555IC Timer as a Square Wave Generator

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***Abstract*—This is a simple explanation of how to use certain components to create a square wave output and how to choose your component values to get the desired frequency of oscillation, the equations will be explained through how the internals of these base components work.**

I. Introduction

THE purpose of this document is to clarify how these oscillator systems work but requires a basic understanding of how certain components work including digital circuitry such as an SR Latch and analogue components such as comparators.

II. 555 IC Timer

The very traditional 555 square wave generator circuit is generally the go to for generating square waves due to its low cost, easy variability and reliability proven by its years of use as the most popular IC ever.

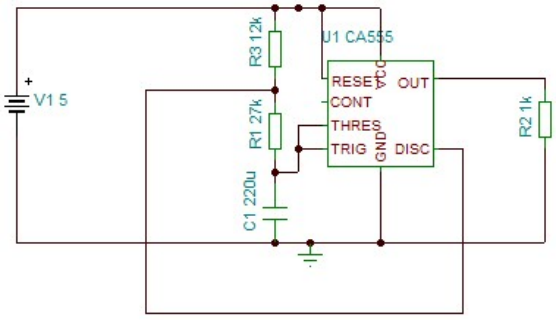

Fig. 1. Simple 555 IC Timer square wave output circuit

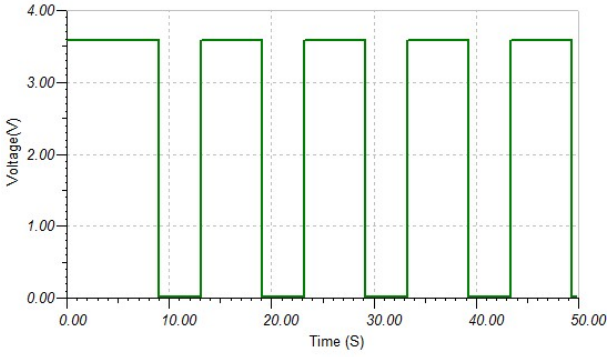

Fig. 2. Square wave output from Fig. 1.

III. Theory

The 555 IC timer functions generally by setting up a potential divider with 3 equal resistors where 2/3rds of the voltage is compared to the threshold and if so the SR latch outputs a High which is inversed to give a low at the out terminal. As the SR latch is high this triggers the transistor allowing current to flow from the capacitor to ground through the discharge channel which in this case is through R1, this is the parameter that sets the time low of an oscillation. Assuming the capacitor has charged and is now discharging the voltage is lowering and this time we look at the second comparator (in red), Once the voltage at this point goes below (Effectively equal to) 1/3rd of Vcc, given by the potential divider) the SR latch is forced output to low meaning the transistor is turned off forcing the capacitor to stop discharging, this then is inverted on the out pin to give a positive giving us our reliable square wave. The time high is therefore given by the value of time for the capacitor C1 to charge to 2/3rds the voltage from 1/3rd and time low is given by the discharge from 2/3rds to 1/3rd meaning different duty cycles can be achieved by different values of resistors but can be chosen to give a duty cycle of 50% meaning a normal square wave. As the system relies on the voltage dropping after reaching 2/3rds before the system reaches 1/3rd charge there is a setup time where the first pulse will not be the length calculated, this can be worth being mindful of.

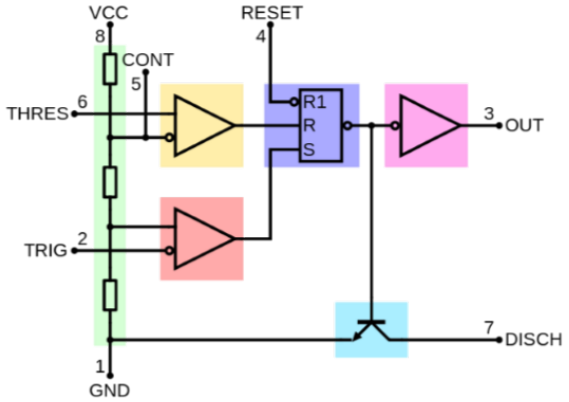

Fig. 3. Internals of a 555IC timer

IV. Calculations

The value of the time low in an oscillation is given by: T=0.693*R1*C As it is the time required for the capacitor to discharge from 2/3rds voltage to 1/3rd voltage Whereas for time high while charging is given by: T=0.693*(R1+R3)*C

As the capacitor charges through the 2 resistors not just R1 A single oscillation is therefore given by T= 0.693*(R1+R3)*C + 0.693*R1*C = 0.693*C*(2*R1+R3) For a duty cycle of 50% we know the time is equal in both regions so using our first 2 equations we get: 0.693*(R1+R3)*C=0.693*R1*C Therefore : R1+R3 = R1 We can see that to get a 50% duty cycle we can just move where the discharge connection is made on the circuit so that the time constants for charging is the same as that for discharging. Unfortunately from the internal diagram we can see that our discharge connection when the SR latch is high makes a direct connection to the ground which would short our supply out assuming the transistors constant current isnt low. So instead of connecting the pin 7 to our high rail we just use 2 separate resistors equal in value one from positive rail to capacitor the other from discharge connection to the capacitor. As a quick check we should apply our maths to the circuit designed and check that against the simulation T= 0.692*(27k+12k)*220u+0.693*27k*220u=10.06 Which our graph agrees with given the 10s separation after the setup time

V. Conclusion

The frequency of oscillation of a 555 ic timer can be set using the equations defined above by changing the circuit paramaters and therefore can create a variable frequency supply by having either a variable capacitor or resistor. The duty cycle of the oscillation can also be set through the circuit components once again by the equations stated in section IV.

References

[1] NE555 Datasheet, Archived from Texas Instruments, September 2014 https://web.archive.org/web/20170628232239/http://www.ti.com/lit/ds/symlink/ne555.pdf