5. Build instructions

5A: Software/Hardware Set Up

Step 1: Install Micropython onto Pico

Flash the Raspberry Pi Pico with MicroPython. Follow the directions in this link:
https://www.raspberrypi.org/documentation/microcontrollers/micropython.html

Step 2: Install Thonny IDE

After flashing MicroPython onto the Pico, we need to upload the Sidekick's code to the microcontroller.

Download the Thonny IDE. This will be used to load the provided code onto the Pico.
https://thonny.org/

Once downloaded, install, and follow the prompts for set up with MicroPython and the Raspberry Pi Pico.

Step 3: Download the Sidekick snapshot

Go to the Sidekick GitHub page to download all the necessary files:

https://github.com/rodolfokeesey/Liquid-Handler

Go to the folder marked "Pico Snapshot" and download the contents. Now return to Thonny. Navigate to View -> Files.

Step 4: Upload the Sidekick snapshot to Pico

In the upper panel, navigate to where you downloaded the snapshot files. On this (Windows) machine it's under:

C:\Users*User Name*\Desktop\PicoSnapshot10_1_21

Then, right click on each item in the snapshot, and click "Upload to /" in the dropdown. This saves each of the files onto the Pico.

Step 5: Opening the main loop

Once all the files are uploaded, press the "Open Icon" then select the Raspberry Pi Pico. Open the main.py file.

Step 6: Running the main loop

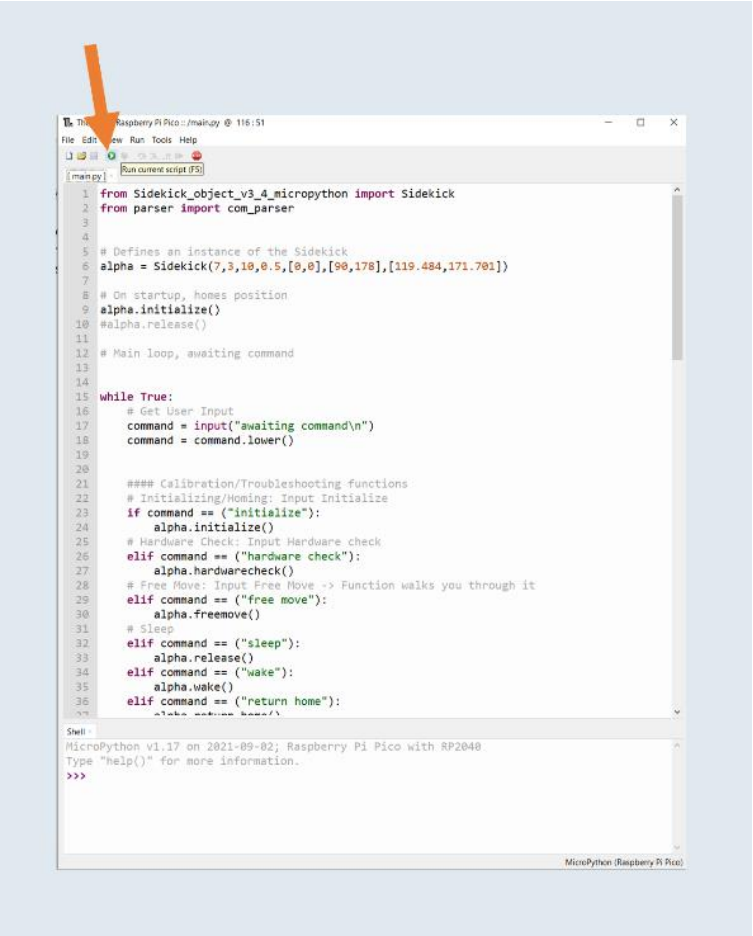

Figure 11: Running main.py

Once opened, press the green “run current script” button (Fig. 7). This initializes the main loop of the robot. Because the Sidekick is not currently attached to any hardware, nothing will happen. Just disconnect the Pico from the computer. Do not press the “Stop” button in Thonny. The main loop should be left running. The Pico is now flashed with the Sidekick’s code.

Step 7: Ordering the custom PCB

Product Detail

Gerber file:	SideKickV3_Y4	Build Time:	1-2 days
Layers:	2	Dimension:	81.8 mm * 69.3 mm
PCB Qty:	5	Different Design:	1
Delivery Format:	Single PCB	PCB Thickness:	1.6
Impedance:	no	Layer stackup:	
PCB Color:	Green	Silkscreen:	White
Surface Finish:	LeadFree HASL-RoHS	Deburring/Edge rounding:	No
Outer Copper Weight:	1	Gold Fingers:	No
Flying Probe Test:	Fully Test	Castellated Holes:	no
Remove Order Number:	No	4-Wire Kelvin Test:	No
Material Type:	FR4-Standard Tg 130-140C	Paper between PCBs:	No
Appearance Quality:	IPC Class 2 Standard	Confirm Production file:	No

Figure 12: The JLCPCB order options for the Sidekick PCB

The Sidekick has a custom PCB designed in Fritzing. The files for the PCB are in the “PCB” folder on the Sidekick’s GitHub page. We used JLCPCB to manufacture a set of 5 boards (https://jlcpcb.com/). Upload the SidekickV3.zip file to JLCPCB. The settings for the board are pictured in **Figure 8**.

Step 8: 3D Printing Sidekick components

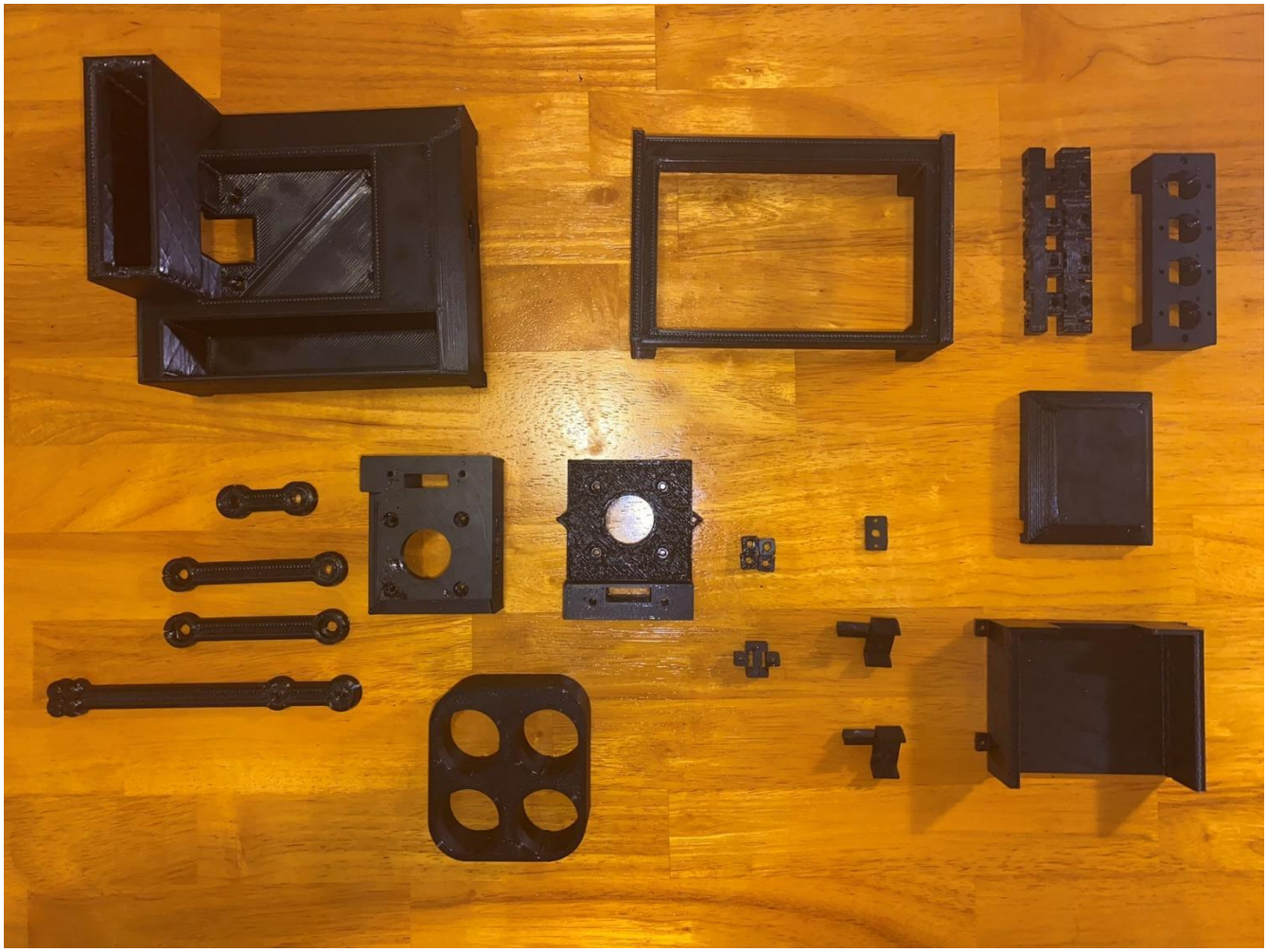

Figure 13: The 3D-printed parts Sidekick components.

Go to the folder marked “3D Assets” and download all files. We recommend printing the models in PETG, as it has greater strength, higher temperature tolerance, and slightly better chemical resistance than the more commonly used PLA, while still being relatively easy to print. If you do not have access to PETG, you may print them in PLA, but monitor the armature for slippage against the shaft due to motor heat. Print 8 copies of the foot.stl file, and one copy of every other file.

Print with the following settings:

20% Infill
Support Everywhere
15% Support Density
3 Wall Perimeter, or equivalent 1.2 mm Perimeter

One prototype (pictured throughout) was printed on a Creality CR10S Pro V2, using PETG. The layer heights were set to 0.42 mm on a 0.6 mm nozzle and printed with an 80 °C bed temperature and 240 °C nozzle temperature. A second prototype was printed on a Prusa MK3S using PLA with 0.35 mm layer height and 0.4 mm nozzle.

5B: Preliminary Wiring

Step 1: Prepare wires

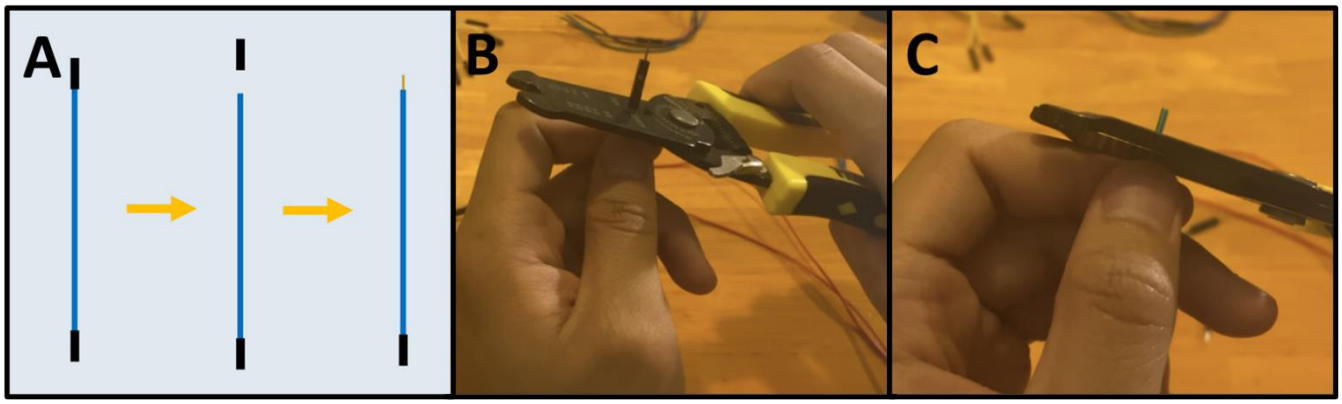

Figure 14a-c: The procedure for preparing the Dupont connectors

See **Figure 14a** for an overview of the wire preparation, 12 male-to-female Dupont connectors are needed. Cut the male end from a male-female Dupont connector (Fig 14b), then strip the remaining wire to expose the bare wire (Fig. 14c). Use these stripped wires for steps 2-3. **Be sure to match the wire colors in the diagram** which will allow you to easily follow the instructions for connecting the cables into the PCB.

Step 2: Splice Dupont Connectors to Stepper Motors

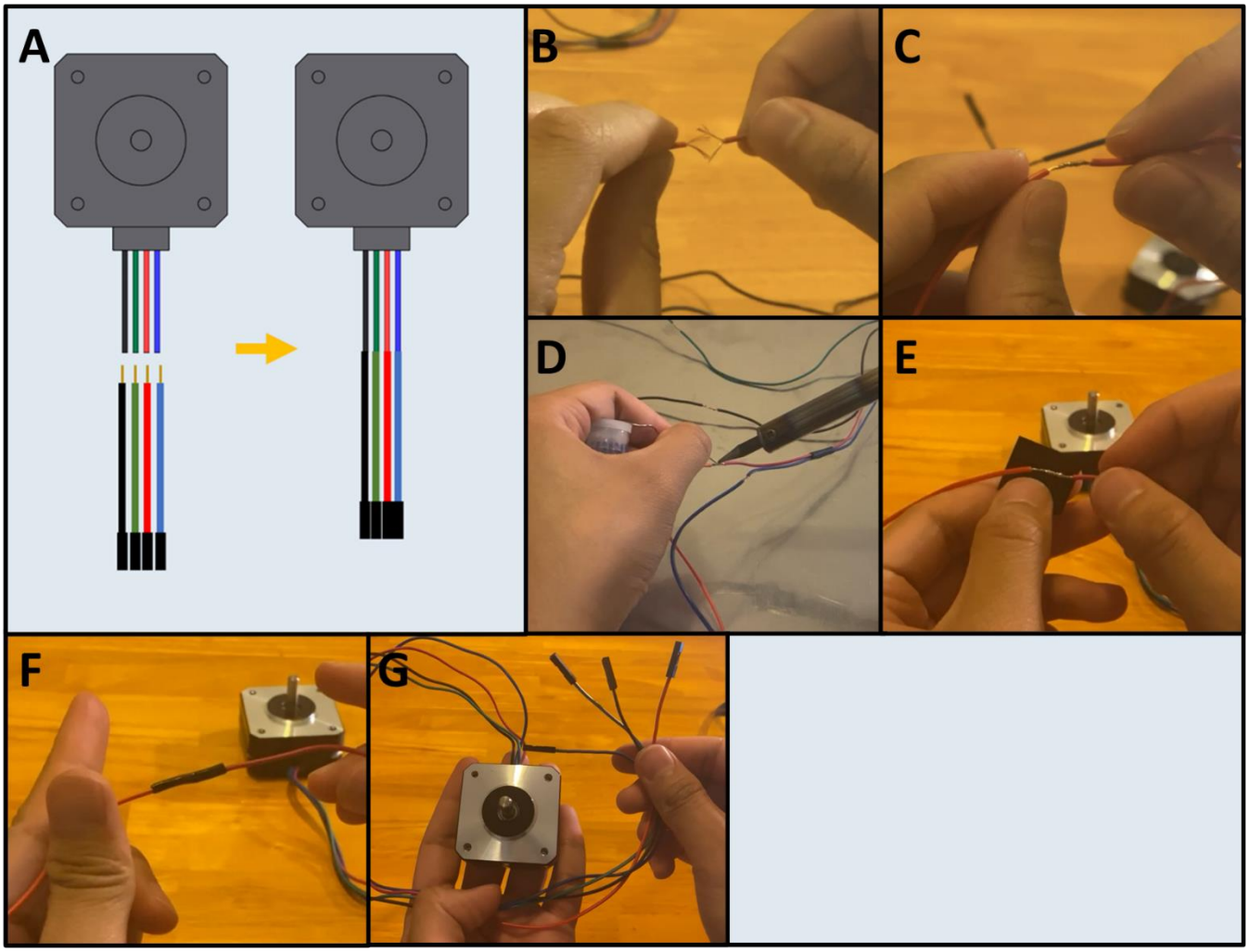

Figure 15a-g: The procedure for splicing the prepared Dupont connectors to the stepper motors.

Figure 15a gives an overview of the cable connection. Use wire strippers to strip away the insulation from the ends of the stepper motor wires. Then, splice matching colored Dupont cables prepared in Step 1 (Fig. 15b) to the stepper motor wires, the resulting connection should look like (Fig. 15c). Then solder the connection (Fig. 15d) and wrap the exposed wire with electrical tape (Fig. 15e). The resulting join should look like (Fig. 15f). Repeat for the remaining cables and stepper motors (Fig. 15g) This elongates the stepper motor cables and allows them to connect to the male header pins of the PCB.

Step 3: Connecting wires to the Limit Switches

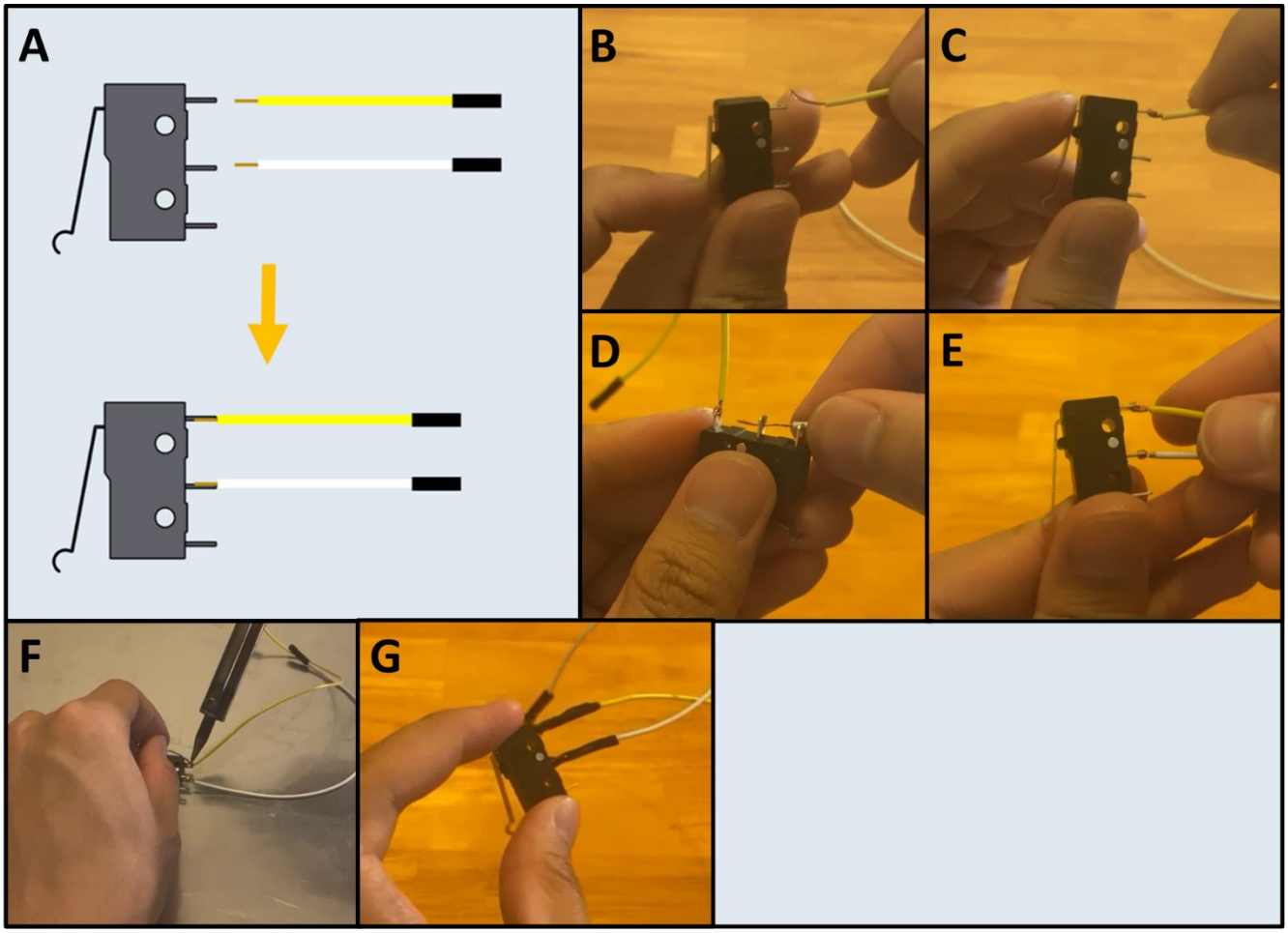

Figure 16a-g: The procedure for connecting the prepared Dupont cables to the two limit switches.

Figure 16a gives an overview of the limit switch preparation. Gather a limit switch and a prepared Dupont cable (Fig. 16b). Wrap the stripped end of the prepared cable around the exposed lead of the limit switch (Fig. 16c). Repeat with the middle lead (Fig 16d-e). Solder both the joins (Fig. 16f) and wrap with electrical tape (Fig. 16g). Repeat for the second limit switch.

Step 4: Wiring the Purge Button

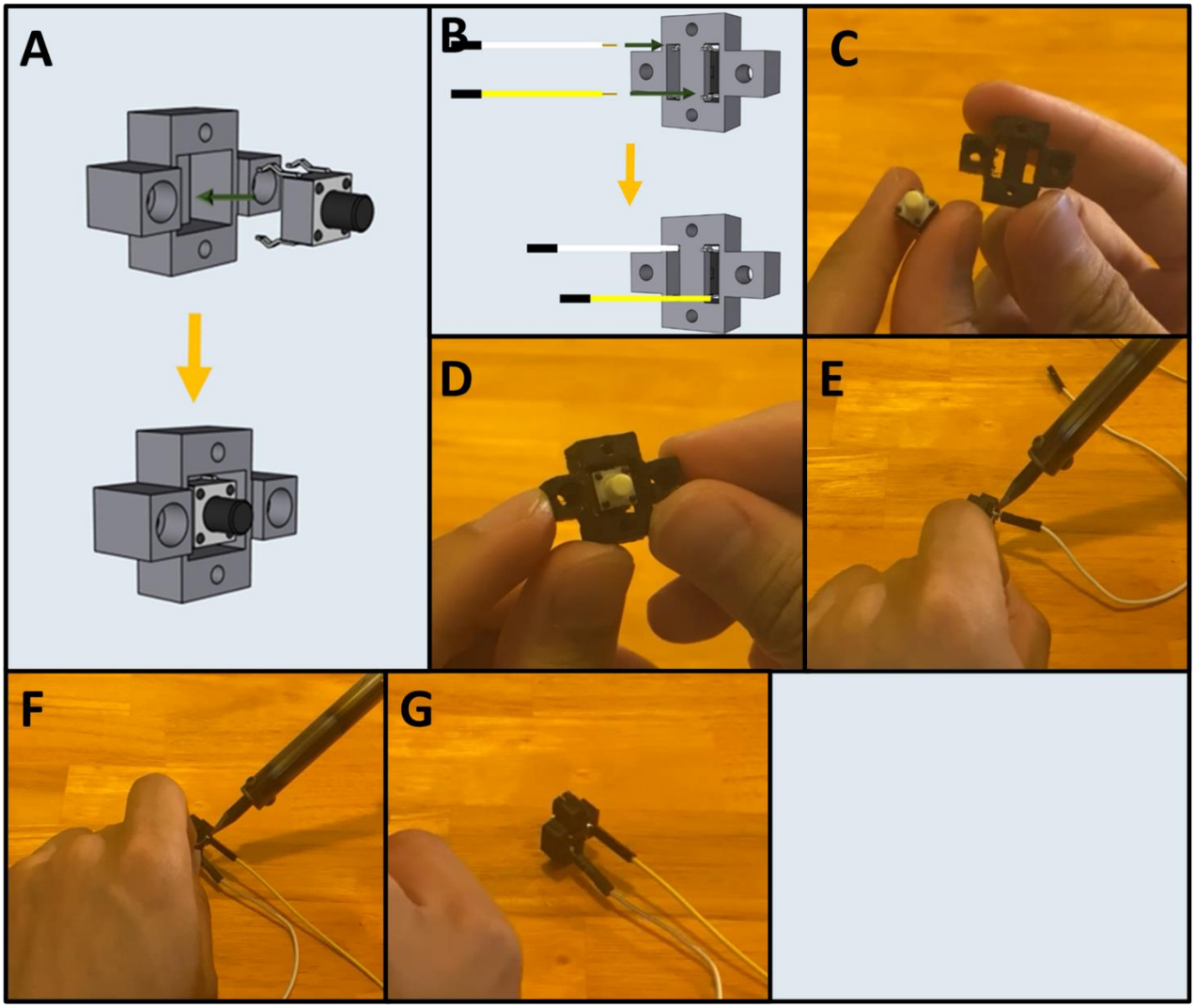

Figure 17a-g: The procedure for preparing the purge button.

