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Design and implementation of an astable multivibrator

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Abstract

The purpose of this paper was to design and implement an astable multivibrator circuit using a 555 timer integrated circuit (IC). An astable multivibrator is a type of electronic oscillator that generates a continuous stream of rectangular voltage pulses without any external triggering. The key motivation behind this work was to develop a simple and cost-effective astable multivibrator that can generate waveform signals for various timing and pulse generation applications. The circuit was designed using standard 555 timer configuration with resistors R1=3.3kΩ, R2=5.6kΩ and capacitor C1=100μF to control the pulse characteristics. The supply voltage was 9V DC. As per the design calculations, the circuit was expected to generate a 1Hz rectangular waveform with 61% duty cycle. The circuit was tested by observing the output waveform on an oscilloscope which matched closely with the designed values, validating the correct working of the implemented astable multivibrator. The active devices in the 555 timer IC generate the oscillations by alternately charging and discharging the timing capacitor based on certain voltage threshold levels, as set internally. Overall, through this work, a functional 555 timer based astable multivibrator was designed and its working was verified experimentally. Such multivibrator circuits find wide applications in timing controls, waveform generation, modulators, timers and other digital systems. The simple implementation makes it useful for learning and prototyping needs.

Keywords: 555 timer IC; Astable multivibrator; Oscilloscope; Square wave pulse; Transistors

1. Introduction

As the world keeps growing in technology, over the years, electronic circuits got more and more complicated and it became impossible to have advanced applications without multiple states [1]. An electronic oscillator is an electronic circuit that produces a periodic, oscillating electronic signal, often a sine wave, square wave or a triangle wave. Oscillators convert direct current (DC) from a power supply to an alternating current (AC) signal [2]. Oscillators are broadly classified into two categories namely sinusoidal and non-sinusoidal oscillators. Sinusoidal oscillators produce a sine wave output and the non-sinusoidal oscillators produce a square or pulsed output [3]. Multivibrator circuits are basically non-sinusoidal oscillators with regenerative feedback. A multivibrator is an electronic circuit used to implement a variety of simple two-state devices such as relaxation oscillators, timers and flip-flops [4]. It consists of two amplifying devices (transistors, vacuum tubes or other devices) cross-coupled by resistors or capacitors Multivibrators are classified into three types based on the circuit operation, namely Astable multivibrators, Bistable multivibrators and monostable multivibrators [5]. The astable multivibrator is not stable and it repeatedly switches from one state to the other. In monostable multivibrator, one state is stable and remaining state is unstable. A trigger pulse is the root to the circuit to enter the unstable state. When the circuit enters into the unstable state, then it will return to the normal state after a fixed time. A bistable mutivibrator circuit is stable that can be changed from one stable state to the other by an external trigger pulse [6]. Unlike the Astable, monostable and bistable multivibrators require the addition of clock pulses or trigger to cause them to change their state, clock pulses are generally continous square

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or rectangular shaped wave-form [5]. This multivibrator circuit is also called as flip-flop which can be used to store one bit of data. However, for the course of this work we are dealing with an astable type of multivibrator. This type of multivibrator includes two amplifying stages that are connected with a two capacitive-resistive coupling networks in a positive feedback. The design of the astable multivibrator using a 555 timer IC is done by using resistors and capacitors. The 555 timer IC affords exact time delay from microseconds (ns) to hours (hrs). The oscillation frequency can be measured manually by small modification. 555 timer IC (integrated circuit) is a relatively cheap, stable and user-friendly integrated circuit.

2. Methodology

Most multivibrator circuits employ complex and sophisticated design while some use bipolar junction transistors (BJT) and Operational Amplifiers (Op Amps) to achieve the same result. Here, a less expensive approach is used and it is based on the use of a 555 timer integrated circuit (IC). With this method, the astable multivibrator generates a continuous stream of square ON-OFF pulses that switches between two voltage levels, the frequency of the pulses and their duty cycle are dependent upon the RC network values.

