THE 555 TIMER AND ITS APPLICATIONS

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ABSTRACT. The 555 timer is one of the most useful electronic devices in the market. The 555 timer was first introduced by Signetics but today it is manufactured by nearly all semiconductor firms. The cost of this device is low and it is widely available. The 555 timer has lots of uses such as: Mark Space Adjustment, Pulse Width Modulation and Inductive Current Detection just to name a few.

1. INTRODUCTION

The 555 has some unique advantages and capabilities, such as: low-cost, high operating voltage (5-15V) range, it is high powered and at the same time able to be triggered by small currents. It is usable astable or multivibrator modes.

The last feature of the 555 timer is the most commonly used feature. Here is the composition of a 555 timer:

Fig. 1.1: Internal Circuit of a 555 timer.

The 555 circuit is composed of two comparators, one ohmic ladder, one flip-flop and a discharging transistor, as it is shown in figure 1.1.
This circuit can be connected as a monostable multivibrator or an astable multivibrator. The 555 when used in monostable mode is shown in figure 1.2a. The trigger input sets the flip-flop which drives the output to high. The discharge transistor is turned off and therefore the capacitor $C_t$ is charged via $R_t$. When the voltage on the $C_t$ reaches the control voltage, which is defined by the three resistor voltage divider ($V_{cont} = \frac{2}{3}V_{cc}$), the flip-flop is resetted. This turns the discharge transistor on, which will discharge the $C_t$. Thereafter, the circuit will be charged again by a new pulse generated by the trigger. The timed period is given by the equation:

\[
T = 1.1 \left( R_t \times C_t \right)
\]

Were $T$ is the output pulse high period, $C_t$ the charging capacitance measured in Farads and $R_t$ the charging resistor in Ohms.

If the circuit is used as an astable multivibrator (figure 1.2b), comparator 2 of figure 1.1 sets the flip-flop. Then, the voltage on the capacitor $C_t$ falls below $\frac{1}{3}V_{cc}$, while comparator 1 resets the flip-flop when the voltage on the capacitor becomes greater than $\frac{2}{3}V_{cc}$. In this case, the discharge transistor is turned on. Which in turn will discharge the capacitor $C_t$ via $R_t$ with time given by $T$. This allows the 555 to be used as an oscillator. The time at the high and charging period is given by the equation:

\[
T_h = 0.7 \left( R_a + R_b \right) C_t
\]

While the time for the low period is given by the equation:

\[
T_l = 0.7 \left( R_b \times V_C \right)
\]

We can observe from the above equations that the duty cycle of the oscillator is always greater than 50% and that the charging time is always greater that the...
discharging time since $R_a + R_b > R_b$. Thus enabling us to see the oscillatory behavior of the 555 timer.

2. **Applications**

The broad use of the 555 timer as monostable or oscillator surpasses every other possible use. On the other hand the 555 can be an inexpensive alternative to many other different chips, therefore it is possible to solve some problems which at first seem huge, by the use of this 8 pin chip. Some advanced possible applications of the 555 are going to be presented in the following sections.

The 555 timer is a wonderful device that enables us to utilize it for certain applications that would otherwise involve costly circuitry or devices. Here are some of them:

2.1. **Mark Space adjustment.**

![Figure 2.1: Circuit for Mark-Space adjustment.](image)

The standard 555 oscillator circuit (figure 1.2b) has a disadvantage of having a duty cycle that is greater than 50%. However, this can be remedied by the use of a diode placed in parallel to $R_b$ (figure 2.1). Making it possible to charge $C_t$ only through $R_a$ resulting in mark-space adjustment that can be defined by the resistances of $R_a$ and $R_b$.

The duration of the high output and charging time is given by the equation:

\[
T_h = 0.7 (R_a * C_t)
\]

The effect of the diode forward bias voltage is neglected, as it is the case in most applications.

While the duration of the low output is given by the equation:

\[
T_l = 0.7 (R_b * C_t)
\]

This is the actual time equation since the diode is off during the discharge of the capacitor.
2.2. Pulse Width Modulation.

One of the most common used requirements of microcontroller-based or any digital circuits is to have the ability of transforming analog signals to digital signals. A/D circuits are expensive. They requiring clocks and voltage references which make the circuit more complex thus increasing cost. By using an inexpensive 555 chip it is possible to add A/D functionality in your circuits. This is provided that the delay of the A/D conversion is not crucial to the application, as is the case in most custom circuits.

In figure 2.2a the basic principle of the PWM circuit is shown. As you can see it is a variation of the monostable circuit figure 1.2a. The 555 is triggered by the CPU (with a negative pulse), this sets the flip-flop of figure 1.1. This will result in switching off of the discharge transistor. The capacitor $C_t$ is then charged until the voltage on $C_t$ becomes equal to the input voltage $V_{in}$. The moment comparator 1 resets the flip-flop, the output pulse is finished.

Unfortunately, the voltage on the capacitor is an exponential function in T. It would be better that the charging time be linear, so that the duration of the pulse would be linearly proportional to $V_{in}$.

This can be achieved by the use of the circuit of figure 2.2b which is a DC current supply. It is constructed using two current mirrors. This circuit is simple but there are many alternative DC current sources that can be used.

The current can be approximated by this equation:

$$I = \frac{(V_{cc} - 1.0V)}{R_b}$$

Yet this is a rough approximation, since transistor variations will not cover this current across accurately therefore the need for resistor adjustments, or PWM calibration.

2.3. Inductive Current Detection. In many applications such as a touch switch, current flow detection, or a revolution counter, it is desirable to be able to detect the existence of current flow in a circuit. In most application, this would be done using a current transformer. But a typical current transformer output a large voltage
pulse of around 5V. Power consumption can be kept low by using low inductive current which he 555 can detect.

![Figure 2.3: The Current Transformer Interfacing Circuit.](image)

The interface of a current transformer to a 555 monostable timer is given in figure 2.3. The diodes are present because the output of the current transformer is not well defined and the transient L-R-C oscillations could drive the output voltage high above the supply voltage $V_{cc}$ resulting in the overheating of the 555 timer.

By altering the value of resistor $R$ in figure 2.3, you change the sensitivity of the device, the smaller the value of $R$ is, the more sensitive and the larger the power consumption becomes. Since value of $R$ varies for every application, the user would have to experiment with different $R$ values to achieve the desired sensitivity level.

The user should also select the appropriate value for the charging resistor $R_t$ of figure 1.2a and the size of the capacitor $C_t$. $R_t \times C_t$ should be big enough to give the output pulse an adequate length, yet be small enough so that the 555 will be could be quickly reset versus the maximum frequency of the input signal.

3. Conclusion

We can see that the 555 timer is a marvelous device with a lot of important uses. It is clear that with a proper understanding of the device it can be utilitied for a variety of applications.

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