

ECE 214 - Lab #8 — Astable Multivibrator Oscillator Circuit

5 April 2021

Introduction

In this lab, you will design, simulate, build, and test an astable multivibrator oscillator. The output signal from the oscillator should have the same frequency and duty cycle needed to drive the Boost Converter circuit built in [Lab #7](#), and will replace the waveform generator used in [Lab #7](#).

Parts List

1. $800\ \Omega$ resistors (3)
2. $30\ \text{k}\Omega$ resistors (2)
3. $60\ \text{k}\Omega$ resistors (2)
4. $0.1\ \mu\text{F}$ ceramic capacitors (2)
5. 2N7000 NPN transistors (3)
6. Capacitors to achieve correct oscillation frequency and duty cycle

Pre-Lab

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](#). In the actual implementation, the voltage controlled switches will be replaced with NMOS transistors.

1. Assume the voltage-controlled switches (S_1 and S_2) are closed when the control voltages (V_{C1} and V_{C2}) are $> 1.5\ \text{V}$, and open when the control voltages are $< 1.5\ \text{V}$.
 - (a) Describe and analyze the half-circuit model of this oscillator as discussed in class.
 - (b) Analyze the full-circuit model and explain how it works.

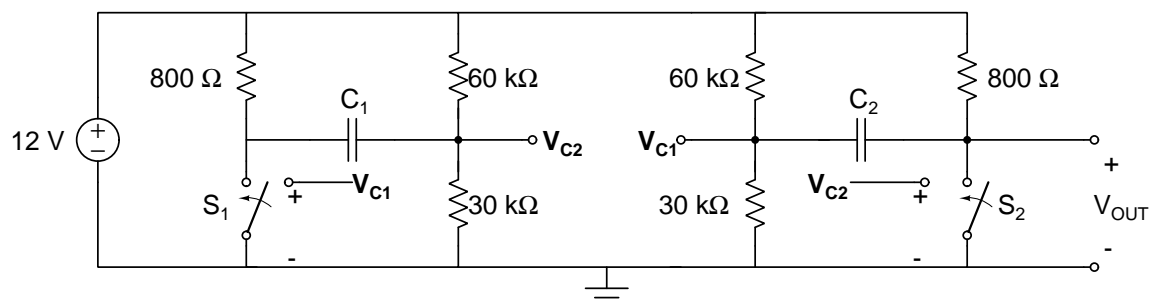


Figure 1: Astable multivibrator circuit using ideal switches.

- (c) Derive the equations that describes the frequency of the output signal when the capacitors C_1 and C_2 have the same value.
- (d) When $C_1 = C_2 = 0.1 \mu\text{F}$, what is the expected output frequency?
2. 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. This transistor has a nominal $V_t=1.5 \text{ V}$.
3. 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.
4. 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 1d**?

Lab Procedure

1. Build the multivibrator half-circuit circuit shown in **Figure 3**.
2. Set the waveform generator (WG) to produce a triangular waveform with a voltage swing from 0 to 5 volts, and a frequency equal to that found in **step 4** 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 $\pm 50 \text{ mV}$. This gate voltage will be called V_{T0} . Try and obtain at least two 2N7000 transistors that have nearly the same V_{T0} voltage.

