ECGR 3120–Section 001

University of North Carolina at Charlotte
Department of Electrical and Computer Engineering

Inkjet Capacitor Project

Iteration 1: No voltage

Iteration 2: Vertical Only/Varied Parameters

Iteration 3: Vertical & Horizontal/H Configuration

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This report was submitted in compliance with UNCC POLICY 407 THE CODE OF STUDENT ACADEMIC INTEGRITY, Revised November 6, 2014 (http://legal.uncc.edu/policies/up-407) MAA.

Objectives:

Iteration 1

1. Simulate the motion of the droplet when no voltage is applied across the capacitor. How much time would it take for the droplet to reach the center of the paper?

Iteration 2

2. Simulate the act of drawing a vertical line (similar to the letter "I") along the center of the paper at 300 dpi resolution. How much time would it take to draw the letter 'I'?
3. Plot the profile of applied voltage V(t) across the capacitor versus the time t for drawing the letter 'I'. This profile of V(t) should look like a staircase. V(t) will remain constant until a droplet exits the capacitor chamber, and immediately it will switch to the next value in order to control the next incoming droplet. How big the letter 'I' could be drawn on the paper?
4. Resimulate the act of drawing letter 'I' as big as possible consuming as small time as possible for each of the following adjustment of the parameter:
   a. The distance between the capacitor and the paper L2 is threefold increased, and everything else remains same
   b. L1 is twofold increased, and everything else remains same
   c. The charge of the droplet is fivefold increased, and everything else remains same.
   d. The horizontal speed at which the gun shoots the droplet is twofold increased, and everything else remains same
   Droplet diameter is tenfold increased, and everything else remains same
   e. Droplet diameter is tenfold increased, and everything else remains same
   f. Plot the profile of applied voltage V(t) versus time t for all.

Iteration 3

5. If you want to draw the letter 'H' on the paper, you have to add an additional capacitor to impose a velocity component to the droplet. Design the additional capacitor to draw the biggest possible 'H' on the paper. You have to decide the design parameter of the capacitors to draw the 'H' shape (length, width of the capacitor plates, and their spacing). Simulate the entire process of drawing the biggest possible 'H' shape in 300 dpi resolution. Plot the voltage profile V(t) applied across the capacitor vs time t for both the capacitor. Both the voltage profile would look like a staircase.

Equipment Used:

1. MATLAB for Simulations & Voltage Plotting
2. GitHub for Project Storage
3. Microsoft Word for Project Report

Introduction:

This project seeks to simulate the role of capacitors in the control of charged ink droplets, common to various types of inkjet printers. Parameters such as charge, droplet diameter, capacitor geometry, etc. are modified and simulated, with associated voltage applied to the capacitor plates being plotted as well. The above objectives are completed with the use of MATLAB and stored in the following GitHub repository, as well as briefly reviewed within the following YouTube video as well:

GitHub Repository Link: https://github.com/Polaris-IPT/3120-Inkjet-Capacitor-Simulations---PolarisIPT.git

YouTube Video Link: https://youtu.be/mtJWD6aAYJ4

Iteration 1:

Objective #1

For iteration 1, zero voltage is applied to the capacitor, resulting in zero vertical accleration on the droplets, resulting in them simply passing through the capacitor and hitting the center of the page. Through the given simulations, and some basic calculations, the expected time for the first droplet to pass through and hit the paper from the nozzle was about 0.15 ms, which is almost the same value found in the simulation:

Droplet time Calculated: $t = \frac{d}{v_x} = \frac{3mm}{\frac{20m}{s}} = 0.15ms$