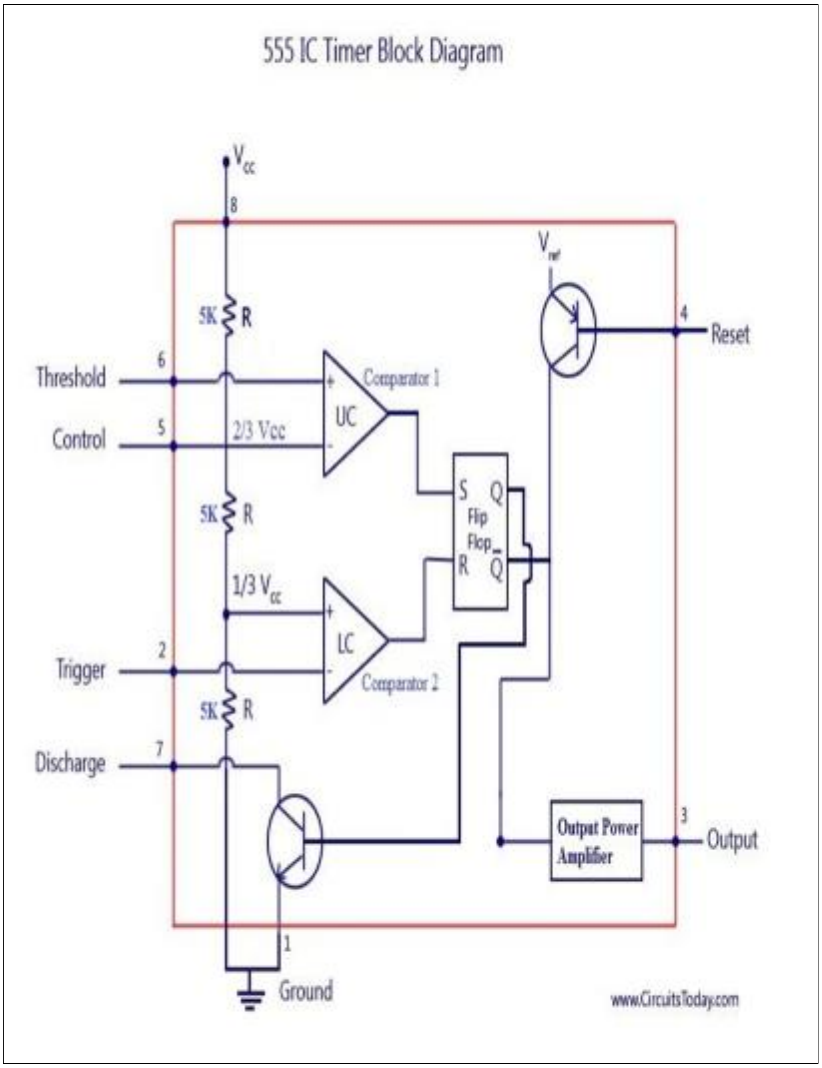

Figure 1 Circuit diagram of 555 timers IC

2.1. Operations of 555 timer

The trigger and threshold pin are connected together so, there is no need of external trigger pulse. The comparator will output HIGH while charging the trigger pin is still lower than 1/3 of supplied voltage. At this time, the output of timer is High. Once the voltage across reaches 1/3 of the voltage, the trigger comparator will output LOW, keeping the situation unchanged as both R and S input of the flip-flop are LOW. Once the voltage across the capacitor reaches 3/7 of applied voltage, the threshold comparator will output HIGH to R input of the flip-flop. Now, the capacitor will start discharging through resistor R_2 and also through the discharging transistor. The output of 555 timer is low at this point. Once the voltage across capacitor drops to 1/3 of the supplied voltage, the trigger comparator will output HIGH. (Goyal, 2015).

