Generation of FM signals using IC555

1 Objective

- Generation of FM signals using IC555 configured as voltage controlled oscillator.

2 Circuit and Its Working Principle

A voltage-controlled oscillator or VCO is an electronic oscillator whose oscillation frequency is controlled by a voltage input. Therefore, if a message signal is applied at the control input of the VCO, the frequency of the output signal will vary according to the amplitude of the message signal. This leads to the generation of FM signals.

For the implementation of the VCO, we consider IC555 timer.

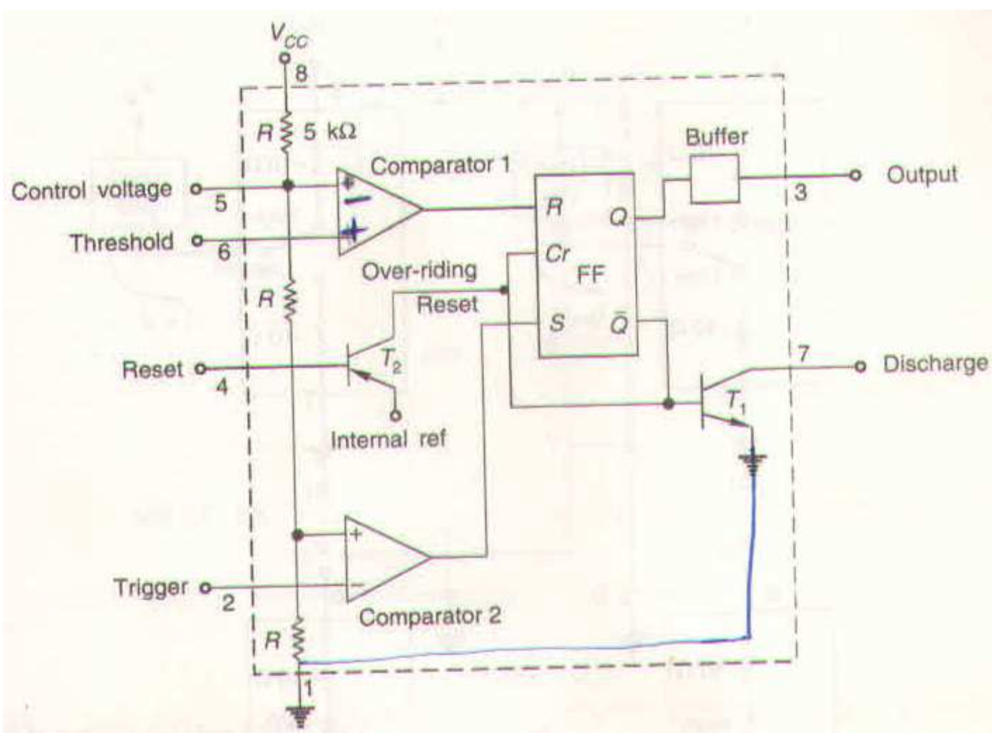

Figure 1: Functional block diagram of 555 timer

Figure 1 shows the functional block diagram of IC555. The control input is applied at PIN 5 and the output is obtained at PIN 3.

