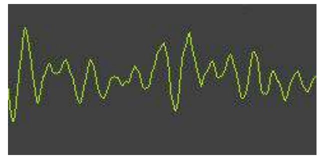
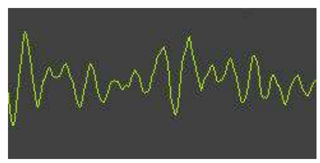
Electrical Waveforms



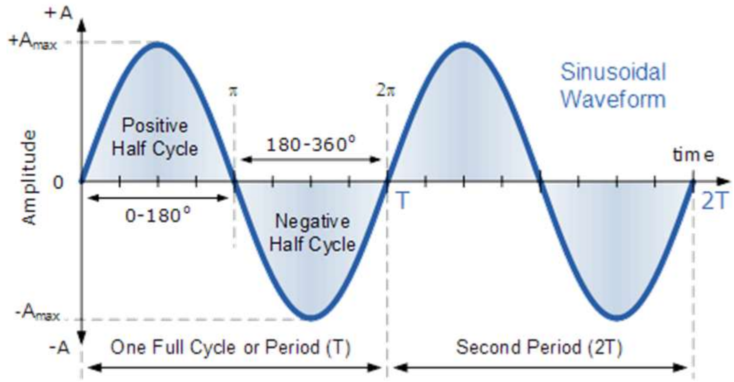
- 1. Uni-directional Waveforms – these electrical waveforms are always positive or negative in nature flowing in one forward direction only as they do not cross the zero axis point. Common uni-directional waveforms include Square-wave timing signals, Clock pulses and Trigger pulses.
- 2. Bi-directional Waveforms – these electrical waveforms are also called alternating waveforms as they alternate from a positive direction to a negative direction constantly crossing the zero axis point. Bi-directional waveforms go through periodic changes in amplitude, with the most common by far being the Sine-wave.

Electrical Waveforms



- Period: – This is the length of time in seconds that the waveform takes to repeat itself from start to finish. This value can also be called the *Periodic Time*, (T) of the waveform for sine waves, or the *Pulse Width* for square waves.
- Frequency: – This is the number of times the waveform repeats itself within a one second time period. Frequency is the reciprocal of the time period, ($ƒ = 1/T$) with the standard unit of frequency being the *Hertz*, (Hz).
- Amplitude: – This is the magnitude or intensity of the signal waveform measured in volts or amps.

A Sine Wave Waveform



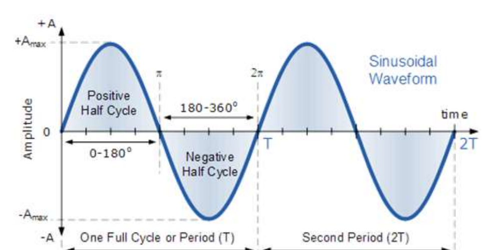
- Units of periodic time, (T) include: Seconds (s), milliseconds (ms) and microseconds (µs).
- **Frequency** with units of **Hertz, (Hz)**. Then Hertz can also be defined as “cycles per second” (cps) and 1Hz is exactly equal to 1 cycle per second.

A Sine Wave Waveform

- **Relationship between Frequency and Periodic Time**

$$\text{Frequency} = \frac{1}{\text{Periodic time}} \quad \text{or} \quad f = \frac{1}{T}\ \text{Hz}$$

$$\text{Periodic time} = \frac{1}{\text{Frequency}} \quad \text{or} \quad T = \frac{1}{f}\ \text{sec}$$



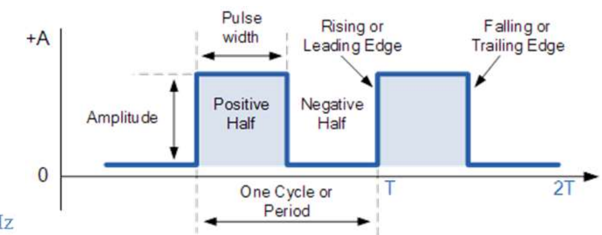
Prefix	Definition	Written as	Time Period
Kilo	Thousand	kHz	1ms
Mega	Million	MHz	1us
Giga	Billion	GHz	1ns
Tera	Trillion	THz	1ps

Square Wave Electrical Waveforms

- A **Square Wave Waveform** is symmetrical in shape and has a positive pulse width equal to its negative pulse width resulting in a 50% duty cycle. Square wave waveforms are used in digital systems to represent a logic level "1", high amplitude and logic level "0", low amplitude.

