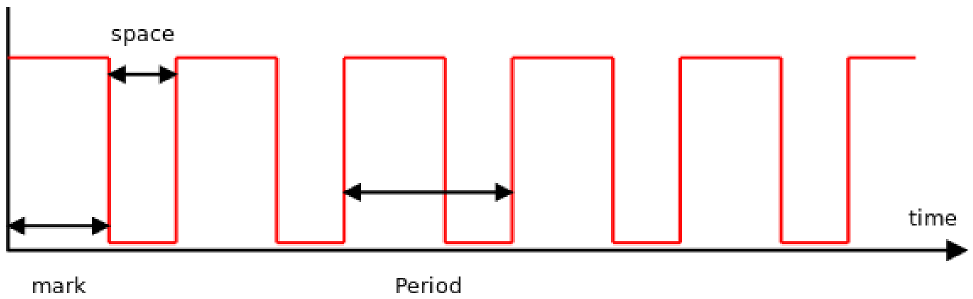
Astable Circuits

Introduction

An astable circuit is one that oscillates continuously between two states, it cannot settle into just one state. If the output is Logic 1 it will become Logic 0, if the output is Logic 0 it will become Logic 1.

The period of oscillation is determined by the timing components used. The output is HIGH for some period of time (called the Mark) and LOW for some period of time (called the Space). The mark - space ratio is determined by the choice of timing components and the design of the circuit.For a square wave, a mark - space ratio of 1:1 is required.

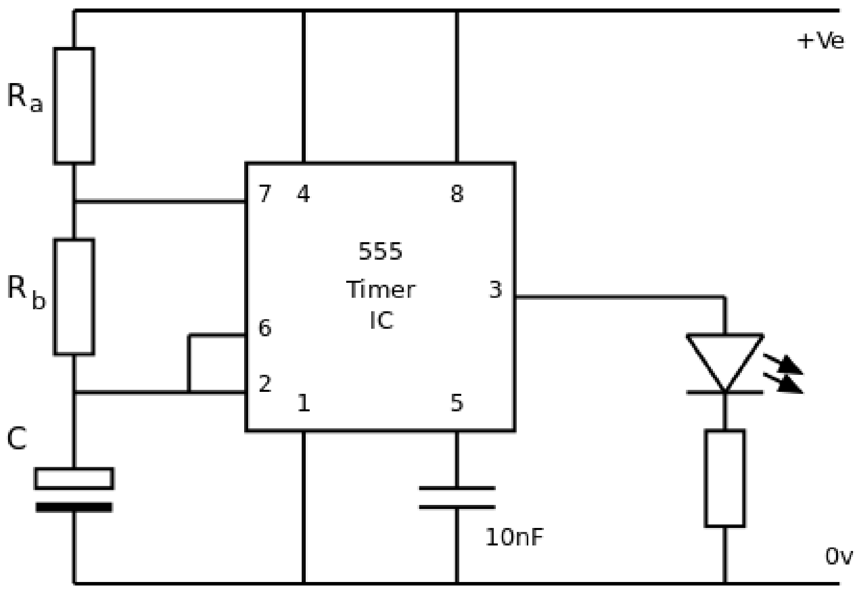
The period (T) of oscillation is the time for one complete cycle - this is related to the frequency by the equation *Frequency = 1 ÷ Time Period*



$$f = \frac{1}{T}$$

555 Astable Circuit

The 555 IC is used as an astable using the circuit shown. There are three timing components, R_a, R_b and C



555 Astable Time Period and Frequency

The time period depends on Ra, Rb and C.

The OUTPUT only oscillates when RESET (Pin 4) is held HIGH. If RESET (Pin 4) is momentarily LOW (connected to 0 V) then the output is reset to LOW and if RESET is held LOW, the OUTPUT stays LOW (0 V).

The time period of the 555 astable is given by the equation

$$T = 0.7 \times (R_a + 2R_b) \times C$$

As $f = \frac{1}{T}$ the frequency of the 555 astable is given by

$$f = 1.44 / [(R_a + 2R_b) \times C]$$

Note: The equations for Time Period and Frequency are equivalent because 1 / 0.7 = 1.44.