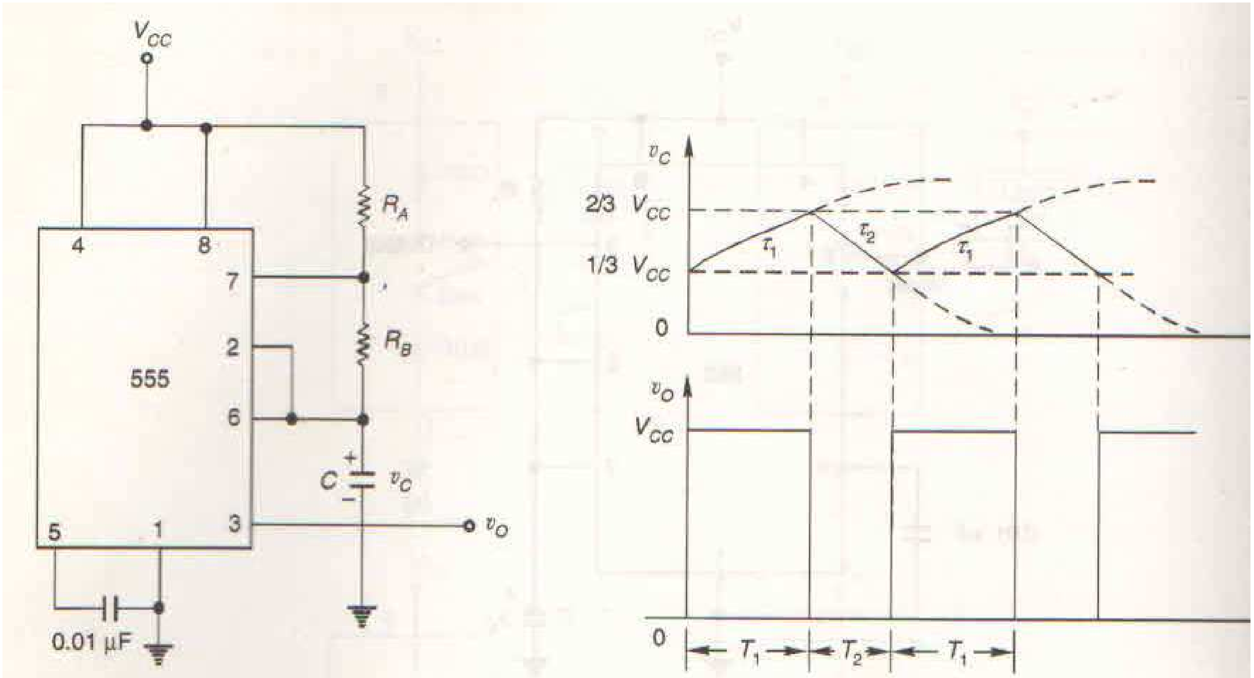

Figure 2: An astable multi-vibrator using IC555 and the corresponding waveforms

Figure 2 shows the circuit of an astable multi-vibrator using IC555. The control input point PIN 5 is connected to a capacitor 0.01uF. The output voltage v_0 and the voltage v_C across the capacitor C (connected at PIN 6) are shown in Figure 2. Observe from Figure 1 that the voltage at the negative point of comparator 1 is $\frac{2V_{CC}}{3}$. Since the control point (PIN 5) is connected to a capacitor, the control input voltage will remain at $\frac{2V_{CC}}{3}$. Moreover, the voltage at the positive end of comparator 2 is $\frac{V_{CC}}{3}$. Therefore, the voltage v_C across the capacitor C will lie in the range between $\frac{V_{CC}}{3}$ and $\frac{2V_{CC}}{3}$ as shown in Figure 2. The output v_0 will a square pulse waveform with on time T_1 and off-time T_2. T_1 and T_2 are given by

$$\begin{aligned} T_1 &\approx 0.7C(R_A + R_B) \\ T_2 &\approx 0.7CR_B \end{aligned} \tag{1}$$

The frequency of the square pulse is known as the *free-running* frequency and is given by

$$f_{\text{free}} = \frac{1}{T} = \frac{1}{T_1 + T_2} = \frac{1.4}{C(R_A + 2R_B)} \tag{2}$$

The voltage v_C (in yellow) across C and the output v_0 (in pink) as obtained from circuit simulator are shown in Figure 3.

In order to use IC555 as a frequency modulator, it must be configured as VCO. The message signal should be applied to the control input PIN 5 as shown in Figure 4. Therefore, instead of having a fixed control voltage (i.e. $\frac{2V_{CC}}{3}$), we now have a control signal (message) of varying amplitude. Figure 5 shows typical v_0 (in pink) and v_C (in yellow) after applying the square-wave message signal at PIN 5. The message signal is shown in green. Observe that the output is the desired FM signal.

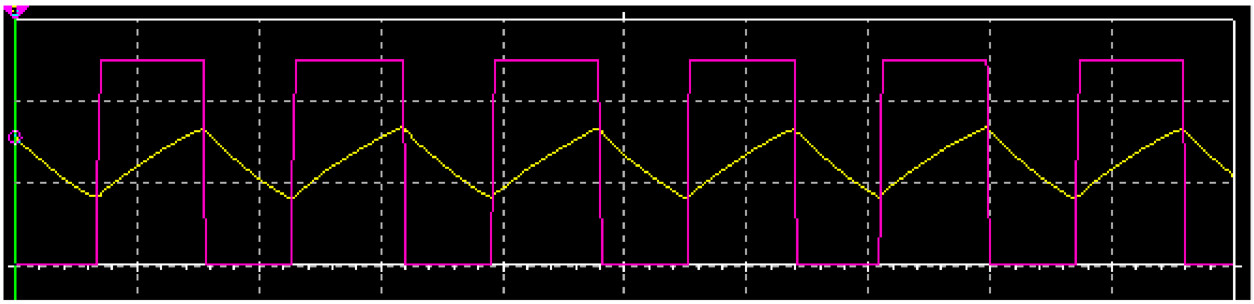

Figure 3: The output and capacitor voltage for the IC555 in the astable multivibrator mode