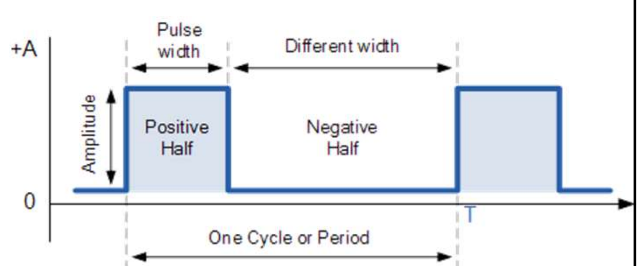
$$\text{Frequency} = \frac{1}{\text{"ON" time} + \text{"OFF" time}}$$

$$\text{Frequency} = \frac{1}{\text{Period}} = \frac{1}{10\text{mS} + 10\text{mS}} = 50\text{Hz}$$



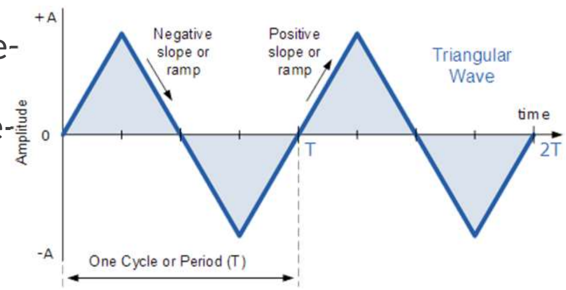
Rectangular Waveforms

- two pulse widths of the waveform are of an unequal time period. Rectangular waveforms are therefore classed as "Non-symmetrical" waveforms



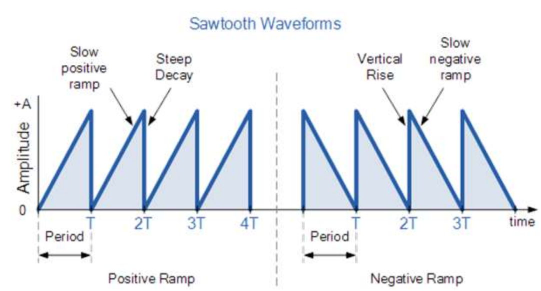
Triangular Waveforms

- **Triangular Waveforms** the positive-going ramp or slope (rise), is of the same time duration as the negative-going ramp (decay) giving the triangular waveform a 50% duty cycle. Then any given voltage amplitude, the frequency of the waveform will determine the average voltage level of the wave.

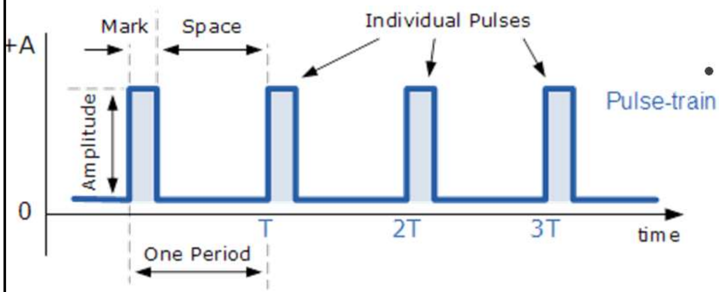


Sawtooth Waveforms

- The positive ramp **Sawtooth Waveform** is the more common of the two waveform types with the ramp portion of the wave being almost perfectly linear. The Sawtooth waveform is commonly available from most function generators and consists of a fundamental frequency (ƒ) and all its integer ratios of harmonics, such as: 1/2, 1/4, 1/6 1/8 … 1/n etc.