Droplet time Simulated: $t = 0.154ms$

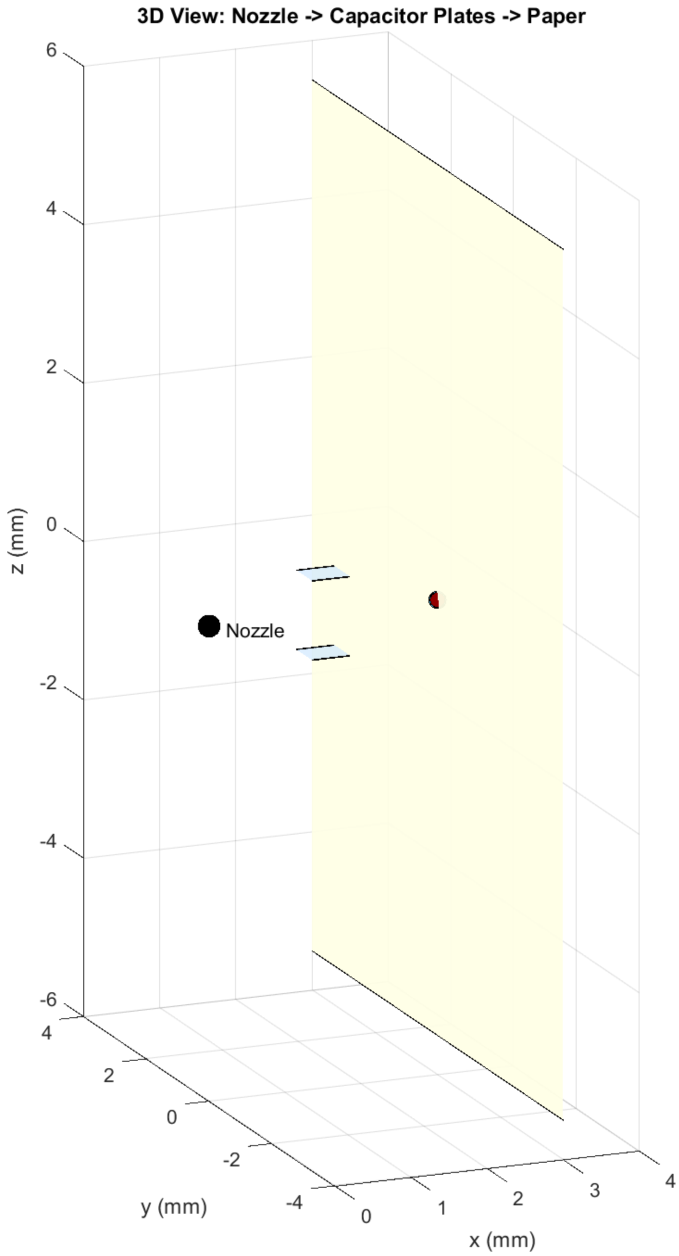

Figure 1: Inkjet Capacitor with Zero Voltage Applied – Iteration 1

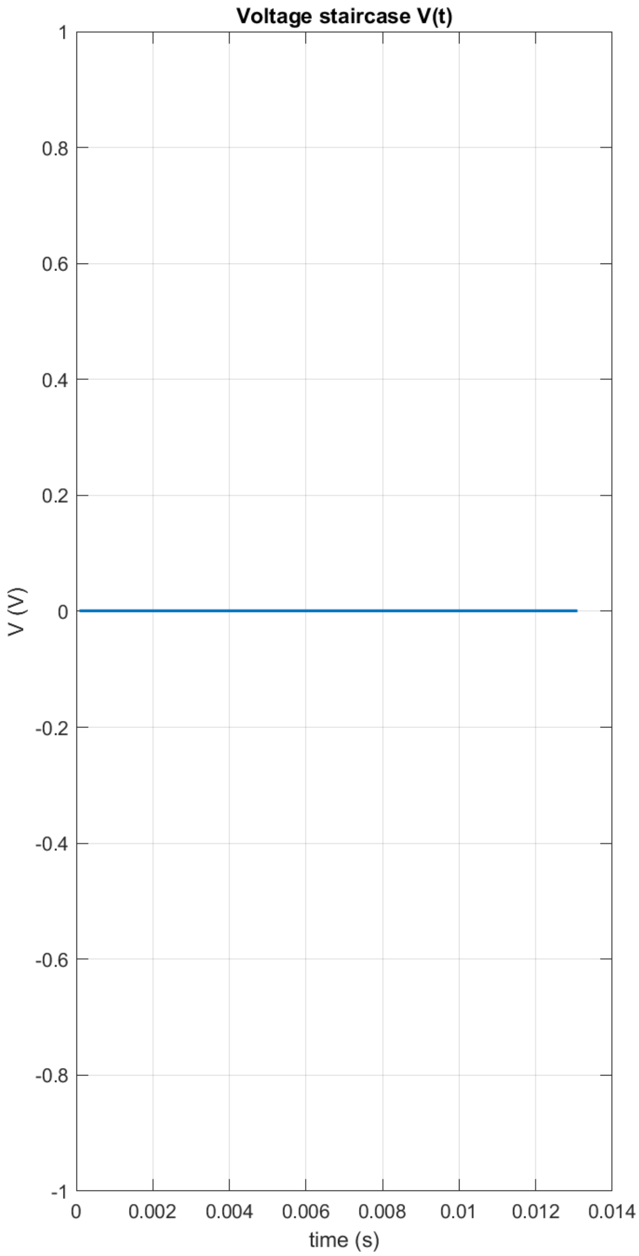

Figure 2: Inkjet Capacitor Input Voltage over Time – Iteration 1

Iteration 2:

Objective #2

Now things get interesting. For Objective #2, a simple line is drawn on the piece of paper utilizing the inkjet capacitor with varied applied voltage over time. The droplets contain some amount of charge, which we assume in this iteration to be 0.19 nC, with Vx = 20 m/s and the diameter of droplets is also assumed to be 84um.

With these assumptions in mind; as well as the exact same capacitor geometry, by varying the voltage over time in steps, each droplet can be accelerated to various degrees, resulting in different landing locations on the paper. Greater voltage results in greater distance traveled, and thus with the simulation starting from the top and heading down, the maximum voltage is utilized, which lowers over time, before becoming negative and sending the droplet downwards. This effectively creates a simple line of ink on the page, all from simply modifying the vertical acceleration of the droplets. This arrangement does not affect the Vx value at all, which increases the potential range of droplets upon the page. As for the time needed to create this full line, through the associated simulation it was found to be roughly 17ms to fully send every droplet sequentially onto the paper by the inkjet capacitor system. The simulation with inkjet capacitor, nozzle location, and droplets on the page is given below as a reference.

Objective #3

For Objective #3, the voltage staircase plot is given below. The associated simulation outputs are given below, with the voltage staircase varying the direction of the droplets trajectory via changes in the magnitude and polarity of the applied voltage.

The maximum size of the 'I' created depends on a couple of factors, but the most important are the applied voltage and the size of the capacitor plates; If voltage is increased, than the droplets experience greater acceleration, and travel further before hitting the page. If the capacitor plates are too large, or too close together, than there is a risk of droplets hitting the plates, which would also limit the potential range.

An important relation is found here, as greater capacitance results from large plate area and smaller distance between plates; which results in more stored charge and thus stored energy for a given applied voltage. This is particularly important in the case of capacitors with closer plates, which intensifies the field and both increases capacitance and the forces per unit voltage. However, to avoid plates becoming obstacles, a lower capacitance is preferred, if the voltages can be increased greatly to effectively move the droplets to their chosen locations.