Figure 17a-b gives an overview of the purge button preparation. Gather the button housing, button, and a yellow and white, male to female Dupont cable (Fig. 17c). Press the button into the button housing (Fig. 17d) and then solder the male leads of the Dupont cable to the button leads (Fig 17e-f) in the configuration indicated on Figure 17b. The finished button should look like Figure 17g.

Step 5: Attaching Dupont Cables to LPL Pumps

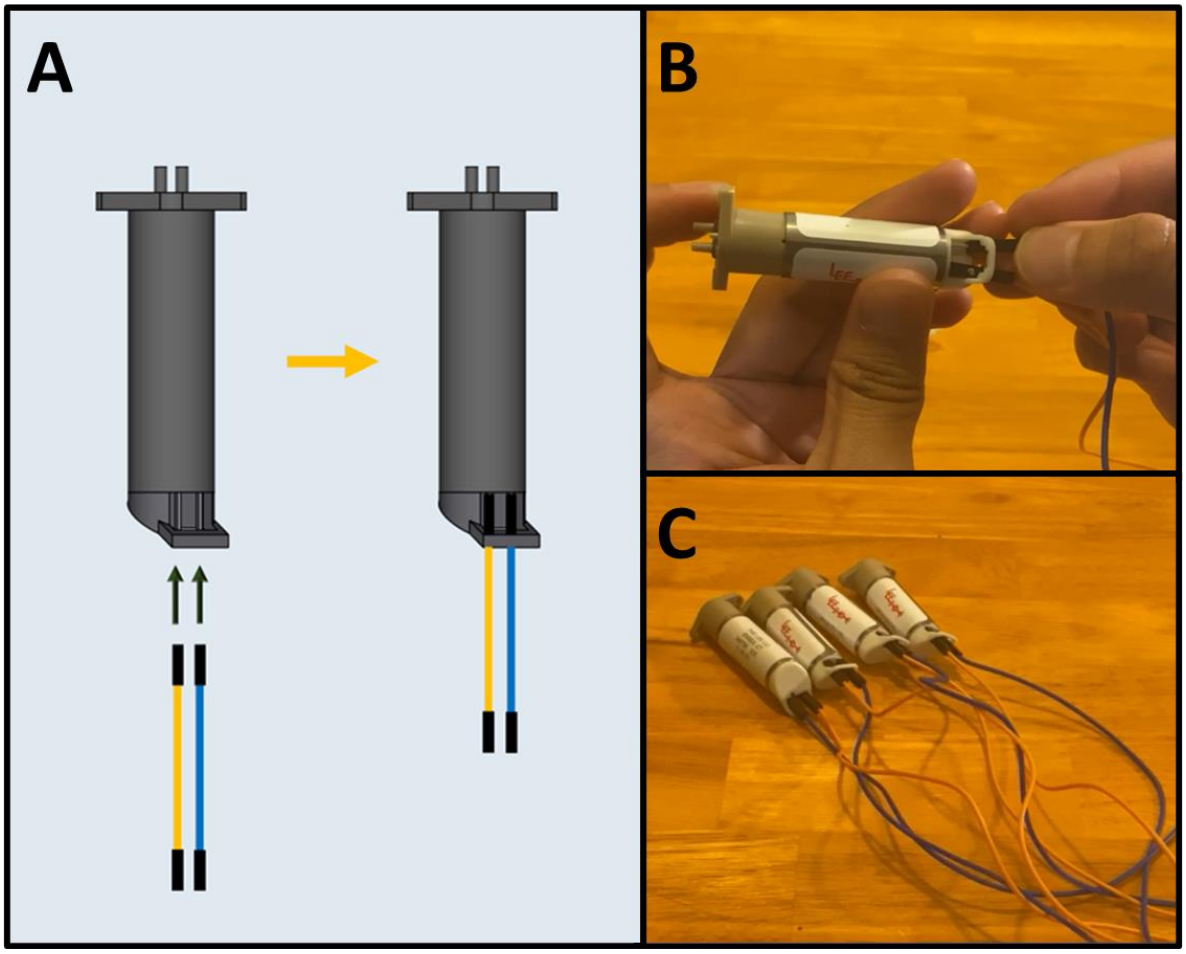

Figure 18a-c: The procedure for preparing the LPL pumps.

Figure 18a gives an overview of the pump procedure. Gather the four LPL micropumps, four blue female-to-female Dupont connectors, and four orange female-to-female Dupont connectors. Attach one blue and one orange female-female Dupont connectors onto the two contacts of the LPL pump (Fig 18b). Follow the configuration indicated on Figure 18a. Repeat three more times for the rest of the pumps (Fig. 18c).

5C: Armature

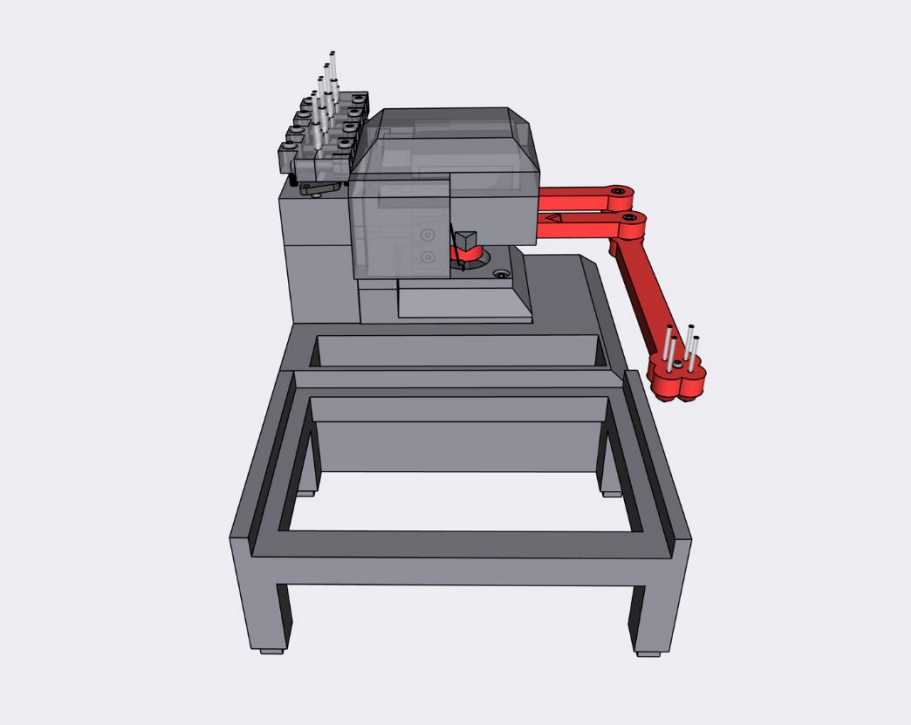

Figure 19: Assembling the Sidekick Armature

Step 1: Assembling Arm One

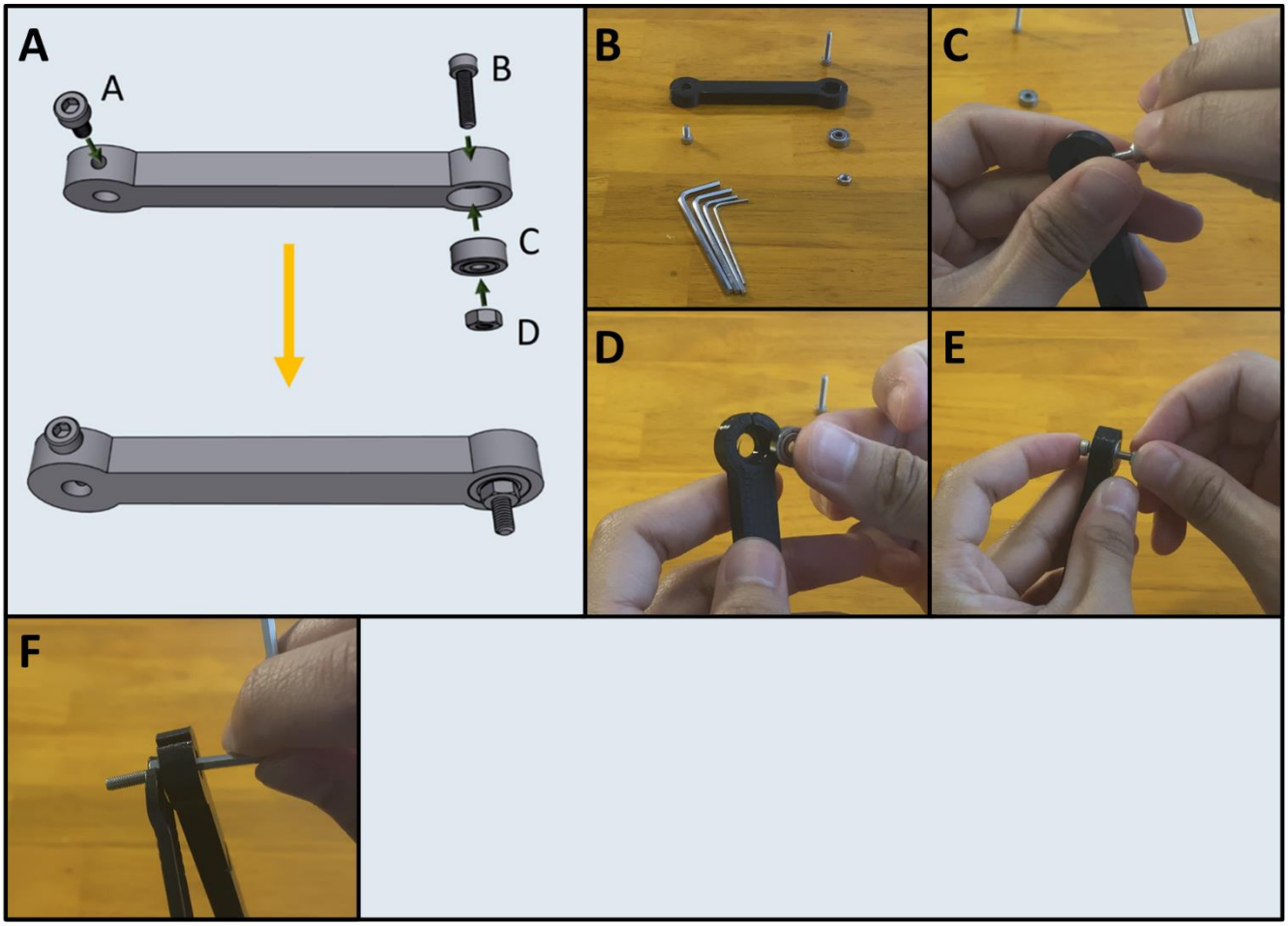

Figure 20a-f: The procedure for assembling Arm One.

Figure 20a gives an overview for the assembly of Arm One. Gather (A) an M3 x 6 screw, (B) an M3 x 12 screw, (C) a 623-2Z ball bearing and (D) an M3 hex nut. After gathering the necessary items (Fig 20b) thread the M3 x 6 screw into the side of Arm One (Fig. 12c). Press fit the bearing into the other end of the arm (Fig. 20d) and pass the M3 x 12 screw through the bearing and thread the M3 hex nut onto the other end (Fig. 20e). Tighten the M3 x 12 screw by holding the M3 nut with a plier (Fig. 20f).

Step 2: Assembling Arm Two

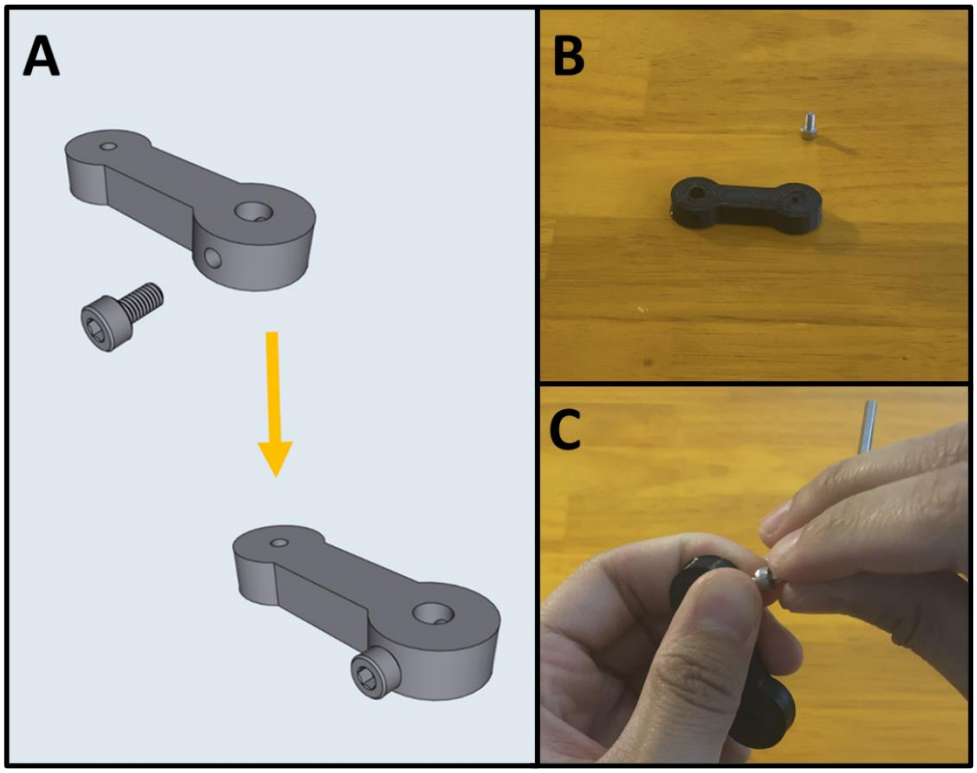

Figure 21a-c: The procedure for assembling Arm Two

Figure 21a gives an overview for the assembly of Arm Two. Gather the 3D-printed Arm Two, and an M3 x 6 screw (Fig. 21b). Thread the M3 x 6 screw into the side of Arm Two (Fig. 21c).

Step 3: Assembling Arm Three

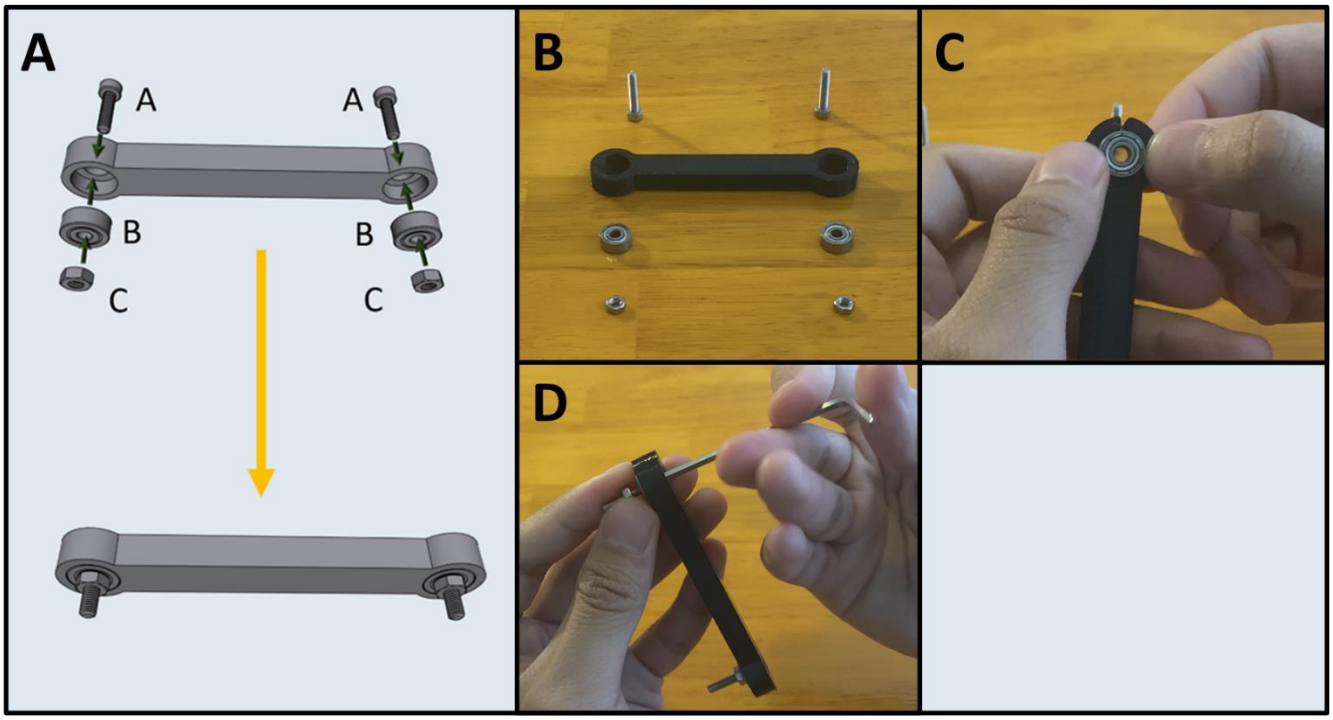

Figure 22a-d: The procedure for assembling Arm Three.

Figure 22a gives an overview for assembling Arm Three. This step requires (A) two M3x12 screws, (B) two 623-2Z ball bearings and (D) two M3 hex nuts. After gathering the required hardware and the 3D-printed Arm Three (Fig 22b), press fit the ball bearing into Arm Three (Fig. 22c), then pass an M3x12 screw through the bearing and thread a hex nut onto the screw (Fig. 22d). Repeat for the other end.

Step 4: Connecting Arms Two and Three

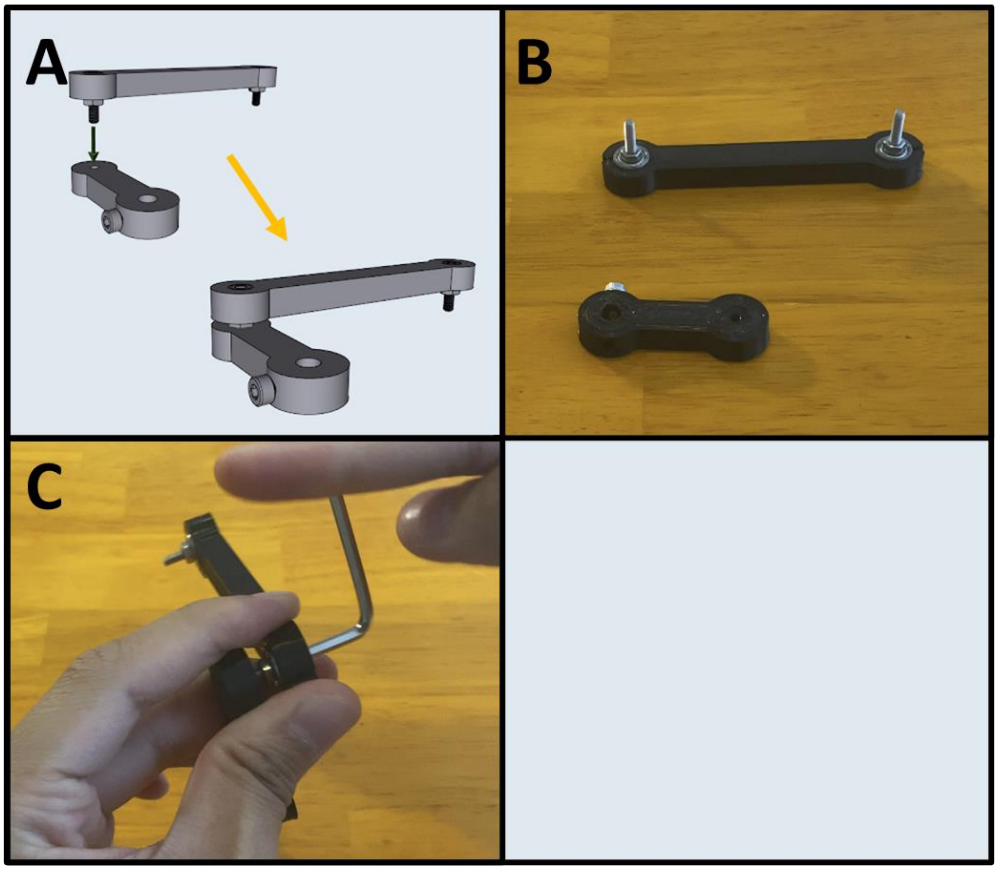

Figure 23a-c: The procedure for connecting Arms Two and Three.

Figure 23a gives an overview for the connecting of Arms Two and Three. Gather both arms (Fig. 23b). Thread the remaining length of the M3 x 12 screw of Arm Three into Arm Two (Fig. 23c). Both ends of Arm Three are identical, so it does not matter which side is attached to Arm Two. After attaching, rotate Arm Three to check for any binding. The arm should be able to rotate freely.

Step 5: Prepare the center point of Arm Four

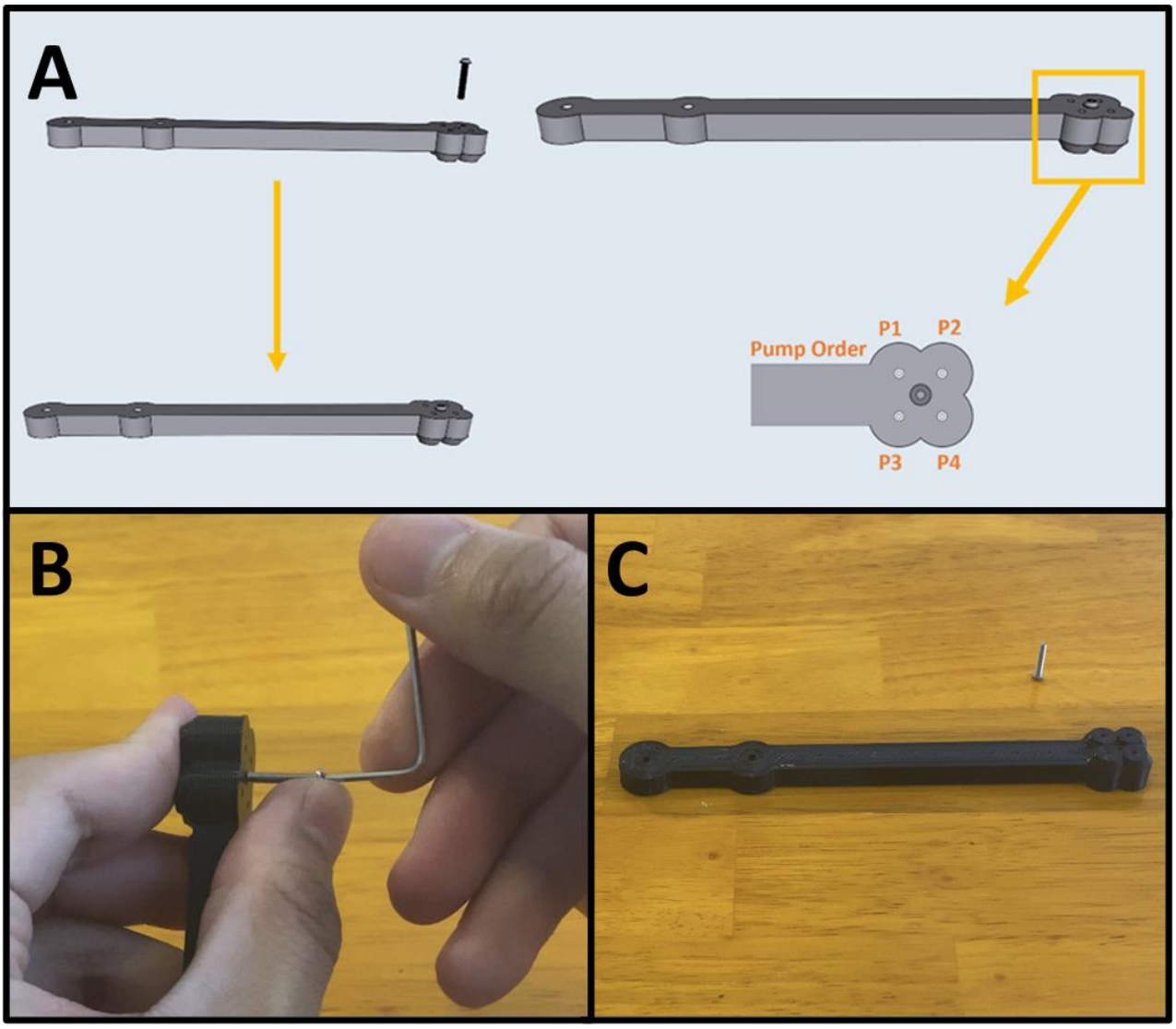

Figure 24a-c: Prepping the center-point of Arm Four.