555 Astable Mark - Space Ratio

SPACE: In operation the output Q is LOW whilst the capacitor discharges - as this happens Pin 7 is held LOW by the internal circuitry of the 555 IC and so the capacitor discharges through R_b only. The time for this discharge is:

$$T_{space} = 0.7 \times R_b \times C$$

(the voltage across the capacitor halves)

MARK: When the capacitor is sufficiently discharged the output goes HIGH and Pin 7 is allowed to float. The capacitor now charges through Ra and Rb and so the time to charge is:

$$T_{mark} = 0.7 \times (R_a + R_b) \times C$$

The space is always shorter than the mark. The mark-space ratio cannot be 1:1.

MARK - SPACE RATIO: The ON time divided by the OFF time is called the Mark - Space ratio. The Mark - Space ratio is given by:

$$\frac{T_{ON}}{T_{OFF}} = \frac{R_a + R_b}{R_b}$$

PERIOD: The total time period is given by adding the MARK and SPACE together:

$$T_{period} = T_{mark} + T_{space}$$

$$T = 0.7 \times (R_a + 2R_b) \times C$$

555 Astable Considerations

The 555 Astable is quick and easy to build. However, the following points should be noted:

- The 555 takes a lot of current as the output changes state. This can affect other ICs using the same power supply. A large value capacitor (47 μF) connected near to the 555 IC will help to reduce the impact of this problem
- The mark-space ratio cannot be 1:1. For a true square wave a different circuit is required
- If R_a << R_b the mark-space ratio is almost 1:1 and the time period is given by

$$T = 1.4 \times R_b \times C$$

e.g Ra = 1k, Rb = 47k etc

- The output of the 555 can source or sink up to 100 mA

555 Astable - Calculating timing component values

There are three components that determine the time period. The best way to approach the problem of what components to use is to (a) always use R_a as 1k unless there is a good reason such as needing a particular mark-space ratio, (b) make an informed intelligent guess for the value of C and then (c) calculate the value of R_b.

The value of R_b must be greater than 1 kΩ and less than 1 MΩ.

As an example, this is how to calculate the values required for a 555 based astable with a frequency of 100 Hz.

- f = 100 Hz requires T = 0.01 s
- No requirement for mark-space ratio is required and so we are free to choose
- Start with R_a = 1 kΩ (just a free choice but always a sensible option)
- It is easier to choose the capacitor value as we have a wider choice of resistors
- Choose C = 10 μF (just a guess)
- Calculate R_b = 115 Ω. This is too small, go back and guess a better capacitor
- Choose C = 10 nF (an informed guess)
- Calculate R_b = 714 kΩ. This is better but not convenient.
- Choose C = 22 nF (an even better guess)
- Calculate R_b = 324 kΩ, use 330 kΩ which is good enough

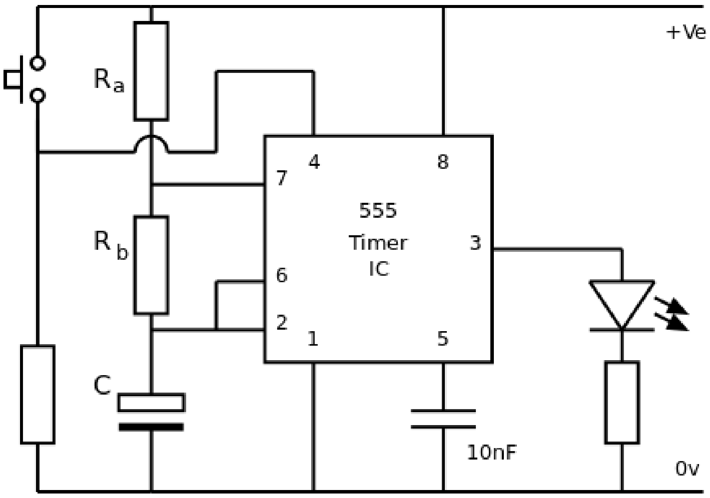
555 Astable RESET (Pin 4) used as an ENABLE

The RESET pin, Pin 4, on the 555 can be used as an enable

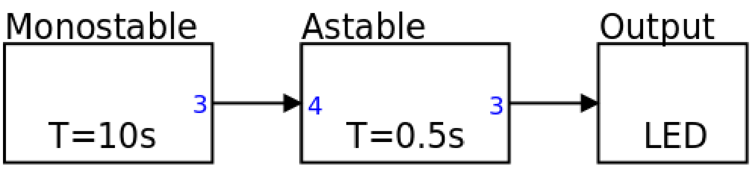
When Pin 4 is HIGH, the 555 Astable will oscillate

When Pin 4 is LOW, the output of the 555 Astable is 0 V (LOW) and the circuit does not oscillate

A push button (or other similar input) or a different subsystem can be used to control the 555 Astable by making Pin 4 either HIGH or LOW. In the circuit shown below, pushing the button makes Pin 4 HIGH and the Astable oscillate so that the LED flashes. When the button is not pushed, the pull down resistor (4k7 Ω) keeps Pin 4 LOW and the LED does not flash.