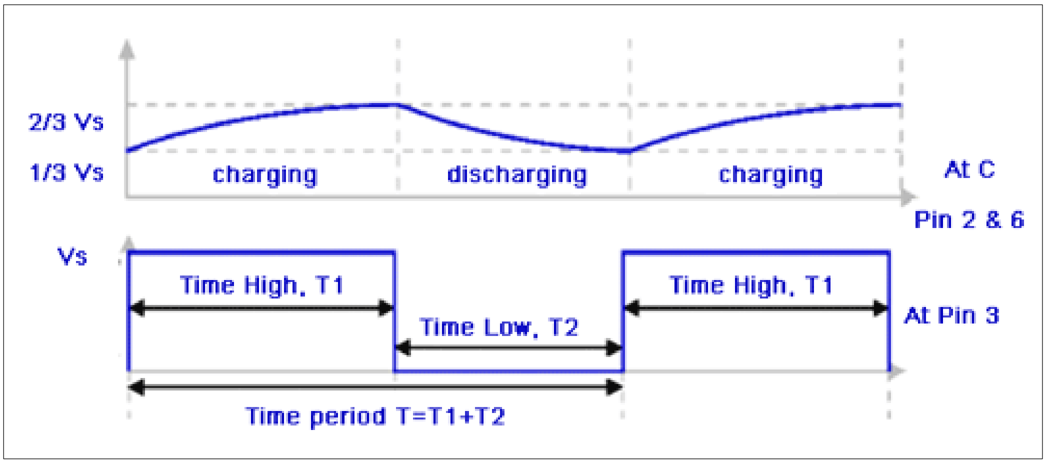

Figure 2 Output of the 555 timer IC

Consequently, the output of this configuration can be easily calculated using the formula below. The Low time depends on R_2 and capacitor and the High time depends on R_1,R_2 and capacitor.

High Time $(T_H) = 0.693 \times (R_1 + R_2) \times (C_1)$ .... (1)

Low Time $(T_L) = 0.693 \times (R_2) \times (C_1)$ .... (2)

Period of one cycle $(T) = T_H + T_L = (R_1 + 2R_2) C_1$ .... (3)

Frequency $(F) = 1.44/ (R_1 + R_2) C_1)$ .... (4)

Duty cycle% = $(T_H/T) \times 100$ .... (5)

2.2. Complete Circuit Diagram

The figure below shows the complete circuit diagram of Astable Multivibrator using a 555 timer IC. Powered from a 9volt DC source is applied to the circuit. The timer is switched ON, i.e. the output is HIGH, and the transistor Q_2 will be in cut off region on receiving a LOW input signal. The capacitor charges through both the resistor R_1 and R_2 toward Vcc. The capacitor charging time is $T_1 = 0.693 (R_1 + R_2) \times C$.

