the beginning of Class #19

### Introduction

At this point in the semester, everyone should have the basic skill set to build some simple electronics projects. The skills include building and testing circuits, doing simple analysis, etc. as listed above. During this class time, it is hoped that everyone will have some fun applying these skills. There are three projects described below. Complete them in order, but it is not necessary to finish all three. Do as many as you can but do not be concerned with doing all unless you have time and are motivated to do so. In each case the goal is to get the circuit to work using available components, which will require some modification of the design. Once a circuit is working, it should be again modified in some manner to achieve some significant difference in performance. For each project, characteristic voltages are to be monitored using Analog Discovery and, in one case, exported to Matlab for analysis. A report is to be written that documents what was done and provides an explanation of the performance of the circuit using fully annotated data plots. Again, you do not have to do all three projects.

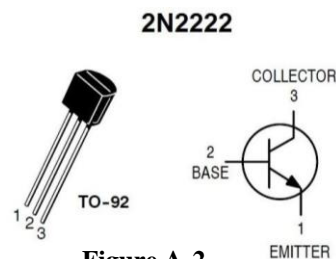
## Part A – ‘Simplest’ LED Flasher Circuit

There is a simple (small number of components) circuit, designed by Richard Cappels, described and discussed by him at [http://cappels.org/dproj/simplest\\_LED\\_flasher/Simplest\\_LED\\_Flasher\\_Circuit.html](http://cappels.org/dproj/simplest_LED_flasher/Simplest_LED_Flasher_Circuit.html). The circuit diagram for the circuit is shown in Figure A-1. This circuit uses a 2N2222 transistor in a non-standard configuration. Transistors have two PN junctions (diodes have one such junction). While we know that diodes usually only allow current to flow in one direction, if we apply a large enough reverse voltage, a PN junction will avalanche and carry lots of current. This is where the negative going part of the diode I-V curve comes from at large negative voltages. This avalanche process does not damage the device (if the current is not too big), so it can be done over and over. To get out of the avalanche mode, the current has to drop below some value, at which point usual diode operation begins again and current is totally stopped. Richard Cappels uses this idea in his circuit in which the large capacitor is charged up until it reaches the avalanche voltage for the base-emitter junction. The capacitor then discharges through the LED. Once the current is low enough, the transistor blocks the current and the process starts over.



For this project, we are faced with the following challenges:

- No 12V supply. However, we do have 9V batteries. You are to combine two batteries in series to produce 18V. Another option is to use a left over power supply from a computer or some other device that you might have or be able to borrow from somewhere. The 9V batteries are the recommended approach because it will be easier to work on this circuit at home, if necessary. Because the voltage is larger, the 1kΩ resistor probably will not be the right value. Cappels discusses what is necessary to get the circuit to run, so he provides a big hint on whether this resistor needs to be larger or smaller.
- No 2N2222 transistor in your parts kit. We will provide this device. Another issue is that you have probably never used a transistor in a circuit. The symbol in the circuit shows how it is to be wired. Only two of the three connections are used. Check out the Wikipedia page on 2N2222 transistors to see how it is connected. <https://en.wikipedia.org/wiki/2N2222>.
- No 330μF capacitor in your kit. Cappels notes that smaller capacitors will just pulse faster. Build the circuit with the largest one you have and then possibly modify the circuit by adding other capacitors in parallel to increase the capacitor to get closer to or even larger than 330μF. Once you get the circuit to pulse, you may want to try other values to see how it works differently.
- The function of the 100Ω resistor is to set the current through the LED. It is unlikely that this is the best choice for whatever LED is used in this circuit. LEDs operate over a fairly broad range of currents, so the LED will likely flash, but it may carry too much current at some point in the cycle, so this resistor should probably be changed. It is only possible to determine if it is the best choice by measuring the actual voltage and currents.