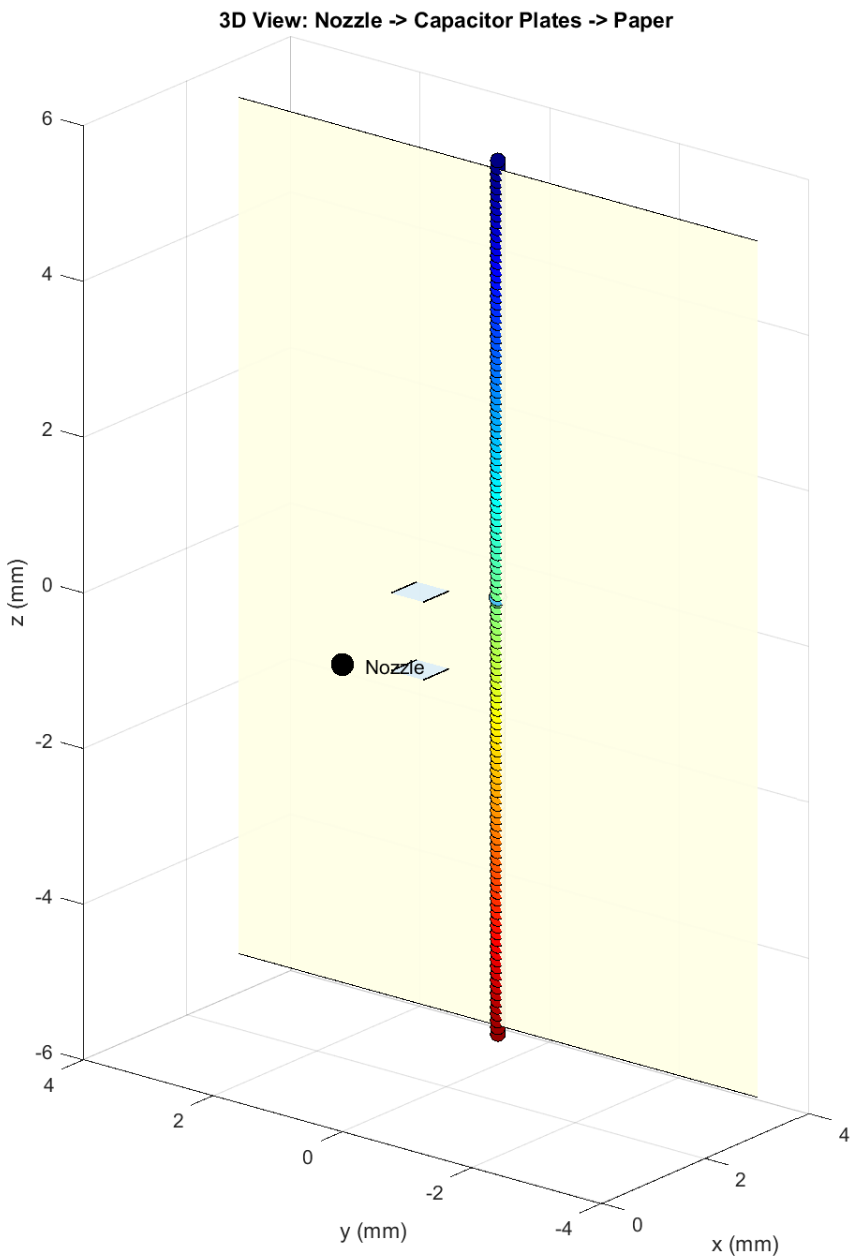

Figure 3: Inkjet Capacitor Simulation with Default Values – Iteration 2

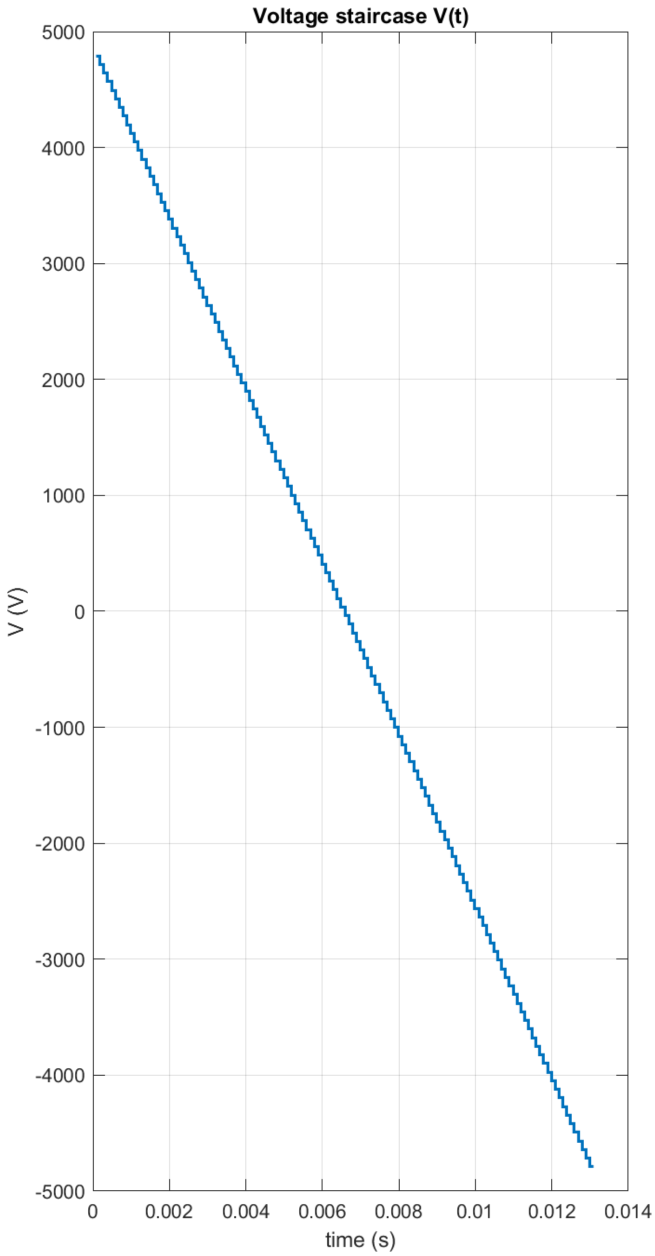

Figure 4: Inkjet Capacitor Voltage Staircase for Default Values – Iteration 2

Objective #4

For part A, the distance between the capacitor and the piece of paper was increased threefold, putting the exit of the capacitor 3.75mm away from the paper compared to before, where it was 1.25mm away. The time required to complete this the drawing of the line was slightly longer than default values, at roughly 18 ms. Below is the associated simulation and voltage staircase plot with respect to time.

Important to note is the voltage staircase plot, which maxes out at +/- 2000 volts as opposed to the default values, which achieve full paper coverage at a little under +/- 5000 volts; this is due to lowered electric field strength required to induce the vertical acceleration to reach farther points, which is an advantage of placing the firing mechanism alongside capacitor at a greater distance from the paper.

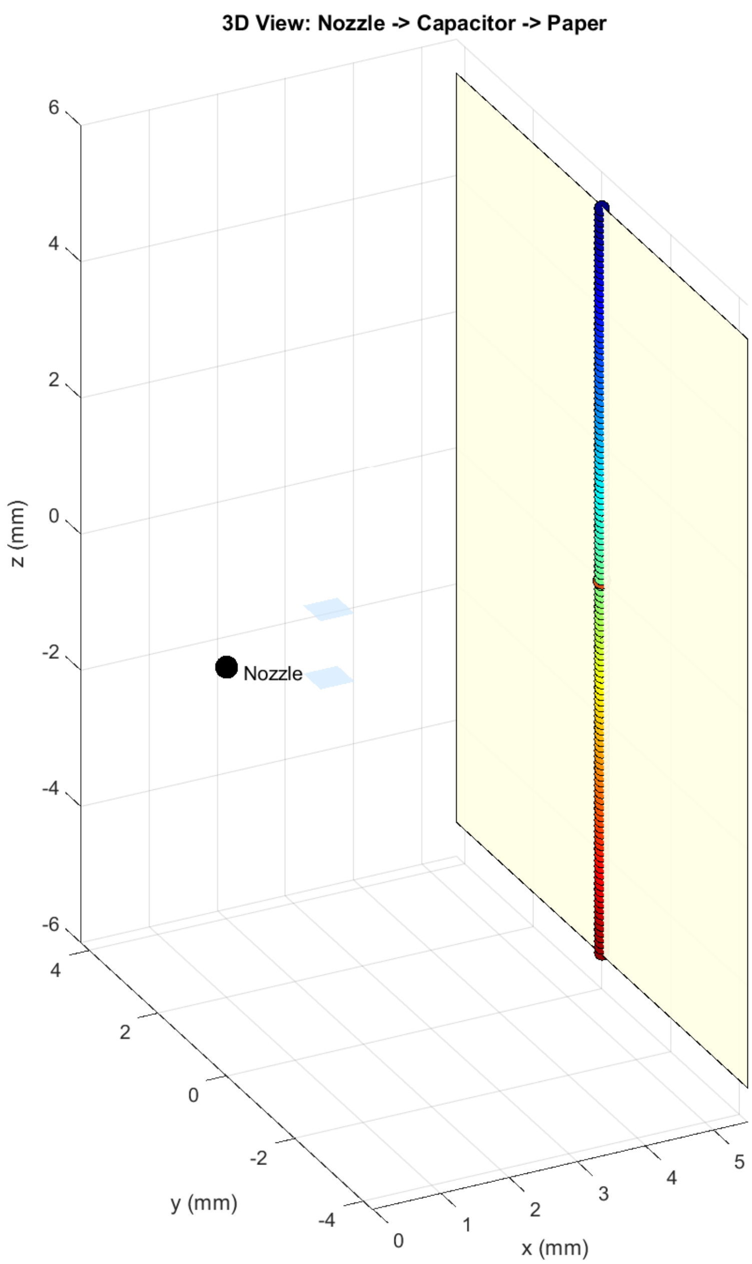

Figure 5: Inkjet Capacitor Simulation with 3x Distance Cap from Paper – Iteration 2