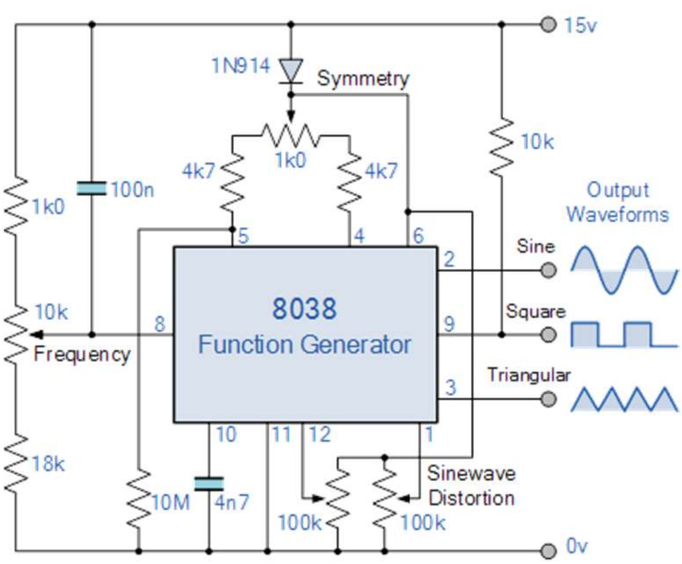


Pulse Waveform



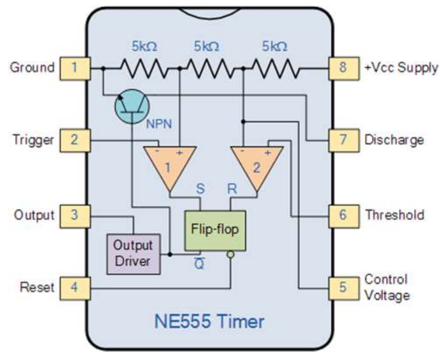
- A **Pulse Waveform** or "Pulse-train" as they are more commonly called, is a type of non-sinusoidal waveform that is similar to the Rectangular waveform we looked at earlier. The difference being that the exact shape of the pulse is determined by the "Mark-to-Space" ratio of the period and for a pulse or trigger waveform the Mark portion of the wave is very short with a rapid rise and decay shape as shown below.

Waveform Generator IC

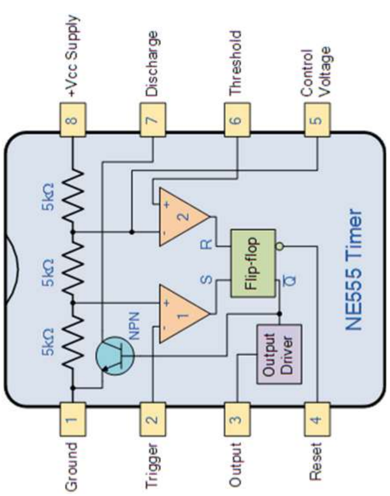


555 Timer Tutorial

The 555 Timer is a commonly used IC designed to produce a variety of output waveforms with the addition of an external RC network



SE555 Precision Timing Module



•• Pin 1. – **Ground**, The ground pin connects the 555 timer to the negative (0v) supply rail.

•• Pin 2. – **Trigger**, The negative input to comparator No 1. A negative pulse on this pin "sets" the internal Flip-flop when the voltage drops below 1/3Vcc causing the output to switch from a "LOW" to a "HIGH" state.

•• Pin 3. – **Output**, The output pin can drive any TTL circuit and is capable of sourcing or sinking up to 200mA of current at an output voltage equal to approximately Vcc – 1.5V so small speakers, LEDs or motors can be connected directly to the output.

•• Pin 4. – **Reset**, This pin is used to "reset" the internal Flip-flop controlling the state of the output, pin 3. This is an active-low input and is generally connected to a logic "1" level when not used to prevent any unwanted resetting of the output.

