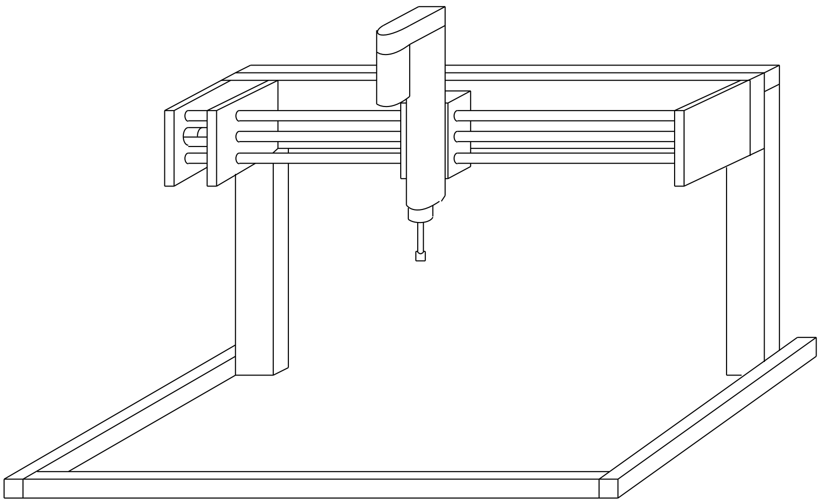
AUTOMATED DIPPING SYSTEM (ADS) MANUAL

August 2023



Lucas O'Brien and Pablo Pardo Vargas

Contents

1 Introduction

The Automated Dipping System (ADS) was created in the summer of 2023 to automate the fabrication of nanoengineered materials. It is capable of growing up to four samples at a time through a combination of immersions in nanoparticle and crosslinker solutions, and rinse cycles. The GitHub for the project can be accessed here[1].

The skeleton of the ADS consists of an aluminum extrusion frame. This holds the linear stage actuator, which allows for motion in the x-direction. The position of the stage is controlled by a Nema 23 stepper motor. Mounted on the stage is a linear actuator, which controls motion in the y-direction. The linear actuator is mounted via an optical rail, to allow for adjustments to the vertical positioning. The sample holders are attached to the end of the linear actuator via a custom manufactured Teflon piece. On the left side of structure is a limit switch. This serves two purposes: it prevents the stage from moving too far left, and it allows the program to calibrate in the x-direction.

The ADS is controlled by an Arduino Mega ADK and a laptop. Once it has been calibrated, the dipper has two modes: dipping mode, where it runs through a predetermined dipping cycle, and joystick mode, where it can be controlled by the joystick. While in dipping mode, the dipper has an LCD screen to record the number of cycles completed to allow the user to track the number of layers grown.

The computer is equipped with a graphical user interface (GUI) to allow the user to program the dipping cycle. Once the dipping cycle has been started, the dipper is able to run without the computer, although reconnecting it (via the CONNECT button on the GUI) will cause the dipper to re-calibrate and the cycle will be interrupted. Therefore, when there is not a good reason to disconnect the computer, it is recommended that it is kept plugged in during the dipping cycle.

2 Using the ADS

2.0.1 Key Points

- When power is restored to the dipper and the computer is disconnected, or the computer is reconnected, the dipper will recalibrate.
- The order and orientation of sample holders matter.
- Check that the solution vials are in the right place using joystick mode before running a dipping cycle.
- Before running a dipping cycle, remember to double check the positions, times, rinse cycles, and number of layers.
- Connect the computer by pressing CONNECT, and begin the cycle by pressing SUBMIT.

2.1 Setup

2.1.1 Calibration

Upon being connected to power (when not receiving power from the computer), or reconnecting with the computer by pressing the CONNECT button on the GUI, the ADS will automatically calibrate. So no solutions are spilled in the case that the dipper calibrates while the sample holders are being dipped, the calibration begins with 20 seconds of upward motion to ensure that

[1] `https://github.com/pfpv0/Dhirani-lab-dipping-machine`

the linear actuator begins in the fully retracted position. Then, the stepper motor moves the stage left until it hits the limit switch, where it sets the position to be zero. After the dipper is calibrated, it will be in joystick mode.