Figure 24a gives an overview of the center-point preparation, and a diagram of the pump order on the end effector. Gather an M2x12 screw and the 3D-printed Arm Four (Fig. 24b). Thread in the M2x12 screw into the center point of Arm Four (Fig. 24c).

5D: Motor Mount Assembly

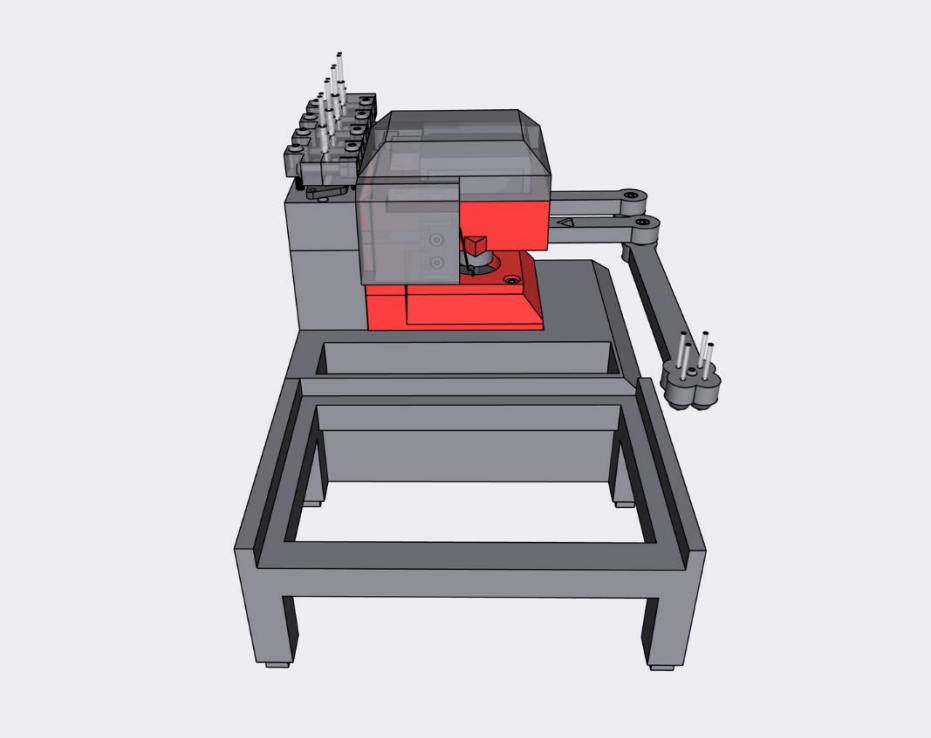

Figure 25: The Sidekick Motor Mount Assembly

Step 1: Mounting the Top Stepper Motor

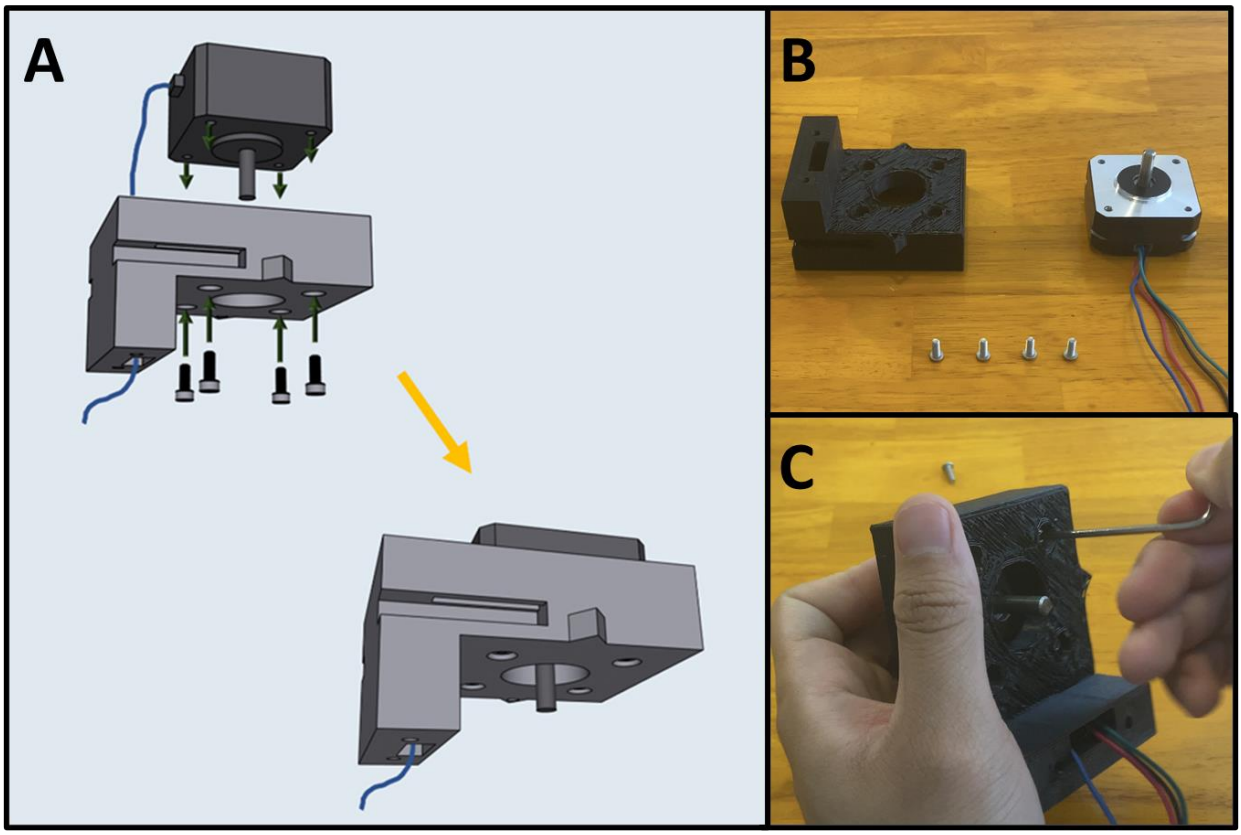

Figure 26a-c: The procedure for mounting the upper stepper motor.

Figure 26a gives an overview for mounting the upper stepper motor. Gather the 3D-printed upper motor mount, four M3x8 screws, and a prepared stepper motor (Fig. 26b). Place the stepper motor into the top mount, with the stepper motor wires facing the cable management channel. Then secure the motor in place with four M3 x 8 screws (Fig. 26c).

Step 2: Attaching Limit Switches to Switch Mounts

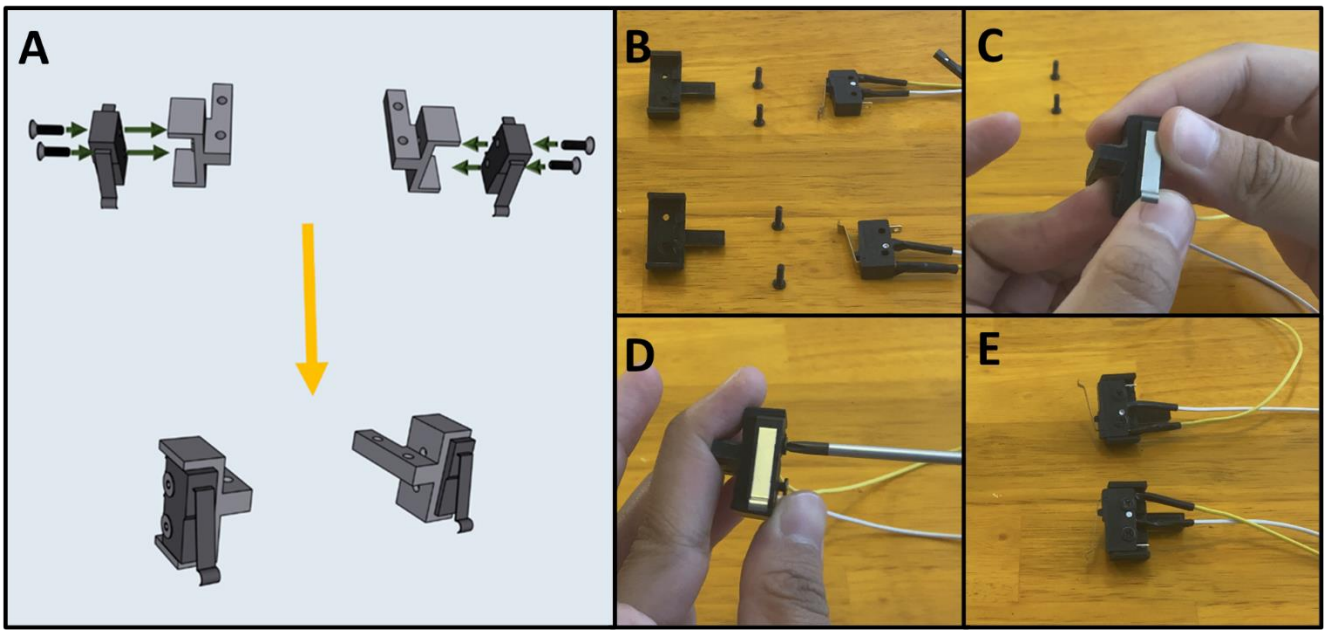

Figure 27a-e: The procedure for attaching the limit switches to their mounts.

Figure 27a gives an overview for attaching the limit switches to the Upper Motor Mount. Gather the two prepared limit switches, the two 3D-printed switch mounts, and four M2.5 x 8 screws (Fig 27b). Press the Limit Switch onto the Limit Switch Mount (Fig. 27c) and secure them in place with two M2.5 x 8 screws (Fig. 27d). Repeat the procedure for the other limit switch (Fig. 27e).

Step 3: Attaching Limit Switch Mounts onto Top Motor Mount

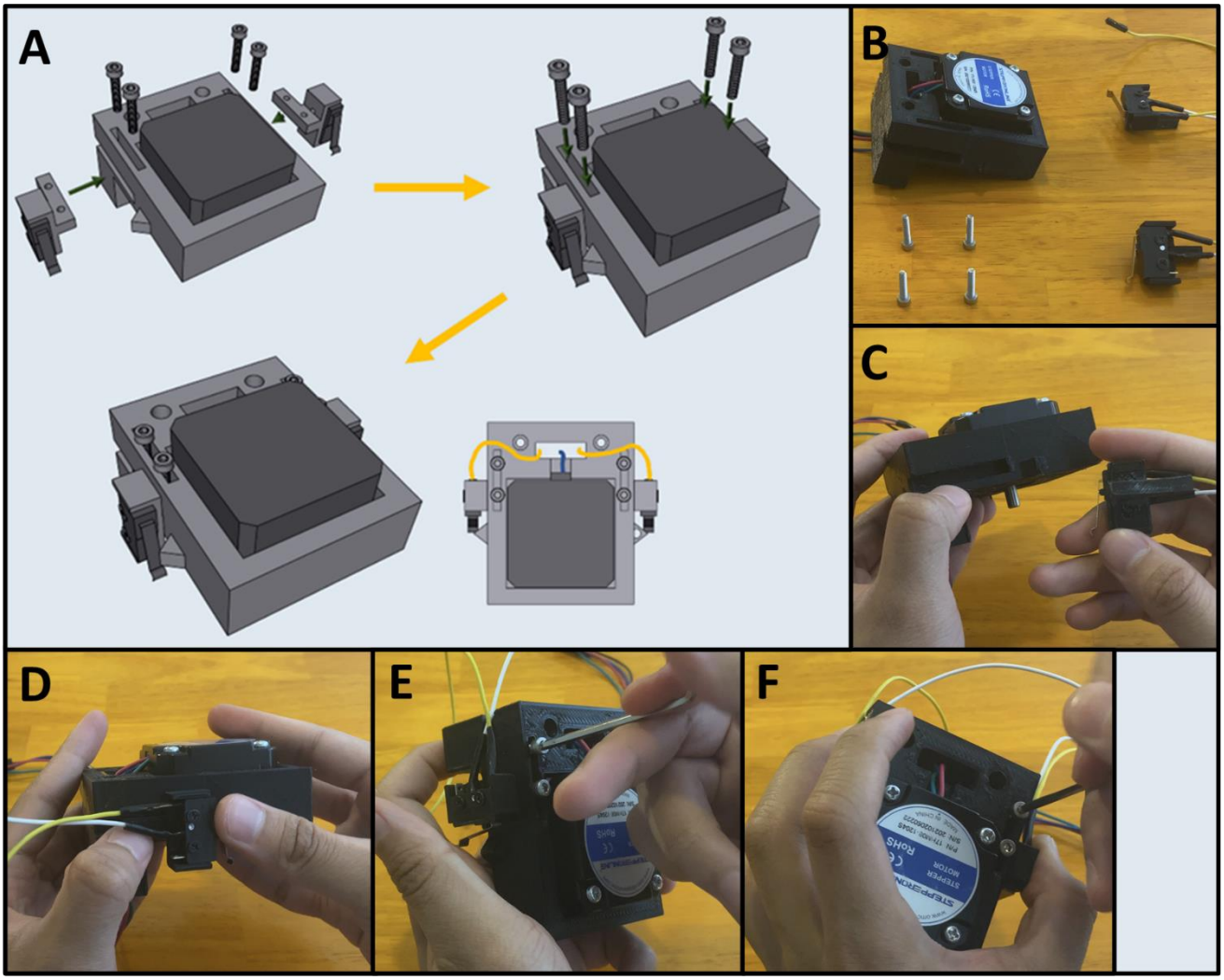

Figure 28a-f: The procedure for mounting the limit switches to the Upper Motor Mount.

Figure 28a gives an overview for attaching the limit switch assemblies to the Upper Motor Mount. Gather the Upper Mount Assembly, four M3 x 16 screws, and the two limit switch assemblies (Fig 28b). Press the limit switch assemblies into the notches of the Upper Motor Mount (Fig. 28c-d). Then screw two M3 x 16 screws onto each of the limit switch mounts to secure them to the Upper Motor Mount (Fig. 28e-f). Pass the limit switch cables through the cable management channel indicated by the yellow-colored lines indicated in Figure 28a.

Step 4: Attaching Arm One onto the Upper Motor Assembly

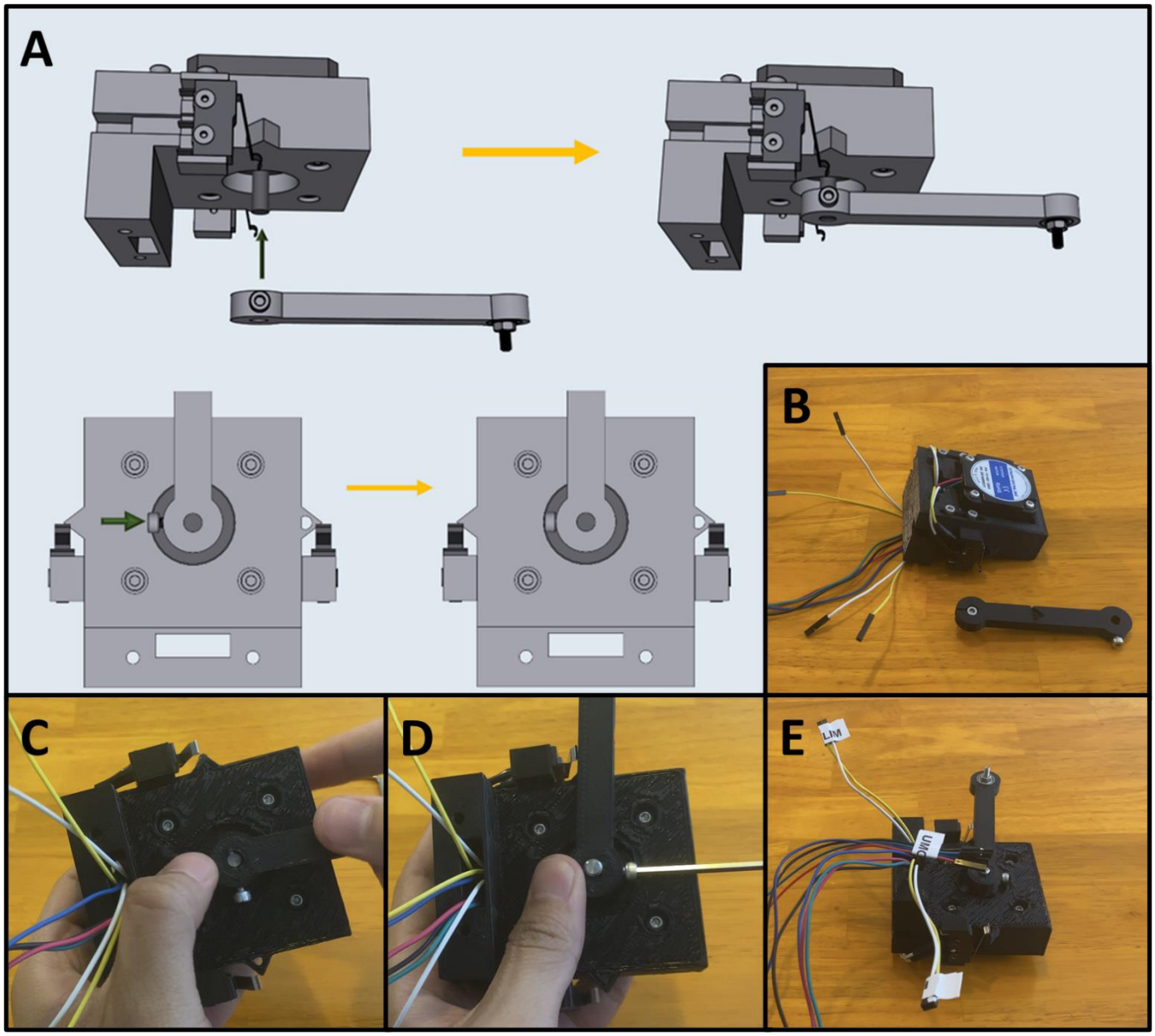

Figure 29a-e: The procedure for attaching Arm One onto the Upper Motor Assembly.

Figure 29a gives an overview of attaching Arm One onto the Upper Motor Assembly. Gather the Upper Motor Assembly and Arm One (Fig. 29b). Press fit Arm One onto the shaft of the Upper Stepper motor as indicated (Fig. 29c). The arm should be able to rotate and engage the limit switches, without scraping against the top of the motor mount. Once satisfied with the position of Arm One, tighten the M3 x 6 screw on Arm One to secure it to the motor shaft (Fig. 29d). Label the end of the cables of the electrical components with a unique tag to assist in wiring (Fig. 29e).

Step 5: Setting Home Position for Arm One

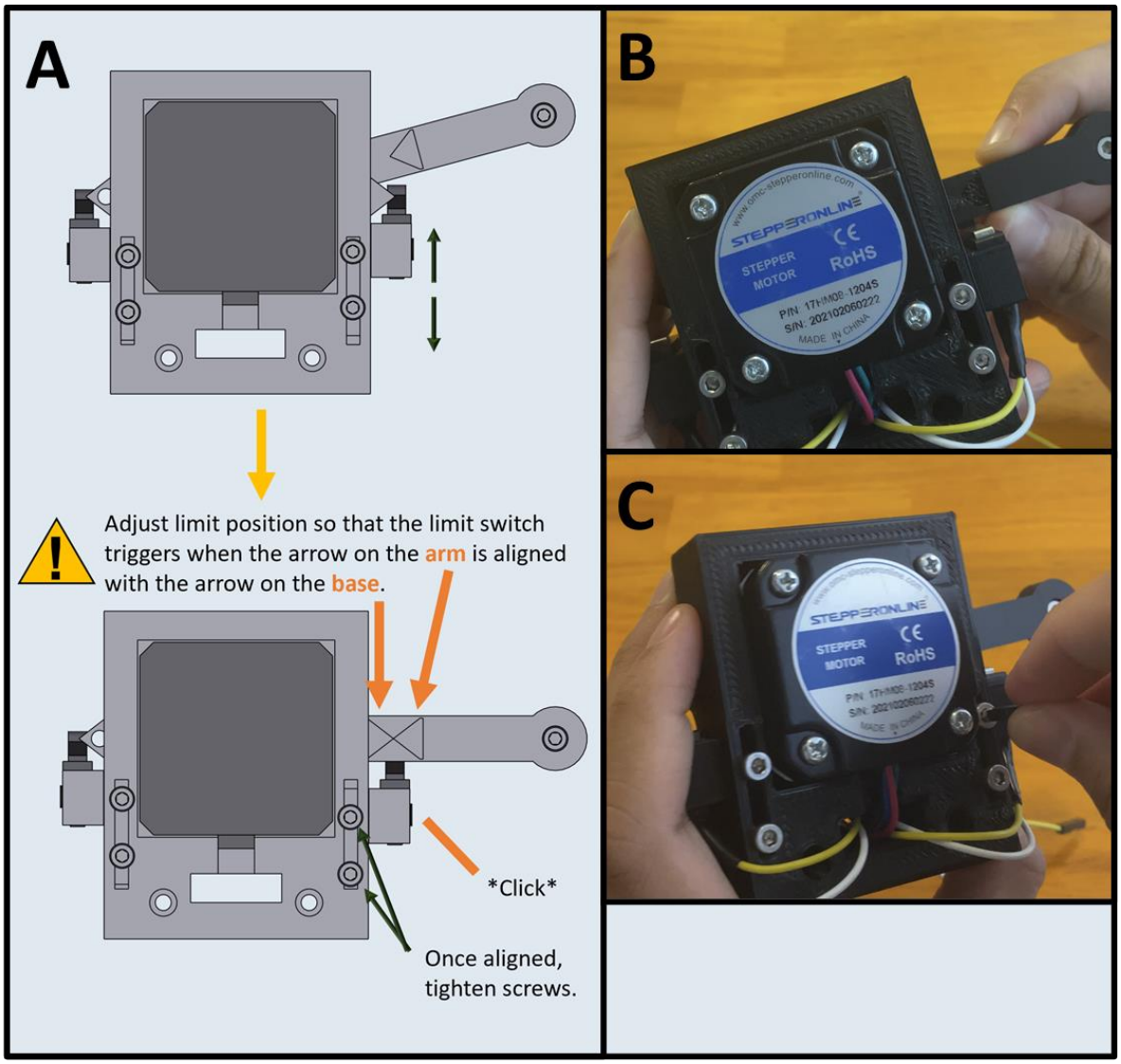

Figure 30a-c: The procedure for setting the home position for the front limit switch.

Figure 30a gives an overview for setting the limit switch position. Adjust the Front Limit switch mount, so that the limit switch is engaged once Arm One is at the correct zero position, indicated by the alignment of the triangle on the Upper Motor Mount (Fig. 30b). Once the Front Limit Switch Mount is in the correct position, tighten the two M3x16 screws (Fig. 30c).

