Ocillator using 555 timer (`EC_555_1.sqproj`)

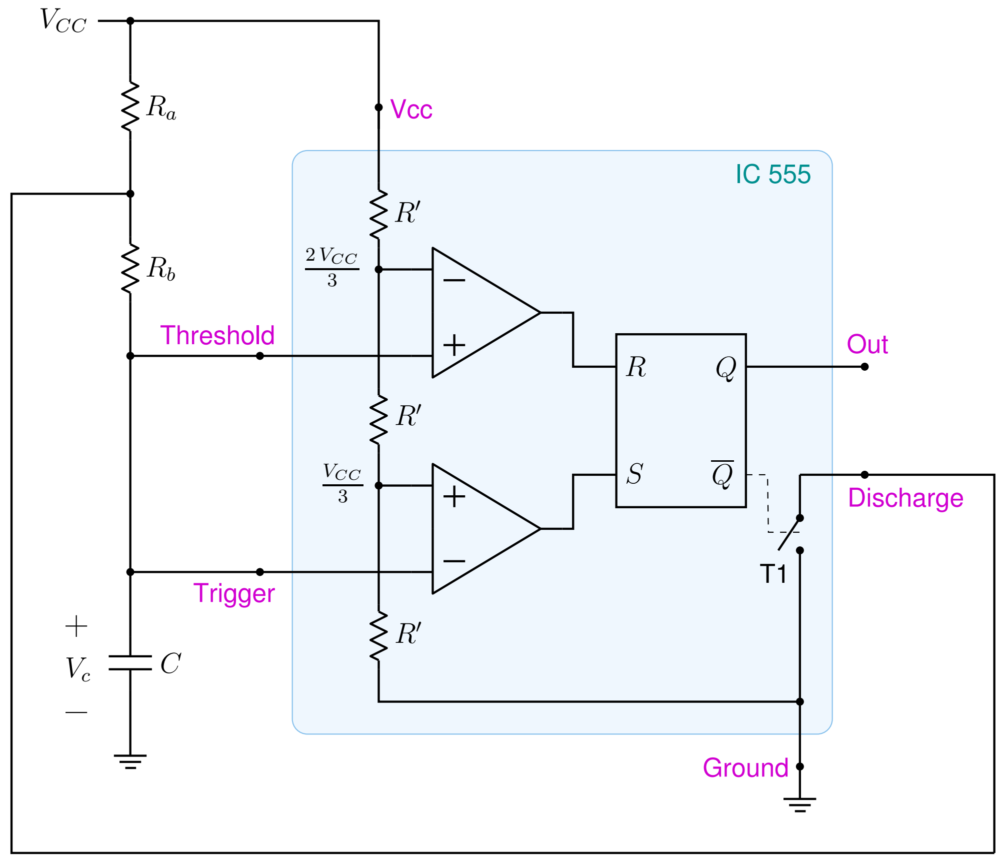

Figure 1: Oscillator circuit based on the 555 timer.

Question: For the oscillator circuit shown in Fig. 1, $R_a = 0.5\,\text{k}$, $R_b = 0.5\,\text{k}$, and $C = 0.5\,\mu\text{F}$.

(a) Draw the waveforms $V_{\text{out}}(t)$ and $V_c(t)$.

(b) Find the oscillation frequency and the duty cycle.

Solution:

The trigger and threshold inputs are tied together in this circuit, and we have $V_{\text{trigger}} = V_{\text{threshold}} = V_c$. The circuit operation can be understood by realizing that the following conditions hold (see Fig. 2):

$V_{CC}/3 < V_c(t) < 2\,V_{CC}/3$	$R=0, S=0$	flip-flop holds its state.
$V_c(t) < V_{CC}/3$	$R=0, S=1$	flip-flop is set ($Q=1$).
$V_c(t) > 2\,V_{CC}/3$	$R=1, S=0$	flip-flop is reset ($Q=0$).