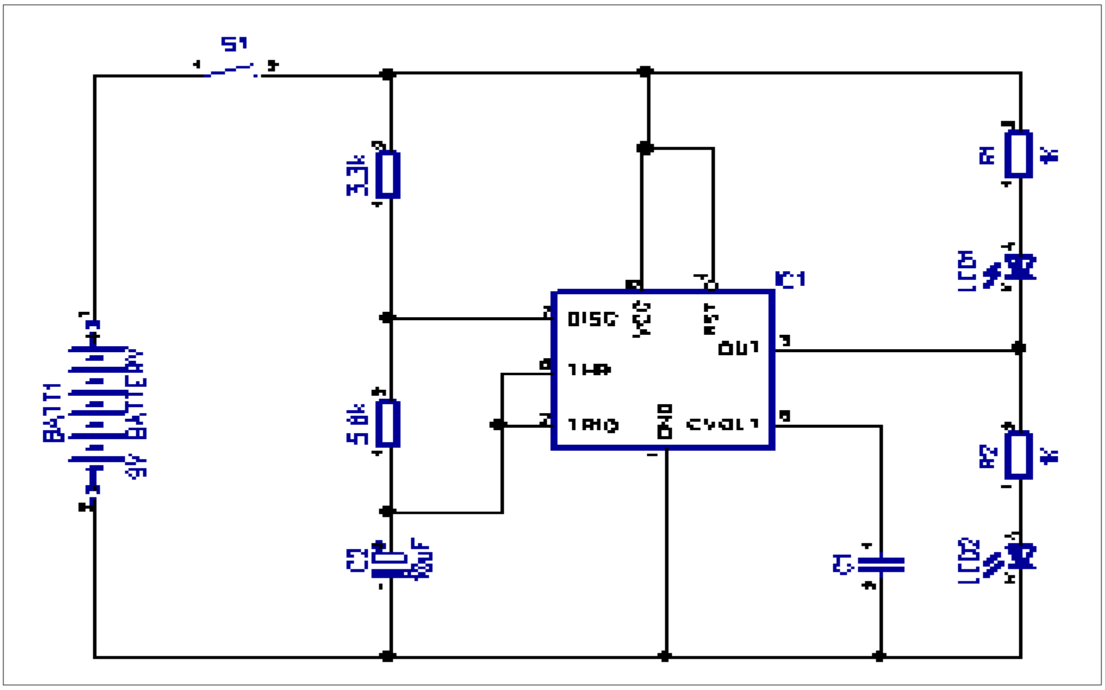

Figure 3 Circuit diagram of Astable Multivibrator using 555 timer IC

This capacitor voltage is the threshold voltage to the upper comparator. As the voltage exceeds 2/3 VCC, the upper comparator output resets the flip-flop, which turns the Timer output to OFF state (provided reset pin is in LOW state). The transistor T will in saturation region, i.e will be turned ON, providing a discharge path for the capacitor through resistor R_2, the discharge time being- **0.693R_2 x C.**

As the capacitor voltage falls below -1/3Vcc, the second comparator output sets the flip-flop, which makes the timer output LOW and the Timer output LOW and the whole process starts again. Thus the timer output oscillates between HIGH and LOW state, generating oscillations, and causing the LEDs to blink at 1sec interval.

2.3. Calculations

$$T_H = 0.693 \text{ X } (3.3\text{X}10^3 + 5.6 \text{ X}10^3) \text{ X } 100 \text{ X } 10^{-6} = \mathbf{0.61677sec} \quad \ldots\ldots\ldots\ldots\ldots(6)$$

$$T_L = 0.693 \text{ X } 5.6\text{X}10^3 \text{ X } 100 \text{ X } 10^{-6} = \mathbf{0.38808sec} \quad \ldots\ldots\ldots\ldots\ldots(7)$$

$$T = (T_H + T_L) = 0.61677 + 0.38808 = \mathbf{1.005\ Sec} \quad \ldots\ldots\ldots\ldots\ldots(8)$$

$$\text{Frequency (F)} = 1/T = 1/1.005 = 1\text{Hz} \ldots\ldots\ldots(9)$$

$$\text{Duty cycle \%} = T_H/T = (0.61677/1.005)\text{X } 100 = 61 \quad \ldots\ldots\ldots\ldots\ldots(10)$$

Figure 4 Output square waveform on oscilloscope

3. Results

The constructed astable multivibrator circuit was tested by applying a 9V DC supply. The output waveform was checked using an oscilloscope connected across the output pin (pin 3) of the 555 timer IC. The oscilloscope displayed a continuous train of rectangular pulses with a measured time period of 1.02 sec, which closely matched the theoretically calculated value of 1.005 sec. The high time (TH) of the pulse was found to be approximately 0.63 sec while the low time (TL) was around 0.39 sec. This resulted in a duty cycle of about 61.8% based on the formula:

$$\text{Duty cycle} = (TH/\text{Total time period}) \times 100.$$

The frequency of oscillation was calculated to be 0.98 Hz from the oscilloscope, which agreed well with the expected frequency of 1 Hz as per the design calculations using the RC network values of 3.3 kΩ, 5.6 kΩ and 100 μF. Additionally, it was visually verified that the two LEDs connected to the output were blinking alternatively for equal intervals of time at 1 sec rate, further validating the intended astable operation. The close agreement between the theoretically expected and experimentally measured timing parameters confirmed that the 555 timer circuit was working properly in astable multivibrator mode to generate free running rectangular pulses at the designed frequency and duty cycle. Minor discrepancies of 2-3% between calculated and measured values can be attributed to practical tolerances of the electrical components used as well as oscilloscope resolution constraints. Nonetheless, the functionality of the implemented circuit was successfully demonstrated. As intended, it can provide a simple waveform generator source for digital logic circuits and other square wave-based applications.

4. Conclusion

It would be inferred that multivibrators are vital circuits in the world of digital electronics. The development of this project has been carried out accordingly. The implementation of the project was also achieved. The overall goal was to develop an astable multivibrator that is dedicated to the generation of waveform for used in digital circuitry.

The use of waveform generated by the circuit provides many advantages over a traditional signal generator. These include excellent accuracy of output frequency, extreme flexibility for modulation and timing sequence.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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