ECE 214 - Lab #8
Astable Multivibrator

30 March 2020

Introduction: In this lab, you will design, simulate, build, and test an astable multivibrator oscillator.

Pre-Lab:

The astable multivibrator oscillator circuit, implemented using ideal switches, is shown in Figure 1.

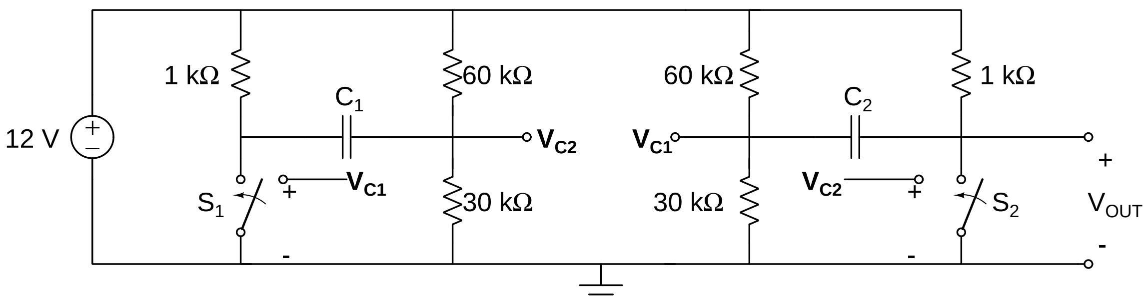

Figure 1: Astable multivibrator circuit using ideal switches.

1. Assume the voltage-controlled switches (S_1 and S_2) are closed when the control voltages (V_{C1} and V_{C2}) are > 1.5 V, and open when the control voltages are < 1.5 V. Analyze this circuit and explain how it works. Derive an equation that describes the frequency of the output signal when the capacitors C_1 and C_2 have the same value.
2. When $C_1 = C_2 = 0.1\ \mu$F, what is the expected output frequency?
3. The NMOS transistor can function as a voltage-controlled switch. In an NMOS transistor, current flows from the drain (D) terminal to the source (S) terminal when the gate (G) to source (S) voltage (V_{GS}) is greater than the threshold voltage (V_t) of the transistor. No current flows from the D terminal to the S terminal when V_{GS} is less than V_t.

   Simulate the operation of the astable multivibrator circuit using the 2N7000 NMOS transistors to implement the voltage-controlled switches, as shown in Figure 2. In NGspice, use the **2N7000_mod** symbol for the transistor model.
4. Plot the voltage at each end of one capacitor as a function of time. It does not matter which capacitor you choose. Record the simulation results in your notebook to compare with what you will measure in lab.
5. What is the simulated oscillation frequency and the voltage swing of the output signal? Does the simulated circuit oscillate at the frequency predicted in step 2?

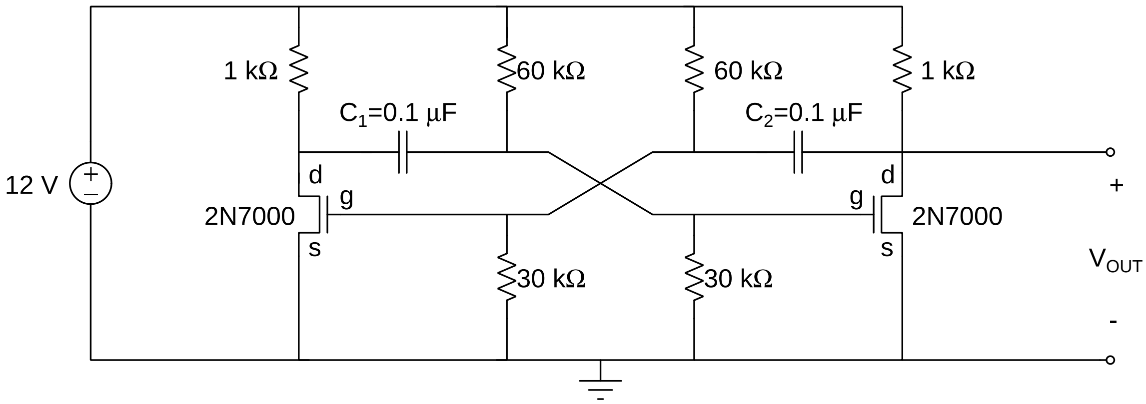

Figure 2: Astable multivibrator circuit of Figure 1 with 2N7000 transistors used as voltage-controlled switches.