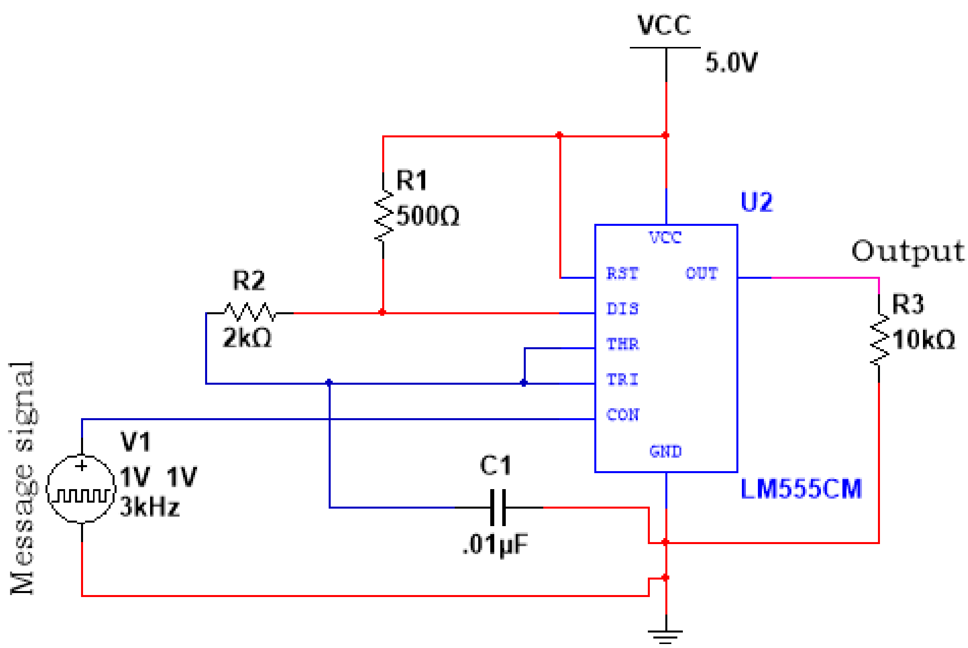

Figure 4: Generation of FM signals using IC555

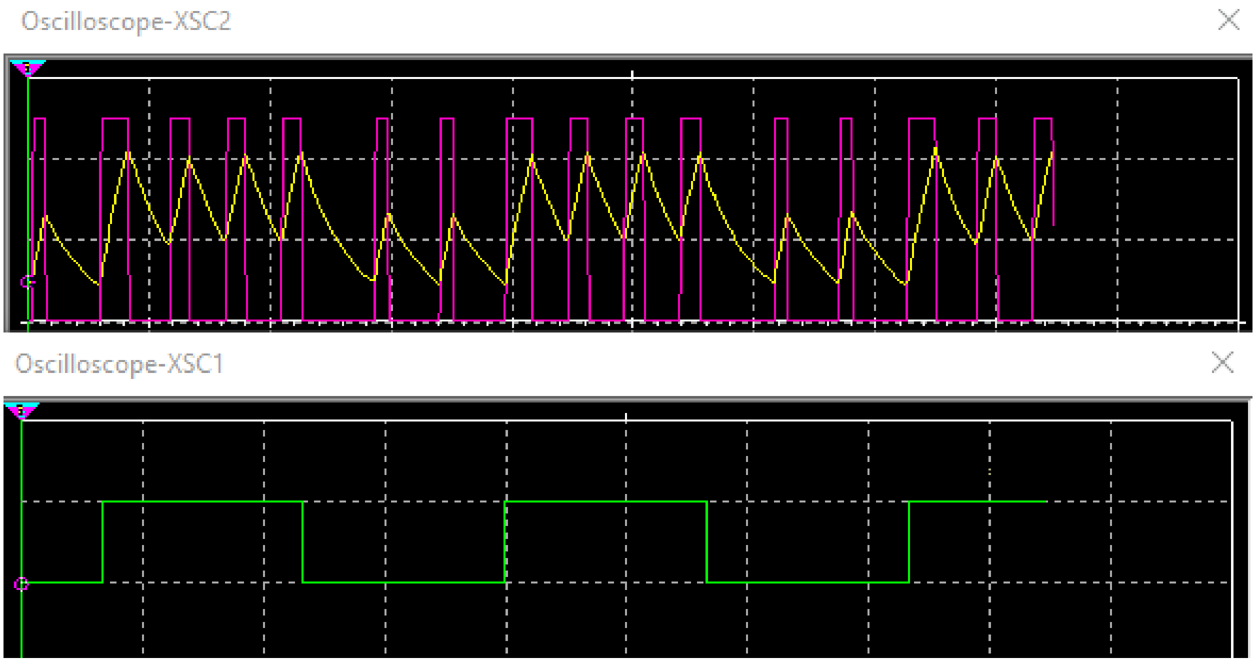

Figure 5: The output and capacitor voltage for the IC555-based frequency modulator

3 Lab Procedures

Perform the following steps:

- Configure the IC555 in the astable multi-vibrator mode as shown in Figure 2 with $R_A = 500\Omega, R_B = 2k\Omega, C = 0.01\mu F$.
- Calculate the carrier frequency f_{free} which is equivalent to the free running frequency of the 555 timer. Use (2) and verify with the observed frequency.
- Now connect IC555 as shown in Figure 4. Apply a message square pulse of freuqncy 3kHz to PIN 5.
- Adjust the amplitude and the offset of the message signal so that you get the waveforms shown in Figure 5.
- Plot the relevant waveforms.
- Take readings of f_{HIGH} and f_{LOW} from the oscilloscope by measuring the time period of the high frequency segment and the time period of the low frequency segment.
- Compute the frequency deviation $\triangle f = (f_{\text{HIGH}} - f_{\text{LOW}})/2$.
- Compute the modulation index.
- Apply a sinusoidal message signal and observe the change in the output.

Questions

1. Explain the working principle of the astable multi-vibrator using IC555.
2. Derive (1).