When you build the circuit, set up the Analog Discovery scope to measure the voltage across the capacitor, the transistor, the LED and the 100Ω resistor. You have only two channels so you will have to make more than one set of measurements and, possibly, use a math channel. You should also have channels that show the current through each of the resistors. Export your data to Matlab and plot the four voltages simultaneously. Also plot the current through the transistor (also the current through the small resistor) vs the voltage across the transistor and test the idea that the transistor acts something like a negative resistor when avalanching. This may or may not work, but we have the ability to check this out, so we should try it. Be sure to fully annotate your plots, indicating what is happening at each point. Your goal is to get the circuit to pulse, but you might also want to try different component values to improve the quality of the pulsing (you get to define what you think is higher or lower quality).

## Part B – An Optical Theremin

Now that you have seen how a Theremin works, you will build a circuit based on the 555 timer circuit built previously. In this case, rather than using standard resistors to achieve a particular train of output pulses, two photocells (aka Light Dependent Resistors or LDRs) will be used to change both the frequency and duty cycle of the output. There is a fairly annoying video describing how to build this device on YouTube (see Figure B-1) <https://www.youtube.com/watch?v=xDrF6O6sokM>.

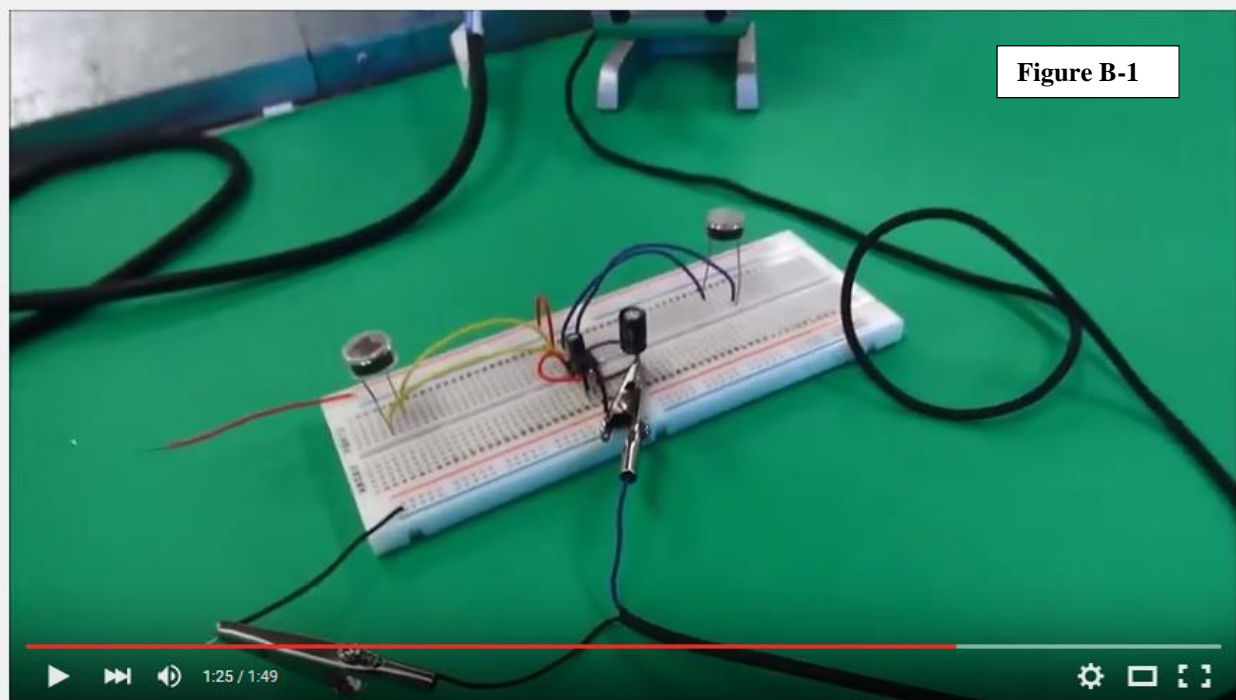
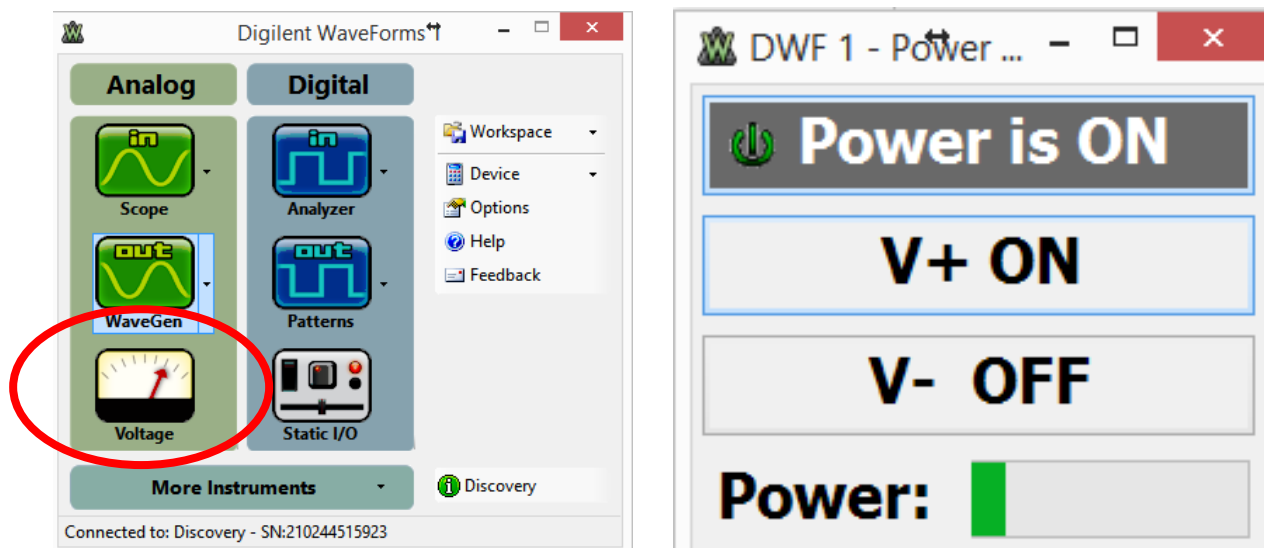


