ECE 214 - Virtual Lab #8
Astable Multivibrator Oscillator Circuit
Modified for Simulation Only

3 April 2020

Introduction: In this lab, you will design and simulate an astable multivibrator oscillator circuit. The output signal from the oscillator will have the same frequency and duty cycle needed to drive the Boost Converter circuit designed and simulated in Lab #7, and will replace the ideal function generator used in Lab #7. Include all results from the analysis, along with simulation results, in narrative form, in the technical report.

Circuit Design and Analysis: The basic operation of the astable multivibrator oscillator circuit can be understood by examining an implementation of the circuit using ideal switches, as shown in Figure 1.

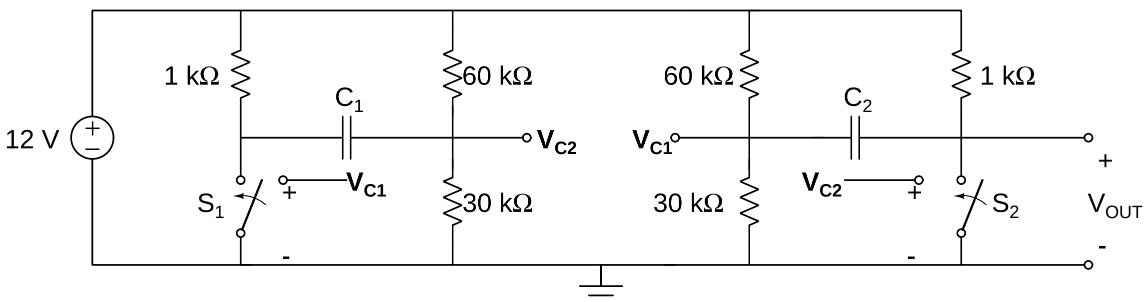

Figure 1: Astable multivibrator circuit using ideal switches.

In an actual implementation of this circuit, the voltage controlled switches would be replaced with NMOS transistors. Assume that the threshold voltage (V_t) of the transistors is 1.5 V. Under this condition, 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.

1. Describe and analyze the half-circuit model of this oscillator as discussed in class.
2. Analyze the full circuit and explain how it works.
3. Derive an equation that describes the frequency of the output signal when the capacitors C_1 and C_2 have the same value.
4. When $C_1 = C_2 = 0.1\ \mu$F, what is the expected output frequency?
5. Determine the approximate values of C_1 and C_2 needed to provide the frequency required for the Boost Converter of Lab #7.

Simulation of Astable Oscillator: In the implementation of an astable oscillator, NMOS transistors are used as voltage-controlled switches. 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.

1. Simulate the operation of the astable multivibrator circuit using the 2N7000 NMOS transistors to implement the voltage-controlled switches, as shown in Figure 2. Use the values of the capacitors determined in step 5 above. In NGspice, use the **2N7000_mod** symbol for the transistor model. This transistor has a nominal $V_t = 1.5$ V.

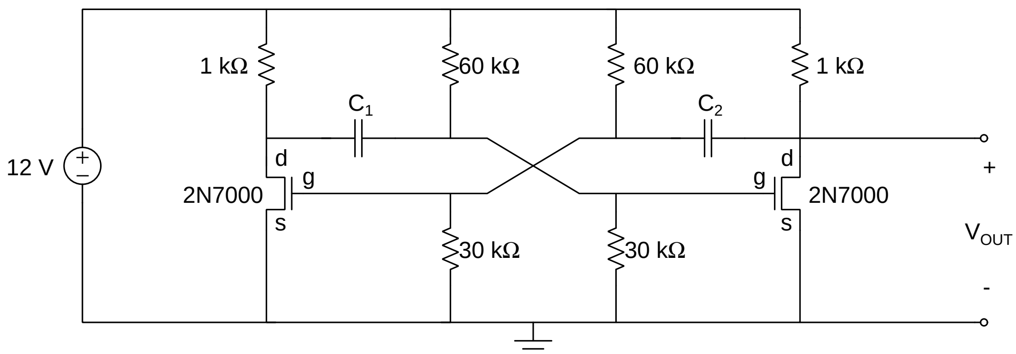

Figure 2: Astable multivibrator oscillator circuit of Figure 1 with 2N7000 transistors used as voltage-controlled switches.

2. Plot the voltage at each end of one capacitor as a function of time. It does not matter which capacitor you choose. Does the frequency agree with your analysis from above? If not, adjust the capacitance values until the output frequency from the oscillator meets the frequency requirement from the function generator in Lab #7.

3. Modify the oscillator to produce both the frequency and the duty cycle required 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 found 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 found in Lab #7 to produce a 30 ± 0.25 V_{DC} output voltage from the boost–converter.

4. The shape of the output signal can be improved by reducing the amount of capacitance on the output node. Add a third transistor to the circuit, to act as a buffer, as shown in Figure 3. This third transistor will invert the output signal. Hence, you will need to switch capacitors C_1 and C_2 to maintain the same duty cycle at the output.

5. In the report, include a final schematic with all of the component values labeled. When finalizing the capacitor values, use standard capacitor values, or combinations of standard

capacitor values. Standard capacitor values are values that are available for purchase from an electronic parts suppliers such as Digikey (`https://www.digikey.com`) or Mouser (`https://www.mouser.com`).

6. Perform a component sensitivity analysis on the resistor and capacitor values in this circuit. Determine an appropriate tolerance for each resistor and capacitor. The component sensitivity analysis simulation will be described in class.

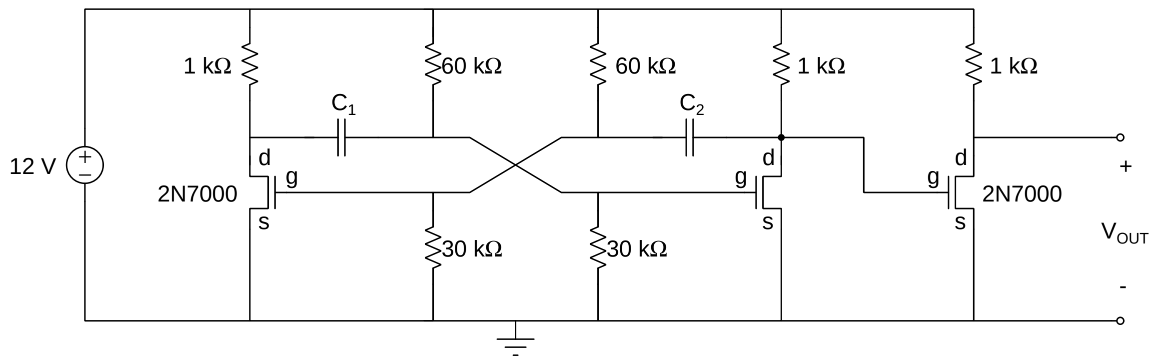

Figure 3: Astable multivibrator oscillator circuit of Figure 2 with an added 2N7000 transistor used as an output buffer.

7. Record the final capacitor values and the simulated output waveform in your report.

8. Update the BoM in the Appendix of the report to include the components needed for the astable multivibrator circuit.