PWM Generator Using 555 Timer IC

What is PWM?

Pulse Width Modulation (PWM) is a widely used technique in modern electronics for delivering power efficiently in systems like motor control and lighting control. Instead of supplying a continuous analog signal, PWM delivers power in the form of fast switching pulses.

The key parameters of a PWM signal are:

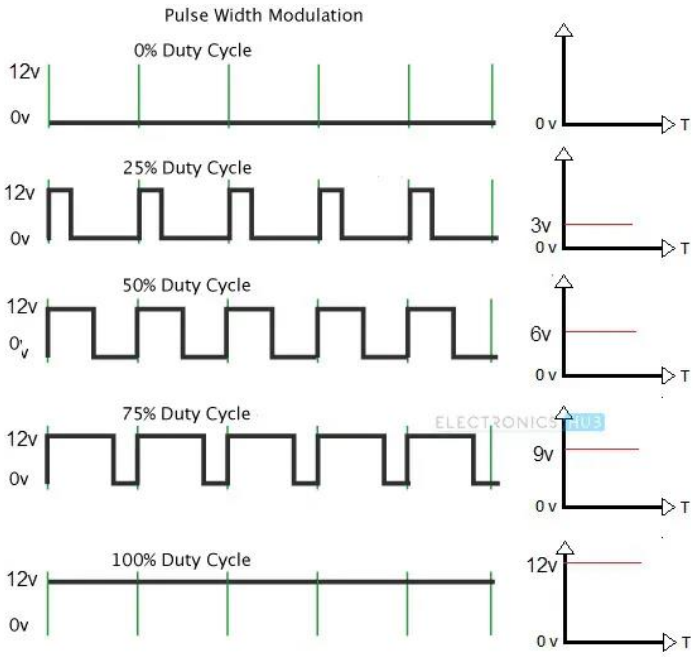
- **Duty Cycle:** Determines the percentage of time the signal stays HIGH during one cycle, influencing the average output voltage.

$$D = \frac{T_{high}}{T} \times 100$$

Where $T = T_{high} + T_{low}$.

- **Frequency:** Defines how many cycles occur per second.

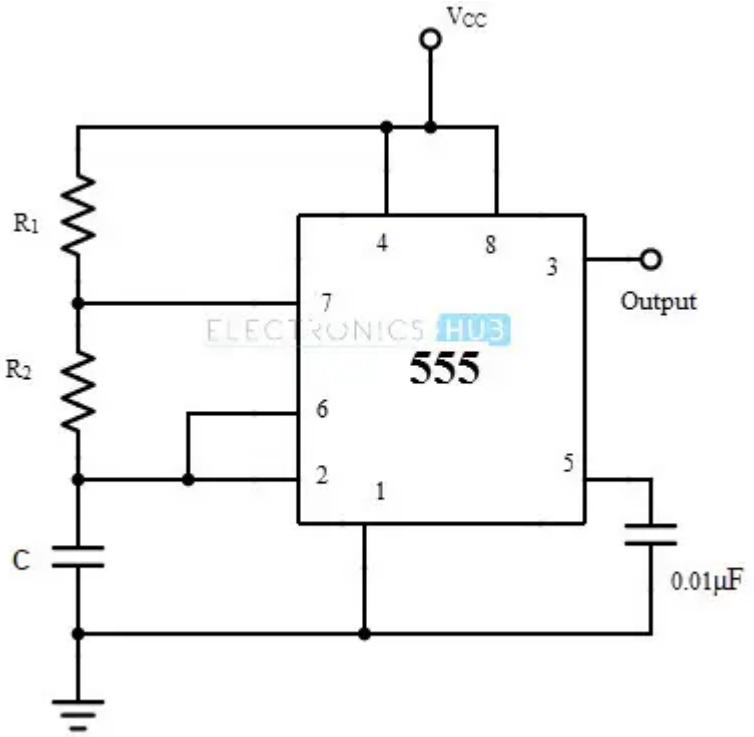
The image below illustrates different PWM signals with varying duty cycles and their corresponding output voltages:



How 555 Timer Works in Astable Mode

A **555 Timer IC** in astable mode operates as an oscillator without a stable state. It continuously toggles between HIGH and LOW states, making it ideal for generating PWM signals.

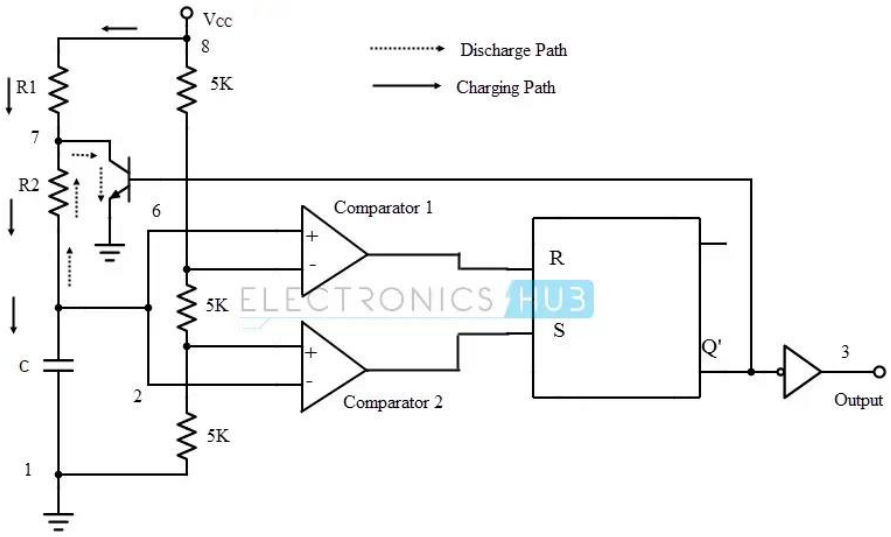
The circuit requires three additional components: two resistors and a capacitor. The simplified astable mode circuit is shown below:

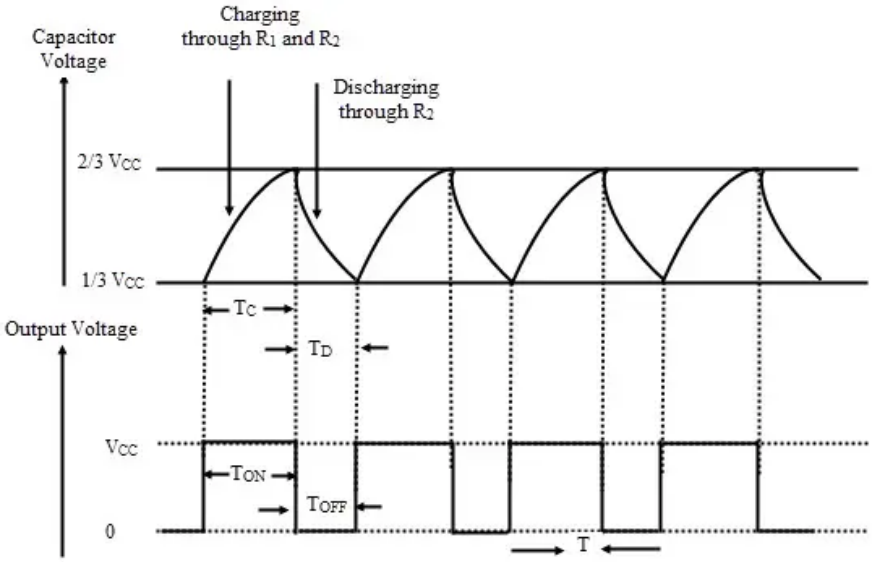


Operation:

1. Initially, the output is LOW, and the internal transistor of the 555 Timer discharges the capacitor through one of the resistors.
2. When the capacitor voltage drops below $\frac{1}{3}V_{cc}$, the output becomes HIGH, and the transistor turns OFF. The capacitor then charges through the resistors until its voltage exceeds $\frac{2}{3}V_{cc}$.
3. This cycle continues, producing an oscillating output signal.

The relationship between the capacitor voltage and output signal is shown below:





Duty Cycle and Frequency Formulas

For this circuit, the duty cycle and frequency are calculated using the following formulas:

$$T_{on} = 0.693 \times (R_1 + R_2) \times C$$

$$T_{off} = 0.693 \times R_2 \times C$$

$$T = T_{on} + T_{off} = 0.693 \times (R_1 + 2R_2) \times C$$

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

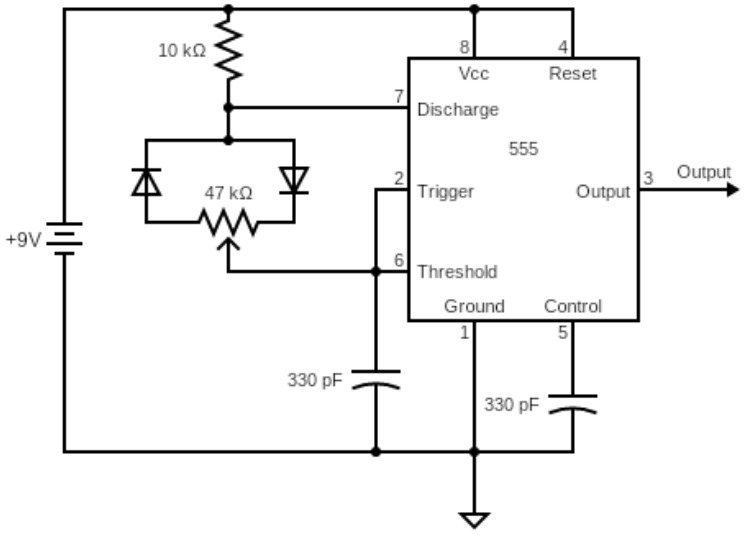
555 Timer PWM Generation

To generate a PWM signal, modifications are made to the basic astable circuit:

- Replace one of the resistors with a potentiometer.
- Add diodes in the charging and discharging paths of the capacitor.

The charging and discharging times of the capacitor determine the ON and OFF durations of the PWM signal, allowing the duty cycle to be adjusted by varying the potentiometer.

The circuit diagram for PWM generation using a 555 Timer IC is shown below:



For this project, the following components were used:

- **Resistor (R1):** 10kΩ
- **Potentiometer (R2):** 47kΩ
- **Capacitor (C):** 330pF ceramic capacitor
- **Diode:** 1N4007 (general-purpose rectifier diode)
- **Power Supply:** 9V battery

By sliding the potentiometer's wiper, the charging and discharging times of the capacitor are controlled, effectively adjusting the duty cycle of the PWM signal.

Working of the Circuit

In this modified circuit:

- The capacitor charges through R_1, one of the diodes, and the right side of R_2.
- It discharges through the other diode and the left side of R_2.
- Adjusting the potentiometer changes the capacitor's charging and discharging times, thereby controlling the duty cycle.

This setup allows for a variable duty cycle, essential for controlling the MOSFET in the DC-DC converters.

Conclusion

The PWM signal generated by this circuit is used to control the MOSFET switching in **Boost Converter**, **Buck Converter**, and **Buck-Boost Converter** projects. Adjusting the potentiometer enables precise control over the duty cycle, which is critical for regulating the output voltage of these converters.

Reference:

This content was adapted from the article on Electronics Hub.