Figure B-1

For this project, we are faced with the following challenges:

- Only one LDR in the parts kit. Additional photocells will be provided.
- Speaker – no speaker should be used. Rather, an earbud should provide the sound. To protect the earbud, replace the large capacitor in the design by a  $1\text{k}\Omega$  resistor in series with the earbuds. Recall that the resistance of a single channel on typical earbuds is about  $32\Omega$ .
- Connection to earbuds. As is shown in the photo, alligator clip leads can be used for this purpose. Some will be available, but probably only two per group. These will have to be returned at the end of class.
- Power supply – The 5V power supply that is part of Analog Discovery should work fine for this application. A 9V battery can also be used, but the resistor connecting the output to the earbud channel should be at least doubled in size.
- Light source – the lights in the room are bright but will likely not be bright enough to produce the full experience with the circuit. An additional light source (e.g. camera flash LED) should be used (not provided).
- In the video, nothing is shown connected to pin 5 of the 555. It helps the device work a bit more reliably if a  $0.01\mu\text{F}$  capacitor is connected as shown in Figure A-1 of Experiment 6.

Use Analog Discovery to monitor the output from the 555 timer chip and the voltage across the earbud. Show that the ratio of the two voltages is consistent with the voltage divider action at the output. Monitor the voltage for a representative set of lighting conditions on each photocell. Save the plots in your report. It is not necessary to export the data to Matlab for this experiment. In your report discuss the (fully annotated) characteristics of the plots and why each plot is different. Be specific.



**Figure B – 2**

To provide the 5V from Analog Discovery, connect the red wire to the point where 5V is needed and be sure that ground (black wire) is connected to circuit ground. To turn on the power, click on the Voltage icon in WaveForms. The window at the right will appear. Turn on V+ and turn off V-. The click on the top button to turn power on. The green bar at the bottom will show how much of the available power is being used. When too much power is used, WaveForms will shut things off.

### **Part C – LED Fading with 555 Timer**

The final project is found at <http://www.instructables.com/id/LED-fading-with-a-555-timer/> and involves the use of both a 555 timer and a transistor. Note in the discussion of how to change the circuit (once it is operating) you will see that it is possible to include an LDR here too. For this circuit, monitor representative voltages including the voltage across the LED. The report should include a discussion of the differences in the output with and without fading.