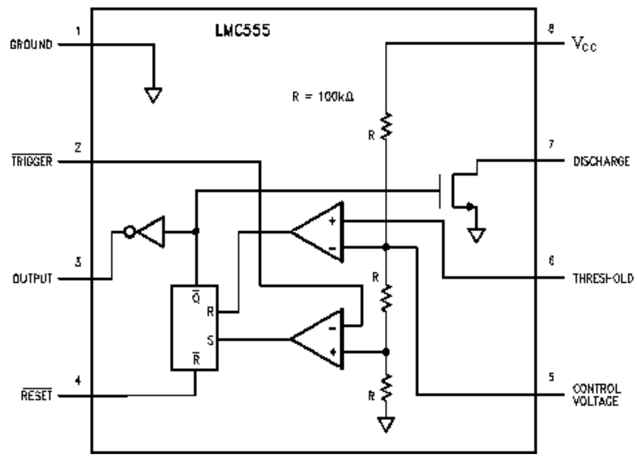
Lab 10
555 timer

In this lab you will build different types of oscillators using the 555 timer chip. The 555 timer uses two comparators and a digital flip-flop to control an output driver and a 'discharge' transistor (see sketch below). The comparators switch state at $\frac{1}{3}$ and $\frac{2}{3}$ of the supply voltage (V_{CC}), called the 'trigger' and 'threshold' levels respectively. When the trigger input (TR) falls below $\frac{V_{\mathrm{CC}}}{3}$ the output voltage goes high and the discharge transistor behaves like an open switch. When the threshold input (TH) rises above $\frac{2V_{\mathrm{CC}}}{3}$ the output goes low and the discharge transistor shorts the discharge terminal (pin 7) to ground.



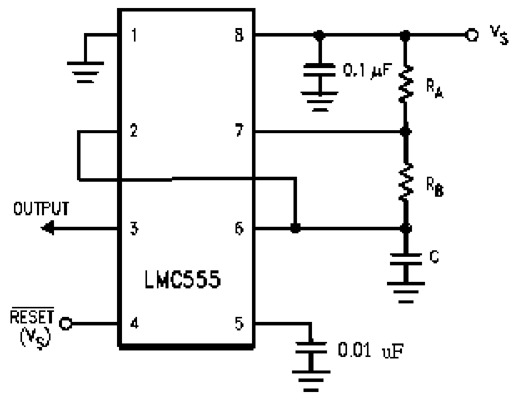
Pre-lab

1. Pick resistor values in step 1.
2. Compute the duty cycle in step 4
3. Develop the necessary theory to address the questions in step 5.
4. Answer the question in step 7.
5. Pick the resistor value in step 9.

Astable multivibrator

Build the astable (or relaxation) multivibrator pictured below. C charges up through R_A and R_B until its voltage V_C reaches the threshold level $\frac{2}{3}V_{\mathrm{CC}}$. The discharge transistor then turns on connecting the junction between R_A and R_B to ground and discharging (relaxing) C until $V_C = \frac{1}{3}V_{\mathrm{CC}}$, whereupon the discharge transistor turns off and the process is repeated. The period of oscillation is given by

$$T = 0.69\,(R_A + 2R_B)\,C.$$



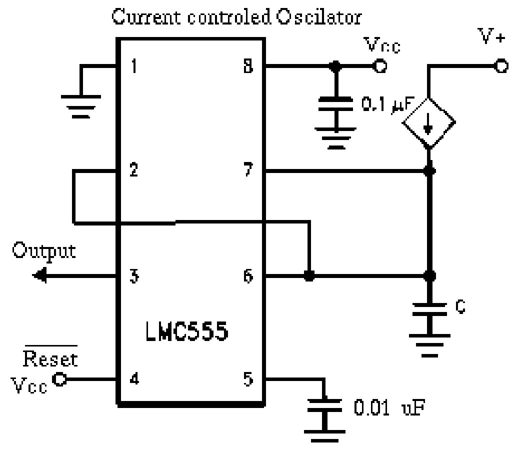
1. Design the circuit to have a period of $T = 2\,\text{ms}$ with $R_A = R_B$ and $C = 0.1\,\mu\text{F}$.
2. Test the circuit by plotting the voltage on the output and across the capacitor as a function of time. Verify that the capacitor voltage levels at which the circuit switches agrees with theory.
3. Measure the frequency of oscillation and compare with theory.
4. Why is the duty cycle different from 50 %? Compare the measured duty cycle with theory.
5. Short R_B. How does this affect the waveform? If you are using a BJT type 555 the discharge should be linear, because the base current is constant. In that case, what is the base current assuming $\beta = 100$? If you are using a CMOS 555 the discharge should be exponential. In that case, what is the on resistance of the FET channel? You can find it from the initial slope of the exponential decay.
6. Measure the output frequency for a supply voltage of 5, 10, and 15 V. How does the oscillation frequency vary with supply voltage?

Voltage-controlled oscillator

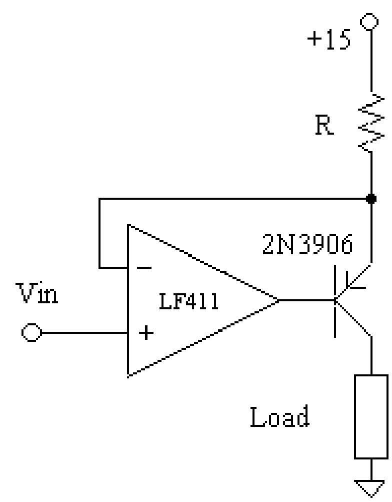
Often a circuit requires a voltage-controlled oscillator, that is, an oscillator who's frequency depends on an input voltage. The frequency of the astable multivibrator above depends only on the values of RA, RB and C. By using a voltage-controlled current source to charge C, one can adjust the charging rate and hence the frequency. If a current source charges the capacitor with a constant current I, as in the circuit below, the time for the capacitor to charge from V_{TH} to V_{TR} is

$$T_{\rm ch} = C\frac{V_{\rm TH} - V_{\rm TR}}{I} = \frac{CV_{\rm CC}}{3I}$$

In the circuit below the capacitor will discharge almost instantly, so the frequency of oscillation is $f \approx \frac{1}{T_{\rm ch}}$.



In order to build the circuit we need to create a current source, which is pictured here (from HH figure 4.11).



7. Explain how the current source functions.
8. Build the current source with ±15 V supplies for the op-amp.
9. Determine the value of the resistor to result in frequencies between 5 kHz and 10 kHz as the voltage on the current source is varies between 5 V and 10 V. Hint: the capacitor must charge by voltage $V_{CC}/3$ during one oscillation period, and $V = CQ = CIT$.
10. Test the current source by measuring the voltage across an appropriately sized resistor.
11. Build the oscillator circuit using the current source.

12. Measure the oscillation frequency as a function of the voltage applied to the current source. How does it compare to theory?