Physics 221 - Electronics
Temple University, Fall 2006-7
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Lab Exercise 1: 555 “Timer” Chip Oscillators

Objectives:

- **Apply basic ideas of voltage dividers and RC circuits to control an important integrated circuit, the 555 timer chip.**
- **Build an astable multivibrator (oscillator) circuit with the 555**
- **Build a temperature sensing circuit based on the multivibrator**

An *oscillator* is a circuit with an output that varies periodically in time, without any changes in its input(s). Oscillator circuits of many kinds date back to the work of the radio pioneers in the early part of the 20^{th} century. In this lab we will see how far the ideas of voltage dividers and RC circuits can take us, using the versatile 555 “timer” IC.

A. 555 “Timer” Chip:

The 555 is called a timer chip but it is actually a logic device with no clock or any other internal time reference at all. The state of its output is at all times determined by certain rules applied to its several inputs. To achieve desired behavior, the inputs are often interconnected by external circuitry involving RC components. Refer to Horowitz ande Hill Fig. 5.32 p. 287 for pin-out and logic diagram, or to the Data Sheet you were given. (Don’t puzzle over the logic diagram too much until the lectures on digital logic are complete– but you can use the IC before that!)

Operation of the 555 will be discussed in class but here is a basic rundown. The devices we will use are in “8 pin DIP” packages. The pins are numbered as in the datasheet, 1-4 down one edge and 5-8 up the other edge, with the “dimple” at the top between pins 1 and 8. Pin 3 is the output. The device sets the voltage at pin 3 either “high” (near the positive supply voltage) or “low” (near ground) depending on the state of the inputs.

The main inputs are pin 2 ($\overline{trigger}$, pronounced “trigger-bar”, meaning logical inverse of *trigger*), and pin 6 (“*threshold*”). Don’t forget to connect power (+V$_{cc}$) to pin 8 and ground to pin 1. Also connect pin 4 ($\overline{reset}$) to +V$_{cc}$ for most applications.

Basically the output at pin 3 will go high when $\overline{trigger}$ is driven (more about how it has to be driven in a moment). The output will then just stay high forever, or until *threshold* is driven. So the output shuttles between high and low states under the control of $\overline{trigger}$ and *threshold.*

The *discharge* is an “input-ish” pin that sort of follows the output. When the output is high, *discharge* is an open circuit i.e. it goes nowhere. When the output is low, *discharge* is connected to ground inside the chip.

To “drive” $\overline{trigger}$ one must set it to a voltage *level less than* 1/3 V$_{cc}$. To drive *threshold* one must set it to a voltage level *greater than* 2/3 V$_{cc}$.

1. Basic 555 Astable Multivibrator (Oscillator):

Consider the circuit of Horowitz and HillFig. 5.33 p. 287.

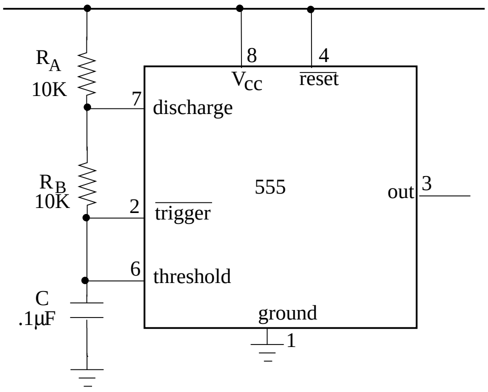

Figure 1: Basic astable multivibrator circuit (Horowitz & Hill Fig. 5.33).

This circuit works roughly as follows. When power is first turned on, **C** has no charge on it and hence no voltage across it. The junction above **C** is therefore initially at ground, and so are *threshold* and $\overline{trigger}$. Since $\overline{trigger}$ is lower than 1/3 V$_{cc}$, the output pin immediately goes high (to +V$_{cc}$) and *discharge* is an open circuit, i.e. not connected to anything inside the chip.

Meanwhile, since the power is on, positive current flows through the two 10 K resistors, and starts to charge up **C**. **C** gradually charges up toward +V$_{cc}$ with time constant 20KΩ x 0.1 μF = 2 msec. The connections to the *threshold* and $\overline{trigger}$ inputs draw negligible current from the “voltage divider” (the two 10 K resistors in series), a characteristic of most integrated circuit inputs.