Step 6: Mounting the Lower Stepper Motor

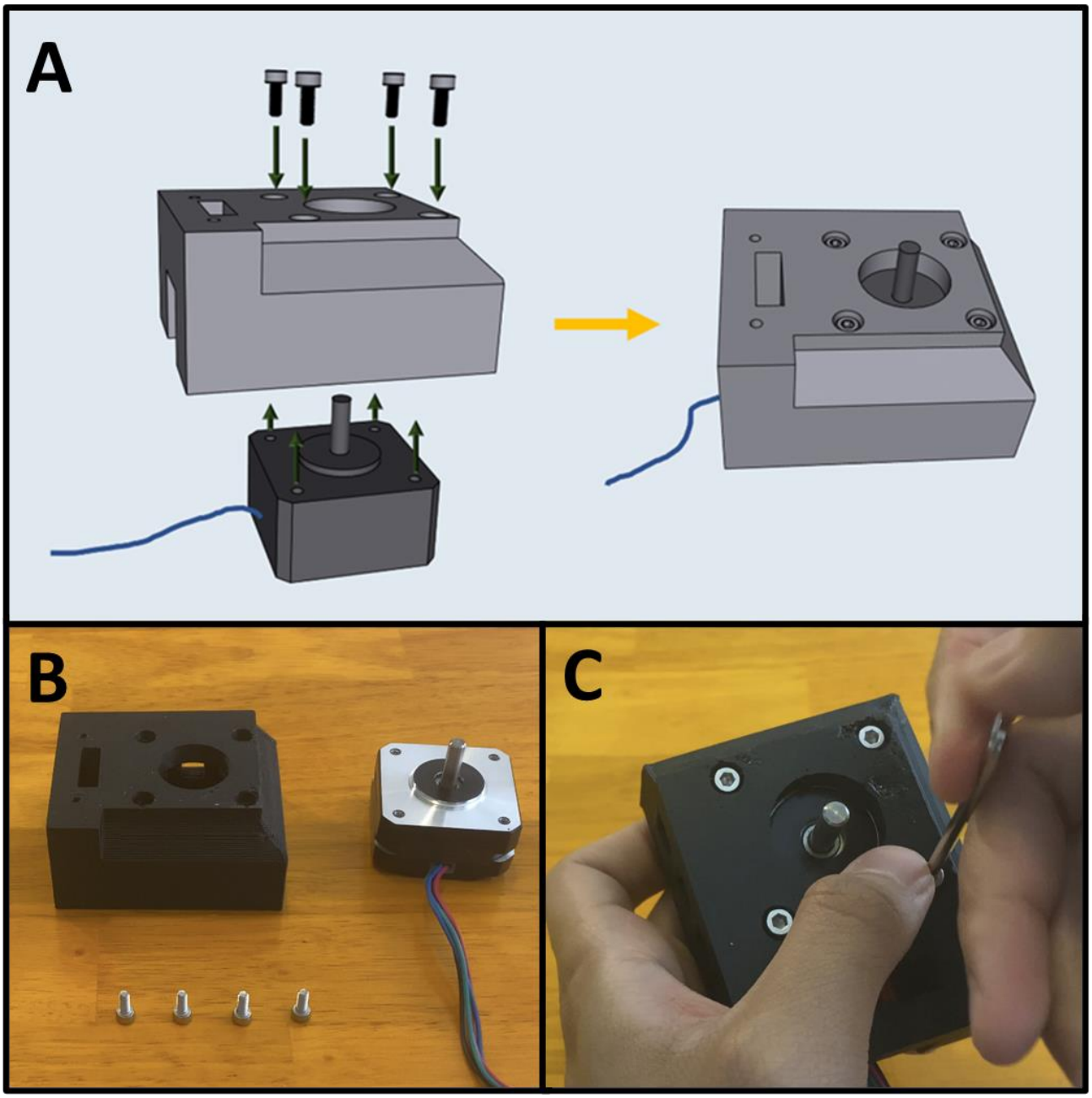

Figure 31a-c: The procedure for mounting the lower stepper motor.

Figure 31a gives an overview of the mounting procedure. Gather the remaining stepper motor, four M3 x 8 screws, and the 3D-printed Lower Motor Mount (Fig. 31b). Place the stepper motor into the lower mount, with the stepper motor wires facing the cable management channel, then secure the motor in place with four M3 x 8 screws (Fig. 31c).

Step 7: Attaching Arm Two and Three to the Lower Motor Assembly

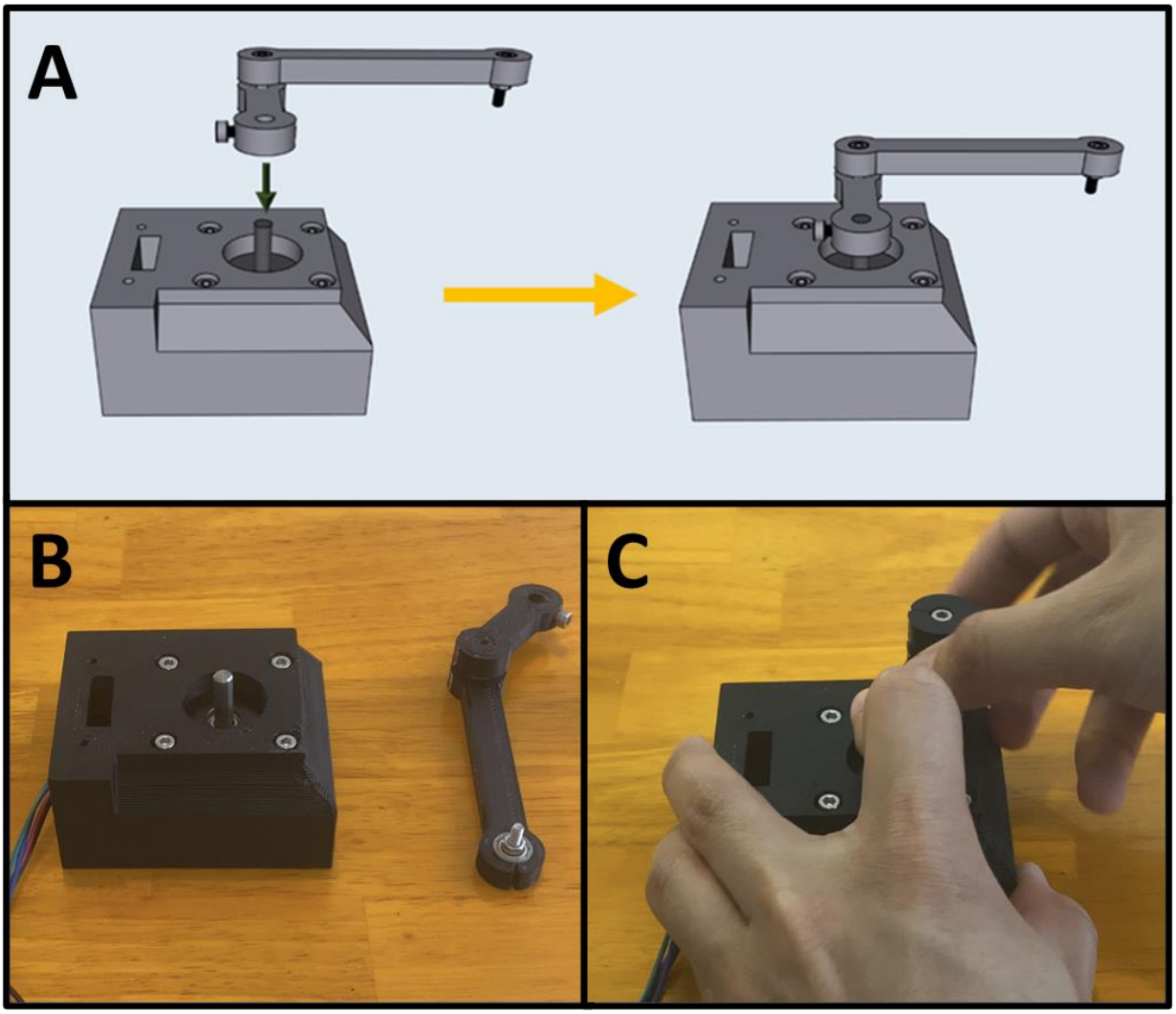

Figure 32a-c: The procedure for attaching Arm Two and Three to the lower motor mount.

Figure 32a gives an overview of the mounting process. Gather the lower motor mount, and the Arm Two and Three assembly. Press fit Arm Two onto the stepper motor shaft with Arm Three facing upwards (Fig. 32c). The arms should be able to rotate freely without catching on anything.

Step 8: Tightening Arm Two on the Lower Stepper Motor

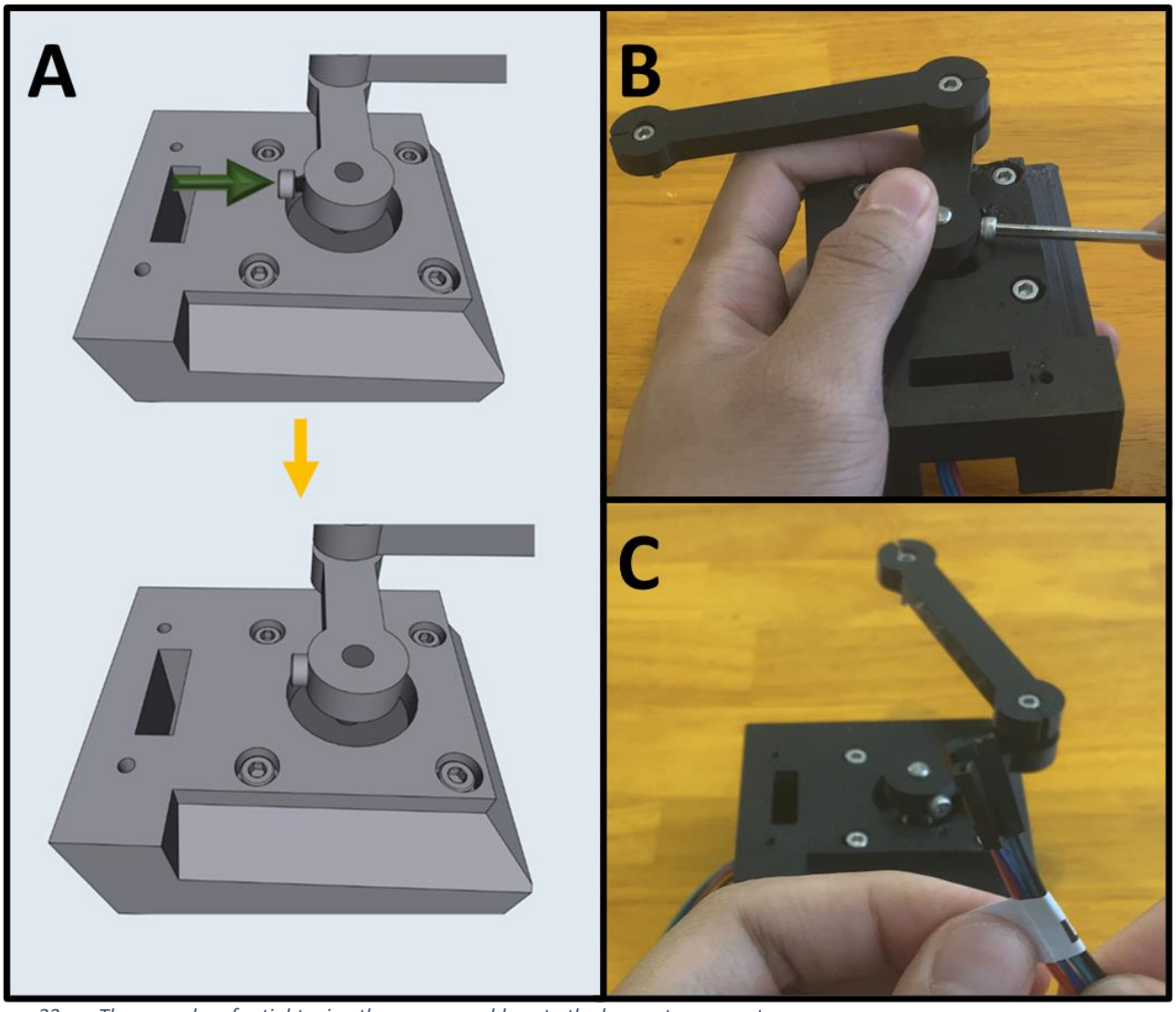

Figure 33a-c: The procedure for tightening the arm assembly onto the lower stepper motor.

Figure 33a gives an overview of the tightening procedure. Once satisfied with the position of Arm Two, tighten the M3 x 6 screw on Arm Two to secure it to the motor shaft (Fig.33b). Note that there are two screw holes on Arm Two. Only one M3 x 6 screw is required to tighten the leg onto the motor shaft, use whichever one is easier. If your motor shaft has a flat face, secure the M3 x 6 screw onto it. Label the lower stepper motor cables (Fig. 33c).

Step 9: Attaching the Upper Motor Assembly to the Lower Motor Assembly

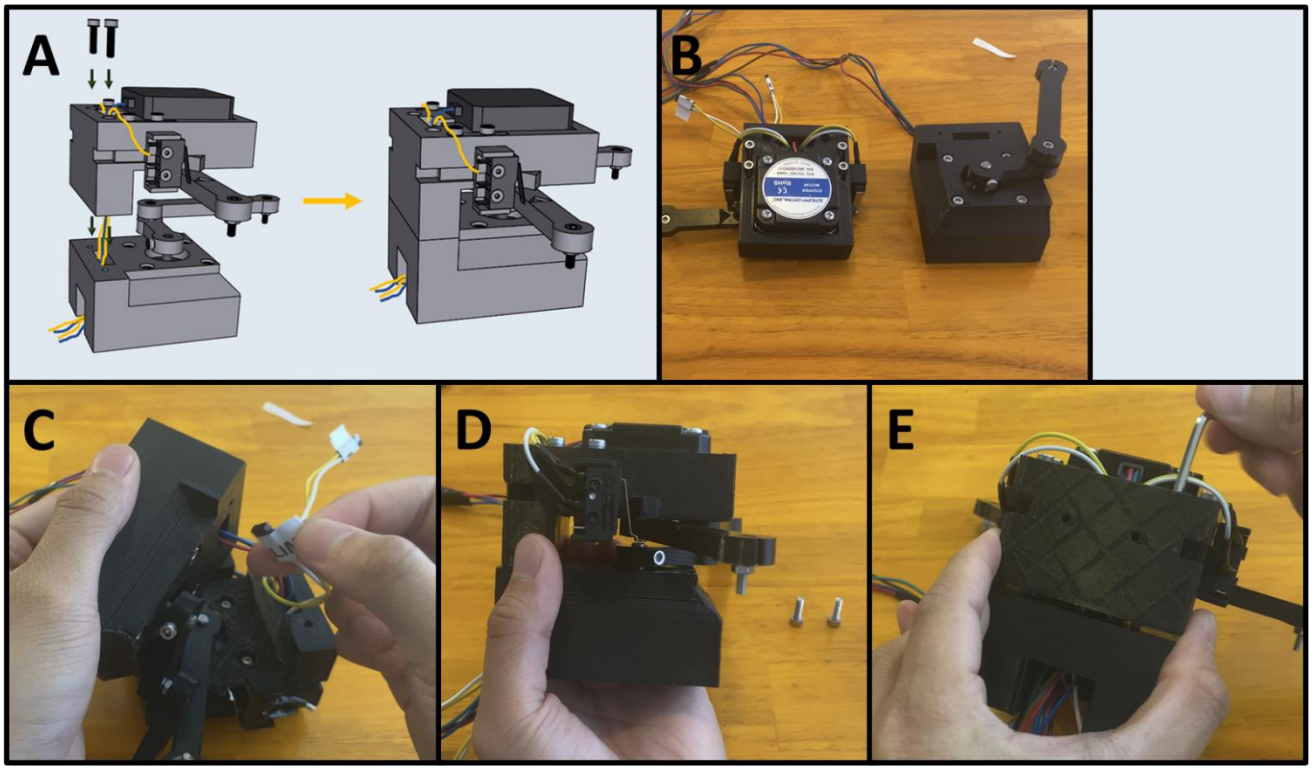

Figure 34a-e: The procedure for joining the Upper and Lower Motor Assemblies.

Figure 34a gives an overview for joining the Upper and Lower Motor Assemblies. Gather the two mount assemblies (Fig. 34b). Thread the cables from electrical components on the Upper Motor Assembly through the cable management tunnel of the Lower Motor Assembly (Fig. 32c-d). Then secure the two together with two M3 x 12 screws (Fig. 34e).

Step 10: Setting Home Position for Arm Two

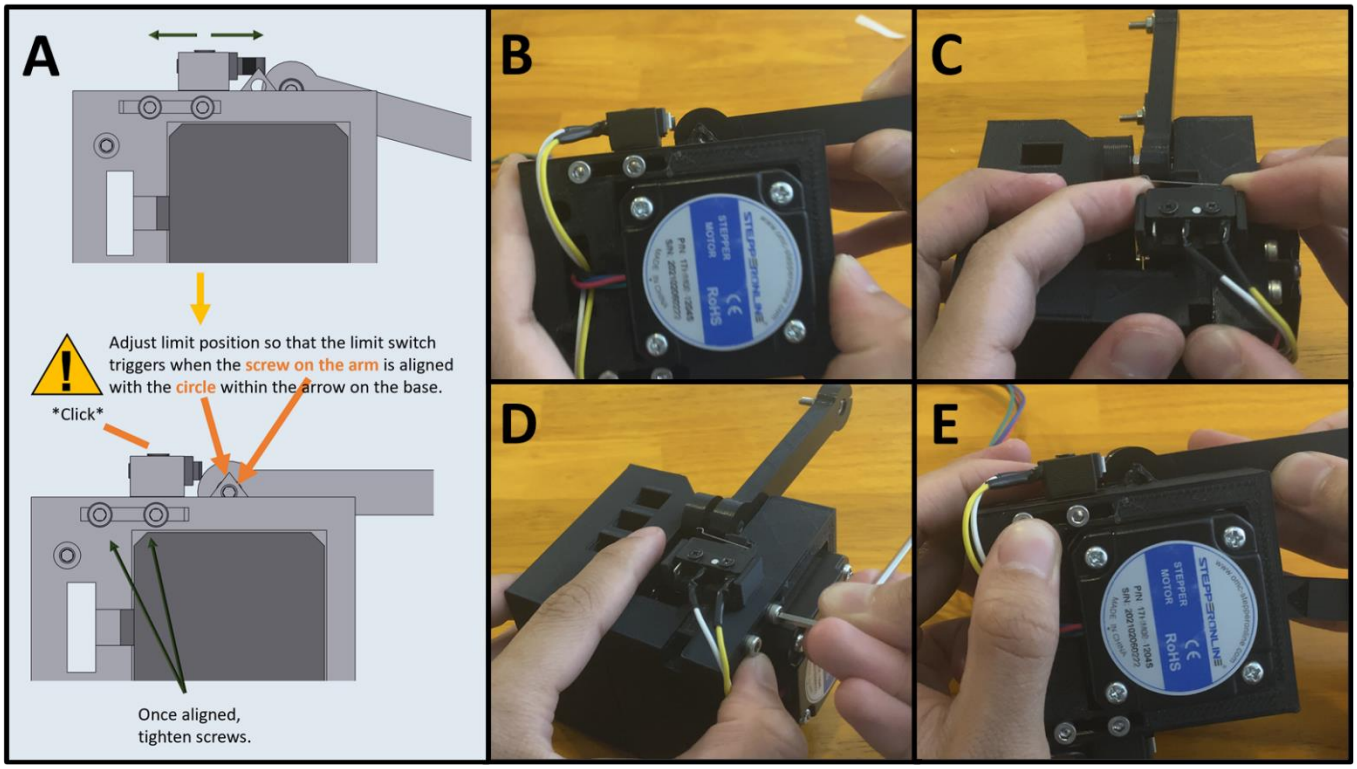

Figure 35a-e: The procedure for setting the home position for Arm Two.

Figure 35a gives an overview for setting the home position for Arm Two. Adjust the Rear Limit Switch Mount, so that the limit switch is engaged once Arm Two is at the correct zero position, indicated by the alignment of screw on the arm aligning with the inscribed circle on the Upper Motor Mount (Fig. 35b). If the limit switch is not in the correct position, loosen the M3 screws, and then push the limit switch into the proper position (Fig. 35c). Once the Rear Limit Switch Mount is in the correct position, tighten the two M3 x 16 screws (Fig. 35d). Double check to ensure that the limit switch is triggered when the screw on the arm is aligned with the arrow on Upper Mount Assembly (Fig 35e).

Step 11: Setting the gap between Arm One and Arm Two

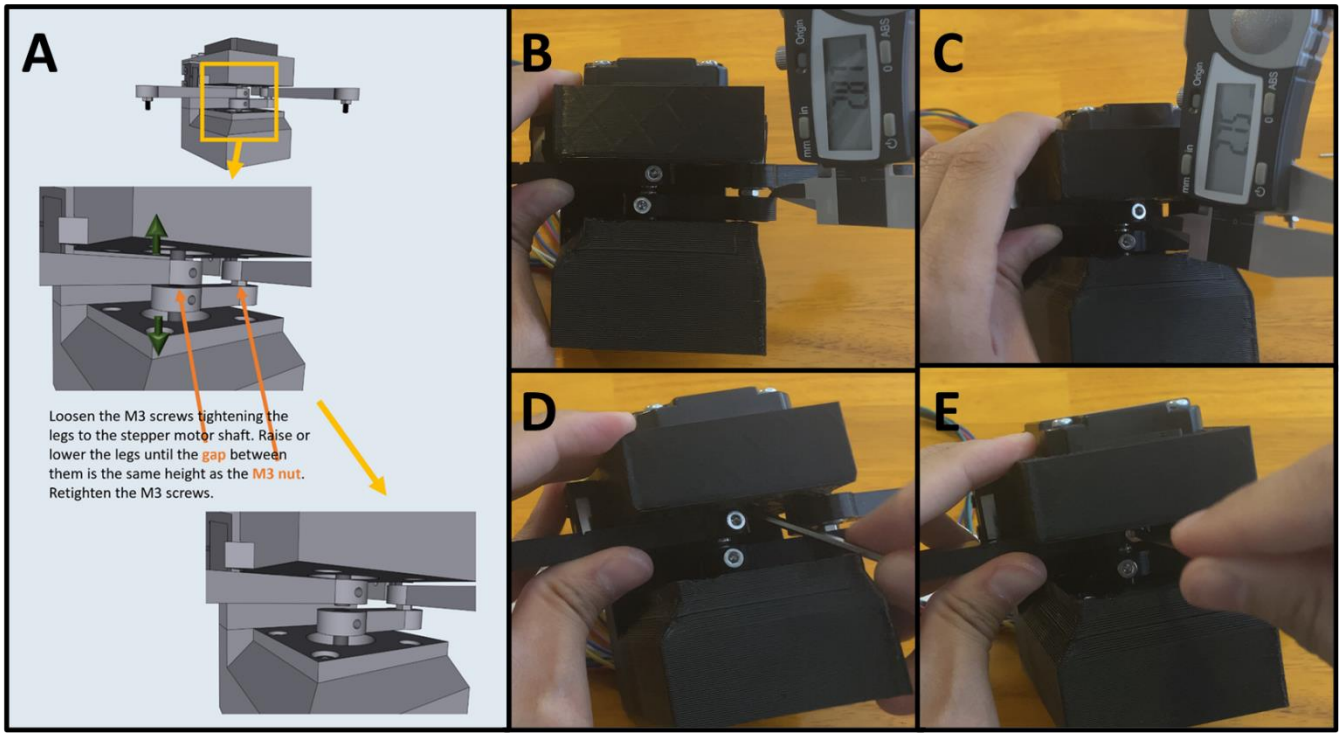

Figure 36a-e: The procedure for setting the gap between Arm One and Two.

Figure 36a gives an overview for adjusting the gap between Arm One and Arm Two, so that the distance between the two is roughly equal to the height of the M3 nut between Arm Two and Arm Three. The distance between Arm One and Arm Three should be about the width of an M3 nut (~3 mm). A caliper is pictured (Fig. 35b-c) but any measuring tool that lets you estimate the distance will work. To adjust the arms, loosen the M3 screws holding them against motor shafts and slide a flat head screwdriver or hex key into the gap (Fig. 35d). When gapping the two arms, be sure that neither arm brushes against the upper or lower motor mount. Once satisfied with the gap, retighten the M3 screws to secure the arms (Fig. 35e).