Lab Procedure:

1. Build the multivibrator half-circuit circuit shown in Figure 3.
2. Set the function generator (FG) to produce a triangular waveform with a voltage swing from 0 to 5 volts, and a frequency equal to that found in step 5 of the Pre-Lab. Use the scope to record the voltage at both the gate (G) and drain (D) of the 2N7000 transistor. By examining when these two voltage traces cross, determine the gate voltage that causes the transistor to switch between the on-state and the off-state. Expand the time and voltage scales on the scope to maximize the accuracy of the measurement. Try and measure this gate voltage within ± 50 mV. This gate voltage will be called VT0. Acquire at least two 2N7000 transistors that have nearly the same VT0 voltage.
3. Build the full astable multivibrator circuit shown in Figure 2. This circuit should oscillate when power is supplied.
4. Examine the voltage at each end of the capacitor with respect to ground. How do these voltages compare with the simulation results in step 4 in the Pre-Lab? Measure the frequency and voltage swing of the output waveform. How do these compare to the simulated results? Explain and discrepancy in your notebook.

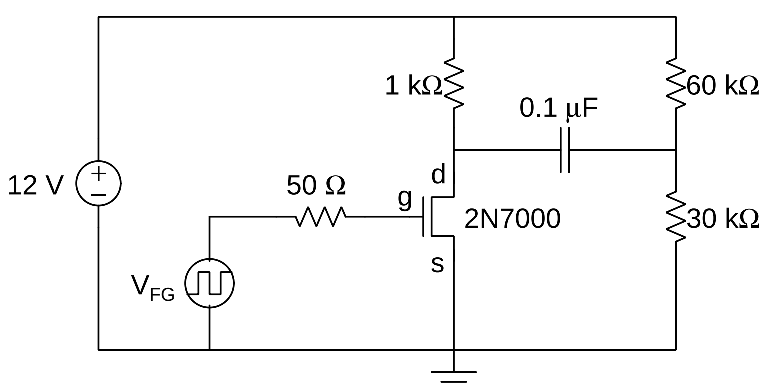

Figure 3: Multivibrator half–circuit.

5. If the measured frequency of the oscillator differs from the simulated frequency, this may be due to the value of VT0 used in the 2N7000 transistor model, which is currently set to 1.500 V. The transistor model is contained in a text file called `2N7000_modified.SP3`, located in the `SpiceModels` directory. On line 26 of this file, change the value of VT0 from 1.500 to the value measured in step 2 of the Lab Procedure. Rerun the simulation and compare the simulated frequency to the measured frequency. How do these results compare with the results obtained above?

6. f the simulated frequency still differs from the measured frequency, you can adjust the value of VT0 and try and obtain better agreement.

7. Modify the oscillator to produce the frequency and the duty cycle needed for the boost converter designed in Lab #7. This can be accomplished by keeping the resistor values constant and adjusting the capacitance values C_1 and C_2. The frequency of oscillation is related to the total capacitance; the duty cycle is related to the ratio of C_1 to C_2. Use hand-calculations, verified by simulations, to determine the values of C_1 and C_2 such that:

   (a) the frequency of the multivibrator circuit matches the frequency needed in Lab #7 to produce a 30 ± 0.25 V_{DC} output voltage from the boost–converter, and

   (b) the duty cycle of the multivibrator circuit matches the duty cycle needed in Lab #7 to produce a 30 ± 0.25 V_{DC} output voltage from the boost–converter.

8. Record the final capacitance values and the output waveform from the oscilloscope in your lab notebook.

9. Do not disassemble the astable multivibrator circuit. You can use the oscillator again as part of Lab #9.

Post-Lab:

1. Simulate your final astable multivibrator design using the measured values of the components you used in lab. Plot the output voltage as a function of time. Determine the frequency, duty cycle, and voltage swing.

2. Compare the simulated results to the measurements you made in lab.

3. Reference this Post Lab in the table of contents of your notebook.