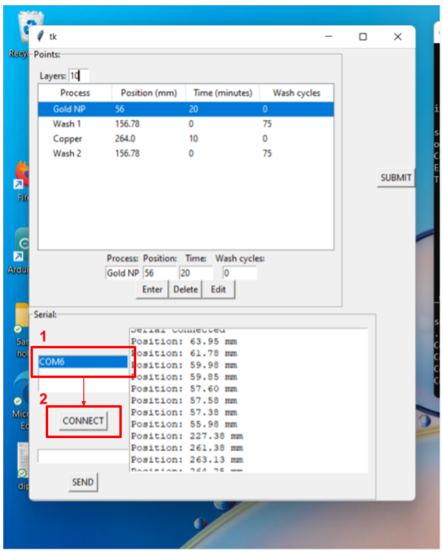
2.1.2 Sample Holders

The four sample holders are placed into the holes in the block which attaches to the linear actuator, and then held in place by pins. The order of the sample holders matter, as the pins do not fit perfectly into each sample holder. Furthermore, the orientation of the sample holders in the block matters. Each sample holder has a marking on the top to signify which number it is. The first sample holder has a single line from the centre to the edge, the second sample holder has two lines making a right angle, and the third sample holder has a line bisecting the top as well as a perpendicular line. These lines align with markings on the block, although it may be easier to remember that the screw on the first three sample holders should face to the left when being placed in the dipper. The fourth sample holder has a circular shape on the top, and fits in the opposite orientation from the rest (i.e. screw facing to the right). Note that the fourth sample holder fits looser than the rest, and will fall out of the block if its pin is removed.

In order to place a sample in the sample holder, put the sample holder upright in the sample changing block. Ensure that the screw is fully loosened. Hold the sample with a pair of tweezers, and use a second pair of tweezers to gently widen the slit in the sample holder. Place the sample in the slit and remove the second pair of tweezers. Hold the sample in place with the tweezers while the screw is tightened. Tighten the screw until the sample is fully secure.

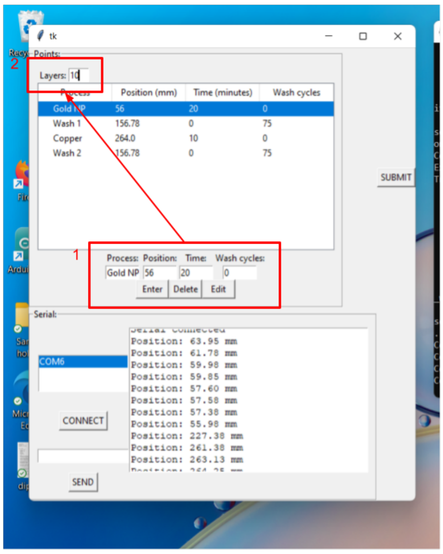
2.1.3 Setting the GUI

To use the GUI to upload a dipping procedure, start by making sure the computer is plugged in to the Dipper. Open the python script in the desktop. Click on the serial output (it should be prefaced by COM) and click CONNECT. If no serial ports are available, try closing the script, reconnecting, and opening again. It may also help to remove power from the dipper before attempting to connect with the computer. Once CONNECT is clicked, the dipper will start its calibration sequence. It will take 20 seconds before there is any movement in the x-direction.



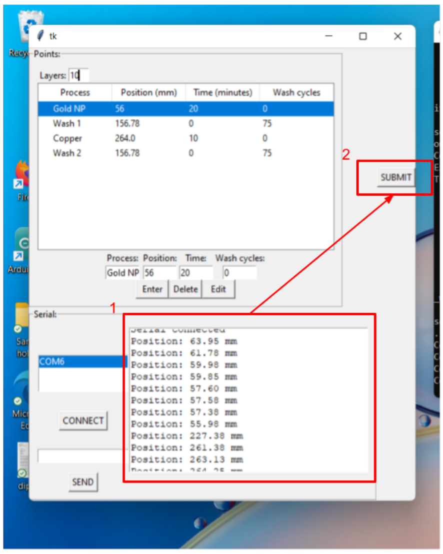
The procedure can be edited using the entries in the marked by the red square. Under "Process", label which step of the dipping cycle you are adding. "Position" refers to the position were the machine will dip, measured in millimeters from the limit switch. "Time" is the time spent submerged, and "Wash cycles" refers to the number of rinse cycles performed. Note the dipper is not able to both wash and dip in the current code because of height differences in the vials and wash basins. Therefore, make sure that one of either "Time" or "Wash cycles" are zero for each entry. Click ENTER to add the step into the procedure, at which point it will be added to the end of the table. You can also edit or delete a step by clicking on it in the table and using the EDIT or DELETE buttons.