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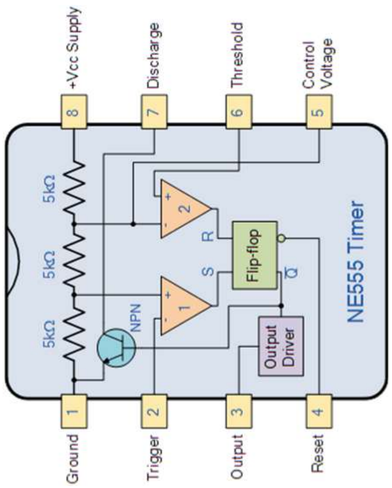
SE555 Precision Timing Module



- • Pin 5. – **Control Voltage**, This pin controls the timing of the 555 by overriding the 2/3Vcc level of the voltage divider network. By applying a voltage to this pin the width of the output signal can be varied independently of the RC timing network. When not used it is connected to ground via a 10nF capacitor to eliminate any noise.
- • Pin 6. – **Threshold**, The positive input to comparator No 2. This pin is used to reset the Flip-flop when the voltage applied to it exceeds 2/3Vcc causing the output to switch from "HIGH" to "LOW" state. This pin connects directly to the RC timing circuit.
- • Pin 7. – **Discharge**, The discharge pin is connected directly to the Collector of an internal NPN transistor which is used to "discharge" the timing capacitor to ground when the output at pin 3 switches "LOW".
- • Pin 8. – **Supply +Vcc**, This is the power supply pin and for general purpose TTL 555 timers is between 4.5V and 15V.

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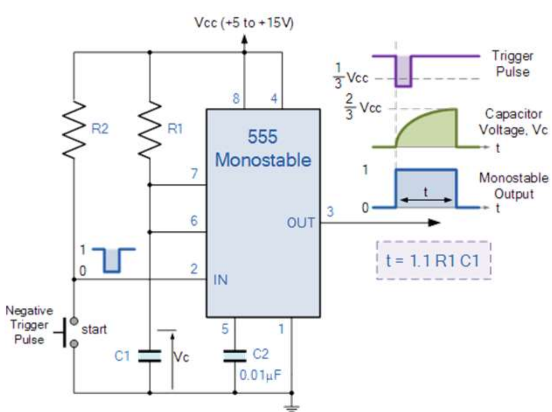
555 Mono stable Multivibrator



- The **Monostable 555 Timer** circuit triggers on a negative-going pulse applied to pin 2 and this trigger pulse must be much shorter than the output pulse width allowing time for the timing capacitor to charge and then discharge fully. Once triggered, the 555 Monostable will remain in this "HIGH" unstable output state until the time period set up by the R_1 x C_1 network has elapsed. The amount of time that the output voltage remains "HIGH" or at a logic "1" level, is given by the following time constant equation.

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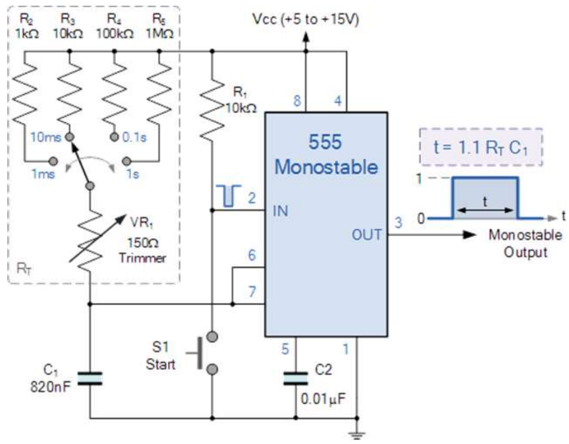
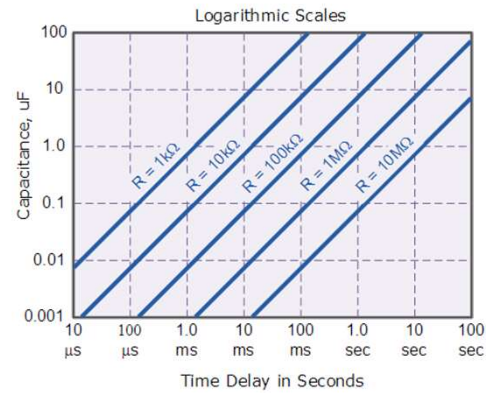
Switchable 555 Timer