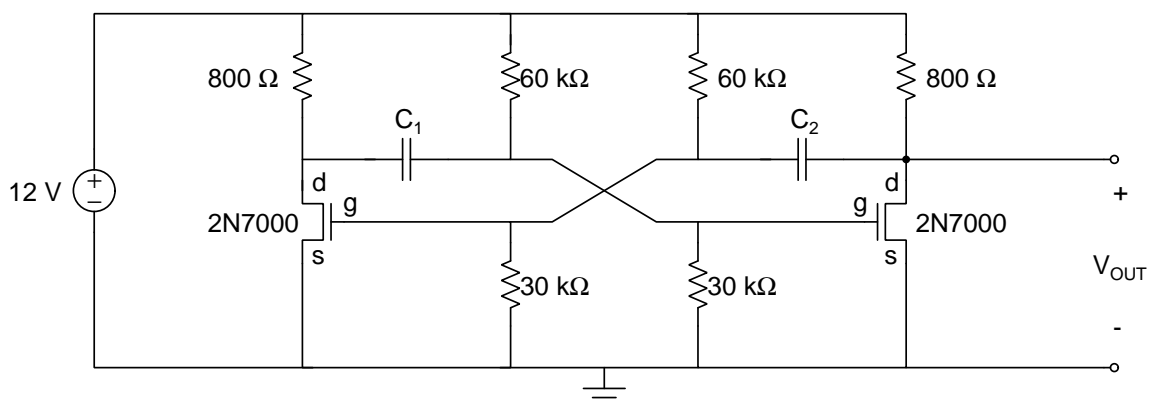


Figure 2: Astable multivibrator circuit of Figure 1 with 2N7000 transistors used as voltage-controlled switches.

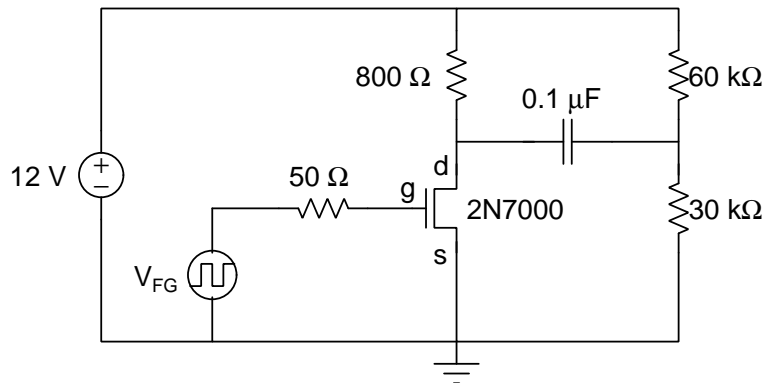


Figure 3: Multivibrator half-circuit.

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 3](#) 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.
5. If the measured frequency of the oscillator differs from the simulated frequency, this may be due to the value of V_{T0} 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 V_{T0} 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. If the simulated frequency still differs from the measured frequency, you can adjust the value of V_{T0} 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 $25 \pm 0.25 V_{DC}$ 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 $25 \pm 0.25 V_{DC}$ output voltage from the boost-converter.
8. 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 4](#). 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.

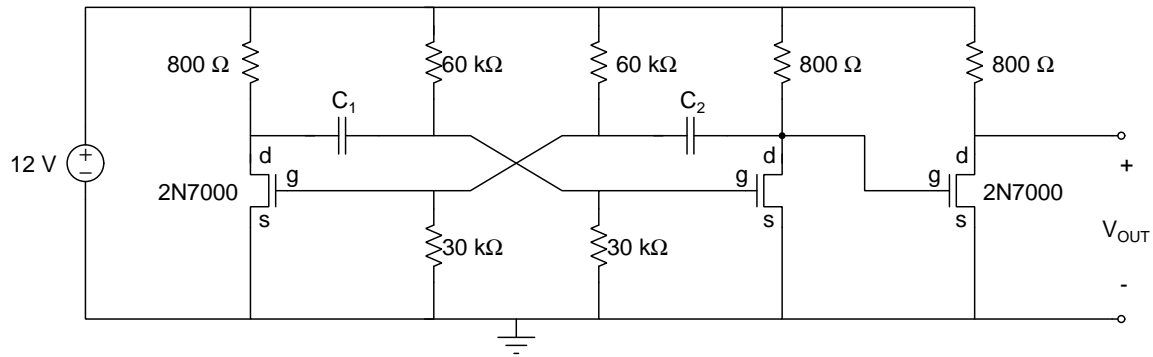


Figure 4: Astable multivibrator oscillator circuit of **Figure 2** with an added 2N7000 transistor used as an output buffer.

9. Measure the output signal and verify that it matches the output from the waveform generator determined in **Lab #7**. Record the final capacitance values and the output waveform from the oscilloscope in your lab notebook.
10. Do not disassemble the astable multivibrator circuit. You can use the oscillator again as part of **Lab #9**.

Post-Lab

1. In your notebook and 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>).
2. Compare the simulated results to the measurements you made in lab.
3. Update the BoM in the Appendix of the report to include the components needed for the astable multivibrator circuit.
4. Simulate the final astable multivibrator design. Plot the output voltage as a function of time. Determine the frequency, duty cycle, and voltage swing.
5. 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.