LABORATORY 8

# Audio Synthesizer

# Guide

## The 555 Timer IC

Inductors and capacitors add a host of new circuit possibilities that exploit the memory realized by the energy storage that is inherent to these components. In this laboratory we will use capacitors to build timer circuits. Timers have a many uses, from lights that turn off automatically after a prescribed period to blinking lights and synthesizers used in sirens or electronic organs. Timers are also used by other electronic circuits, for example as computer clocks. In fact, the 555 timer circuit used in this laboratory is one of the most successful ICs ever: Designed 1970 by Hans Camenzind at Signetics and introduced 1971 (the same year Intel introduced its first—4-Bit!—microprocessor executing up to 60,000 instructions per second), sales are still strong with over 1 billion units sold each year! Can you think of other innovations with similar success and longevity? The first microprocessor has long been relegated to museums.

The notorious RC charging and discharging circuit that is at the basis of so many homework and exam problems is also at the center of many timer circuits (exams are practical, after all). For example, the time it takes to charge a capacitor can be used to delay turning on a device. Likewise, discharging sets the time to turn a device off. Combine these two circuits and you have a clock turning on and off at a rate set by a capacitor and resistors. Turing this simple idea into a complete electronic circuit calls for several functions in addition to the capacitor and charging and discharging resistors. Switches are used to alter between charging and discharging cycles. Comparators determine when a certain voltage level has been reached. Altogether quite a few components are needed to build that timer circuit. The 555 timer includes all these functions in an 8-pin package.

A timer circuit performs two functions: A mechanism for generating the delay, and a device to turn the timer state on and off, based on the delay. The first function is easily realized e.g. by the charging and discharging of a capacitor. The second involved comparing the resulting waveform to set thresholds. Fortunately the circuitry for this function is available as standard components. The most prevalent of these “timer ICs” (IC stands for integrated circuit, meaning a device that combines several electronic functions in a package) it the 555. For some reasons ICs typically have numeric “names” with little or no deeper meaning.

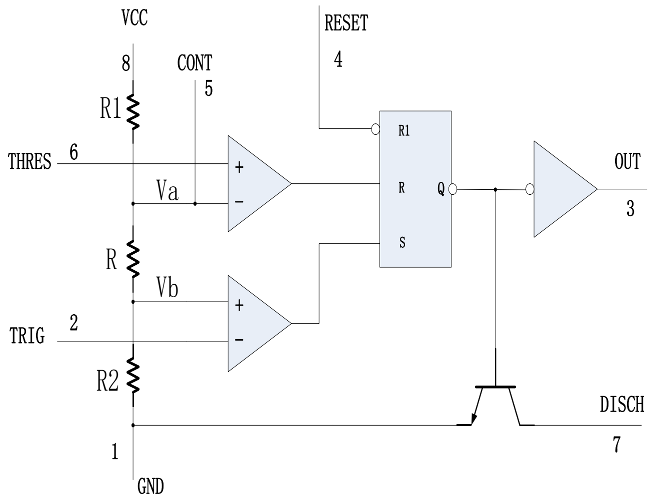


**Figure 1**

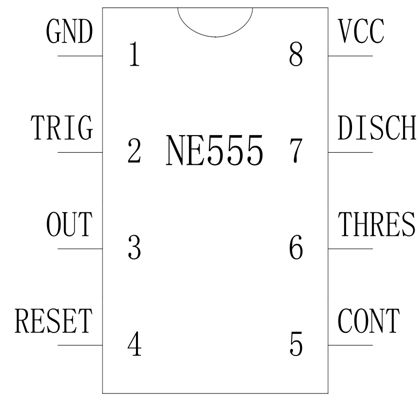


**Figure 2**

Figure 1 shows a simplified circuit diagram of the 555 timer. The box on the right with S and R inputs is a flip-flop and keeps track of the timer state. Its output Q is either VCC or ground. Raising the S input to VCC sets the flip-flop (Q=VCC) which then remains in the set state until the R input is raised to VCC. Figure 2 is the chip pin, and the NE555 has 8 pins.

Raising both S and R results in a random state Q and must be avoided if deterministic circuit operation is desired. Two comparators generate the set and reset signals from inputs “trigger” and “threshold”. The output of a comparator equals Vcc when the voltage at the plus terminal is greater than the voltage at the minus terminal, and 0V otherwise. The resistors R1, R2, R, are equal and consequently Va = 2/3Vcc and Vb = 1/3Vcc.

