King Fahd University of Petroleum and Minerals

Department of Electrical Engineering

EE 434

Industrial Instrumentation

555 timer tutorial

<u>Q1:</u> A monostable configuration circuit using 555 timer is shown in figure1 below. According to the figure below, we can say the following:

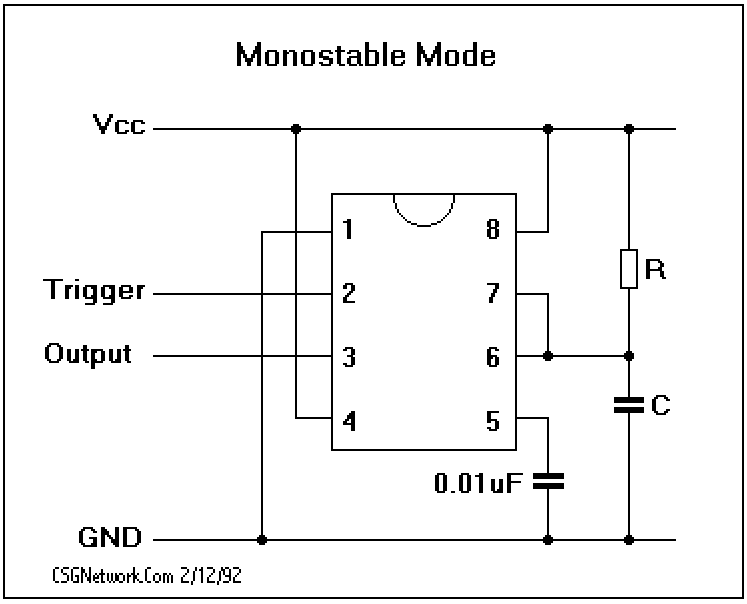

Figure 1: monostable configuration.

Once the trigger push button is pushed, the output of the circuit goes to logic 1 and hence the capacitor C will start charging via the resistor R till the voltage across it reaches a $\frac{2}{3}V_{CC}$ volt. In order to find the period T the capacitor takes to reach to that value, we can do the following:

$$-V_{CC} + iR + V_C(t) = 0$$

$$-V_{CC} + RC\frac{dV_C(t)}{dt} + V_C(t) = 0$$

$$\frac{dV_C(t)}{dt} + \frac{V_C(t)}{RC} = \frac{V_{CC}}{RC}$$

$$\boxed{V_C(t) = V_{CC} + Ae^{-t/RC}}$$

But

$$V_C(0) = V_{CC} + A = 0$$

$$A = -V_{CC}$$

$$\boxed{V_C(t) = V_{CC} - V_{CC}e^{-t/RC}}$$

This is the expression for the voltage across the capacitor as a function of time. The find the period, we can do the following:

$$V_C(T) = V_{CC} - V_{CC}e^{-T/RC} = \frac{2V_{CC}}{3}$$

$$1 - e^{-T/RC} = \frac{2}{3}$$

$$e^{-T/RC} = \frac{1}{3}$$

$$\frac{-T}{RC} = \ln(\frac{1}{3})$$

$$\boxed{T = 1.0986RC = 1.1RC}$$

As for the astable case, the configuration is shown in figure 2 below and we can derive the period expression in a similar manner.

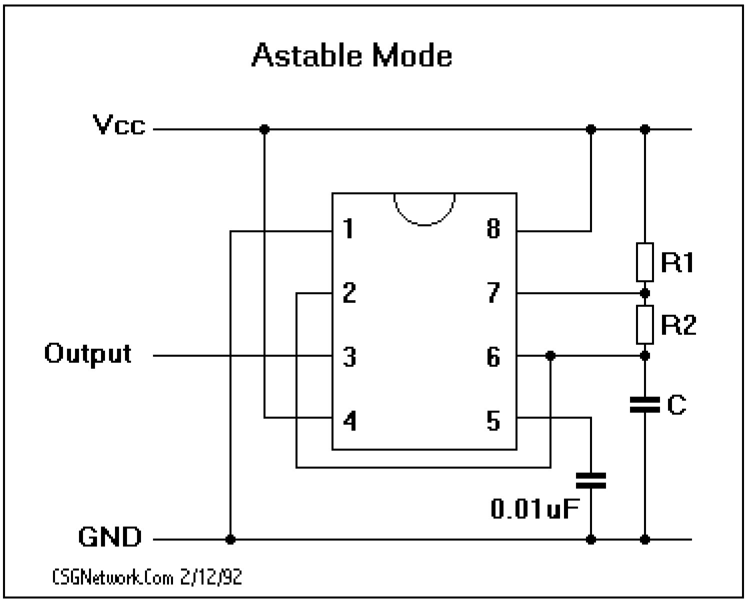

Figure 2: Astable configuration.