Step 12: Attaching Arm Four

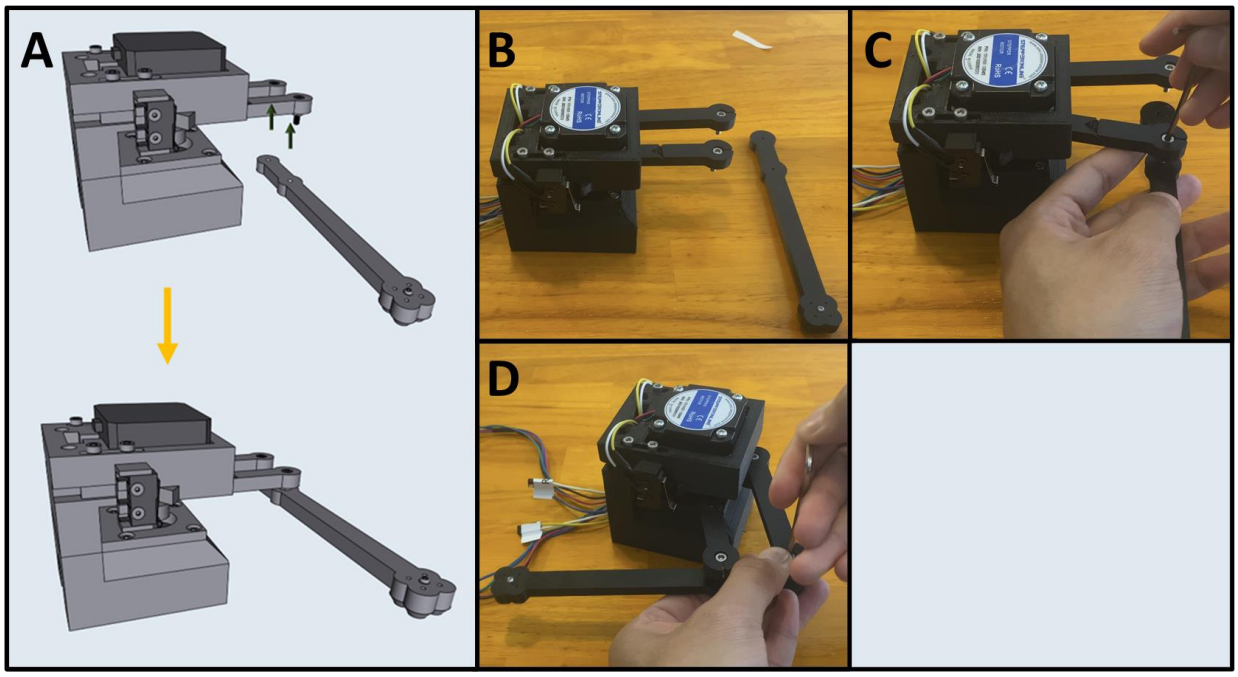

Figure 37a-d: The procedure for attaching Arm Four to the motor assembly.

Figure 37a shows an overview of attaching Arm Four to Arms One and Three to complete the armature assembly. Gather the motor mount assembly and Arm Four (Fig. 37b). Position Arm Four with the nozzle cones facing down and thread the M3 screws from Arms One and Three into Arm Four (Fig. 37c-d).

5E: Base Assembly

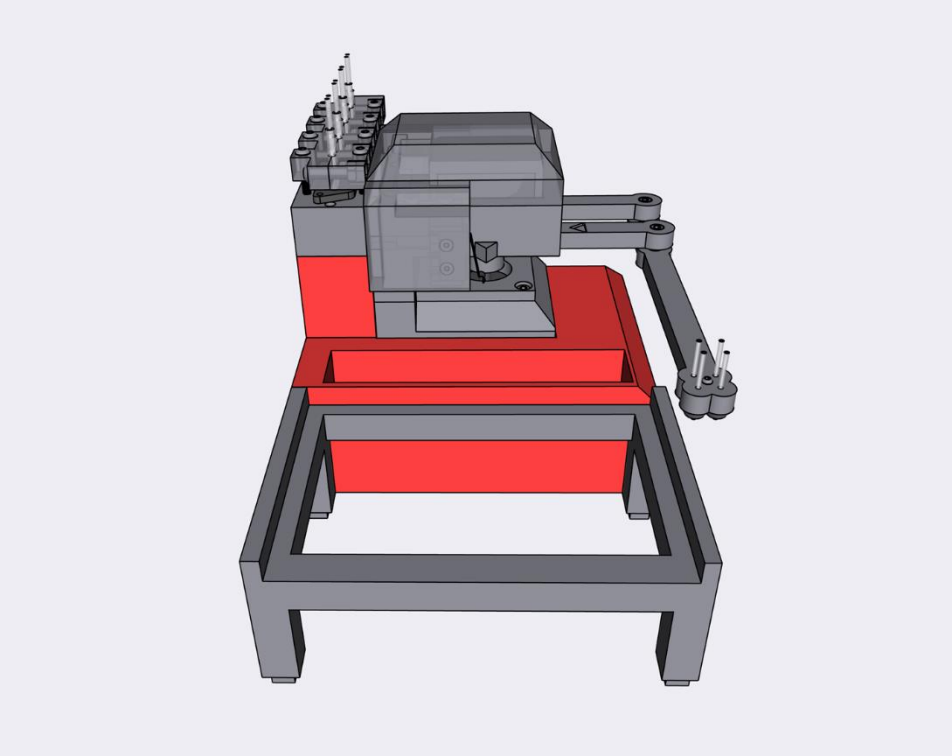

Figure 38: The Sidekick Base Assembly

Step 1: Purge Button Assembly

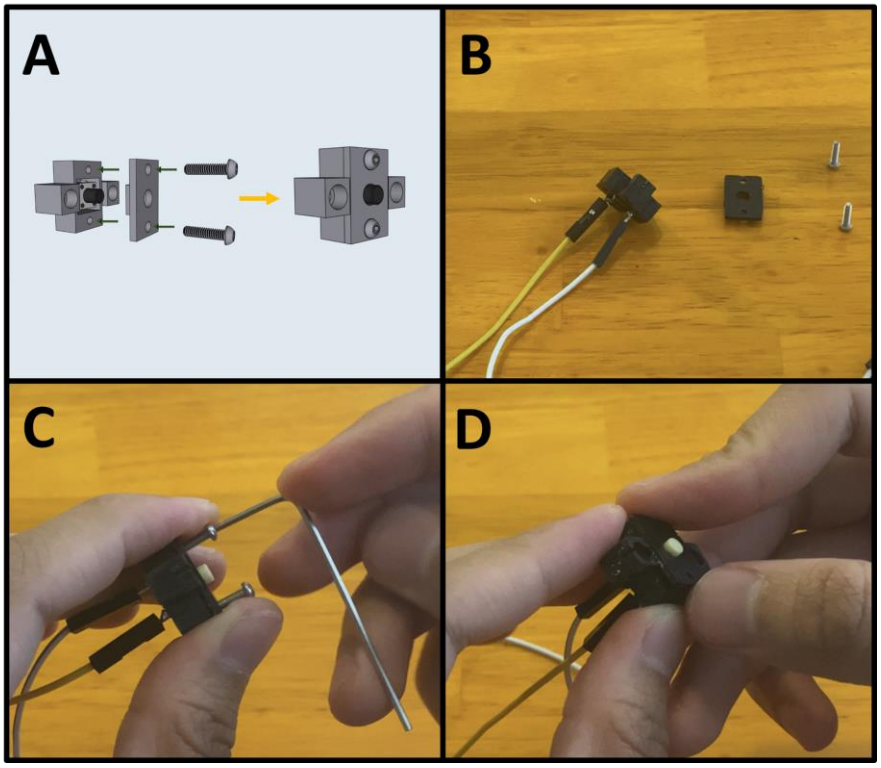

Figure 39a-d: The procedure for finishing the Purge Button Assembly.

Figure 39a gives an overview of the Purge Button Assembly. Gather the button and housing wired in 5B, Step 4, as well as the Button Housing front, and two M2 x 8 screws (Fig. 39b). Place the Button Housing front over the housing and secure it with two M2 x 8 screws (Fig. 39c). The finished assembly is shown in Fig. 39d.

Step 2: Joining the Button Assembly to the Base

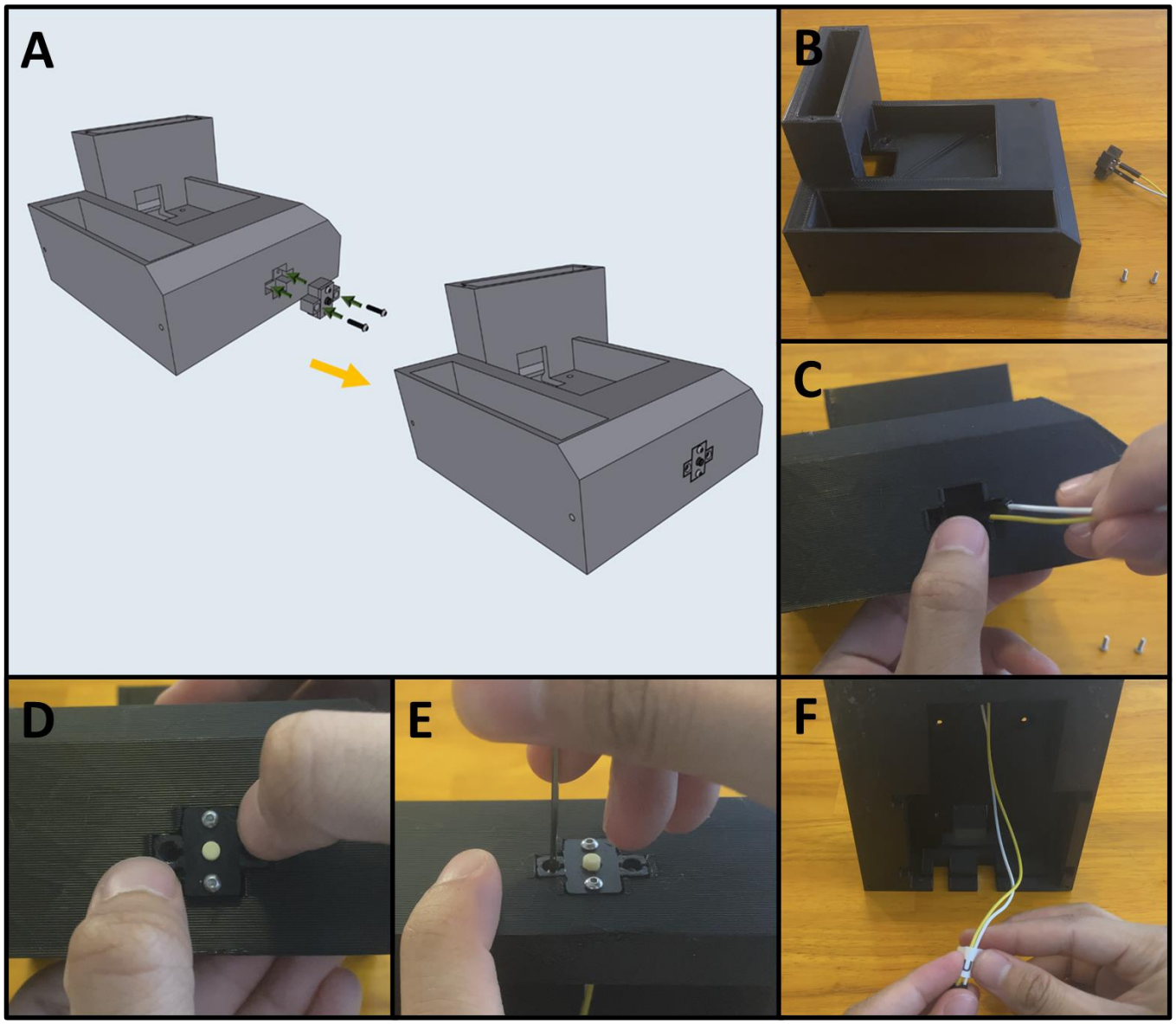

Figure 40a-f: The procedure for attaching the Purge Button Assembly to the base.

Figure 40a gives an overview for joining the Purge Button Assembly to the base. Gather the 3D-printed base, the Purge Button Assembly, and two M2 x 8 screws (Fig 40b). Thread the button wires in the cable management slot in the base (Fig 40c). Then press fit the Button Assembly into the base (Fig. 40d) and secure the assembly with two M2 x 8 screws (Fig. 40e). Label the purge button wires (Fig. 40f).

5F: Base, Final Assembly

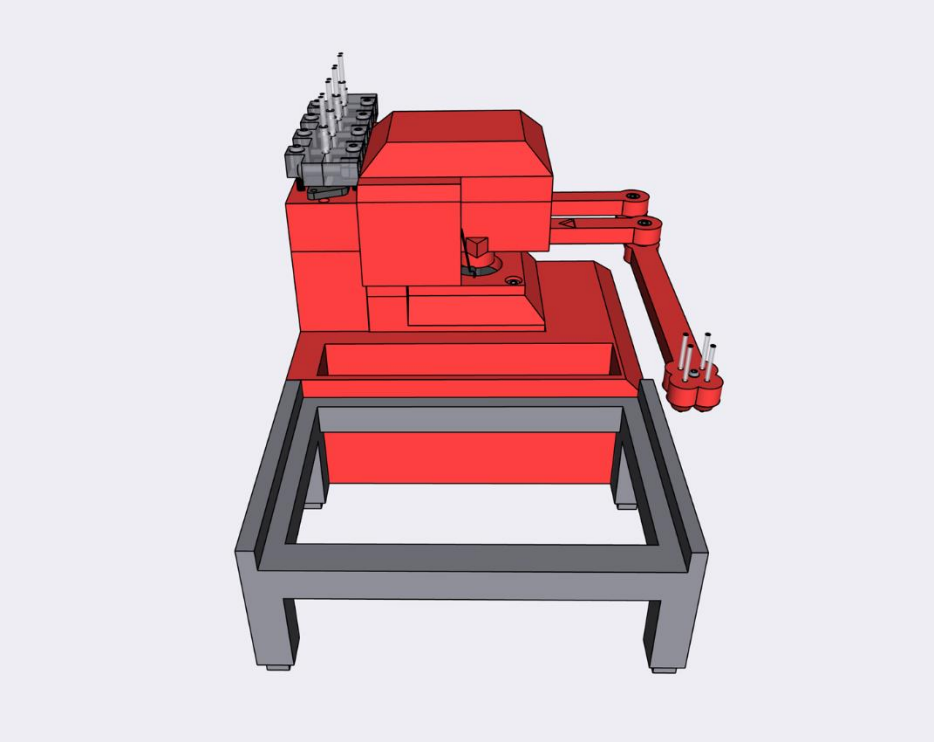

Figure 41: Final Assembly of the Sidekick base

Step 3: Securing Pumps to Pump Mounts

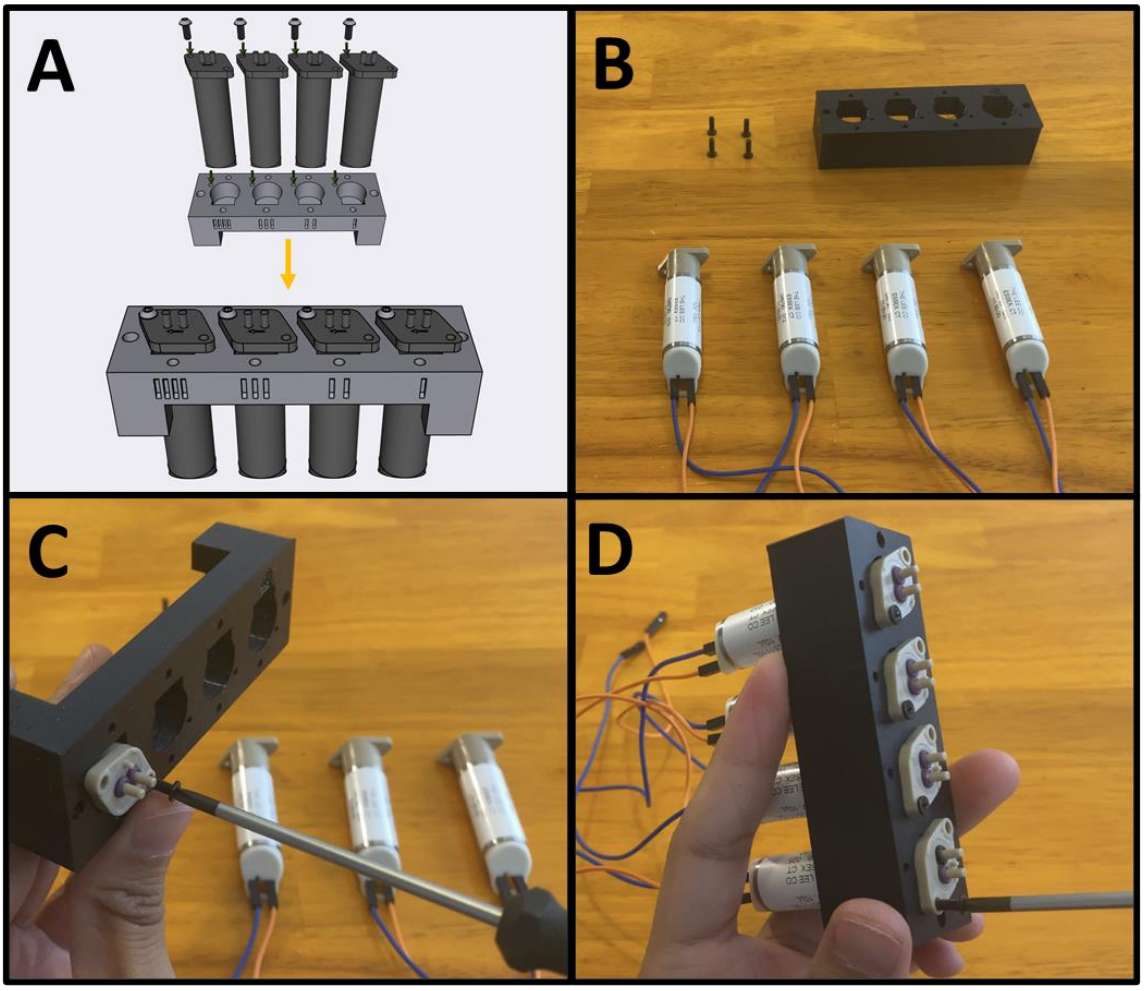

Figure 42a-d: The procedure for mounting the Pumps to the Pump Mount.

Figure 42a gives an overview for mounting the pumps. Gather four M2.5 x 6 screws, the Pump Mount, and the four pumps (Fig. 42b). Mount and secure the pumps to the Pump Mount with M2.5 x 6 screws (Fig. 42c-d). Note that only one screw is needed per pump. This allows the pumps to pivot into alignment when the adapter clamp is installed.

Step 4: Attaching the Pump Assembly to the Base

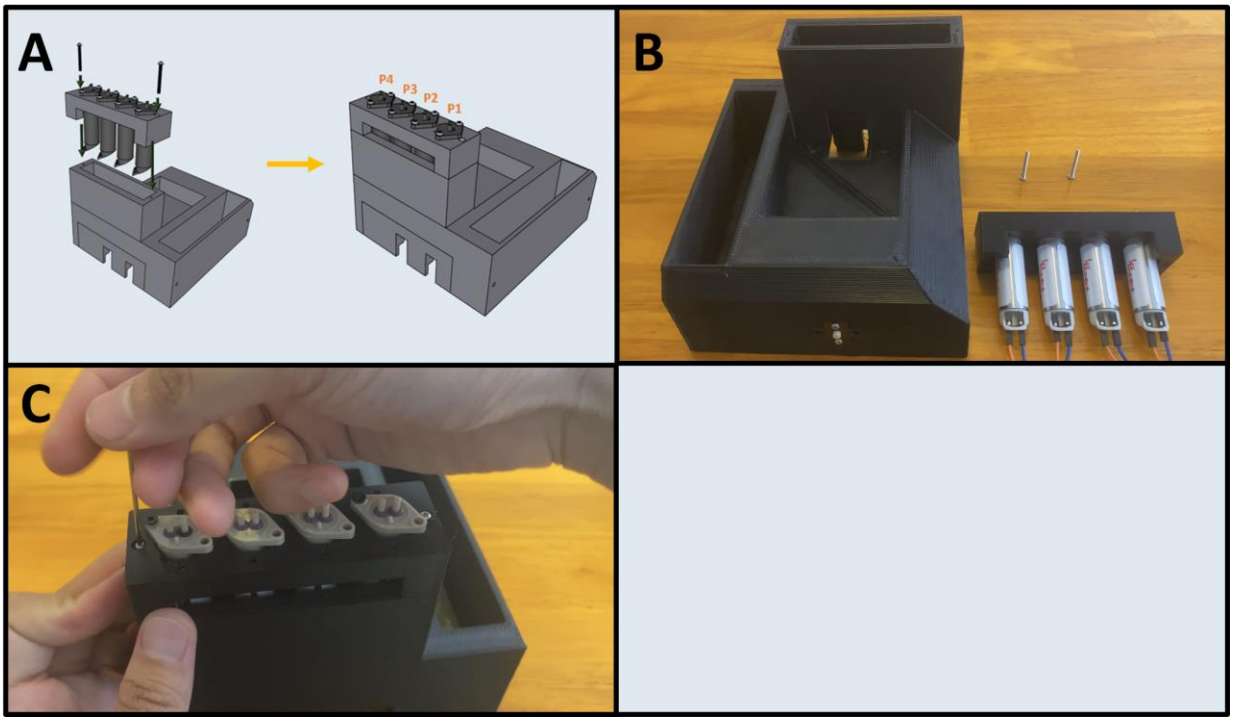

Figure 43a-c: The procedure for mounting the Pump Assembly to the Base.

Figure 43a gives an overview of the mounting process. Gather two M2 x 20 screws, the Pump Assembly, and the Base (Fig. 43b). Mount the Pump Assembly to the Base using two M2 x 20 screws (Fig. 43c).

Step 5: Attach the Motor/Armature Assembly to the Base

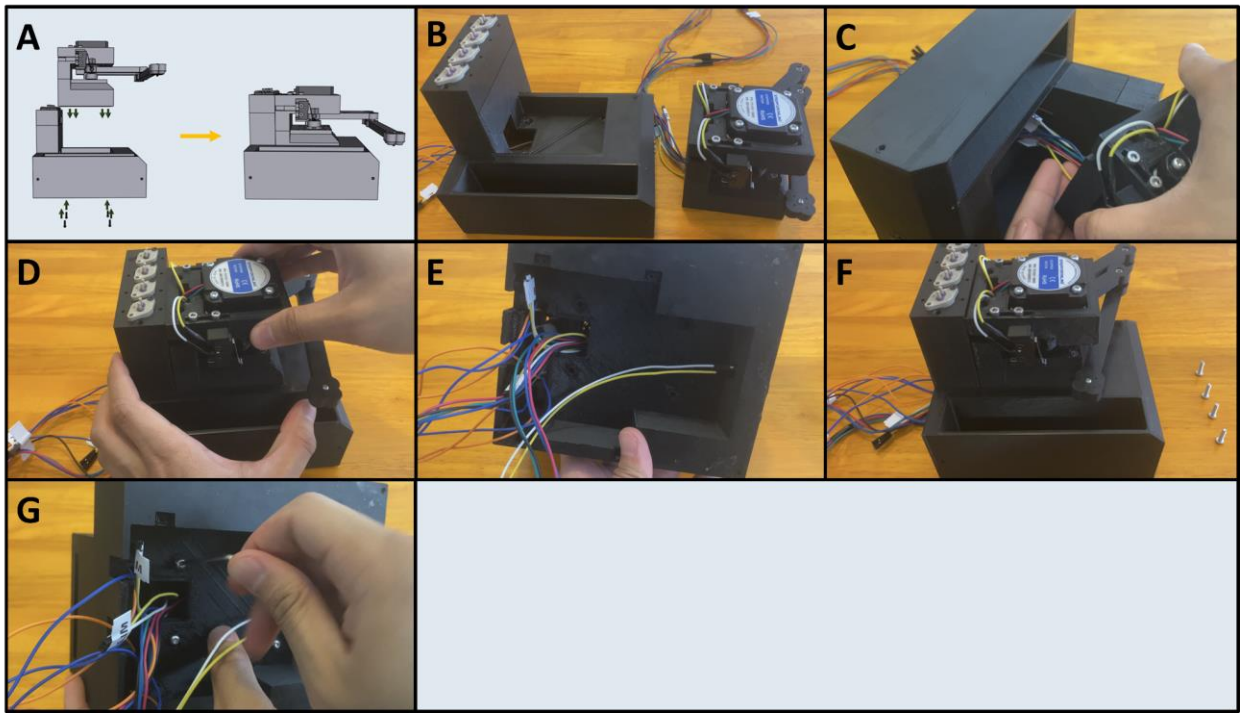

Figure 44a-g: The procedure for mounting the Motor Assembly to the base.

Figure 44a gives an overview of the mounting procedure. Gather the Base and the Motor Assembly (Fig. 44b). Thread the cables from the Motor Assembly into the gap in the Base (Fig. 44c), then seat the entire assembly into the Base (Fig 44d). The cables should all be routed to the underside of the Base (Fig. 44e). Gather four M3 x 8 screws (Fig. 44f) and thread them through the four holes on the underside of the Base and into the Motor Assembly (Fig. 44g).