# LAB8 Prelab

Name ____________________ TA Checkoff ____________________

Teammate ____________________ Score ____________________

## On/Off Timer

Let's now use a 555 timer IC to design an off-timer, also called monostable timer. Figure 3 shows a possible circuit implementation using the 555. The output of the timer is connected to two light emitting diodes (LEDs) through current limiting resistors. Depending on the state of the timer output, one or the other LED is on.

Assume that initially the timer is off, i.e. Q = 0V. Then the "discharge" switch (which is part of the 555 timer IC) connected to the output is turned on, pulling the "threshold" signal low. As long as switch S1 remains open, the "trigger" signal is high.

Closing the momentary switch S1 pulls the trigger voltage low. Consequently, the input to the bottom comparator is $\mathrm{Vb} - 0\mathrm{V} = \frac{1}{3}\mathrm{Vcc} > 0$ and its output, which controls the S input of the flip-flop goes high, setting Q = Vcc. The discharge switch opens, and capacitor C charges through Ra until the top comparator turns on and resets the flip-flop.

This circuit is mildly complex and a single and simple error such as an incorrect connection would result in it not working properly. Since such situations can be very time consuming to investigate in the laboratory, we first verify circuit operation with simulation (Multisim). All devices can readily be simulated. We observe which LED light is on by the switch's on and off.

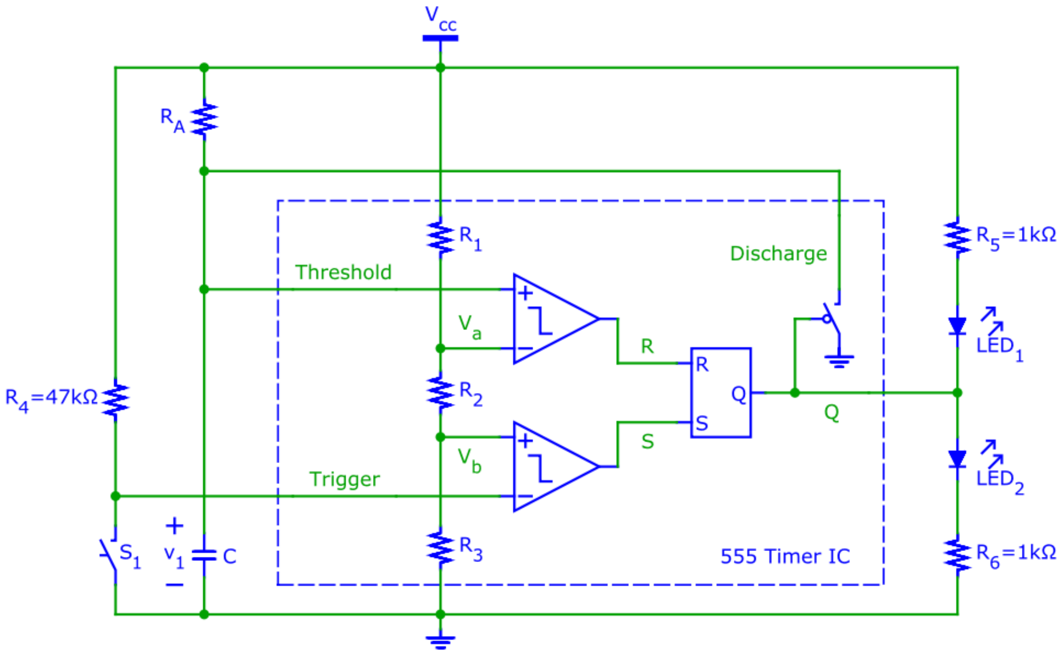


**Figure 3 Monostable timer circuit.**

**Two pins are not identified in this figure, decide the connection of two pins by yourself.**

Hand in the following with your lab report:

(1) Printout of the circuit schematic of multisim, $R_A = 37k\Omega, C = 10uF$. .

(10 points)

(2) A plot of the result of a transient analysis showing the following signals: trigger voltage $V_1(t)$, $V_{out}(t)$. (the input of trigger voltage is square wave)

(15 points)

## Electronic Synthesizer

Audio signals change periodically with time. For example, the music note A4 corresponds to a waveform that repeats with a frequency of 440Hz or every 2.27ms. We can use the 555 timer circuit to synthesize these signals. The configuration shown in Figure 4 shows the connections for astable operation of the timer. The capacitor C is periodically charged and discharged by the circuit.