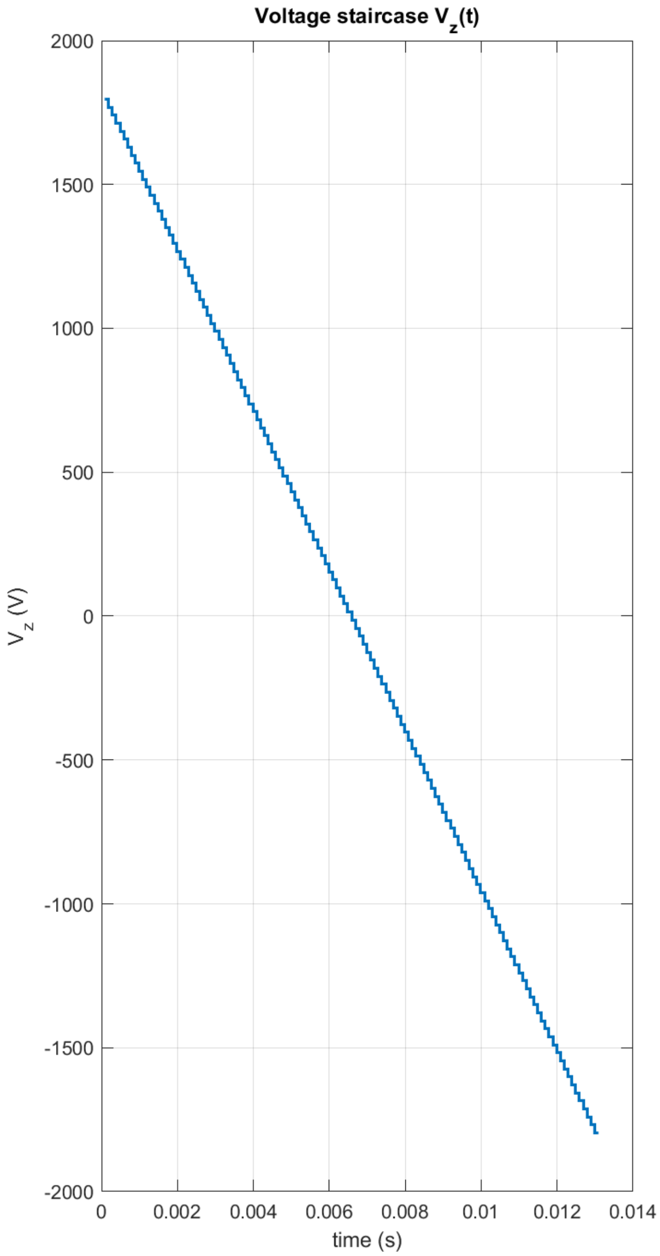

Figure 6: Inkjet Capacitor Voltage Staircase for 3x Distance Cap from Paper – Iteration 2

For part B, the capacitor plate area is doubled, resulting in a longer channel along which the droplets are exposed to the electric field. All other values are kept as default. For this part, the larger plate area results in the droplets experiencing the electric field for longer, which results in a lower max +/- voltage staircase to draw the 'I' of 3000 volts, as opposed to the default 5000 volts. However, this also increases the risk of droplets colliding with the plates of the capacitor, and thus is less desirable then the 3x distance of part A.

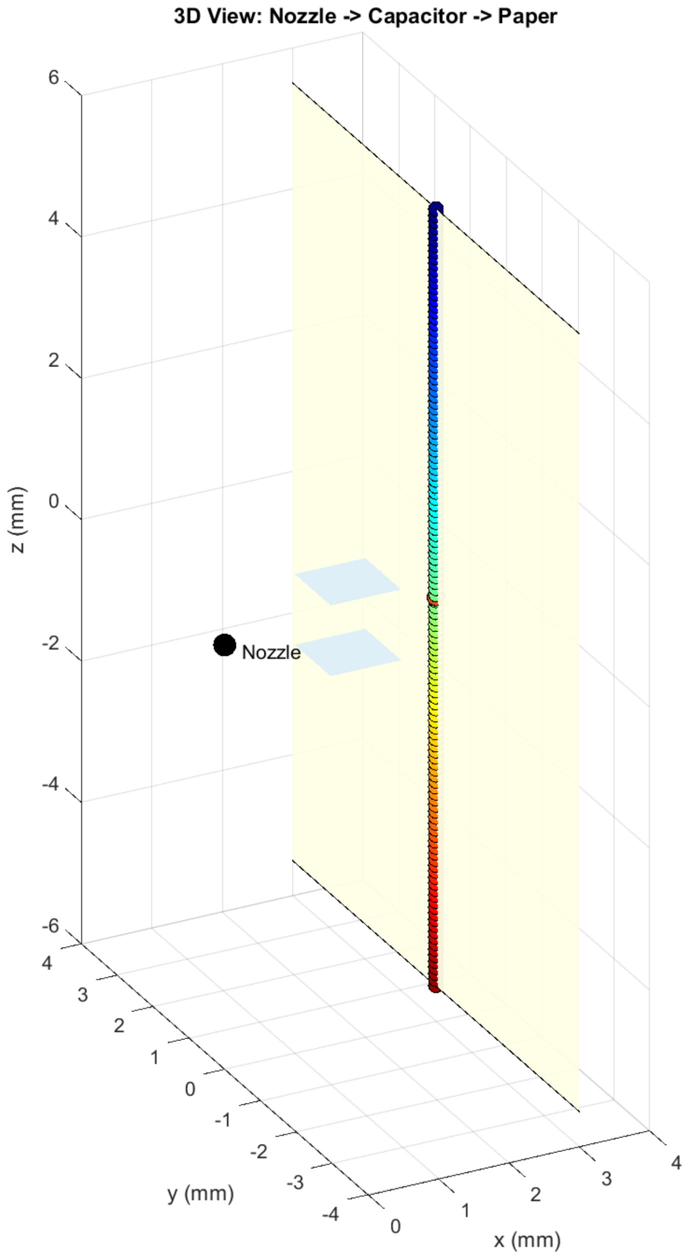

Figure 7: Inkjet Capacitor Simulation with 2x Capacitor Plate Area – Iteration 2

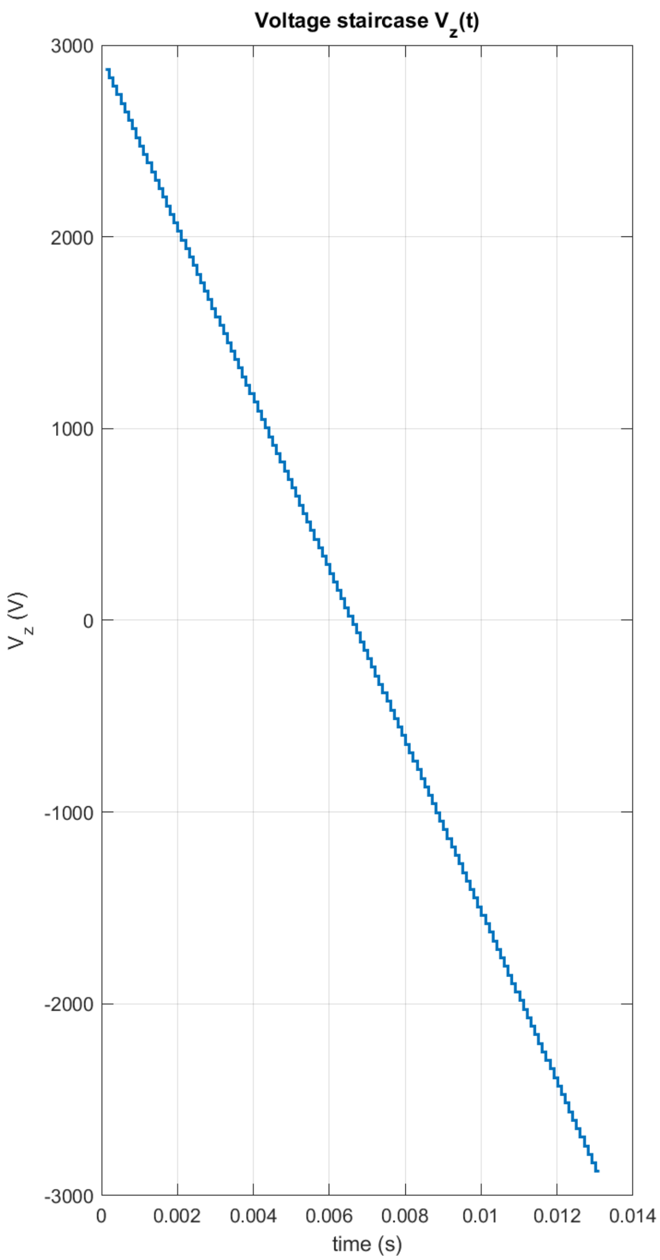

Figure 8: Inkjet Capacitor Voltage Staircase with 2x Capacitor Plate Area – Iteration 2

For part C, the horizontal speed at which the nozzle/droplet gun shoots is doubled, changing from 20 m/s to 40 m/s, with all other values remaining the same. The associated simulations and voltage staircase plot can be found below.

