1. Objectives

1. Learn about the 555 timer integrated circuit and applications
2. Apply the 555 timer to build an infrared (IR) transmitter and receiver

2. The 555 Timer

The 555 timer integrated circuit (IC) has become a mainstay in electronics design. A 555 timer will produce a pulse when a trigger signal is applied to it. The pulse length is determined by the amount of time it takes to charge and discharge a capacitor connected to a 555 timer. A 555 timer can be used to debounce switches, modulate signals, create accurate clock signals, create pulse width modulated (PWM) signals, etc. A 555 timer can be obtained from various manufacturers including Fairchild Semiconductor and National Semiconductor.

A 555 timer is shown below in Figure 1.

![555 Timer Diagram](image)

**Figure 1 - 555 Timer**

Description of the 555 timer pins

<table>
<thead>
<tr>
<th>Pin</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GND Ground Connection</td>
</tr>
<tr>
<td>2</td>
<td>Trigger 555 timer triggers when this pin transitions from voltage at $V_{CC}$ to 33% $V$ voltage at $V_{CC}$. Output pin goes high when triggered</td>
</tr>
<tr>
<td>3</td>
<td>Output Output pin of 555 timer</td>
</tr>
<tr>
<td>4</td>
<td>Reset Resets 555 timer when low</td>
</tr>
<tr>
<td>5</td>
<td>Control Voltage Used to change Threshold and Trigger set point voltages and is rarely used</td>
</tr>
<tr>
<td>6</td>
<td>Threshold Used to detect when the capacitor has charged. The Output pin goes low when the capacitor has charged to 66.6% of $V_{CC}$.</td>
</tr>
<tr>
<td>7</td>
<td>Discharge Used to discharge the capacitor</td>
</tr>
<tr>
<td>8</td>
<td>$V_{CC}$ 5V to 15V supply input</td>
</tr>
</tbody>
</table>
The 555 timer can operate in 3 different modes:

i. Monostable Mode
ii. Astable Mode or free running
iii. Bistable Mode or Schmitt Trigger

2.1. 555 Timer – Monostable Mode

Figure 2 shows a Monostable 555 Timer circuit. The Monostable circuit outputs one pulse for each high to low transition of the trigger pin. The output will return to the “stable” state after a period of time that is a function of the attached resistor and capacitor values.

![Figure 2 - 555 Timer Monostable Configuration](image)

The discharge pin is normally connected to ground (internally). When the trigger pin transitions from \( V_{cc} \) to 33% \( V_{cc} \), the discharge pin is then internally disconnected from ground and the output pin is set high. The capacitor \( C \) then starts to charge through resistor \( R \). The threshold pin detects when the voltage across the capacitor reaches 66.6% \( V_{cc} \). When the voltage across the capacitor reaches 66.6% \( V_{cc} \), the output pin is set low and the discharge pin is connected back to ground. Finally, when the discharge pin is connected back to ground, the capacitor is discharged and the default “stable” state is reached.

The length of the output pulse depends on when the capacitor reaches 66.6% \( V_{cc} \). This rate is determined by the charge capacity of the capacitor, \( C \), and resistance, \( R \). The length of the output pulse, \( t_p \), is:

\[
    t_p = 1.1RC
\]

*In short, starting with a discharged capacitor, the output pin is set high once the trigger pin transitions from high to low, and it remains high (the output pin) until the capacitor reaches 66% of \( V_{cc} \).*

The monostable 555 timer circuit can be used in the following applications:

a) Debounce a momentary/pushbutton switch
b) Turning on an actuator for a set period of time
c) Turn an output from a resistive sensor from analog signal to digital signal. *(Example: A potentiometer is a variable resistor. A project requires determining the position of a potentiometer used for user input. All analog to digital (A/D) converters on a microcontroller have already been used but there are some digital inputs and outputs available. The potentiometer can be used as the resistor in a monostable 555 timer circuit. The microcontroller can then trigger the monostable circuit and measure \( t_p \) since \( t_p \) now depends on the position of the potentiometer)*
2.2. 555 Timer – Astable Mode

Figure 3 shows an Astable 555 Timer circuit. The Astable 555 timer circuit outputs a series of pulses, alternating between two states.

![Figure 3 - 555 Timer Astable Configuration](image)

When the circuit is first turned on, the discharge pin is disconnected from ground (internally) and the output pin is set high since the trigger pin is below 33.3% \(V_{cc}\) (no charge in the capacitor). The capacitor, \(C\), starts to charge through resistors \(R_1\) and \(R_2\). The threshold pin detects when the voltage across the capacitor reaches 66.6% \(V_{cc}\). When the voltage across the capacitor reaches 66.6% \(V_{cc}\), the output pin is set low and the discharge pin is connected back to ground. When the discharge pin is connected back to ground, the capacitor starts discharging through resistor \(R_2\) until the capacitor reaches 33.3% \(V_{cc}\). The cycle then repeats and creates a series of output pulses.