The number of immersion cycles can be set in the box labeled "Layers".



Before the procedure is sent to the Dipper, it is a good idea to check that all the vials are in the right place. The sample holder can be moved to the right place using the joystick, and the position will be printed on the serial monitor.

Finally, start the dipping cycle using the SUBMIT button.



2.2 Using the Dipper

2.2.1 Cycle Count

The LCD screen will display the cycle count, as well as the stop that the ADS is on (i.e. which step of the process it is on). The LCD screen will not work if the computer is unplugged, as the Arduino does not have enough power without the computer. If the LCD screen is blank, reconnecting the computer on will restart it, and it will display the correct cycle count. A new layer is when the linear actuator is fully retracted at the end of the last stop of the cycle. For example, in the case of the example procedure, this will be when the linear actuator is fully retracted after finishing Wash 2.

2.2.2 Stopping a Cycle

If the ADS has completed the number of immersion cycles set in the "Layers" box, the dipper will automatically come to a stop at the initial position set with the linear actuator in the fully retracted position after running the specified number of cycles. To stop a cycle before the layer count has been reached, remove power to the dipper. This will stop it from moving, but will not stop the computer from continuing to count the layers, so be sure to record the number of layers grown when power is removed.

2.2.3 Restarting a Cycle

Restarting the Dipper is relatively simple. If the Dipper stopped after completing the inputted number of layers, you can simply click SUBMIT again. If the Dipper was stopped manually, click CONNECT. Reestablishing serial connection with the Arduino automatically restarts. This will cause it to recalibrate. After calibration, click SUBMIT.

3 Troubleshooting and Repairs

3.1 Electronics

The electronics are housed in the grey box beside the dipper. There are three main components: an Arduino Mega ADK to communicate with the computer, a microstep driver to communicate with the stepper motor, and a motor driver to communicate with the linear actuator. The microstep driver (for the stepper motor) communicates with the Arduino through pins 30 and 31. Pin 30 is responsible for changing the direction of the motor, and pin 31 is responsible for moving the motor. The motor driver communicates with the Arduino through pin 40 and 41.

The joystick communicates with the Arduino through pin A2 and A3, and receives 5V power from the Arduino. The limit switch is attached to pin 48. **Please note** that only two of the wires on the limit switch are in use: the black wire is redundant as the orange wire is attached to ground on the Arduino. Finally, the LCD screen is attached to the Arduino through the SDA and SCL pins, receives 5V power from the Arduino, and is grounded to the Arduino. The pins are summarized in Fig. 3.1.1.

Component	**Pin #**	**Wire colour**
Microstep Driver DIR+	30	Yellow
Microstep Driver PUL+	31	Green
Motor Driver IN2	40	Yellow
Motor Driver IN1	41	Green
Joystick VRX	A3	Blue
Joystick VRY	A2	Green
Limit Pin	48	Red
LCD Screen SDA	SDA	Purple/orange
LCD Screen SCL	SCL	Blue/yellow

Fig. 3.1.1 Summary of Arduino pins

An internal electronics diagram is shown in the appendix. The power and ground for all the internal electronics attach to the Molex, which is plugged into the power supply.

Note that the microstep driver can get hot during use, so it is important to ensure that the fan is working well to keep it from overheating. The inputs ENA-, ENA+, DIR-, and PUL- on the microstep driver are all wired to ground. The driver communicates with the stepper motor through B-, B+, A-, and A+, which attach to the yellow, blue, green, and red wires of the stepper motor, respectively. The microstep driver receives 24V power from the power supply.

