EE 255
ELECTRONICS I LABORATORY
EXPERIMENT 9
APPLICATIONS OF IC BUILDING BLOCKS

OBJECTIVES

In this experiment you will

- Explore the use of a popular IC chip and its applications.
- Become more familiar with application notes.
- Learn how new applications are developed for special-function ICs.

INTRODUCTION

In actual practice, we often use op-amps and special-purpose integrated circuit modules rather than design all of our circuit with discrete components. We do this for reasons of *economy*. By using IC "building blocks," we save design and development time (and its associated cost), as well as physical space or volume needed for our circuit. Often, but not always, we also reap the benefit of laser-trimmed, precision circuitry that might be difficult to develop with commonly-available discrete components.

There are hundreds of thousands of these special-purpose IC chips to choose from. To get started, we will use this experiment to explore one of the most-popular integrated circuits of all time: the 555 timer. You may have used this chip in a previous lab, but in this experiment you will design several applications that are very important. You will have the opportunity later to work with other fascinating chips in Electronics II lab, in senior design or in designing your own projects.

LAB PREPARATION

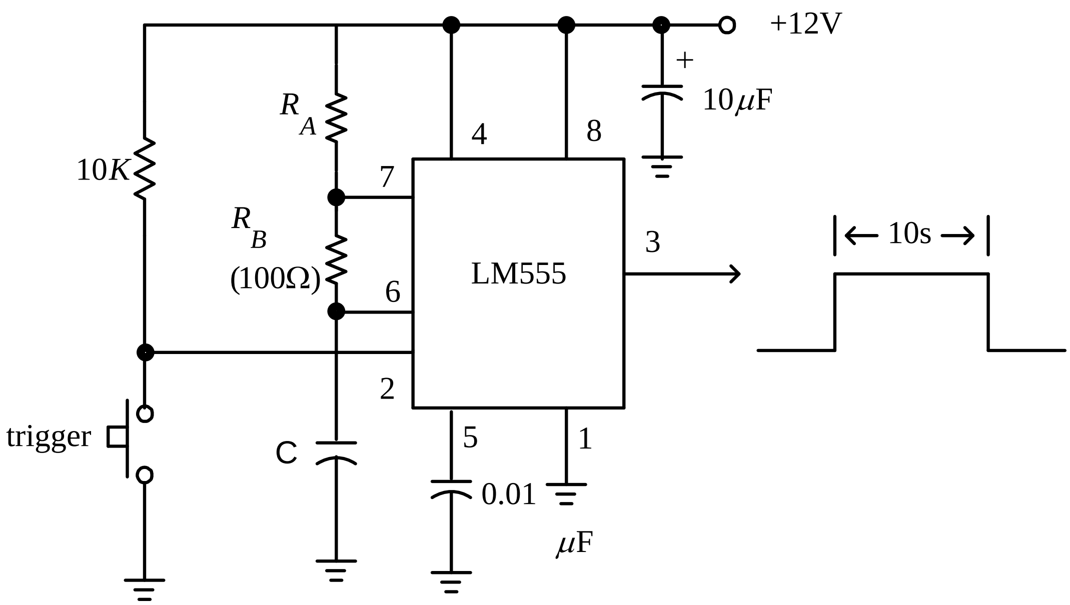
Read through this lab before class. This will allow you to prepare before hand. Look up the data sheet for the LM 555 Timer: www.national.com/ds/LM/LM555.pdf. Most important will be the first pages that introduce the chip as well as the pin connection diagram for the 8-pin DIP on page 2. The application section begins on page 7 of the data sheet. Read about the monostable and astable multivibrator and make sure you understand them. A thorough explanation is given in your textbook.