Monostable Nomograph

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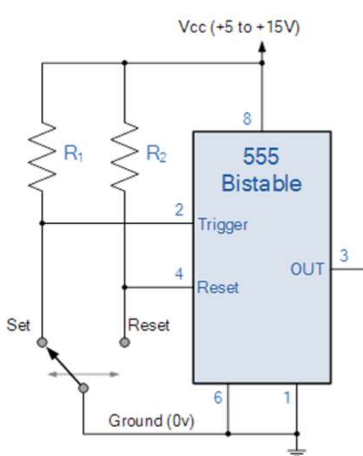
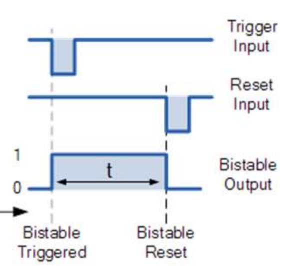
Bistable 555 Timer (flip-flop)





- The switching of the output waveform is achieved by controlling the trigger and reset inputs of the 555 timer which are held "HIGH" by the two pull-up resistors, R1 and R2. By taking the trigger input (pin 2) "LOW", switch in set position, changes the output state into the "HIGH" state and by taking the reset input (pin 4) "LOW", switch in reset position, changes the output into the "LOW" state.

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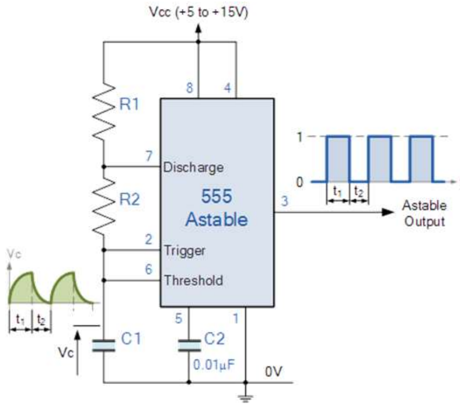
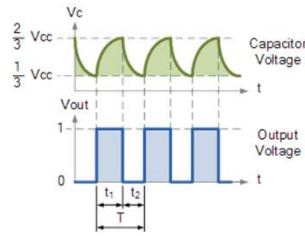
555 Astable Muitivibrator
Basic Astable 555 Oscillator Circuit





