ECE20007: Project 2: The 555 Timer

Ben Manning, Purdue University
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ECE20007 Mini Projects

In ECE20007, there will be a series of two mini projects that will be completed to test your individual skills and abilities in electronics. **These labs will be individual.** You will still be in pairs with your lab partner at your bench, but you are expected to make the circuits and measurements yourself with your own lab kit. You can communicate with your lab partner, TAs, or other students, but you are expected to work out the math, do the experiments, and complete the report as an individual assignment.

You will have 1 week of lab time to work on the project and your report.

These labs will be written and submitted as a formal lab report, but you will not be required to setup the entire report for the first project, which you will just include your procedure and results. For the second project, you will be expected to include an Introduction, theory, procedure, results, and a conclusion.

The projects will equate to 25% of your final grade, including the final project at the end of the semester. The mini projects will each be 7.5% of your final grade, with the final project being 10%.

The main purpose of these projects is to get you thinking in a more experimental mindset, testing different ways of presenting data, and thoroughly explaining your process and results. As you move forward in science and engineering, effectively developing and explaining a project or product will become increasingly important, especially when justifying funding or employment. For the projects, the general expectations and best practices will be laid out in this document, but it will be up to you to determine a good process to complete the goals at hand. Below is the general outline for how the projects will work:

Before Lab, and early lab 1:

1. Complete the assigned reading for the project and watch any videos associated with the project. You may want to continue doing general research to get a better understanding on the concepts being used. Make sure to cite your sources.
2. Read through the tasks you will perform, along with effectively understanding what the end goal of the experiment is.
3. Develop a general schematic, along with general steps for how you will approach the tasks of the experiment. This can be changed once you talk with TAs in lab, but you should try to have a good plan ahead of time.

During Lab:

1. Work through your plan to complete the tasks.
2. Take thorough notes, measurements, screenshots, and pictures so that you will have enough information to work on your report after you are done.

After Lab:

1. Review your notes and measurements from lab, and verify you have enough data to justify your explanations and goals. If you do not, you may have to go back to lab to take more measurements.
2. Develop your lab report with the expected sections for that report. If you have at least a rough draft completed before the second lab session of the project, you are welcome to ask for feedback on your formatting, explanations, and your report in general prior to finishing and submitting.

1 The 555 Timer

In the timing lab, we used a capacitor to accurately show how we can time and monitor a circuit. Now that we can reliably determine the voltage on a capacitor after a specific amount of time, it would be nice to be able to use that information to control something. A 555 timer is an integrated circuit that can monitor, charge, and discharge a capacitor to toggle an output either on or off. This circuit was originally designed as in integrated circuit (the black chips) in the 1970's, but variations of the timer have existed soon after the transistor was invented. Being very versatile to allow for one-shot triggers, to oscillators, to motor controllers, and even speaker and LED drivers, the 555 timer is a favorite to many hobby electronics goers, and often argued to be one of the most popular integrated circuits ever made.

1.1 [Very] Quick Overview of the 555 Timer

Important: Have the datasheet out and follow along with the reading to better understand what is going on! The pin configuration and functions page will probably help most here!

There are a total of eight pins on the 555 timer, and all of them play an important role in making the chip work properly. These pins are shown in order in the "Pin Configuration and Functions" section of the 555 timer datasheet. The two pins that are standard on almost all active IC's, as in they need power in order to function, are V_+ and ground pins, which are pins one and eight on the chip.

Looking at the general schematic, we can see that V_+ is in series with three resistors, that form two voltage dividers, where their output voltages go to one of two comparators, a device that compares two input voltages, and toggles an output based on which one is larger. One of these comparators is attached to a trigger pin (pin 2), which will toggle a flip flop, a basic memory circuit, to the "set" stage (high voltage) when the trigger pin is set to low voltage (ground).

The other comparator is attached to a threshold pin (pin 6), which will set the flip flop to the "reset" stage (low voltage) when the voltage on the threshold pin reaches at least 2/3 of the input voltage. There is a "Control Voltage" pin (pin 5) where you can manually set this threshold too, but if you do not want to, connecting it to ground through an external decoupling capacitor will allow for the internal threshold to be quite accurate.

Based on the outputs of these two comparators, the flip flop will send either a high or low voltage to the output pin (pin 3). This output can be attached to a motor controller, lights, speakers, or basically any other load. The equivalent resistance of the timer is very high, so as long as your connection is looking for a voltage around V_+, and your supply can maintain the current needed, you will likely be fine.

When the flip flop sends a low signal, that also tells a transistor attached to the discharge pin (pin 7) to connect to ground. If the discharge pin is attached properly to a capacitor, when the transistor is set, it will discharge the capacitor so it can recharge once the trigger pin is toggled, which again sets the output to high, turning off the transistor and allowing the capacitor to charge. Technically, these are all of the pins that are needed to operate the chip. There is one more pin called "reset" (pin 4) which can manually reset the flip flop without the trigger and threshold operation. This comes in handy at times to be able to manually reset the flip flop, but for this lab, it will always be set to high voltage, effectively disabling the pin.

All of this to say that the threshold and trigger pin work together to change the output of the chip to high or low, and the discharge pin allows for a capacitor to discharge and start the cycle over again. Due to how the pins interact with each other, we can setup the 555 timer to work as a single pulse, like you would see with a door bell (mono-stable mode), or we can set up the timer to continuously discharge and re-trigger itself (astable mode) to allow for flashing, or continuous toggling. These modes can also be combined in multiple ways with multiple timers to make even more complex and useful setups! General schematics for these modes can be found in the 555 timer datasheet.