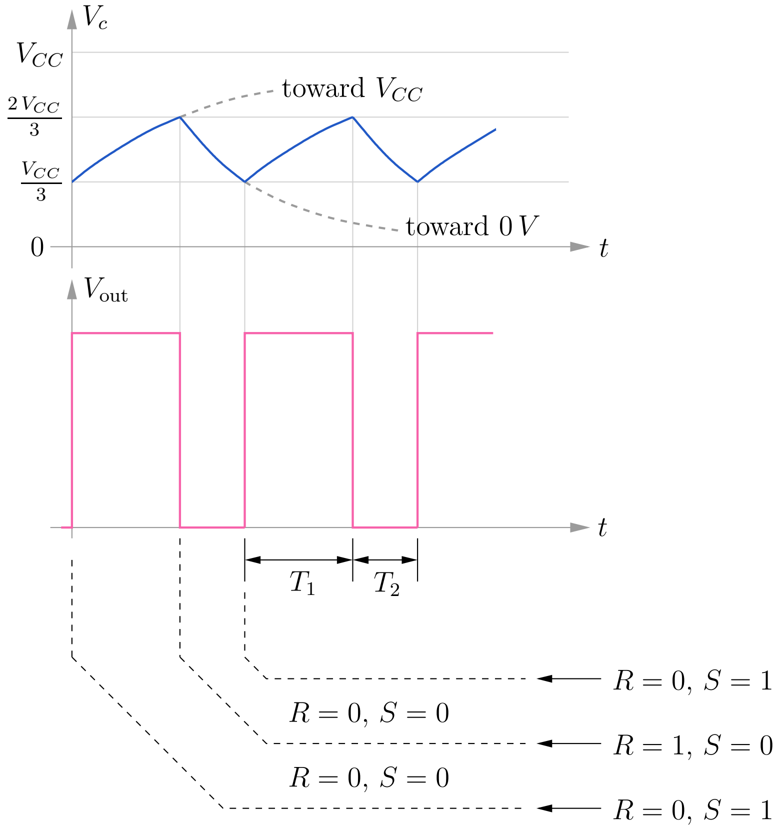

Figure 2: Waveforms for the oscillator circuit of Fig. 1.

Consider the interval marked T_1 in Fig. 2. During this time, $Q=1$, the switch T1 is open, and the capacitor charges toward V_{CC} through (R_a+R_b). However, as soon as V_c reaches $2\,V_{CC}/3$, R becomes 1 (S is still 0), and the flip-flop gets reset to $Q=0$.

When Q becomes 0, $\overline{Q}$ becomes 1, and the switch T1 closes. The capacitor now starts discharging toward $0\,V$ through R_b. However, when V_c crosses $V_{CC}/3$, S becomes 1 (R is still 0), and the flip-flop gets set to $Q=1$, bringing us back to the T_1 phase. The output keeps oscillating between 0 and 1, as shown in Fig. 2.

The intervals T_1 and T_2 can be computed using the above limits for $V_c(t)$ and the appropriate time constants ($\tau_1 = (R_a+R_b)\,C$ during the charging phase, and $\tau_2 = R_bC$ during the discharging phase). The result is,

$$T_1 = (R_a+R_b)\,C\ln 2\,, \quad (1)$$

$$T_2 = R_b\,C\ln 2\,. \quad (2)$$

The oscillation frequency is

$$f = \frac{1}{T_1 + T_2} = \frac{1}{(R_a + 2R_b)C \ln 2}\,, \tag{3}$$

and the duty cycle D is

$$D \equiv \frac{T_1}{T_1 + T_2} = \frac{R_a + R_b}{R_a + 2R_b}\,. \tag{4}$$

Substituting the given component values, we get $T = 0.52\,\text{msec}$, $f = 1.92\,\text{kHz}$, and $D = 0.67$, i.e., 67%.

SequelApp Exercises: Find R_a and R_b to obtain $f = 1\,\text{kHz}$ and $D = 75\%$, assuming C to be $0.5\,\mu\text{F}$. Verify your answers using SequelApp.