Study of IC Timer 555

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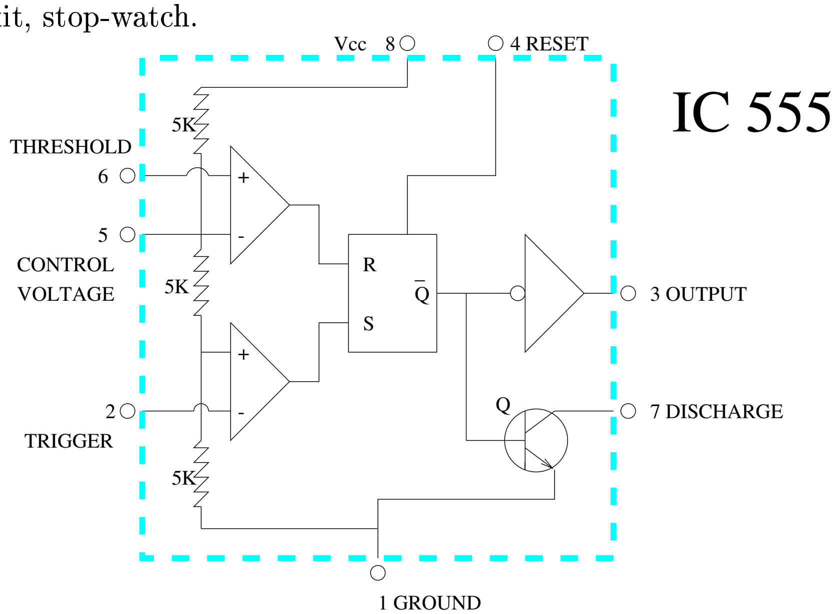
Aim: To study the IC 555 and set it up as a free-running and monostable multivibrator.

1 Apparatus

The IC 555 kit, stop-watch.



2 Theory

IC 555 timer is a highly stable integrated circuit capable of functioning as an accurate tim-delay generator and as a free-running multivibrator. The time delay and frequency is controlled by two external components, a resistor and a capacitor.

The functional block diagram of IC 555 is shown in the figure. It consists of two comparators, a flip-flop, an inverting amplifier, and a control transistor. Three resistors of 5K each form a potential divider so that, the upper comparator is held at a voltage $2/3V_{cc}$, and the lower one at $1/3V_{cc}$. One can see that if the trigger terminal 2 is brought at a voltage lower than $1/3V_{cc}$, it will trigger the lower comparator. The triggering of the lower comparator will bring the flip-flop to the low state, and so the inverting amplifier D will drive the output at terminal 3 high. This also makes the transistor Q non-conductive (because the biasing is zero). This state of the IC will remain so until the voltage across the threshold terminal 6 is raised above $2/3V_{cc}$. This will activate the upper comparator and will bring the flip-flop to a high state. As a result, the output at 3 will go low, and the transistor Q will become conductive.

2.1 Operation as a free-running multivibrator

The IC 555 used as an astable, that is, a free-running multivibrator has its trigger terminal directly connected to the threshold terminal 6. Thus, to start with, the timing capacitor

C has no charge over it. This triggers the lower comparator which, through the control flip-flop and the inverting amplifier, drives the output high and silmultaneously makes the discharge transistor Q non-conductive. As a result, the capacitor starts charging through resistors R_1 and R_2. When the capacitor charges to $2/3V_{cc}$, the threshold level of the upper comparator, it resets the flip-flop, which in turn drives the output to its normal low state and brings the transistor back to conduction. Now the terminal 7 is effectively connected to the ground through the transistor Q. So, the timing capacitor, instead of charging, starts discharging through the resistor R_2. The voltage across the capacitor gradually falls. When the voltage falls to $1/3V_{cc}$, the lower comparator is triggered and once again changes the state of the output and the discharge transistor. This causes the capacitor to charge again. Thus, one cycle is completed and initiates the next.

The process then continues, making the capacitor charge and discharge to $2/3V_{cc}$ and $1/3V_{cc}$ respectively. The high and low times of the IC are thus governed by the charging and discharging times of the timing capacitor. These can be calculated as follows:
duration of the high state = time to charge C from $1/3V_{cc}$ to $2/3V_{cc}$
duration of the low state = time to discharge C from $2/3V_{cc}$ to $1/3V_{cc}$
If the voltage across the capacitor is initially V_0, the voltage after a time t of charging is given by

$$(1 - \frac{V(t)}{V_{cc}}) = (1 - \frac{V_0}{V_{cc}})e^{-T_1/RC}$$

So, the time T_1 for charging from $1/3V_{cc}$ to $2/3V_{cc}$ is given by

$$\frac{1}{3} = \frac{2}{3}e^{-T_1/RC}$$

$$T_1 = log(2)RC = 0.693RC.$$

Discharging time from $2/3V_{cc}$ to $1/3V_{cc}$ is given by

$$\frac{1}{3}V_{cc} = \frac{2}{3}V_{cc}e^{-T_2/RC}$$

$$T_2 = log(2)RC = 0.693RC.$$

In our circuit, the charging is through $R_1 + R_2$ and discharge is only through R_2. Thus the time period of the full cycle is

$$T = log(2)(R_1 + 2R_2)C = 0.693(R_1 + 2R_2)C$$

Frequency is given by

$$f = \frac{1}{T} = \frac{1.44}{(R_1 + 2R_2)C}.$$

2.2 Operation as a monostable multivibrator

A monostable multivibrator has only one stable state, which in our case, will be the low state. So, once triggered, the device will go to the high state, and will return to the low state after a fixed time duration.