$$t_1 = 0.693(R_1 + R_2).C$$

and

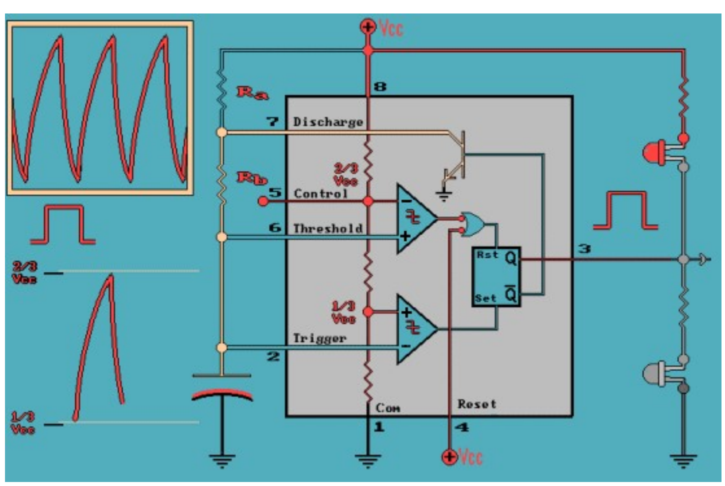
$$t_2 = 0.693 \times R_2 \times C$$

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

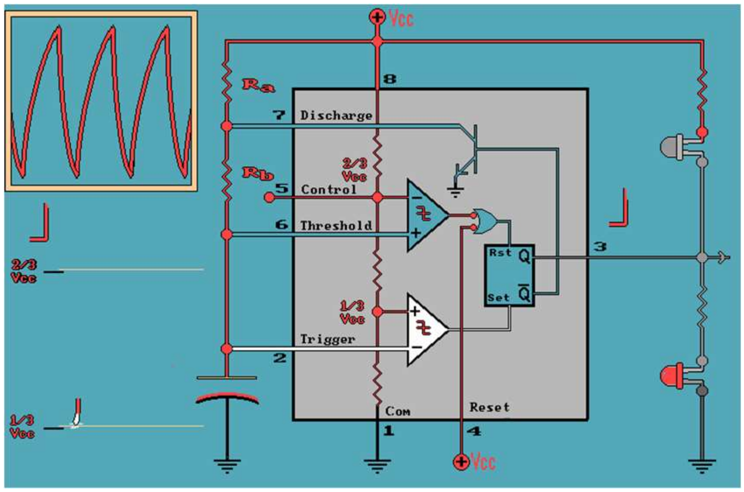
$$T = t_1 + t_2 = 0.693(R_1 + 2R_2).C$$

$$\text{Duty Cycle} = \frac{T_{ON}}{T_{OFF} + T_{ON}} = \frac{R_1 + R_2}{(R_1 + 2R_2)}\ \%$$

555 Astable multivibrator



555 Astable Multivibrator



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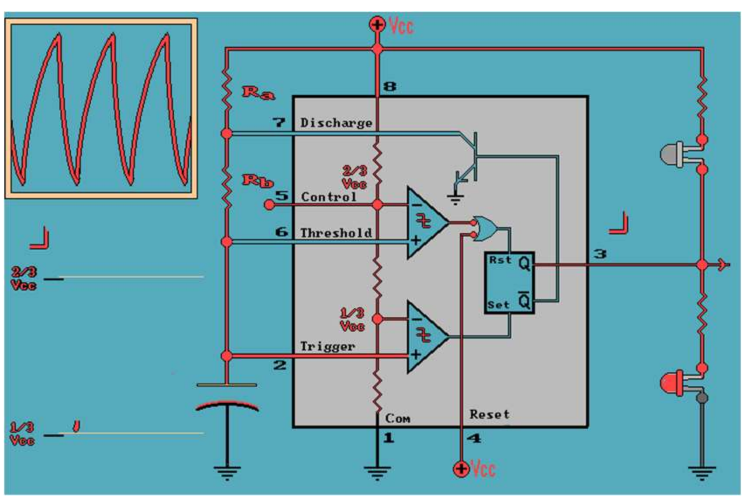
555 Astable Multivibrator



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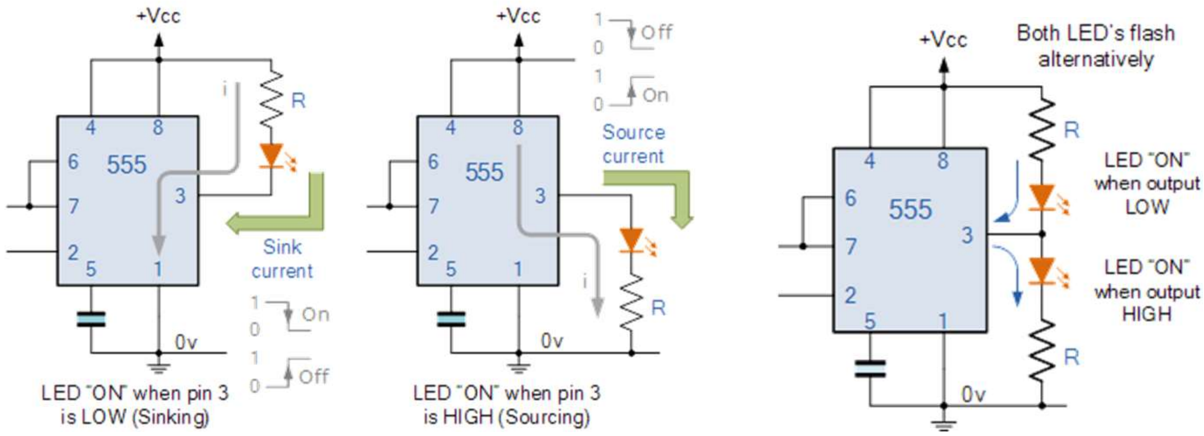
Sinking and Sourcing the 555 Timer Output