Both the mono-stable and astable mode have different ways of determining the timing of the pulse(s). This is important to realize since it is a little different than just calculating the time constant of the circuit, but not too much different. In the mono-stable mode, we are looking for a threshold voltage that is 2/3 of the input voltage. This is close, but not exact to the 63.2% of the input voltage that we get from just calculating the time constant. This means to get a more accurate time constant for the 555 timer, we will calculate our time constant to be

$\tau = 1.1 \cdot R \cdot C$. In astable mode, we want the threshold and discharge settings to happen at different times, so we will be using two resistors to make a voltage divider for the threshold and discharge pins. This means we have can control the rate of the capacitor charging, along with us controlling the discharge rate. Controlling these two states allows us to create a duty cycle, or a pulse for a certain period is reliably on and off for a specific amount of time. Take a look at the datasheet to understand these relationships!

Annoying Fact: The duty cycle formula that is in the TI xx555 datasheet is for the **Normally On** load, not the **Normally off**, which is what we generally think about in circuits like this, since the load would be connected to ground. For the duty cycle of the Normally Off load, the formula is:

$$D = \frac{T_{on}}{T_{on} + T_{off}} = \frac{R_a + R_b}{R_a + 2 \cdot R_b} \tag{1}$$

2 Experiment 1: General use of a 555 Timer

The first experiment is to experimentally compare the operation of the 555 timer in monostable and astable mode. Discuss the differences between the two modes, and how the configurations provide the different modes. Below are some steps that may assist you in observing and discussing the different modes of the 555 timer.

Make sure you have the datasheet for the LM555, or LMC555 Timer available! (They are virtually the same in reference to this lab, and the datasheets are extremely similar. the LMC555 timer can toggle faster, and has lower power requirements, but the pin-outs and operation from our perspective are nearly identical.

1. Create a general flow diagram of the operation of the 555 timer when in mono-stable mode starting with the trigger pin getting set to low, and ending with a pulse being completed.
2. Using values from your kit, determine resistor and capacitor values to get a high output pulse of 3 seconds in mono-stable mode. Construct and demonstrate the operation of the circuit.
3. When looking at the datasheet, you will notice that there is a "normally on" and a "normally off" location for the output. What do both of these mean? Why would one be able to be on when the other is off? Explain this as if you are instructing someone who is just learning about Ohm's Law and how current flows.
4. Create a general flow diagram of the operation of the 555 timer when in astable mode starting with the trigger pin getting set to low, and describing the full duty cycle. (This might end up being a loop...)
5. Using values from your kit, determine resistor and capacitor values to get a 60% duty cycle with a period of 2 seconds. This means that the output will be high for 1.2 seconds, and low for 0.8 seconds, for a total period of two seconds (on for 60% of the time). Construct and demonstrate the operation of the circuit.
6. Using values from your kit, determine resistor and capacitor values to get a 75% duty cycle with a period of 1 second. This means that the output will be high for 3/4 second, and low for 1/4 second, for a total period of 1 second (on for 75% of the time). Construct and demonstrate the operation of the circuit.
7. Instead of using fixed resistance and capacitor values to achieve different timing scenarios, use a variable component, such as a potentiometer to dynamically change the timing circuit in both monostable and astable mode. Where would this be helpful?

3 Experiment 2: Exploring applications of a 555 Timer

One of the reasons why the 555 timer is such a popular chip is because of its wide, wide array of applications. Regardless of your area of study, personal interests, or just general curiosity, finding use of a 555 timer in a project will likely save a lot time and headache. Your second experiment is to explore, test, and discuss an application of a 555 timer that interests you. Find an application of a 555 timer, test the operation, and discuss the pros and cons of the timer in the application. This will look very different for different applications. Choose how to best present the data and observations you make in your report. Below is a table of general applications of the 555 timer, but can be broadened, or narrowed depending on your interests. Multiple 555 timers can be combined to make different combinations of astable and monostable applications too!

PWM generator	Waveform Generation	Frequency Divider	Police Siren	Motion Detector
PPM generator	Tachometer	Cable tester	AM Transmitter/Reciever	LED dimmer
Frequency monitor	Capacitive touch sensor	Pulse detector	Latching Button	LED chaser
DC to DC Converters	Voltage to Frequency Converter	Timer Switch	Doorbell	High Brightness LEDs (without strobing)

Expected deliverables in report:

- Procedure of research and design process, and why this application is of interest to you.
- Spice simulation of operation, and verification of proper operation on oscilloscope.
- Discussion of application. Pros and cons of the design. How can the design be improved or modified to better fit your specific interest?
- Optional: link to short video, no more than 2 minutes, of the timer and operation.
- Extra credit (+10%) if multiple 555 timers are used to fulfil operation.

Overall tips and Follow-up Questions

As a guide, here are some questions that will be worth discussing in your results and discussion section of your lab report. The answers to these questions are likely to be a little subjective. That is why it is a discussion. Just make sure to justify why you think what you think.

- Did the results match what you expected? Why or why not?
- How could the experiment be improved? What went well, what did not go well?
- There is no required way to present your data, but it does need to be presented. Think of ways to present your data effectively. You will need to take multiple measurements at multiple lengths, and showing the error with your data will be important. Remember to **justify** the validity of your data, along with determining if it shows what you want it to show or not.