For all previous parts, a maximum voltage of 5000 volts was plenty, but for part C; 20,000 volts was required to create a line that fully reaches from top to bottom. Clearly, by increasing the velocity, the required voltage to achieve the same range on the paper is also increased, effectively quadrupling from a doubling of the horizontal speed. This feature means that increasing the droplet guns speed is limited by the voltage maximums allowed, and generally lower speeds would be preferred.

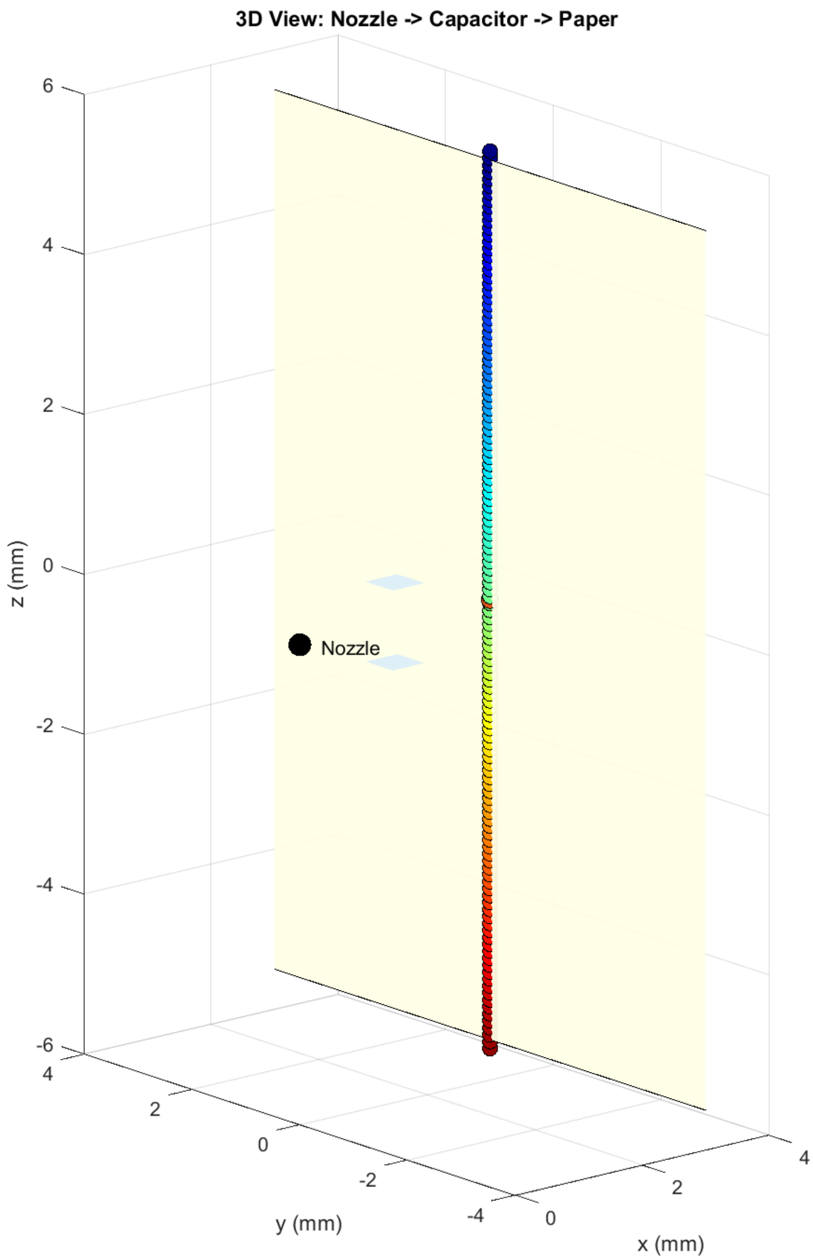

Figure 9: Inkjet Capacitor Simulation with 2x Vx from Droplet Gun – Iteration 2

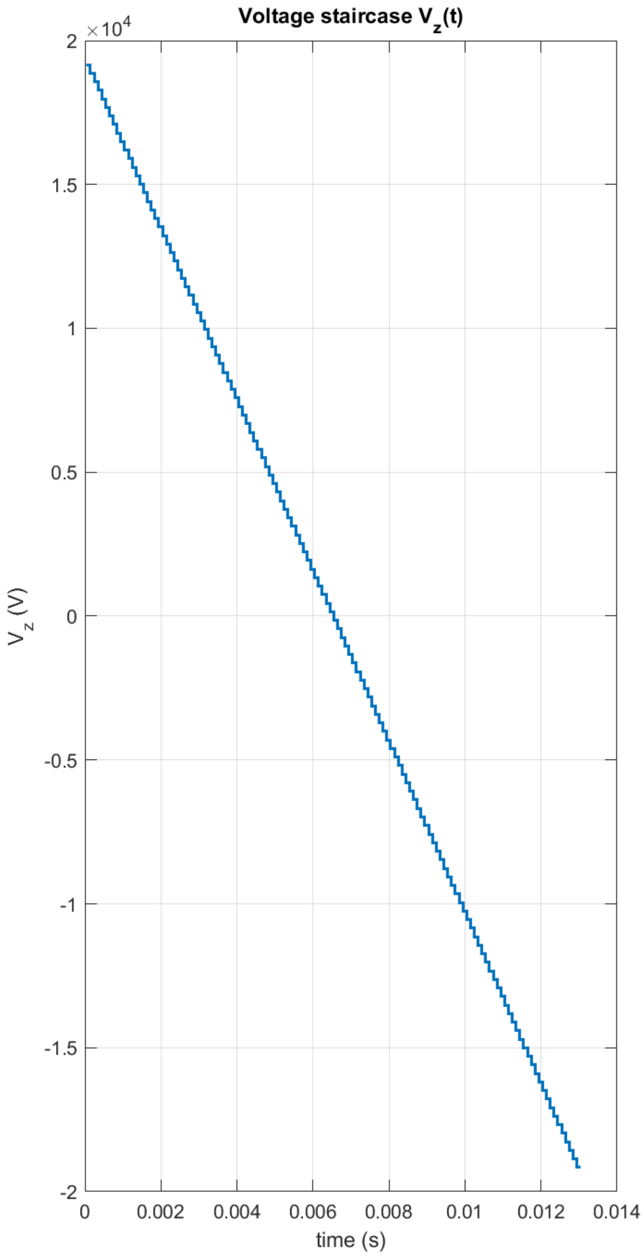

Figure 10: Inkjet Capacitor Voltage Staircase with 2x Vx from Droplet Gun – Iteration 2

For part D, the charge of the droplet is increased by 5x, with all other values remaining at default. The associated simulations and voltage staircase plots are found below.

The increased charge results in greater force upon the charge, requiring a lower maximum voltage of +/- 1000 volts, which is roughly 1/5 the maximum voltage from default, which is a linear relationship between droplet charge and applied max voltage needed to fully cover from top to bottom.