Compared to the Monostable circuit, the Astable circuit connects the trigger pin to the capacitor and adds a resistor between the discharge and threshold pins. An Astable circuit triggers from previous output pulse whereas a monostable circuit requires an externally applied trigger.

*In short, the output pin oscillates from high to low creating a series of pulses as the capacitor charge oscillates from 33.3% to 66.6% \(V_{cc}\) without any external triggers.*

The duration the output pin stays high, \(t_{HIGH}\), is given below:

\[
t_{HIGH} = 0.693 \times C \times (R_1 + R_2)
\]

The duration the output pin stays low, \(t_{LOW}\), is given below:

\[
t_{LOW} = 0.693 \times C \times R_2
\]

The frequency, \(f\), of the series of pulses is:

\[
f = \frac{1}{t_{HIGH} + t_{LOW}}
\]
The Astable 555 timer circuit can be used in the following applications:

a) Modulate transmitters such as ultrasonic and IR transmitters
b) Create an accurate clock signal (Example: There is a pulse accumulator pin on the 68HC11 microcontroller that counts pulses. You can apply an Astable 555 timer circuit set at 1 Hz frequency to the pulse accumulator pin and create a seconds counter within the microcontroller. The pulse accumulator will be covered in later in the course.)
c) Turn on and off an actuator at set time intervals for a fixed duration

3. Remotely Controlled LED using a 555 Timer

An Astable 555 Timer circuit can be used to generate a square wave signal with an accurate frequency. This signal can drive an infrared Light Emitting Diode (LED) through the output pin of the 555 timer. Adding a switch to the IR LED circuit allows a user to choose when to power the IR LED with the signal.

A modulated IR detector can be used to detect the generated infrared wave pulses as long as the pulses frequency matches that of the modulated IR detector. Figures 4 and 5 show the circuits for the IR transmitter and receiver respectively.

![Figure 4 - IR Transmitter Circuit](image)

![Figure 5 - IR Receiver Circuit](image)
4. Lab Task

Your task is to assemble two circuits on physically separate boards for both the transmitter and receiver as per figures 4 and 5. Use the bench power supplies to power each circuit with 5V. Connect an oscilloscope to node A in figure 4 and you should be able to observe a square wave signal. Adjust the 10kΩ variable resistor until the signal at node A is a 38 kHz series of pulses. Your transmitter is now ready.

When the pushbutton is depressed the visible LED on the receiver should blink. Try to turn off the ambient light when you want to test the circuit in case of the ambient noise and make sure the IR LED is in direct line of sight of the IR receiver. If the visible led is blinking randomly, put exposed 35 mm camera film around the IR detector. (Note: Exposed 35 mm camera film blocks out visible light but is transparent to IR)

Questions:
   a) How far away can the transmitter and receiver be before the signal from the transmitter to receiver is lost?
   b) What applications can this circuit be used for?

5. Lab Deliverables

Demonstrate a working circuit setup to your lab instructor in person. Have the oscilloscope connected to the output node of the 555 timer to show the pulse frequency. Submit brief answers to the questions in the previous section by the due date.

6. Bill of Materials

Note that designations are specific to figures 4 and 5.

<table>
<thead>
<tr>
<th>Designation</th>
<th>Description</th>
<th>Part No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>R3, R4</td>
<td>120 Ω Resistor</td>
<td></td>
</tr>
<tr>
<td>R2</td>
<td>10 kΩ Variable Resistor (Potentiometer)</td>
<td>3006Y-1-103LF</td>
</tr>
<tr>
<td>R1</td>
<td>150 Ω Resistor</td>
<td></td>
</tr>
<tr>
<td>C1</td>
<td>10nF Capacitor</td>
<td></td>
</tr>
<tr>
<td>D1</td>
<td>IR LED</td>
<td></td>
</tr>
<tr>
<td>D2</td>
<td>Visible LED</td>
<td></td>
</tr>
<tr>
<td>IC1</td>
<td>555 Timer</td>
<td>LM555CN</td>
</tr>
<tr>
<td>IC2</td>
<td>IR Receiver</td>
<td>GP1UM261XK0F</td>
</tr>
<tr>
<td>S1</td>
<td>Push Button</td>
<td></td>
</tr>
</tbody>
</table>
7. Pinouts

555 Timer (IC1)

IR Receiver (IC2)