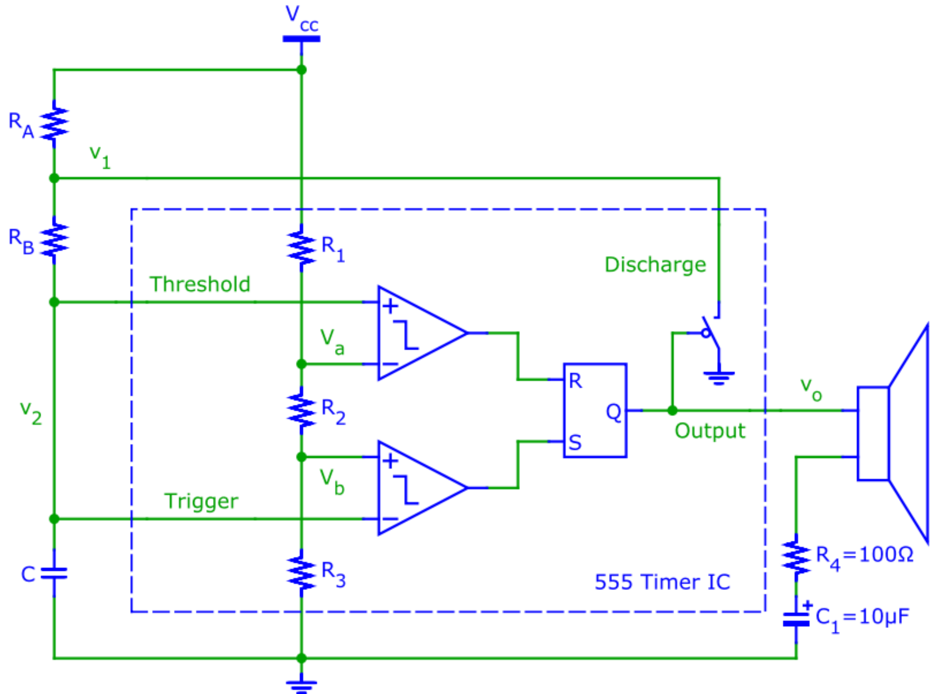


**Figure 4 Circuit configuration for astable timer operation. (The output is connected to a buzzer, according to the different input frequency, make different sounds.)**

Following the approach taken to design the on/off-timer, draw simplified circuit diagrams showing only the relevant components during the charging and discharging of C. $R_B = 2k\Omega \quad C = 0.1\mu F$

Plot the waveforms at nodes $V_2$, and $V_0$ as a function of time. Mark the voltage at the tripping points.

(10 points)

Hand in the following with your lab report:

(1) Printout of the circuit schematic of multisim.

(10 points)

(2) We want to design output frequency of 1.5kHz to 2.8kHz square-wave. The $R_A$ resistance value should be?

(10 points)

| Output frequency (kHz) | $R_A$(Ω) |
|---|---|
| 1.5 | |
| 2.8 | |

# LAB8 Report

Name ______________________ TA Checkoff ______________________

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1. In monostable timer circuit, verify your circuit in the lab. Unlike resistors, capacitors are not marked with a universally valid code. Instead, values are marked using a variety of different and ambiguous notations. Ask your lab assistant for help. As always, observe the polarity markings on all components. For LEDs the longer wire indicates the positive terminal (where current enters). If a momentary switch is not available you can emulate it by making momentary contact with a wire (an admittedly lousy lab technique). Verify the voltage at the timer output and check polarity if the LEDs won't turn on and off as expected.

Demonstrate your circuit to the laboratory assistant. (15 points)

**TA Checkoff**____________

2. In circuit of the electronic synthesizer, you should properly connected circuit. You need through the oscilloscope observe output wave shape whether is the square-wave. By the way, you can get the frequency of output.

Summarize your results in the table below: (10 points)

| Output frequency (kHz) | Simulated $R_A$( Ω ) | Measured $R_A$( Ω ) |
|---|---|---|
| 1.5 | | |
| 2.8 | | |

Next, change the resistance value, it is necessary to see if it meets the design requirements. Demonstrate your circuit to the laboratory assistant. (20 points)

**TA Checkoff**____________

## Reference

[1] UC Berkeley, EECS100 Lab, Fall 2009.