5G: PCB Wiring/Assembly

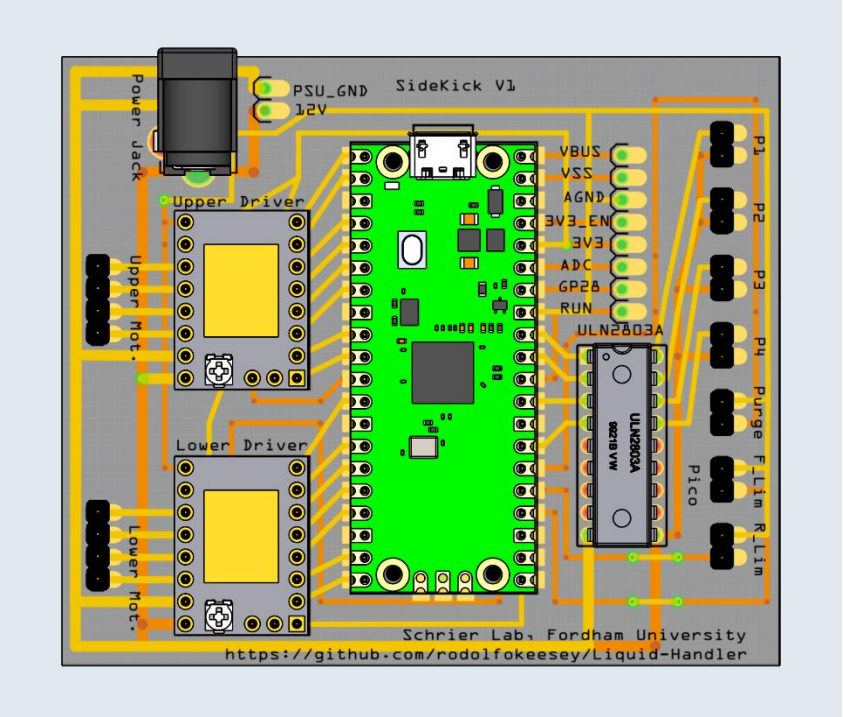

Figure 45: The Sidekick PCB

Step 1: Soldering in the Electrical Components

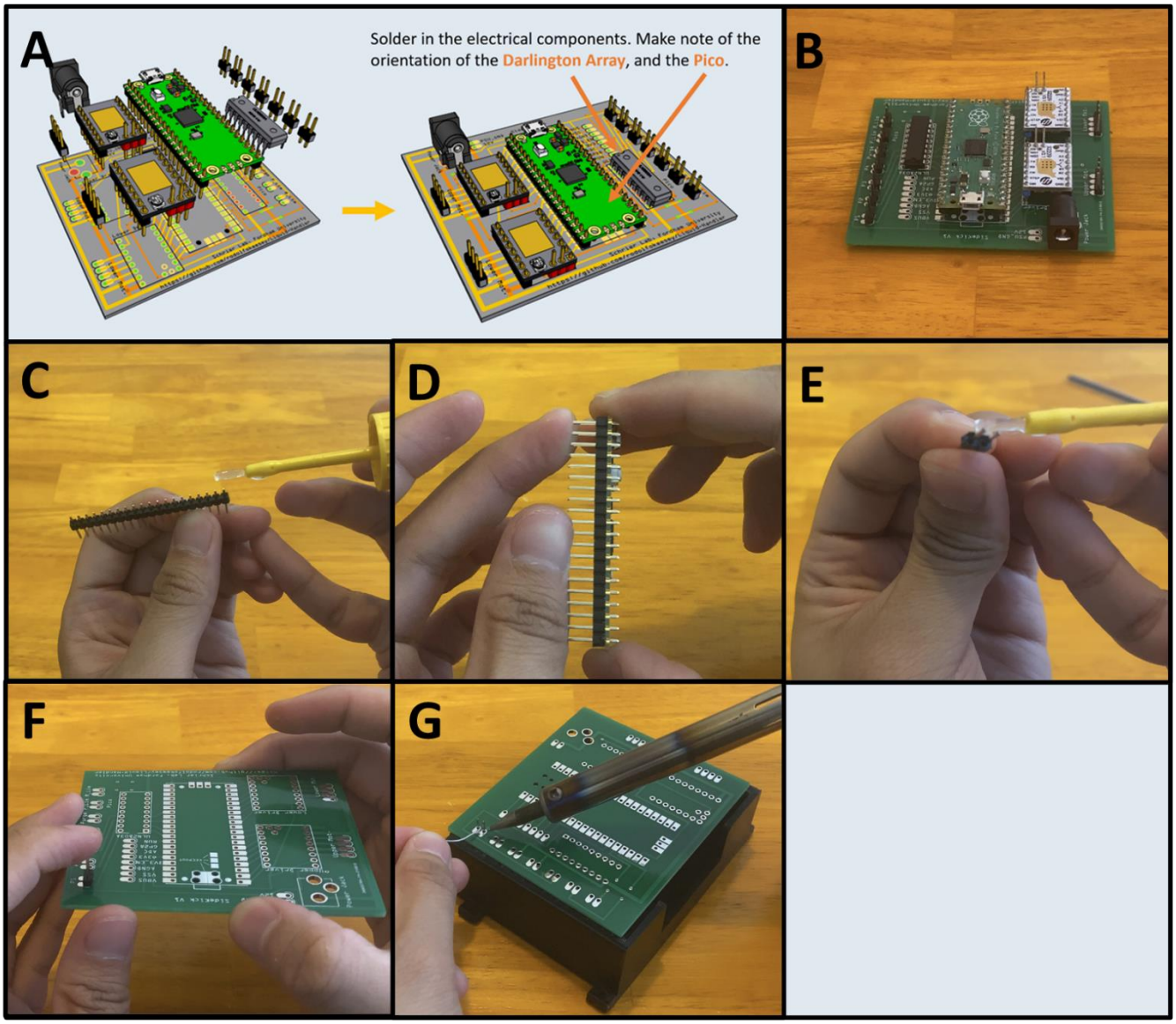

Figure 46: The procedure for preparing the Sidekick PCB.

Figure 46a gives an overview of the PCB assembly. Gather the necessary electrical components: the two stepper motor drivers, the power barrel, the Darlington array, the Raspberry Pi Pico and its associated header pins, and 24 header pins (Fig 46b). If the Pico did not come pre-soldered with its header pins, then solder them on. This is best done by placing a dab of cyanoacrylate glue (Super Glue ®) on each end of the header pins where they would touch the Pico board (Fig 46c). Then press the header pins against the Pico so that the glue forms a light bond to the board (Fig 46d). This will keep the header pins in place so that they can be more easily soldered. After the Pico has been soldered with the two rows of header pins, prepare the PCB board with header pins. Break off seven sets of 2-long header pins. Dab glue on the end of the 2-long header pins (Fig 46e) and press it against the PCB into the two pin slots until the glue dries, holding the pins in place (Fig 46f). It helps to use the PCB tray as a platform to solder on (Fig 46g). Repeat this process for the rest of the header pin holes. In total, there are seven 2-long header pins, and two 4-long header pins. Then, using the same process, solder the Pico onto the board, the stepper motor drivers, power barrel, and the Darlington array.

Step 2: Trim the electrical component pins

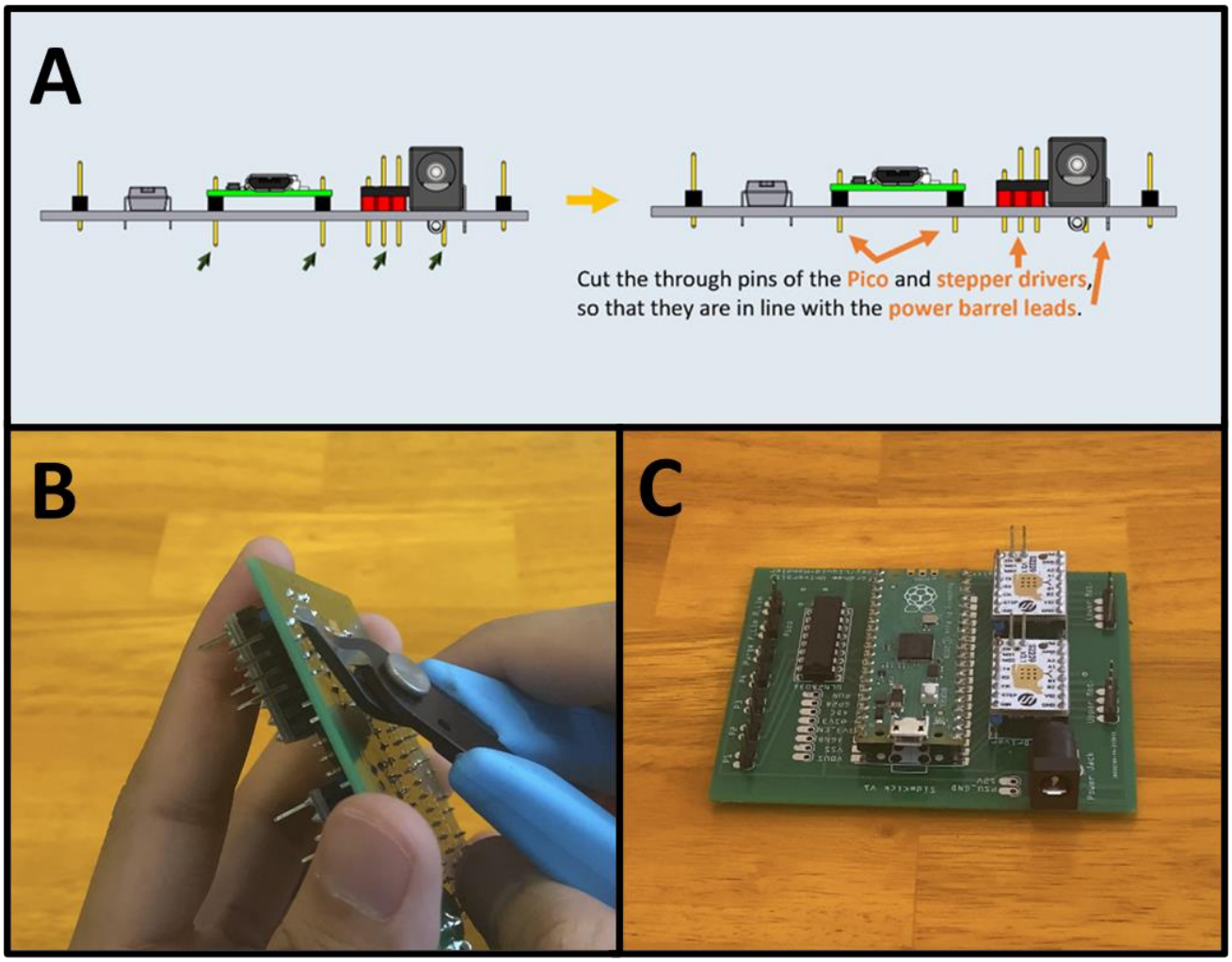

Figure 47a-c: The procedure for trimming the header pins.

Figure 47a gives an overview for the pin trimming process. Cut the excess pin length from the Raspberry Pi Pico, and the two stepper drivers (Fig. 47b). They should be the length of the power barrel leads. This allows for the PCB to slide into the PCB Tray. The resulting prepared PCB should look like Figure 47c.

Step 3: Wiring the Hardware to the PCB

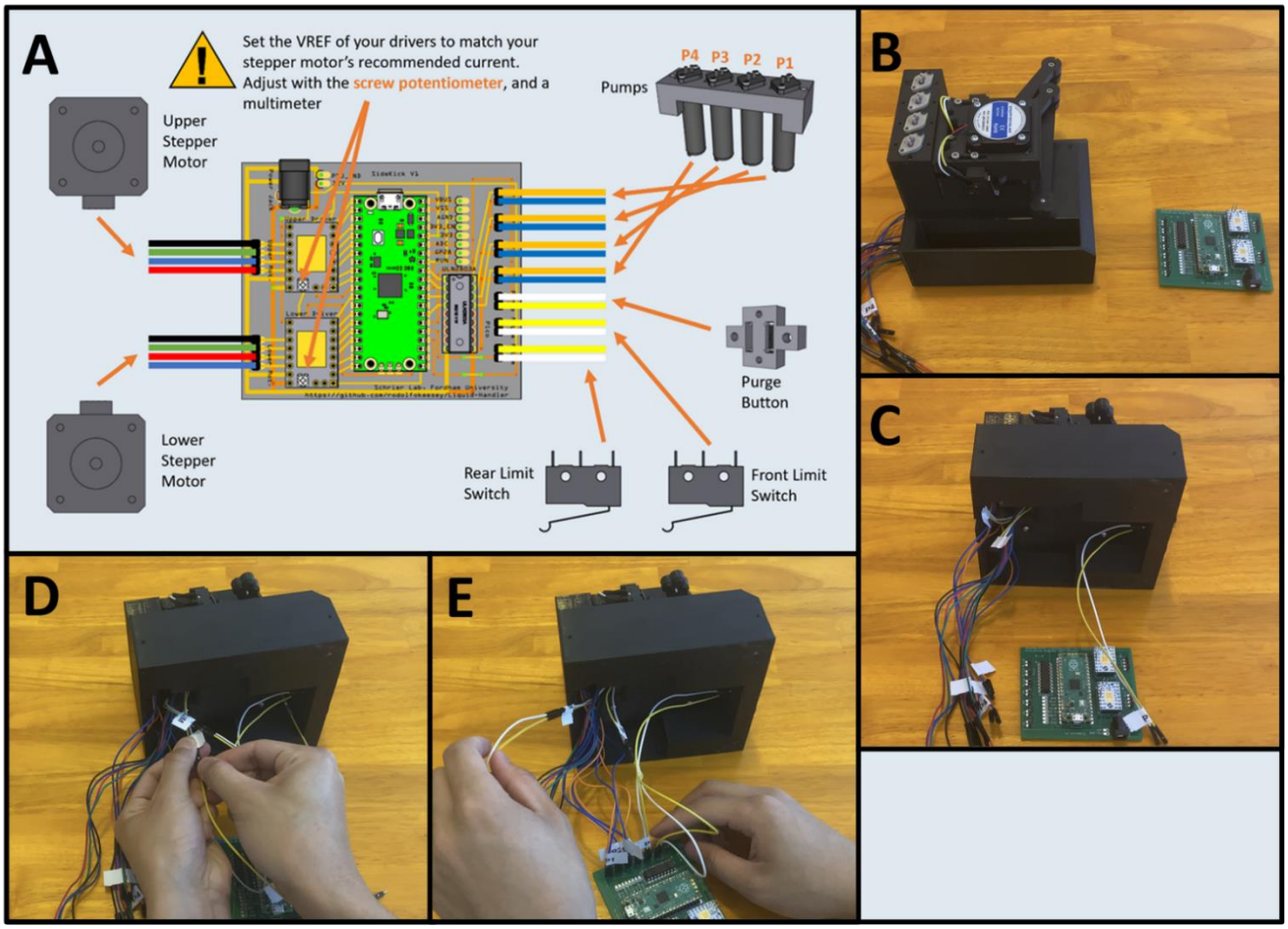

Figure 48a-e: The procedure for connecting the wiring to the PCB.

Figure 48a gives an overview of the connection procedure, and the wiring diagram for each of the pins. Gather the Sidekick and the completed PCB (Fig. 48b). Route all wires from underneath the base of the Sidekick (Fig 48c). If the Dupont connectors for the limit switches are too short, use male-to-female connectors of the same color to extend them out further (Fig 48d). Plug the female ends of the Dupont connectors into the PCB (Fig 48e). Be sure to match the wiring colors to the pins correctly as diagrammed in Figure 48a.

Step 4: Setting Stepper Driver V-Ref

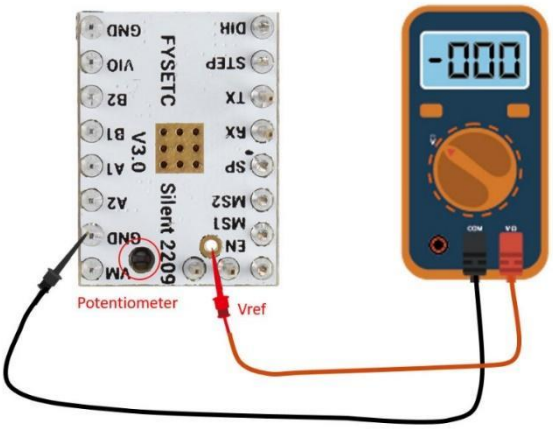

Figure 49: A schematic for how to adjust the VRef of the stepper drive. This figure is from Ref. [36].

After wiring all the hardware, set the V-Ref on the stepper motor drivers to .85 volts (Fig 49). The reference voltage, V-Ref, sets the current output of the stepper driver. Using a multimeter with the power jack of the PCB plugged in, attach the negative probe to the GND pin, and the positive probe to the V-Ref pin noted in Figure 49. Adjust the voltage using the potentiometer and a small flat head screwdriver. The location of the potentiometer is circled in Figure 49. If you are using a different stepper motor from the one in the bill of materials, you will need to use the information sheet to determine the relevant current. The formula relating current to V-Ref for the TMC 2209 stepper drivers is:

Current (root mean square) = V-Ref * 0.71.

A more in-depth explanation for setting the V-Ref can be found in the Fysetc Silent 2209 data sheet. [36].

Step 4: Slide the Wired PCB into the PCB Tray

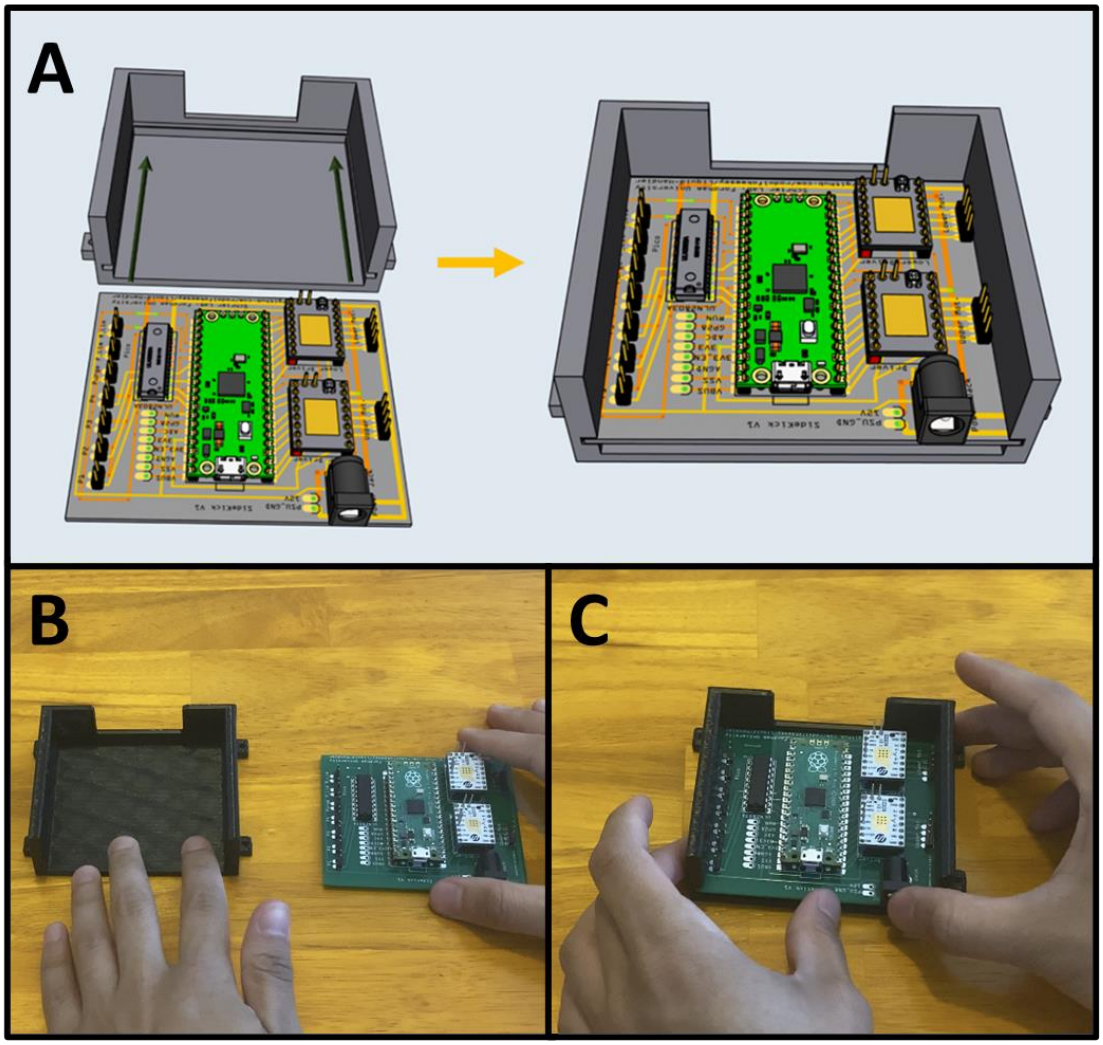

Figure 50a-c: The procedure for sliding the PCB into the tray.

Figure 50a gives an overview of the procedure. Slide the PCB into the PCB Tray (Fig. 50b-c). Route the wires into the gap at the rear of the tray.

Step 5: Ensuring Correct Wiring

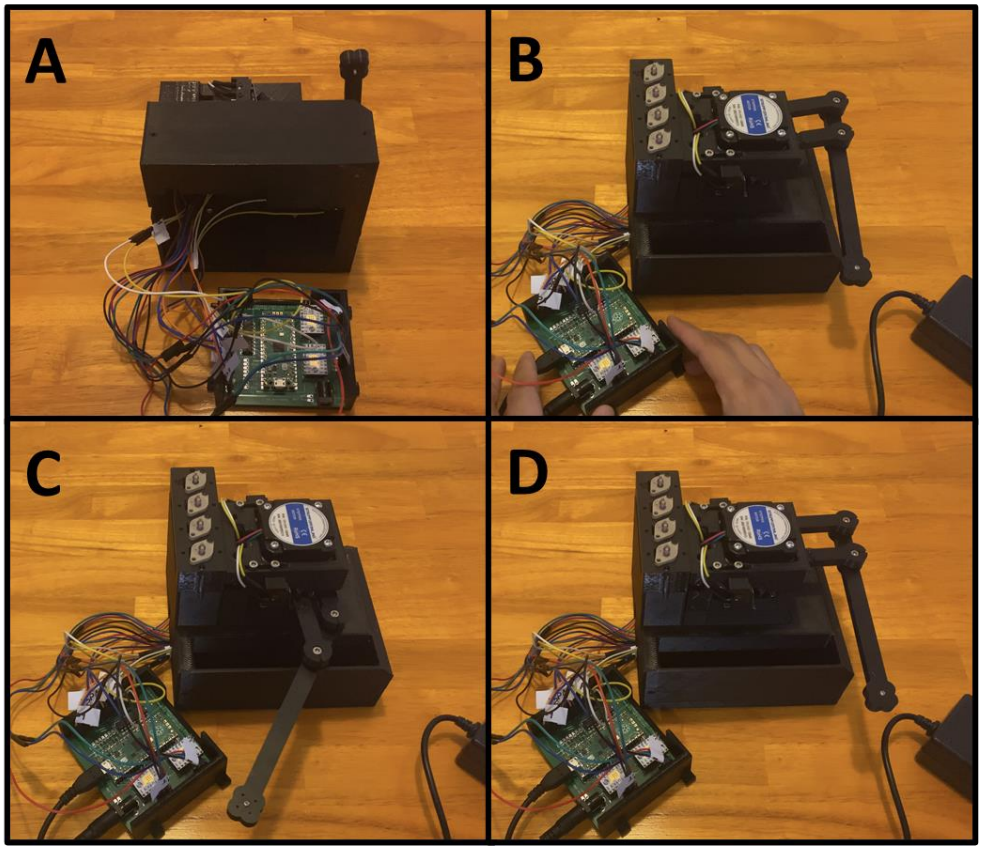

Figure 51a-d: The homing process for the Sidekick.

Before continuing, make sure that all hardware is wired correctly. Once all the wires are correctly plugged in (Fig. 51a) Plug in the PCB power barrel and connect the Pico's USB to a computer (Fig. 51b). Once the Sidekick is plugged in, it should immediately start to home against the limit switches. It will first home against the front limit switch (Fig. 51c), and then the rear (Fig. 51d). If this does not occur, first check the wiring for the limit switches and motors, as the Sidekick will not continue if it cannot home properly.