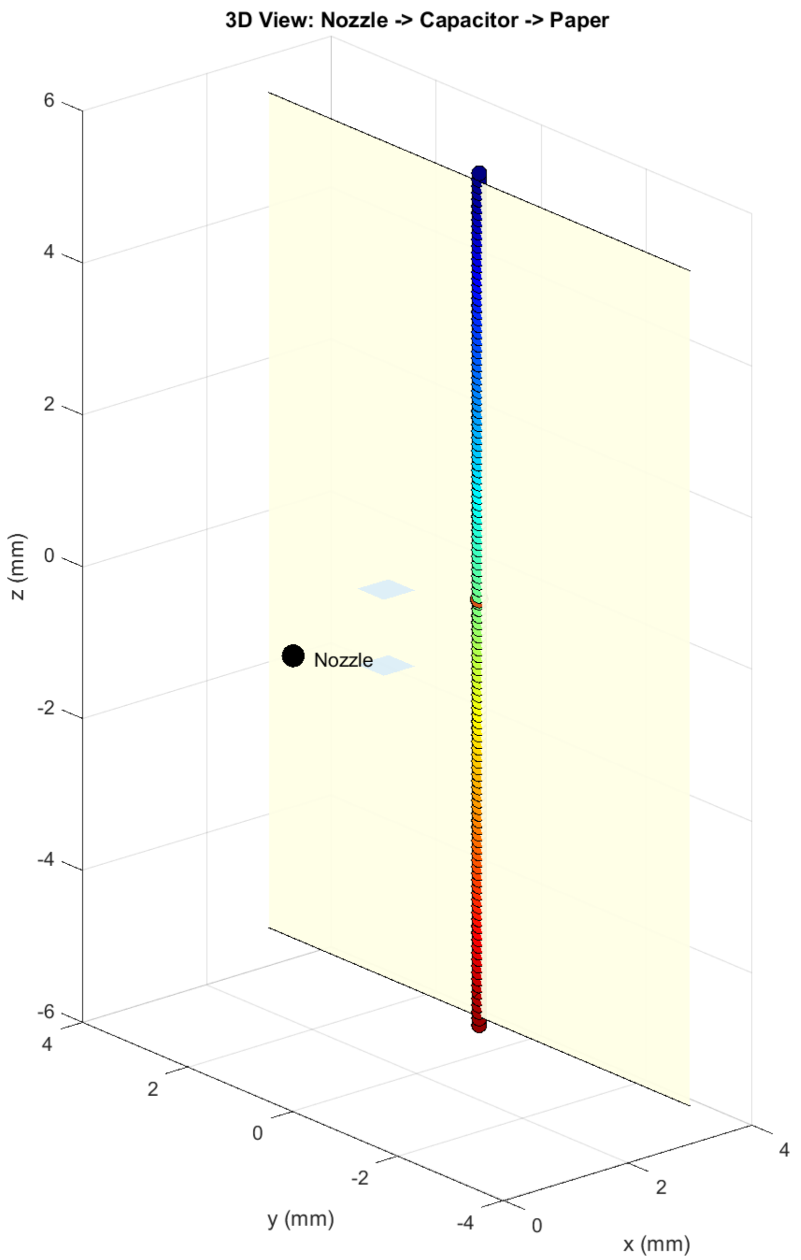

Figure 11: Inkjet Capacitor Simulation with 5x Droplet Charge – Iteration 2

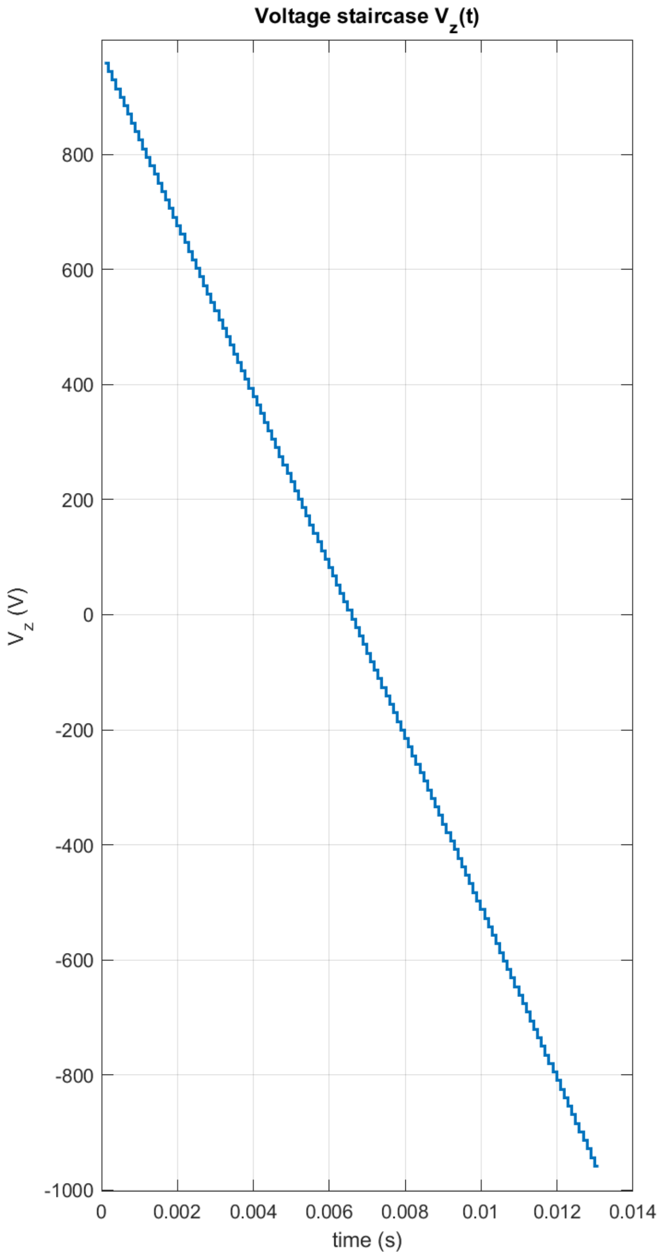

Figure 12: Inkjet Capacitor Voltage Staircase with 5x Droplet Charge – Iteration 2

For part E, the diameter of the droplet was increased by 10x, with all other values kept constant. The associated simulation and voltage staircase are displayed below.

The maximum voltage required to create a line from top to bottom of the page is ridiculously higher, at about 5 Million volts, which is roughly 5000 times larger voltage for only a 10x increase in diameter. Diameter of the droplet of course affects the mass of the droplet, which is real life would increase gravity, but here the important effect is the greater the mass, the greater the force needed to accelerate to some object. That relationship is linear; however, the diameters increase in mass is not, with these effects multiplying and resulting in the large maximum voltage needed.