First, the period of the astable circuit is the sum of the time of discharging and the time of the charging of the capacitor. Thus:

1. The first charging period T_1 : the capacitor will charge via the resistors R_1 and R_2 till the capacitor voltage reaches a $\frac{2}{3}V_{CC}$ volt.

$$-V_{CC} + i(R_1 + R_2) + V_C(t) = 0$$

$$-V_{CC} + (R_1 + R_2)C\frac{dV_C(t)}{dt} + V_C(t) = 0$$

$$\frac{dV_C(t)}{dt} + \frac{V_C(t)}{(R_1 + R_2)C} = \frac{V_{CC}}{(R_1 + R_2)C}$$

$$\boxed{V_C(t) = V_{CC} + Ae^{-t/(R_1+R_2)C}}$$

But

$$V_C(0) = V_{CC} + A = 0$$

$$A = -V_{CC}$$

$$\boxed{V_C(t) = V_{CC} - V_{CC}e^{-t/(R_1+R_2)C}}$$

$$V_C(T_1) = V_{CC} - V_{CC}e^{-T_1/(R_1+R_2)C} = \frac{2V_{CC}}{3}$$

$$1 - e^{-T_1/(R_1+R_2)C} = \frac{2}{3}$$

$$e^{-T_1/(R_1+R_2)C} = \frac{1}{3}$$

$$\frac{-T_1}{(R_1+R_2)C} = \ln(\frac{1}{3})$$

$$\boxed{T_1 = 1.0986(R_1+R_2)C = 1.1(R_1+R_2)C}$$

2. The discharging period T_1: the capacitor will discharge via the resistor R_2 till its voltage drops to $\frac{1}{3}V_{CC}$.

$$R_2 i + V_C(t) = 0$$

$$CR_2 \frac{d\ V_C(t)}{dt} + V_C(t) = 0$$

$$\frac{d\ V_C(t)}{dt} + \frac{V_C(t)}{CR_2} = 0$$

$$\boxed{V_C(t) = Ae^{-(t-T_1)/CR_2}}$$

$$V_C(T_1) = A$$

$$A = \frac{2}{3}V_{CC}$$

$$\boxed{V_C(t) = \frac{2}{3}V_{CC}e^{-(t-T_1)/CR_2}}$$

$$V_C(T_2) = \frac{2}{3}V_{CC}e^{-(t-T_1)/CR_2} = \frac{1}{3}V_{CC}$$

$$2e^{-(T_2-T_1)/CR_2} = 1$$

$$\frac{-(T_2-T_1)}{CR_2} = \ln 0.5$$

$$\boxed{T_2 = 0.69CR_2 + T_1}$$

3. The charging period T_3: the capacitor will charge via the resistors R_1 and R_2 till the capacitor voltage reaches a $\frac{2}{3}V_{CC}$ volt.

$$-V_{CC} + i(R_1 + R_2) + V_C(t) = 0$$

$$-V_{CC} + (R_1 + R_2)C\frac{dV_C(t)}{dt} + V_C(t) = 0$$

$$\frac{dV_C(t)}{dt} + \frac{V_C(t)}{(R_1 + R_2)C} = \frac{V_{CC}}{(R_1 + R_2)C}$$

$$\boxed{V_C(t) = V_{CC} + Ae^{-(t-T_2)/(R_1+R_2)C}}$$

$$V_C(T_2) = V_{CC} + A = \frac{1}{3}V_{CC}$$

$$A = -\frac{2}{3}V_{CC}$$

$$\boxed{V_C(t) = V_{CC} - \frac{2}{3}V_{CC}e^{-(t-T_2)/(R_1+R_2)C}}$$

$$V_C(T_3) = V_{CC} - \frac{2}{3}V_{CC}e^{-(T_3-T_2)/(R_1+R_2)C} = \frac{2}{3}V_{CC}$$