Next, open Thonny and type into the command line, "hardware check" followed by a return. The Sidekick should home against each limit switch, park the nozzle at a 90° angle, and then cycle through energizing each of the pumps. When a pump is energized, it will make an audible clicking sound. The Sidekick will then ask you to press the purge button. Once pressed, it will output "pressed" and when let go, it will output "released". Once the correct wiring is validated, continue to the next step. If any of the components did not behave as described, inspect their associated wiring.

Step 6: Mounting PCB Assembly to Base

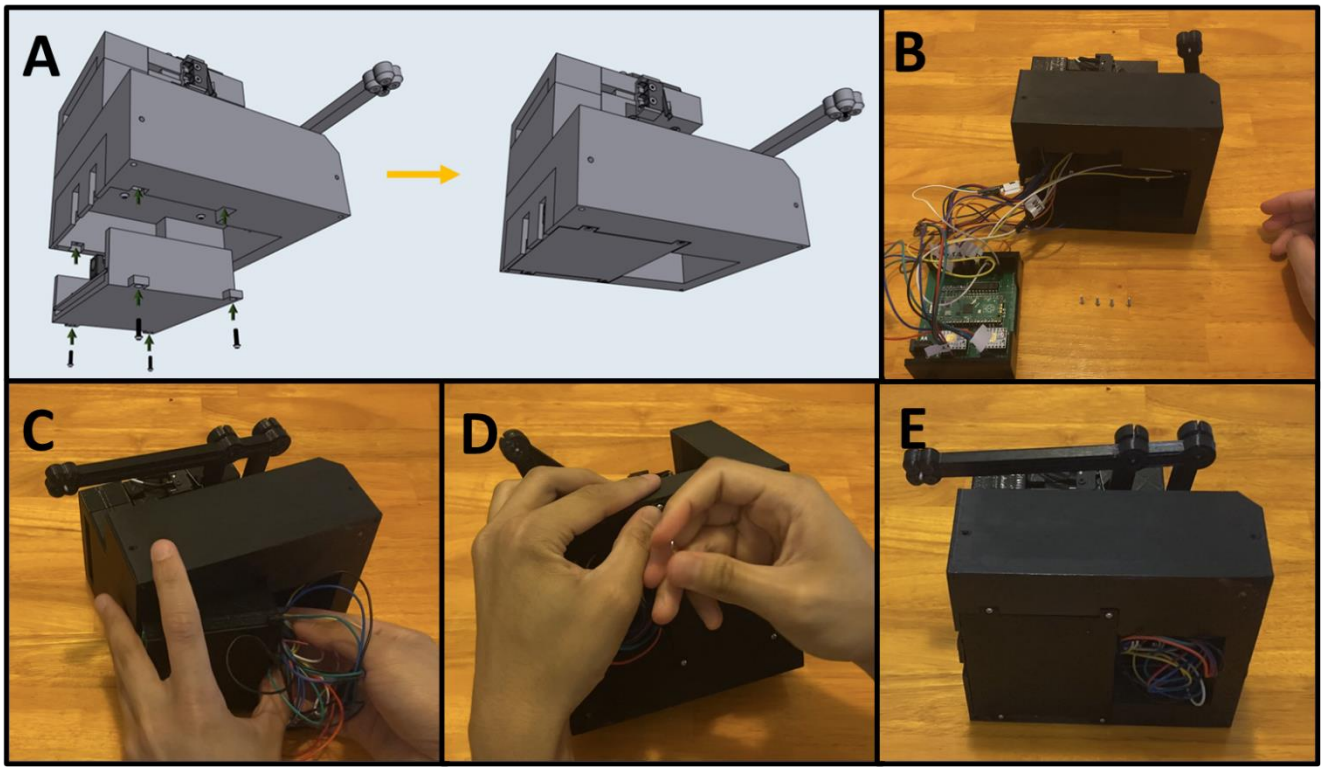

Figure 52a-e: The procedure for mounting the PCB tray to the Base.

Figure 52a gives an overview for the mounting process. Gather the Sidekick and four M2 x 8 screws (Fig. 52b). Route all the wires to the gap in the PCB Tray, and the associated gap in the Base (Fig. 52c). Then, fit the tray into the Base slowly, making sure to keep all the wires routed into the cable management gap. Then thread four M2 x 8 screws to secure the tray in place (Fig. 52d) The cables should all be tucked into the gap in the Base (Fig. 52e).

5H: Plate Holder and Feet

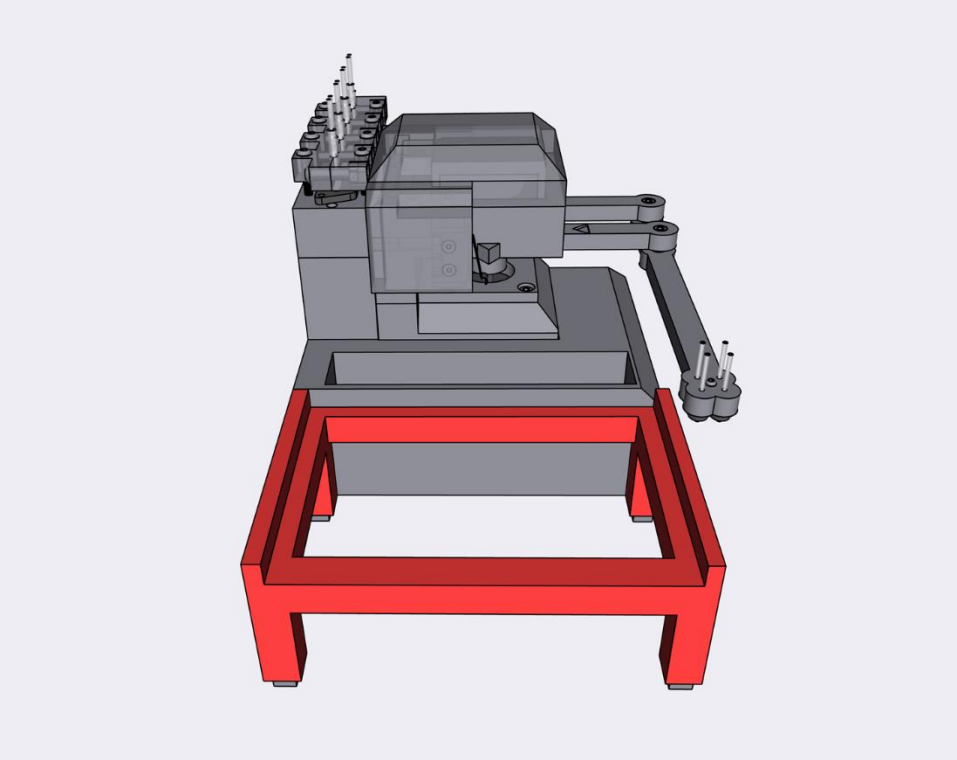

Figure 53: The Sidekick Plate Holder

Step 1: Attach Feet

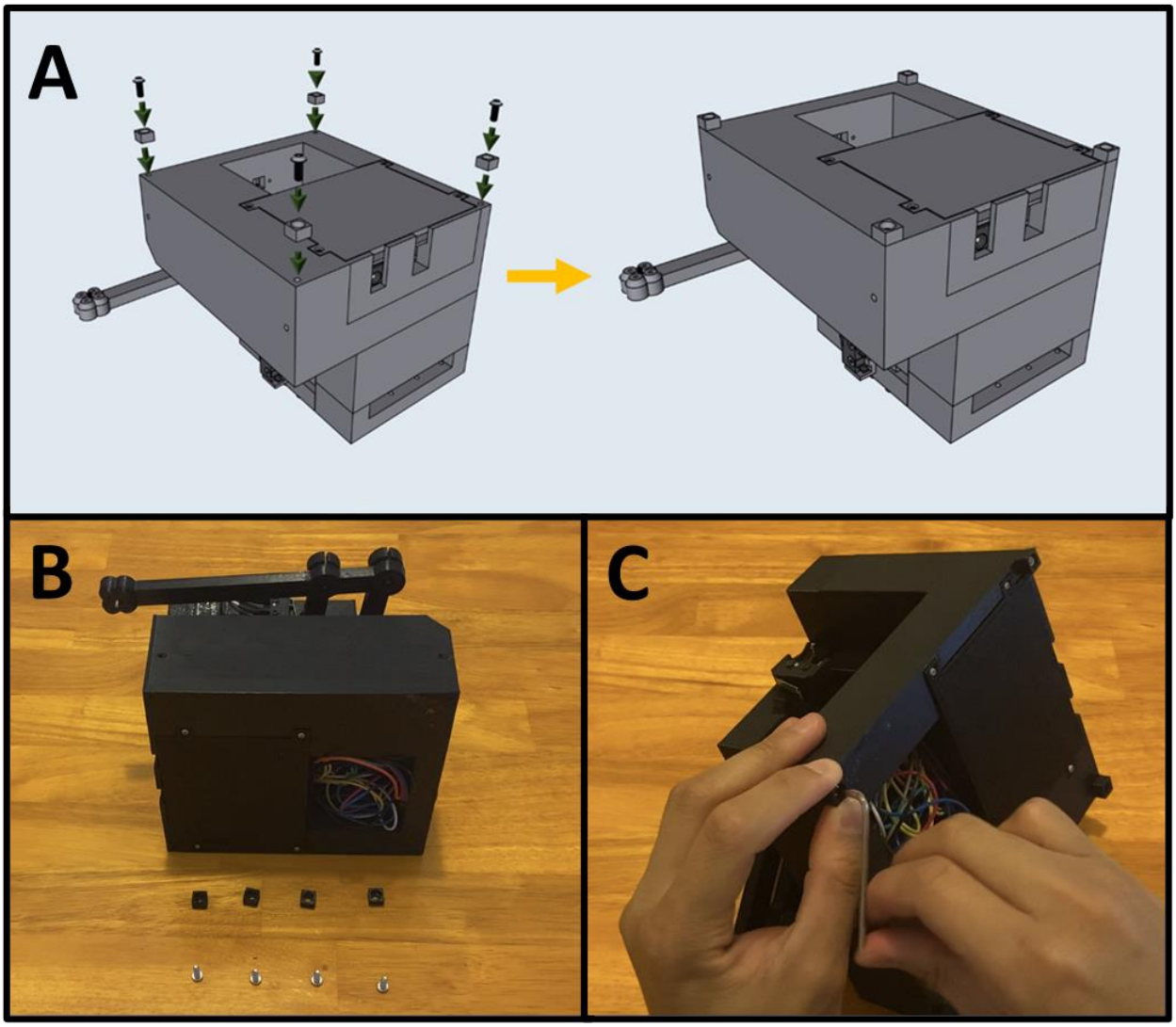

Figure 54a-c: The procedure for attaching the feet to the Sidekick.

Figure 54a gives an overview for attaching the feet. Gather the Sidekick, four 3D-printed feet, and four M3 x 8 screws (Fig. 54b). Attach the feet to the corners of the Sidekick's base (Fig. 54c).

Step 2: Attach Feet to the Plate Holder

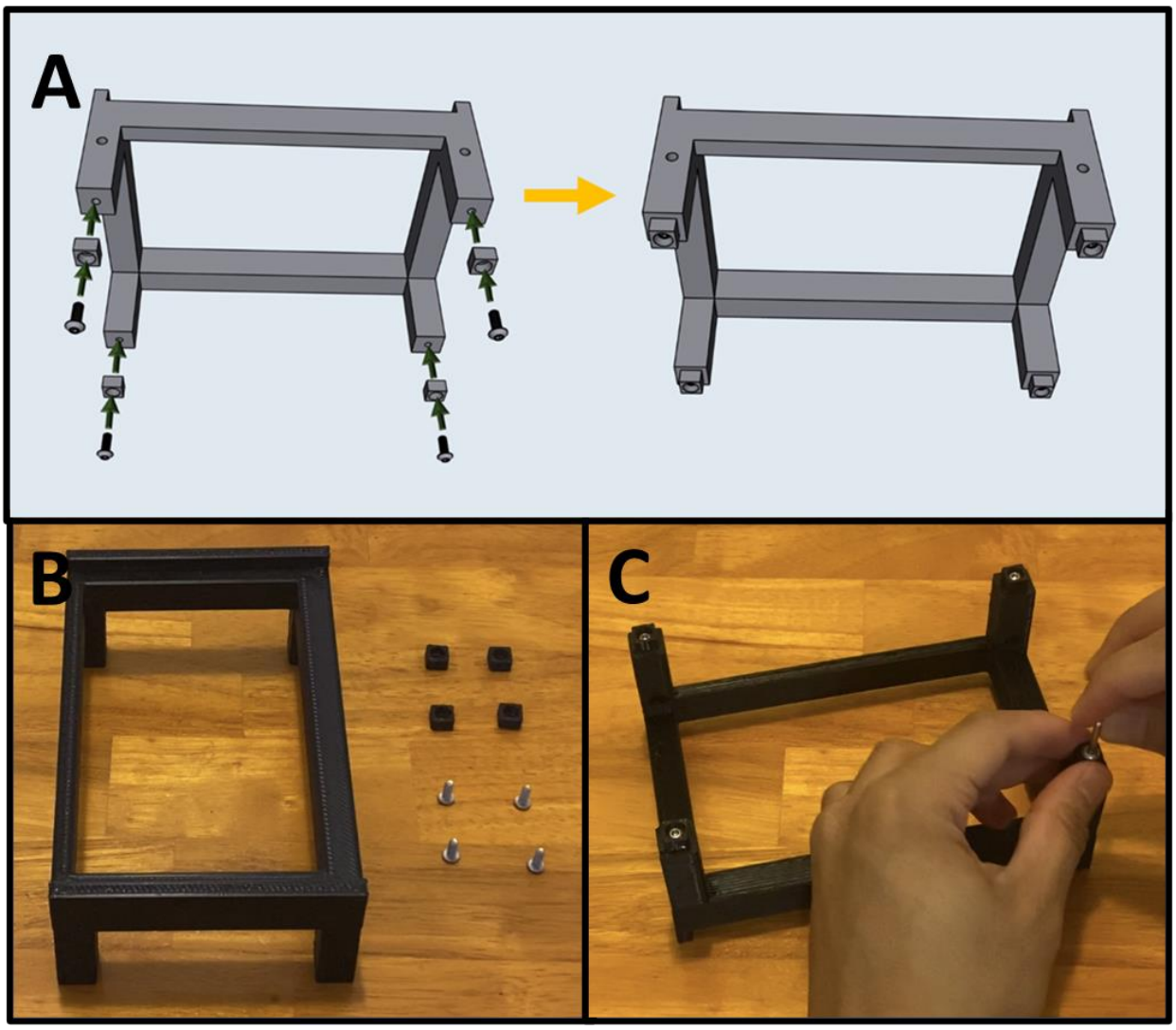

Figure 55a-c: The procedure for attaching the feet to the plate holder.

Figure 55a gives the procedure for attaching the feet. Gather the 96 Well Plate Holder, the remaining four feet, and four M3 x 8 screws (Fig 55b). Attach the four feet to the 96 Well Plate Holder with the four screws (Fig. 55c).

Step 3: Attach Plate Holder to Base Assembly

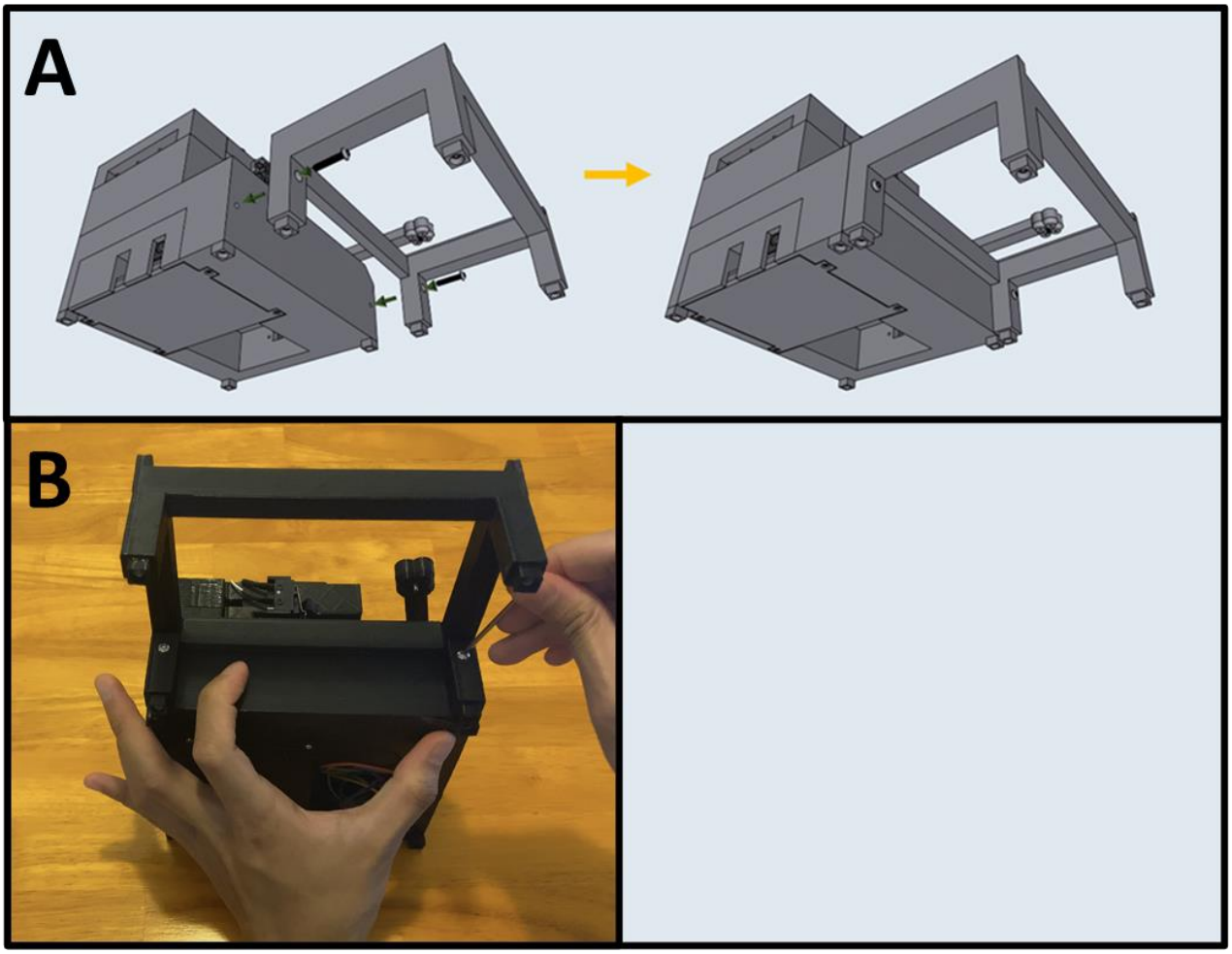

Figure 56a-b: The procedure for attaching the plate holder.

Figure 56a gives an overview for attaching the plate holder. Fasten the 96 Well Plate Holder to the Base assembly using two M3 x 16 screws (Fig. 56b).

5I: Assembling the Adapter Clamp and Tubing

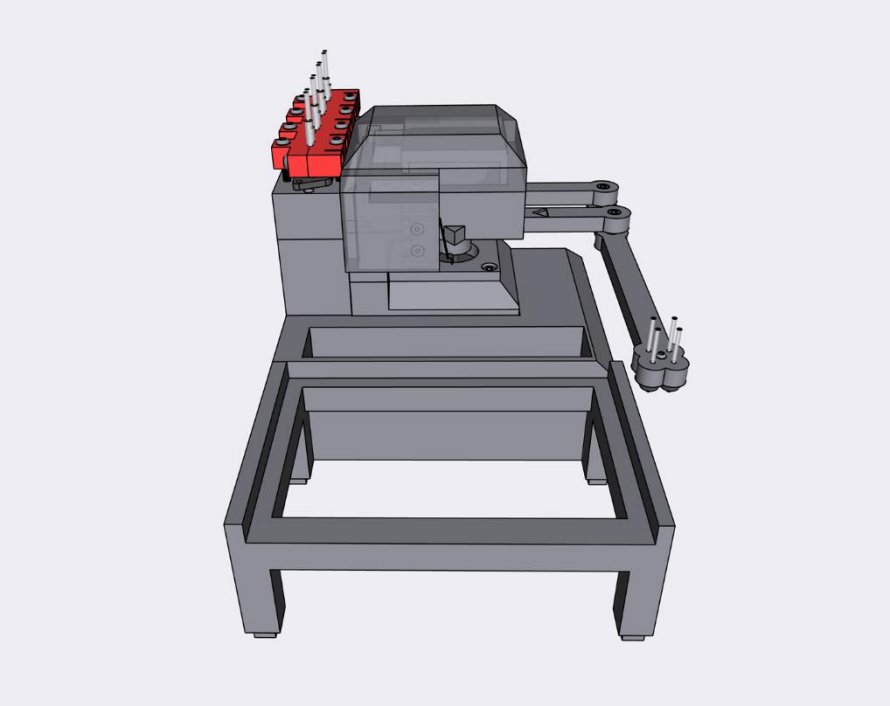

Figure 57: The Sidekick Tubing

Step 1: Assemble the Tubing

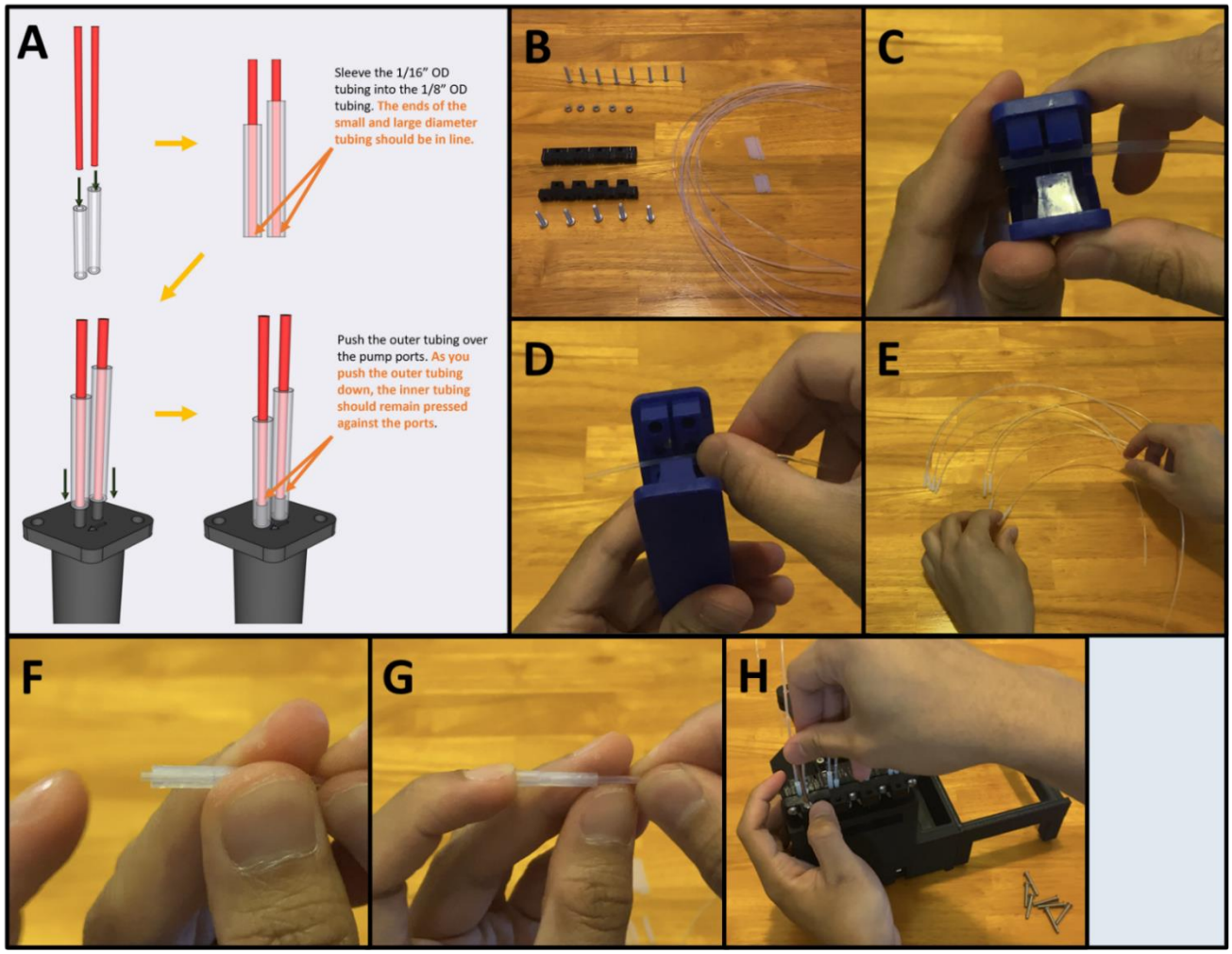

Figure 58a-h: The procedure for preparing the tubing and adapter.