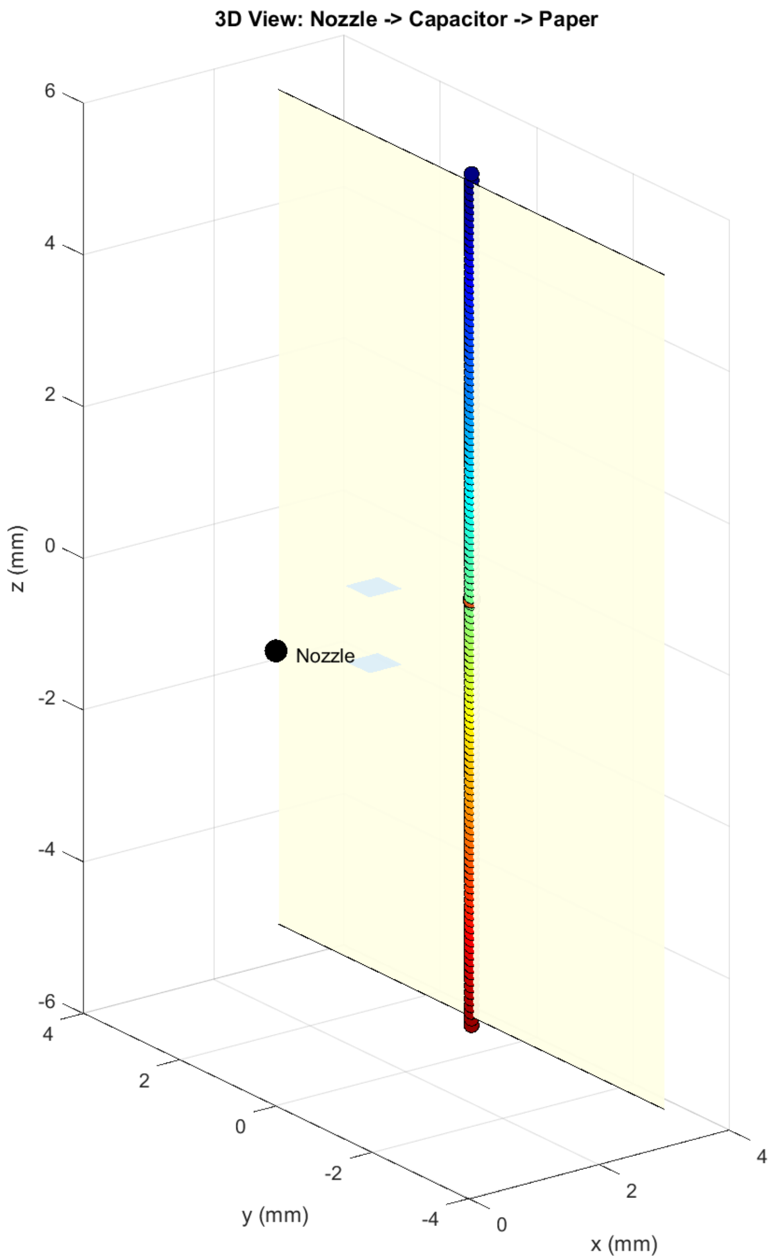

Figure 13: Inkjet Capacitor Simulation with 10x Droplet Diameter – Iteration 2

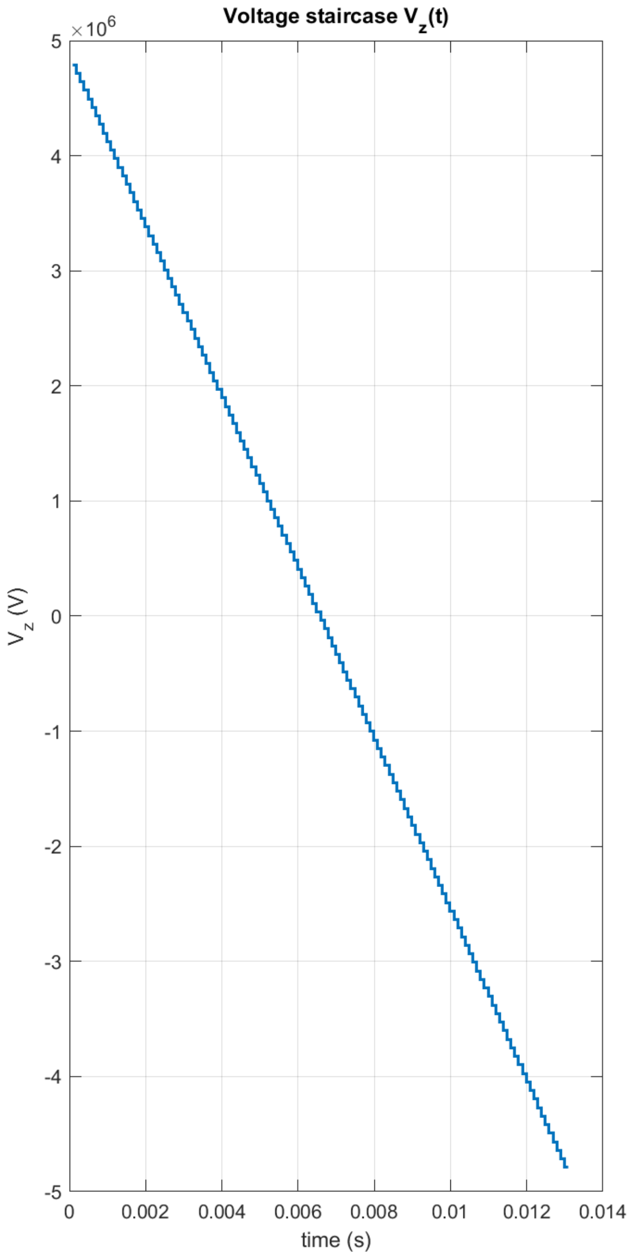

Figure 14: Inkjet Capacitor Voltage Staircase with 10x Droplet Diameter – Iteration 2

Objective #5

For Objective #5, two capacitors are combined to provide 2D resolution, and create actual letters; with an H shape from the droplet gun being designed for 300 DPI. A capacitor with the same dimensions (Area per Plate = 0.25 mm^2; Distance between Plates = 1mm) was chosen.

However, the capacitors are perpendicular to one another, as well as symmetric to the droplet gun and piece of paper. A small bit of space on edges was allocated so as to avoid touching between the capacitor plates, which wouldn't affect the simulation, but of course would realistically affect the capacitors parameters.

Below is the resultant simulation, as well as voltage staircase plots for both capacitors. The H-configuration is created through a three-part process, where one vertical leg is created, then the horizontal connection, before then creating the second vertical leg. This three-step process is characterized by the voltage staircase graphs for vertical and horizontal control capacitors.

For each leg, the vertical and horizontal control capacitors work in tandem to send droplets (usually) diagonally in the y and z directions, with a fixed value of y, creating lines that aren't directly in line with the standard vertical capacitor. To achieve the fixed value of y, the horizontal capacitor is kept at a constant voltage while the vertical capacitor varies.

For the horizontal section, only the horizontal capacitor has voltage applied to it, in a similar staircase to the other simulations; with the vertical capacitor receiving zero applied voltage during this period.