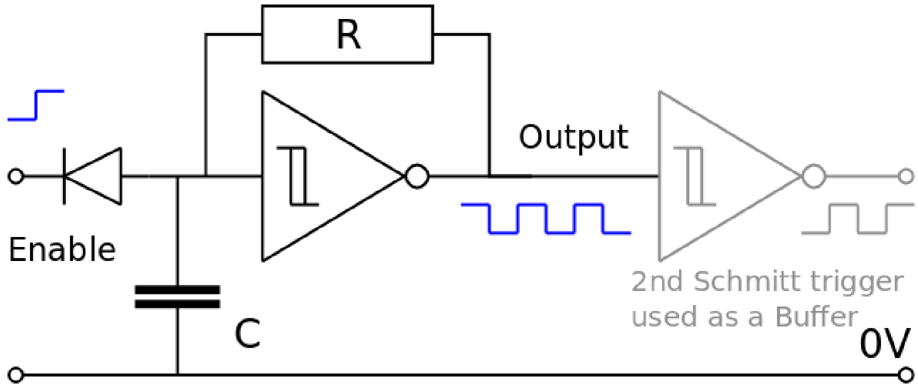
Alternatively the Astable can be controlled by a previous circuit. The system diagram below shows a Monostable with a 10 second time period (Trigger not shown) connected to an Astable with a time period of 0.5 seconds. The output of the Monostable (Pin 3) is connected to Pin 4 on the Astable. When the Monostable is triggered, the LED will flash at 2 Hz for 10 seconds. When the output from the Monostable goes LOW, the output of the Astable is reset and also goes LOW and the LED stops flashing.



Other Astable Circuits

Relaxation Oscillator

A very simple astable with a mark - space ratio of 1:1 is built around an inverting Schmitt trigger. The capacitor charges through the resistor from the output of the Schmitt trigger. To ensure reliable operation a high value resistor should be used (>10 kΩ) and the output should be buffered so that the current from the output of the Schmitt trigger is able to charge the capacitor as expected.



For CMOS based Schmitt trigger chips, the time period T is given by

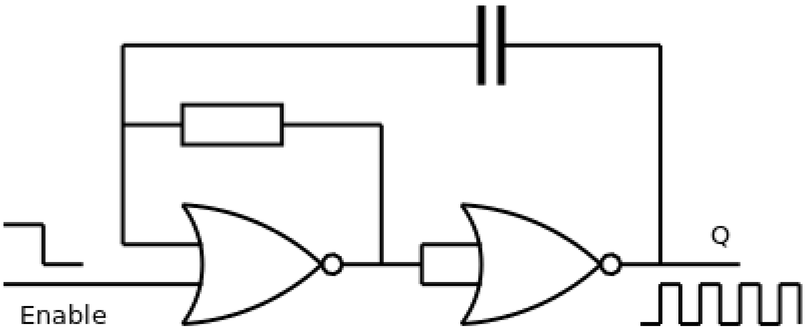
$$T = 0.5 \times R \times C$$

The equation for the time period is just an approximation and depends on the thresholds of the Schmitt trigger used.

In operation, Q will be permanently HIGH when the Enable is held LOW. When the Enable is HIGH, or simply not connected, the astable will oscillate.

NOR Gate Astable

There are many different ways to make an astable circuit using transistors or logic gates. One example is an astable made from NOR gates as shown below. The astable has a resistor and capacitor to determine the time period and an enable to allow the astable to be controlled. This astable produces a clean square wave (mark - space ratio = 1:1). The calculation of the time period depends on the types of logic gates used as different families of logic gate have different threshold voltages.



For CMOS gates, the time period T is given by

$$T = 1.6 \times R \times C$$

The equation for the time period is just an approximation. It is a good idea to make R a variable resistor so that the required time period can be achieved.

In operation, Q will be permanently HIGH when the Enable is held HIGH. When Enable falls LOW, the astable will oscillate.

Website

https://www.electronicsteaching.com/Electronics_Resources/DocumentIndex.html

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