$$1 - \frac{2}{3}e^{-(T_3-T_2)/(R_1+R_2)C} = \frac{2}{3}$$

$$\frac{2}{3}e^{-(T_3-T_2)/(R_1+R_2)C} = \frac{1}{3}$$

$$e^{-(T_3-T_2)/(R_1+R_2)C} = 0.5$$

$$T_3 - T_2 = 0.69(R_1 + R_2)C$$

$$T_3 = 0.69(R_1 + R_2)C + 0.69\mathrm{CR}_2 + T_1$$

Thus, the period of the square wave is $T_3 - T_1$ =

$$T = 0.69(R_1 + R_2)C + 0.69\mathrm{CR}_2$$

$$\boxed{T = 0.69C(R_1 + 2R_2)}$$

Q 2: from the first part, we can choose values for R and C to produce a 1 minute delay pulse.

$$T = 1.1RC = 60$$

$$let \quad C = 50\mu F$$

$$\Rightarrow R = \frac{60}{1.1 \times 50\mu} = 1090.91k\,\Omega = 1.09M\,\Omega$$

Q 3: using the second part of the first problem, we can design the astable circuit to produce mark time (T_3-T_2) of $77\mu s$ and space time (T_2-T_1) of $70\mu s$.

$$T_3 - T_2 = 0.69(R_1 + R_2)C = 77\mu s$$
$$AND$$
$$T_2 - T_1 = 0.69\mathrm{C}\mathrm{R}_2 = 70\mu s$$
$$let \quad \mathrm{C}=0.01\mu\mathrm{F}$$
$$\Rightarrow \mathrm{R}_2 = \frac{70\mu}{0.69 \times 0.01\mu} = 10.145k\Omega = 10.15k\Omega$$
$$\Rightarrow R_1 = \frac{77\mu}{0.69 \times 0.01\mu} - 10.15k = 1.009k\Omega = 1k\Omega$$

Q 4: we can design the second part of the first problem to have the mark time equals to the space time. Thus,

$$0.69(R_1 + R_2)C = 0.69\mathrm{C}\mathrm{R}_2$$

For this to be *almost* true, $R_2 \gg \mathrm{R}_1$

Another way, is to eliminate R_2 from the charging cycle and make R_2=R_1. This is done by placing a diode parallel to R_2 where the cathode terminal connected to the terminal of R_2 with the capacitor. Moreover, the value of R_2=R_1 should be much greater than r_d of the diode.

Q 5: we can modify the astable circuit to produce flashing light with different colors. Let us choose two colors flashing such that when one is on the other is off. The modification is shown in figure 3 below.

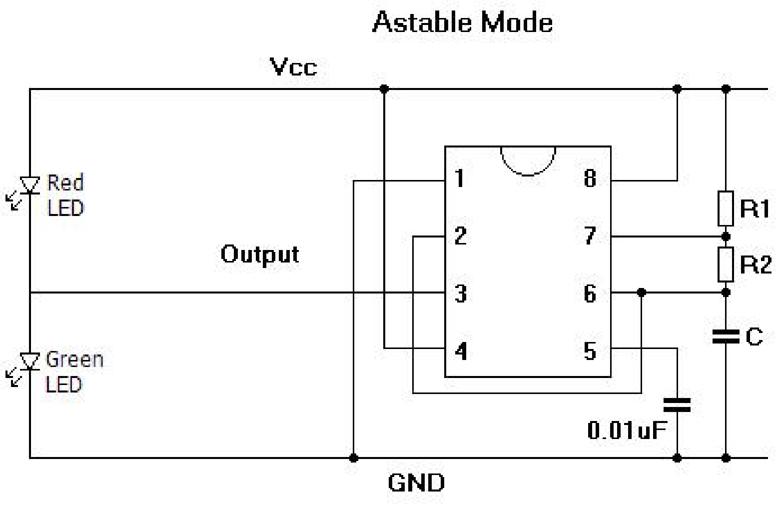

Figure 3: Flashing colors schematic.