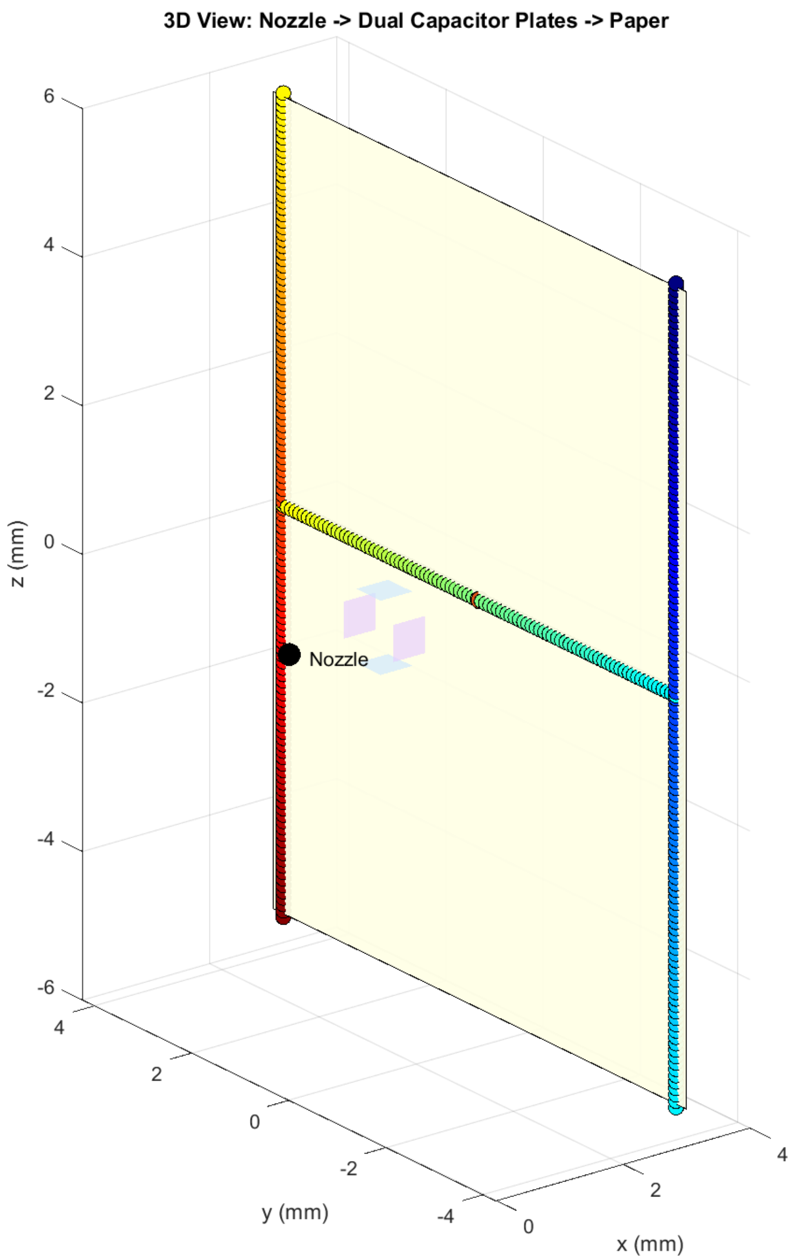

Figure 15: Inkjet Capacitor Simulation with H-Configuration – Iteration 3

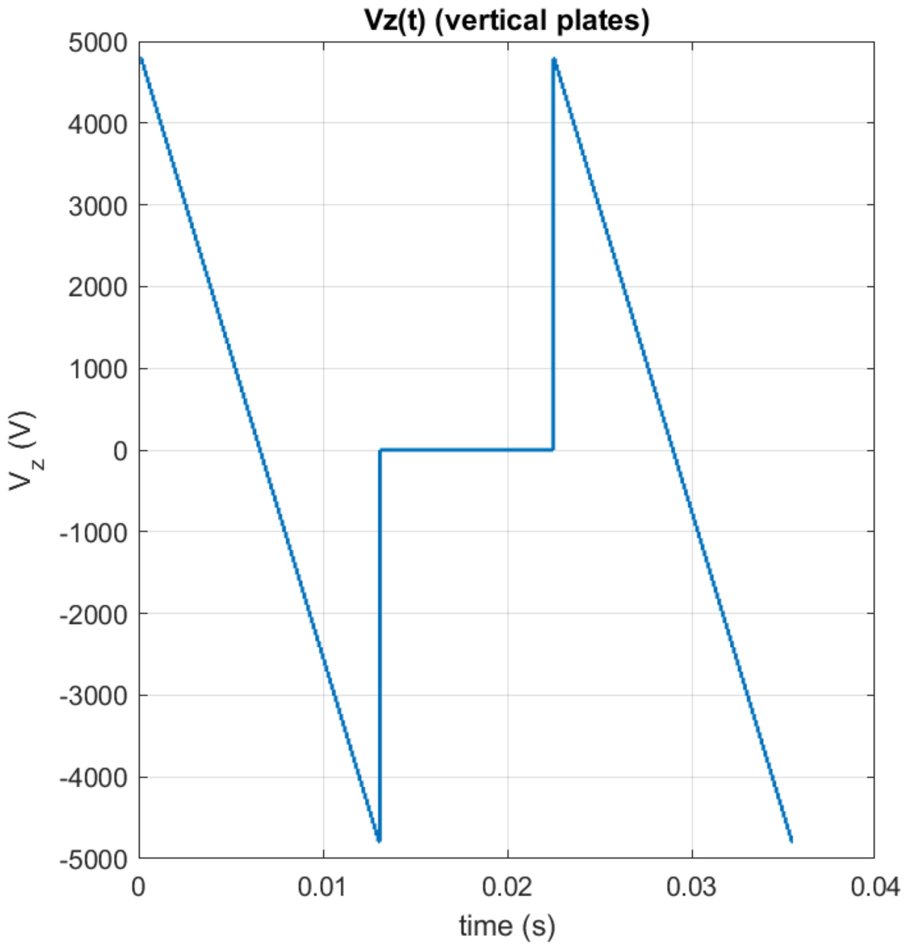

Figure 16: Inkjet Capacitor Voltage Staircase for H-Config. (Vertical) – Iteration 3

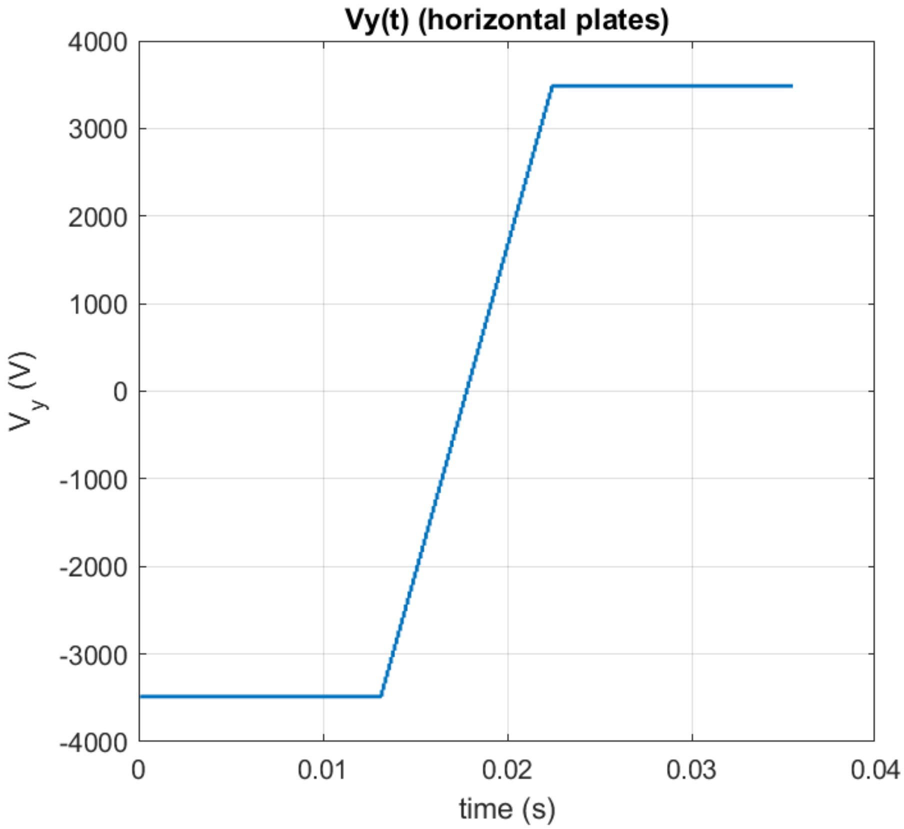

Figure 17: Inkjet Capacitor Voltage Staircase for H-Config. (Horizontal) - Iteration 3

This project was created by me, Miguel Aviles, thank you for reading!