In the monostable hookup, the IC 555 has its trigger terminal 2 connected to some external trigger device, like a switch or the output of a pulse generator. The threshold terminal and the discharge terminal are connected to the timing capacitor which can charge through the resistor R_1 if the discharge transistor is not conductive.

To start with, the timing capacitor has no charge on it and the output is low. If the trigger terminal 2 is temporarily brought at a temperature lower than $1/3V_{cc}$, the lower comprartor gets triggered, which drives the output high and makes the discharge transistor nonconductive. The capacitor now starts charging. When the voltage acrosss it rises to the threshold of the upper comparator $2/3V_{cc}$, the upper comparator is triggered and the output becomes low, the transistor becomes conductive and the capacitor discharges through it immediately. The output now remains low until another trigger signal is sent to the terminal 2. While the output was high, any further triggering would have had no effect.

The duration of the high state can be calculated from the charginng eqation.

$$(1 - \frac{V(t)}{V_{cc}}) = (1 - \frac{V_0}{V_{cc}})e^{-T_1/RC}$$

Here $V_0 = 0$ and $V = 2/3V_{cc}$. Thus

$$\frac{1}{3} = e^{-T/RC}$$

$$T = log(3)RC = 1.1RC.$$

One can see that if a series of negative pulses is applied on the trigger terminal, the output will go high on the first pulse, and will remain high for a time $1.1RC$. All subsequent pulses in this duration will be ignored. After the output goes low, the next pulse will again drive it to a high for a time $1.1RC$. At the output of the IC555 one will see a rectangular wave form whose high width will be $1.1RC$ and the low width will be less than or equal to the interval of input pulses.

3 Procedure

3.1 Setup as a free running multivibrator

Connect the power supply unit (PSU) to IC555 by joining the V_{cc} terminal 8 to +9V of the PSU and the ground terminal 1 to the ground of the PSU.
Connect the threshold terminal 6 directly to the trigger terminal 2.
Connect resistor R_1 between the V_{cc} terminal 8 and the discharge terminal 7.
Connect resistor R_2 between the discharge terminal 7 and the threshold terminal 6.
Connect the timing capacitor C between the threshold terminal 6 and the ground.

1. First choose R_1 and R_2 to be as large as possible - say, 56K and 4.7M - and let C be 0.68μF. Connect the output terminal to the LED. Switch on the power. At this point, the LED should start flashing on and off. Measure the flashing time period with a stop watch. Compare this with the theoretical value.

2. Choose R_1, R_2 and C small. Connect the output terminal 3 to the input of a CRO, and connect the ground of the CRO to the ground of the circuit. Get the rectangular waveform and measure the durations of the high state and the low state. Compare these with the theoretical value.

3. Instead of the output terminal 3, connect the threshold terminal 6 to the CRO input. If the input impedance of the CRO is high, you should be able to see the charging and discharging curves of the timing capacitor C on the CRO screen. Do they appear to be exponential curves?

4. Connect the control voltage terminal to the output of the variable dc source (called voltage trigger in the setup). Connect the output terminal 3 to the CRO input. Vary the voltage by turning the knob. What happens to the waveform? Explain why it happnes.

3.2 Setup as a monostable multivibrator

Connect the power supply unit (PSU) to IC555 by joining the V_{cc} terminal 8 to +9V of the PSU and the ground terminal 1 to the ground of the PSU.
Join the discharge terminal 7 directly to the threshold terminal 6.
Connect resistor R between the threshold terminal 6 and V_{cc}.
Connect the timing capacitor C between the threshold terminal 6 and the ground.

1. Initially choose a large value for R (say 4.7M) and a large value for the timing capacitor too (0.68μF). Connect the trigger terminal 2 to the *manual trigger* switch provided on the setup. Connect the output terminal 3 to the LED. Switch on the circuit. Press the manual trigger switch once. The LED should glow for a short while and then go off. Measure this duration with a stopwatch. Compare it with the theoretical value $1.1RC$.

2. Connect the output of the *variable frequency trigger* provided on the setup to a CRO and note the kind of waveform and its frequency. Make sure that the frequency varies on turning the knob.

3. Connect the trigger terminal 2 to the variable frequency trigger output. Choose a small value of R and connect the output terminal 3 to the CRO. Get the rectangular waveform. Measure the duration of the high state. Vary the frequency of the trigger pulses by turning the knob. Does the duration of the high state change? Why?

4. Connect the CRO to the threshold terminal 6, instead of the output terminal. If the input impedance of the CRO is high, you should see the charging curve of the timing capacitor on the CRO screen.