As soon as the voltage across **C** reaches 2/3 V$_{cc}$, *threshold* is “driven” and the output crashes to zero volts, stopping the capacitor from charging more.

At the same time, *discharge* gets connected to ground inside the IC. Now **C** discharges through just one 10 KΩ resistor into the (grounded) *discharge* pin of the IC. The discharge time constant of **C** is R_B**C**, different than the charging time constant.

Once **C** runs down to 1/3 V_{cc}, $\overline{trigger}$ is "driven" and the cycle starts over almost as from power-up. The output goes high again and *discharge* goes open-circuit, once again starting to charge up the capacitor. (Question- what is different when the cycle starts up on power-up vs. starting over on later cycles?)

In normal operation, the voltage across **C** charges and discharges between 1/3 V_{cc} and 2/3 V_{cc}. These numbers can be used to calculate the oscillation frequency and "duty factor" (fraction of time output is high).

Now set up this circuit on your breadboard. Observe its oscillations at pin 3 of the 555 using your oscilloscope.

Once you have seen the circuit work as drawn in the book, change the time constant by connecting a second identical capacitor in parallel with **C**, and understand the change in frequency this produces. Change R_B by connecting a second identical resistor in parallel and understand the change in the "duty factor" (fraction of time output is high) this produces.

Check out the "reset function" by disconnecting pin 4 from V_{cc} and connecting it to a "pull-up resistor" and one of the slide switches on your breadboard). See diagram below.

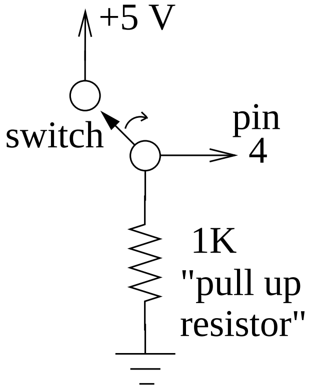

Figure 2: Reset/Pull Up Setup for 555 Timer

The pull-up resistor is a convenient way to control a logic input manually using a switch. When the switch is open, pin 4 is grounded through the pull-up resistor. When the switch is closed, current flowing through the resistor "pulls up" pin 4 to +15 Volts. Pin 4 is called $\overline{reset}$ because the output is reset to zero whenever pin 4 is driven LOW.

Set your scope for Auto Triggering and watch the effect of closing the switch. It might be easier to see if you slow down the oscillations by a factor of 10 or more. How to accomplish this?

Note that with this circuit the output waveform is necessarily "high" more of the time than it is "low". (Explain why this is so.) To make a "low duty factor" pulse train ("low" more of the time than it is "high"), the circuit of Horowitz and Hill Fig. 5.34 charges the capacitor from the output voltage and discharges it through *discharge*. This allows complete flexibility in choosing the duty factor.

2. Simple Thermometer for Telemetry

The following is a simple circuit that will emit a series of audible clicks from the speaker. The rate of clicking depends on the temperature because of the temperature dependent resistor ("thermistor") R1. Circuits just like this are used in weather balloons and the like, with the speaker replaced by input to a radio transmitter.

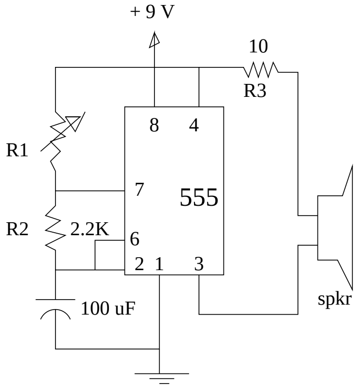

Figure 3: Telemetry Thermometer

Build the circuit shown and verify that it functions as described above. Use your fingers or your breath to heat the thermistor.

Report:

Draw the output waveforms you observed with the different R's and C's in part 1, with labeled time and amplitude axes. In each case, compare the period of the wave to the formula given in the book. Why does R_B appear with a factor of two? (Hint; **C** does not discharge instantaneously.)

Explain how the telemetry thermometer works. How could you make the frequency of clicking at a given temperature 10 times higher? How could you make the sensitivity (d(click rate)/d(Temperature)) as high as possible without changing the thermistor?