4 Appendix

4.1 Electronics Diagram

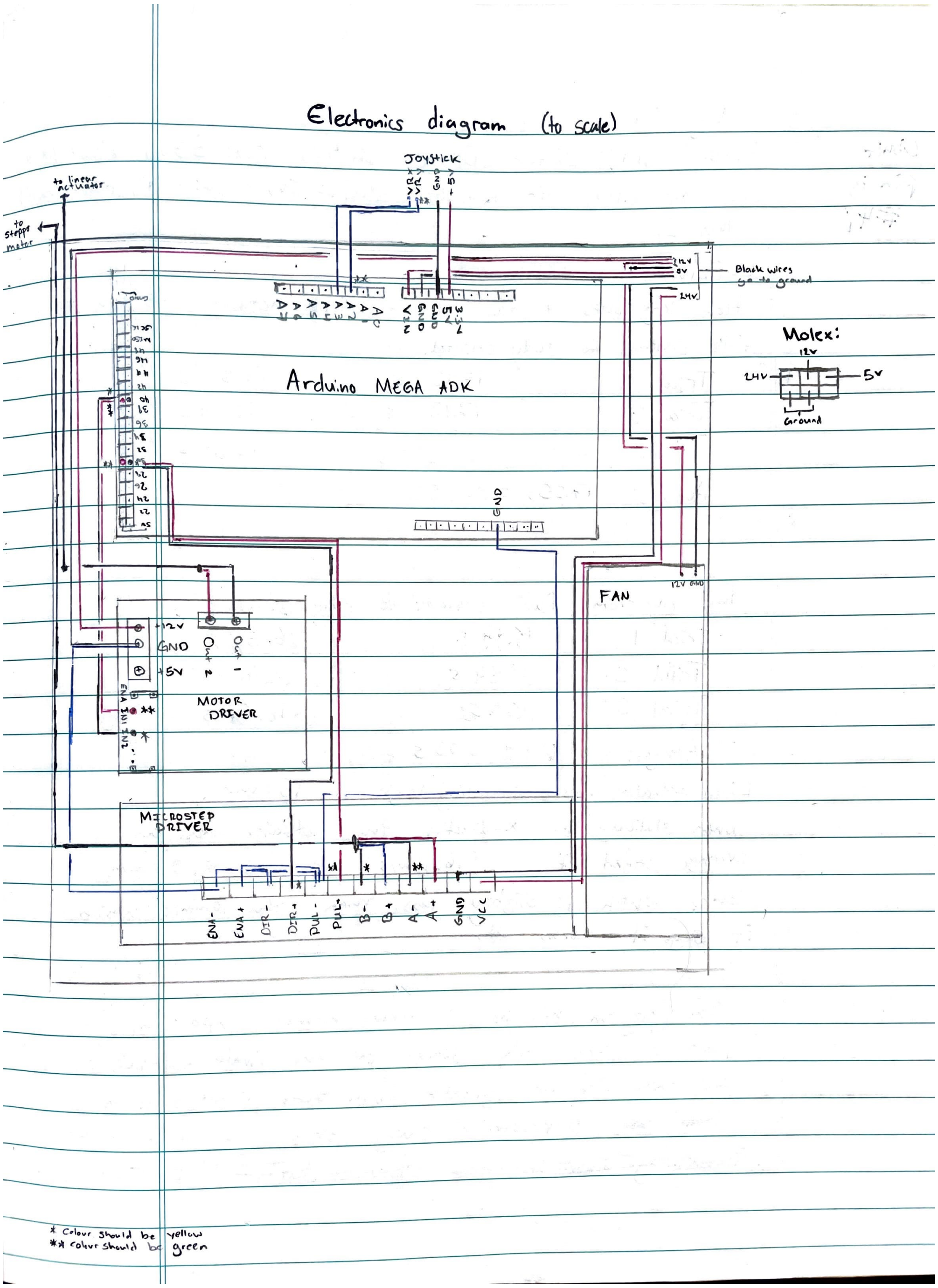


Fig. 4.1.1 Wiring diagram of the electrical components.

4.2 Distance Conversions

In older versions of the code, the distance moved by the stepper motor is measured in half steps, which is equivalent to half a revolution (100 pulses). Each half step is 2.49 mm ± 0.01 mm. Newer versions use measure distance by individual pulses, equivalent to 0.025mm. All these measurements were taken without microstepping on in the microstep driver.

The distance moved by the linear actuator is measured in seconds. The time it takes to fully extend from the fully retracted position is 16.68 ± 0.03 seconds, while the time it takes to fully retract from the fully extended position is 17.25 ± 0.06 seconds. These measurements were taken when the linear actuator did not have the sample holder block attached, so the added weight may change the times slightly.