EXPERIMENT

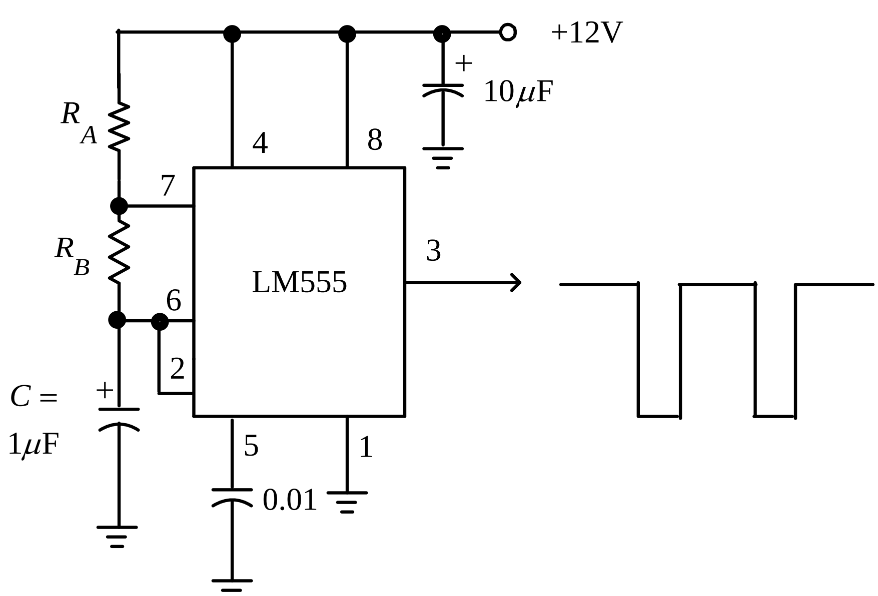
1. Design a monostable multivibrator (one-shot) that will deliver a pulse of approximately 10 seconds when triggered. You can use the nomograph of Fig. 3 in the data sheet (page 7) as a guideline for choosing either R_A or C. You can use the formula given or the nomograph to determine value of the other component. Your circuit should look like the one below. Note that a bypass capacitor is used for the power supply and a resistor R_B should be used if your value of capacitance is large ($\geq$ 10µF).

This will limit the capacitor discharge current when it is shorted by the internal transistor connected to pin 7.

2. Apply power and check to see that the circuit works. You can use the scope probe on the output (pin 3) to see the output go HIGH for 10 seconds, and then return to the LOW state. [This circuit can be used to generate time delays from about 10 μs to several hours. Even longer times (days!) can be generated with additional circuitry.]



3. Design an astable multivibrator that will generate a negative-going pulse approximately 100 μs, approximately every 1 ms. Use a 1 μF capacitor for C. Calculate the value needed for R_B and then, R_A. The circuit is shown below.



4. Power up the circuit and observe the output. How close is your waveform to your calculated parameters?

5. To demonstrate the superiority of this chip's design, carefully vary the power supply voltage between 6 volts and 15 volts. The output frequency and duty cycle should remain fairly constant, even though the output amplitude will change. This is due to the precision voltage divider network in the 555 to determine the switching thresholds.

6. With the scope probe, observe the waveform across the timing capacitor C. You should see a sawtooth wave. We will see later that this circuit can be changed so that the sawtooth become a linear ramp. This is just one of the many possibilities with this versatile IC chip.

FURTHER EXPLORATION

Use the remaining lab time to experiment with some of the other applications. The pulse-width modulation circuit of Fig. 8 is a very useful circuit you might want to try. You can apply a variable dc voltage to pin 5 to observe the pulse-width change or you could supply a low-level sine wave or square wave as well. If you low pass filter the output, you should get a crude sine wave. PWM switching is used extensively in power electronic motor controls and sine wave inverters.

Another important circuit is the linear ramp generator shown in Fig. 12. For this one, you will need to bias the transistor so that it will provide a constant current to charge C. You can use the same astable multivibrator you used previously. Use a 2N3906 PNP device for the current source transistor. Noting that since

$$I = C\,(\Delta V/\Delta T)$$

you should see a linear ramp at pin 6. Note, however, that the constant-current source must be designed so that it will not saturate and will supply a constant current over the required range of Vc. If you can think this out and calculate the required values, you are well on your way to being an electronics engineer!

Another circuit for experimentation is the frequency-to-voltage converter shown on the next page. This can be used to make a tachometer. The op-amp functions as a zero-crossing detector, triggering the one-shot at the beginning of each input cycle. The output pulses are averaged by an RC low-pass filter, so that the meter reading corresponds to frequency. If you use your oscilloscope here instead of the microammeter and resistor, look at the *average* voltage to confirm that it works. Vary the input frequency around 500 Hz to see if there is a linear relationship between frequency and average output voltage.

COMMENTARY

For nearly 25 years, the 555 timer IC was the largest-selling chip in the world! Entire books have been written about the chip, entailing hundreds of applications. It can be used in many consumer and hobby applications, as well as commercial applications with caution.

Designer's Tip: Always use a suitable bypass capacitor at the power supply pin (8) and make sure that you have a good solid ground, especially when using this circuit with digital ICs. Reason: When C is shorted by the internal transistor, there is a large "current dump" through the transistor and through ground pin 1. This can cause the ground pin to jump above ground for perhaps only a few microseconds. This may be just enough to fool the digital gate connected to output pin 3. Many problems can be solved by supplying a good solid ground and a suitable bypass capacitor.