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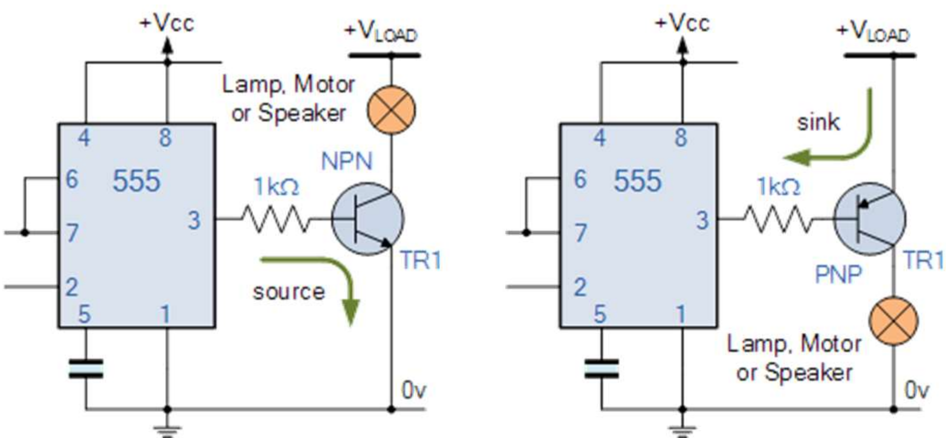
555 Timer Transistor Driver



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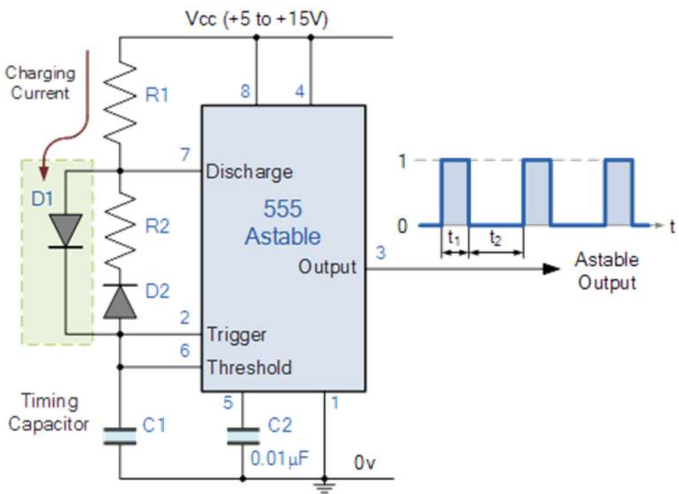
Improved 555 Oscillator Duty Cycle



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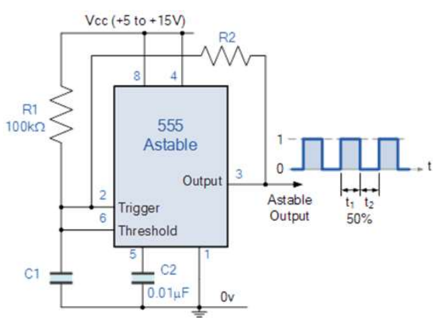
50% Duty Cycle Astable Oscillator



$$f = \frac{1}{0.693(2R_2).C}\ \text{Hz}$$

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