Figure 58a gives an overview of the tubing preparation. Gather the 3D-printed Front Adapter Clamp, the Rear Adapter Clamp, five M4 nuts, five M4 x 20 screws, five M3 x 20 screws, 1/8" OD tubing, and 1/16" OD tubing (Fig 58b). With tubing cutters, cut four sections of 1/8" tubing to 1.7 cm and four sections to 2.0 cm (Fig 58c). The 1.7 cm tubing is for the outlet port, and the 2.0 cm is for the inlet port. Cut eight sections of the 1/16" tubing to 30 cm (Fig. 58d). Insert the 1/16" tubing into the 1/8" tubing (Fig. 58e). Align the inserted tubing so that the ends are aligned (Fig. 58f-g). Then, press the outer diameter tubing over the ports of the pumps (Fig. 58h). As you push the outer tubing down, the inner tubing should remain pressed against the ports, as shown in Figure 58a. The arrow on the port face of the pump indicates the direction of liquid movement. Repeat eight times, for each of the pump inlet and outlet ports. **Please note, the pump port distends the outer tubing. Repeatedly removing and the reattaching the tubing will affect the seal.** It may be necessary to cut off the end of the tubing if it becomes stretched to the extent that it no longer makes a tight seal.

Step 2: Starting the Adapter Clamp

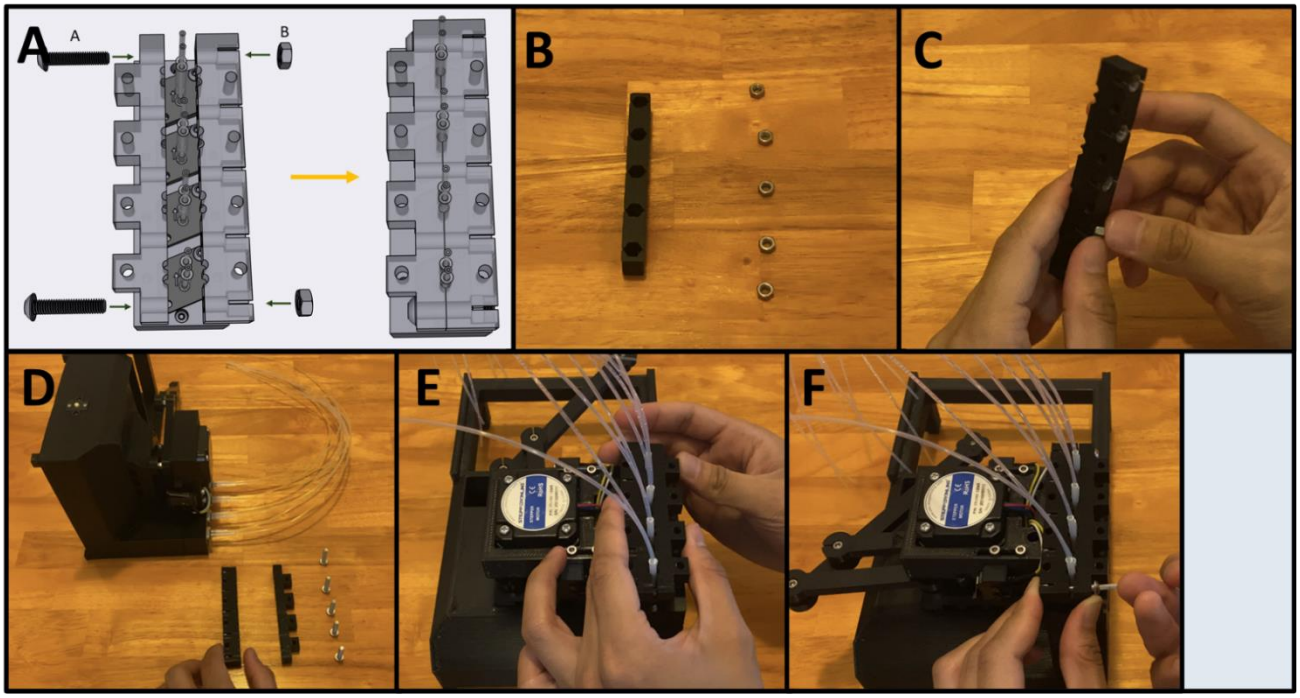

Figure 59a-f: The procedure for assembling the adapter clamp

Figure 59a gives the procedure for assembling the adapter clamp. Gather the Front Adapter Clamp, and the Rear Adapter Clamp, as well as five M4 nuts (Fig. 59b). Press the nuts into the back of the Rear Adapter Clamp (Fig 59c). Gather the Sidekick and five M4 x 20 screws. Sandwich the pump tubing in between the Front and Rear Clamp (Fig 59e). The Rear Clamp (The one with the captive nuts) should be facing inwards, towards the Sidekick. With two M4 x 20 screws, loosely tighten the outer M5 nuts to hold the clamp in place (Fig 59f).

Step 3: Position and Finish Tightening the Adapter Clamp.

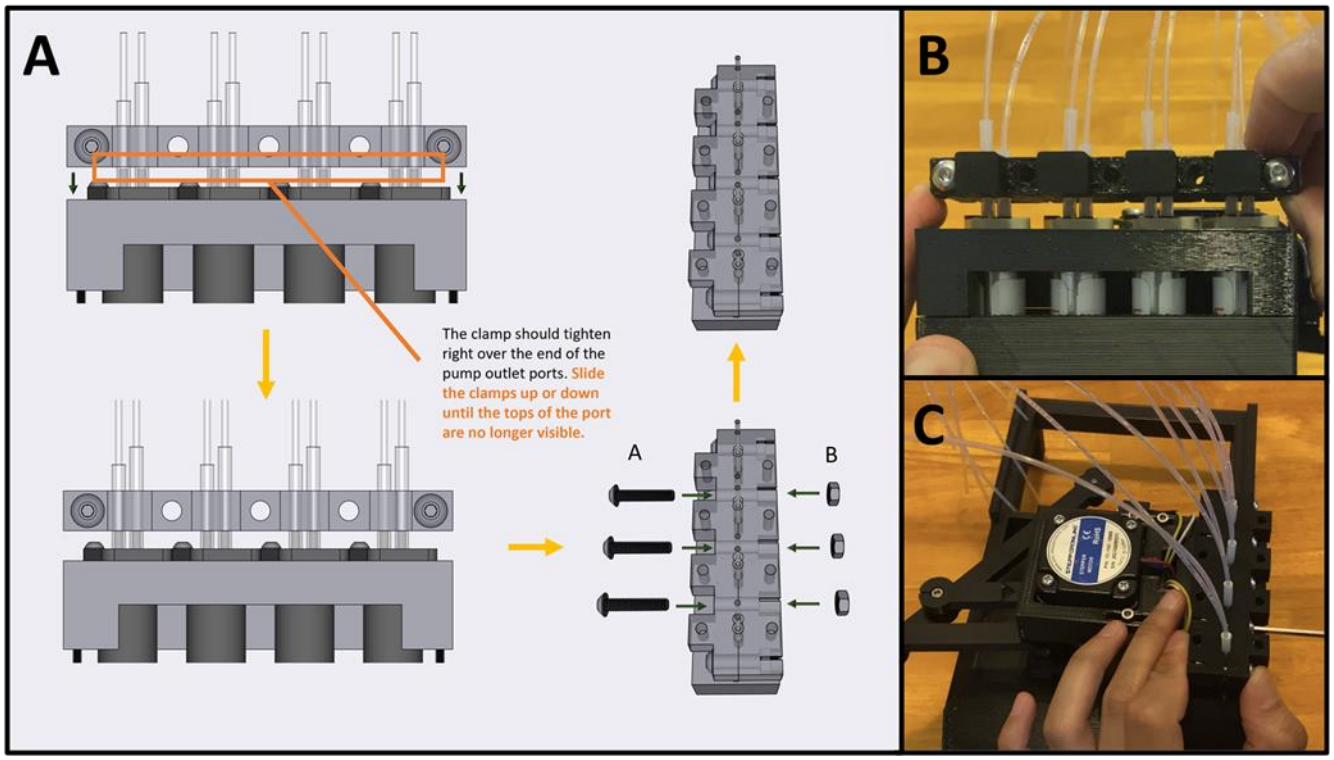

Figure 60a-c: The procedure for finalizing the adapter clamp position.

Figure 60a gives an overview of setting the final position of the adapter clamp. The adapter clamp squeezes the outer tubing onto the inner tubing, and then presses the inner tubing into the pump outlet to create an airtight seal. With the clamp loosely tightened, position it just above the port of the pumps. (Fig 60b). Then screw in the remaining three M4 x 20 screws from the outside in (Fig. 60c). Be sure to tighten all these M4 screws evenly until the clamps are flush together, as they are responsible for squeezing the outer tubing onto the inner tubing. **It will take a significant amount of pressure to mate the clamps together, do not be afraid to thread the M4 screws aggressively**. If a pump is leaking, further tighten the surrounding screws. If they cannot be tightened anymore, lightly tighten the screws mentioned in the following step.

Step 4: Threading in the Vertical Compression Screws

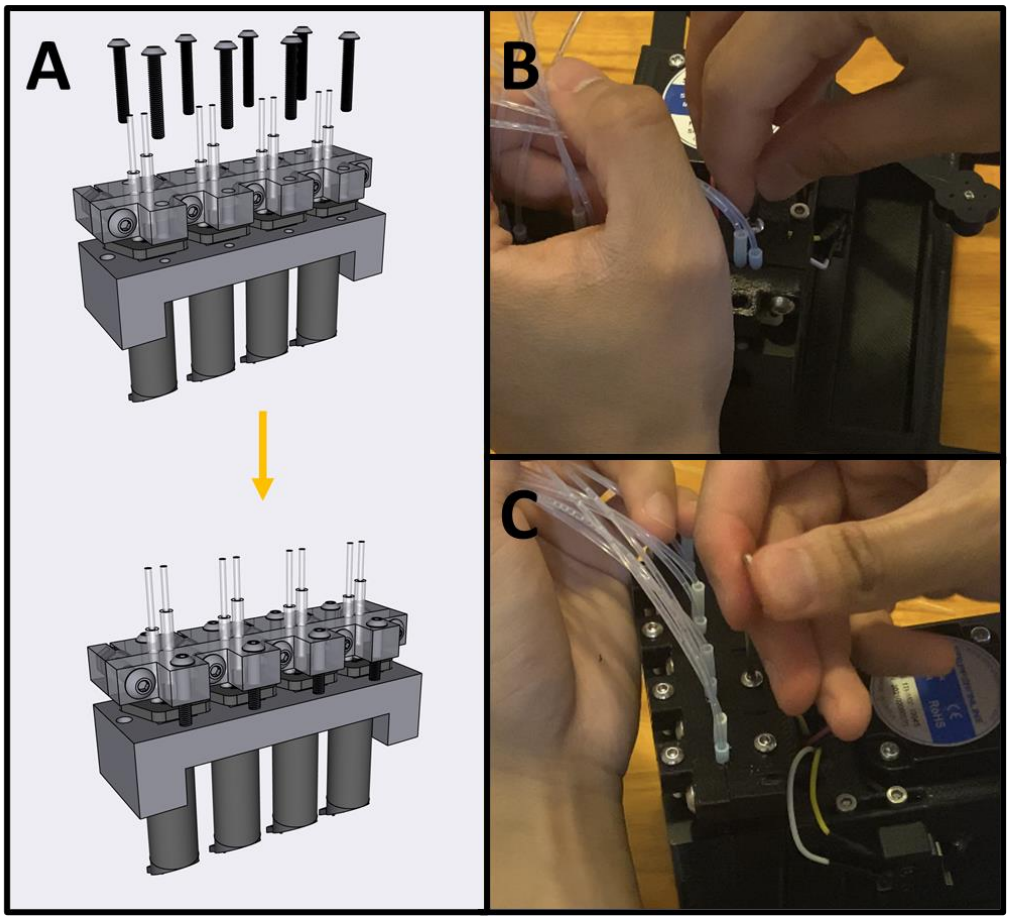

Figure 61a-c: The procedure for threading in the vertical compression screws.

Figure 61a gives an overview for threading in the vertical compression screws. Gather eight M3 x 20 screws and tighten them evenly from the outside in (Fig 61b-c). **Do not overtighten these threads**, you only want to generate enough pressure to press the inner tubing onto the pump ports and but not strip the plastic. If you are still experiencing leaks after tightening both the vertical and horizontal compression screws, you can reprint the clamps, or glue the tubing as a final resort. We printed four different sets of clamps with four different printers: a Creality CR10s Pro V2, a Creality Ender 3, an Ultimaker s5, and a Prusa MK3s. The clamps from the two Creality machines were printed in PETG, and the clamps from the Ultimaker and Prusa machines were printed in PLA. The Creality and Ultimaker clamps were able to achieve leak free operation, but we resorted to glue for the set printed in PLA by the Prusa. **We observed that the rigidity of PLA makes it more difficult to tighten the clamps around the tubing, so we recommend using PETG filament to print the adapter clamps.**

Step 5: Attaching the tubing to the nozzle

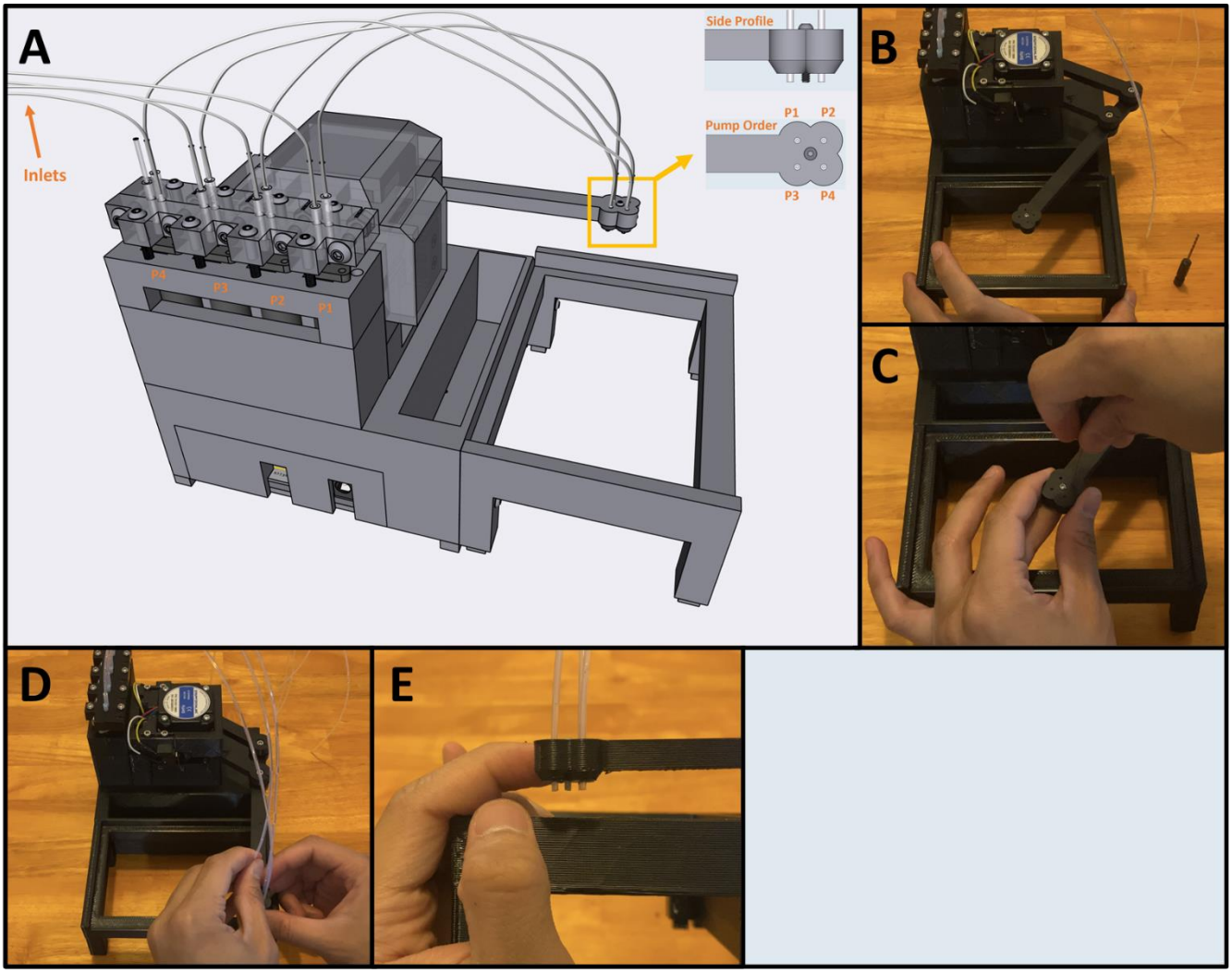

Figure 62a-e: The procedure for attaching the outlet tubing to the nozzle.

Figure 62a gives an overview for sleeving the outlet tubing into the nozzle. Gather the Sidekick and a 1/8” drill bit (Fig. 62b). Match the pump tubing with the pump order given by the diagram in Figure 62a. There are notches in both the pump holder and the nozzle that indicate the pump order. Press fit the tubing outlet into the nozzle, if the tubing does not fit in the holders in the nozzles, drill them out with the 1/8” drill bit (Fig. 62c). Once the holders are drilled out, sleeve the outlet tubing in (Fig. 62d). Repeat four times for each pump, push the tubing through the nozzle until it matches the center screw (Fig. 62e).

Step 6: Creating the Reagent Reservoir

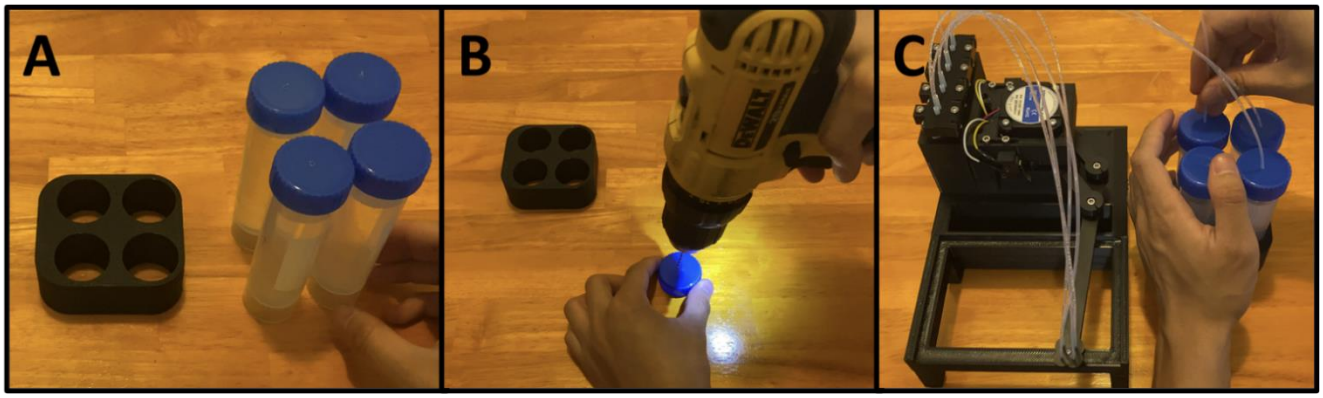

Figure 63a-c: The procedure for making the reagent reservoir.

Gather the 50ml Tube Holder and four 50ml centrifuge tubes (Fig. 63a). With the same 1/8” drill bit, drill out the caps of all four centrifuge tubes (Fig. 63b). Pass the tubing through the drilled holes (Fig. 63c).

Step 7: Attach the 96 Well Plate and the Purge Vial

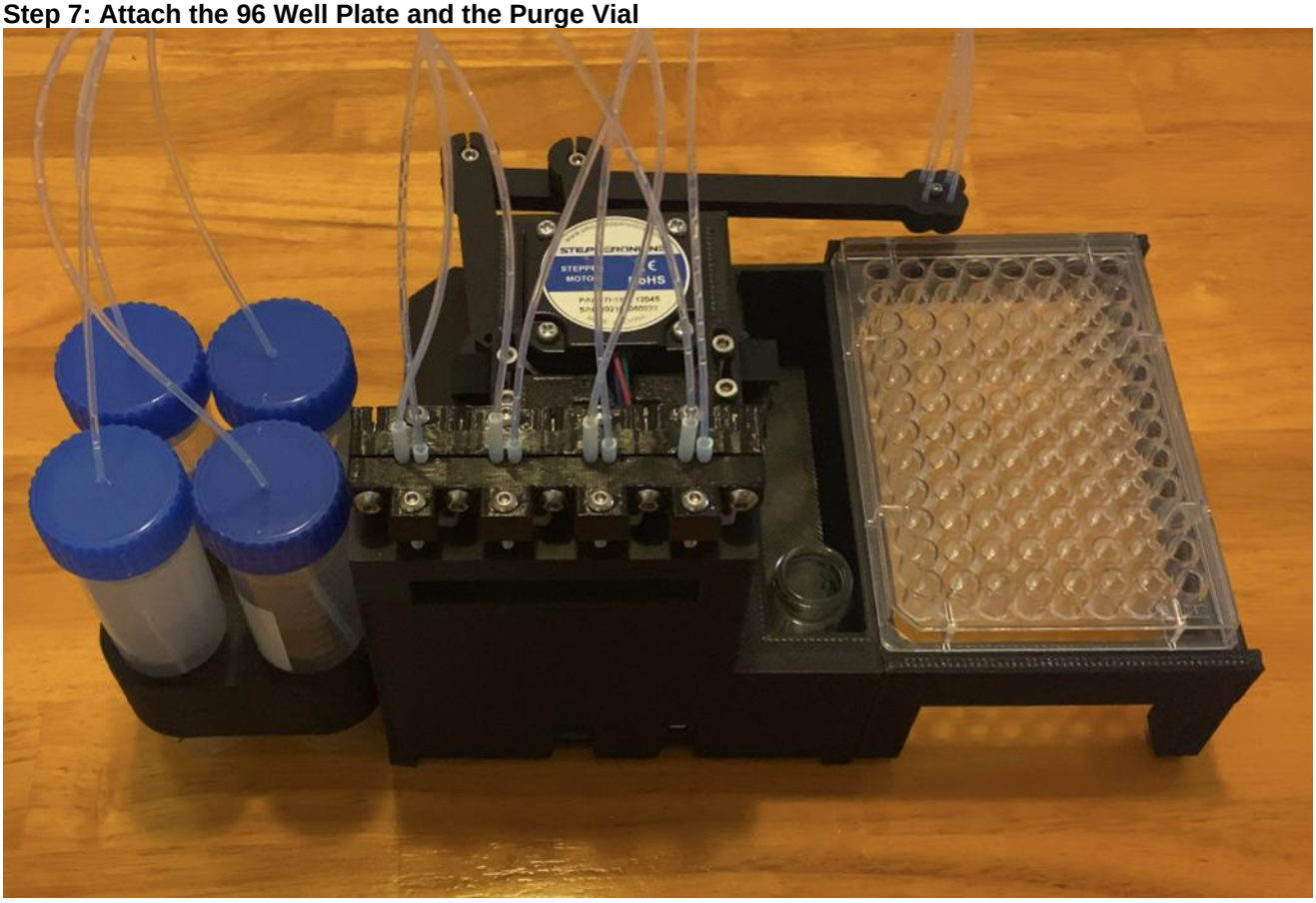

Figure 64: The completed Sidekick

Slide in the 96-well plate and the purge vial as pictured in Figure 64. The assembly of the Sidekick is now complete.

6. Operation instructions

Step 1: Connecting via Thonny's Serial Console

After assembling the Sidekick and validating the correct wiring, reconnect the Sidekick to the USB port of the controlling computer, and connect it to the power supply. The Sidekick reads commands from the USB serial port, allowing any application or programming environment that supports serial I/O to communicate with it. For ease of use, we recommend starting with the serial console within Thonny. Once the Sidekick is connected to the host computer, it will start homing against the limit switches. Then type any command into the Thonny serial console. For an example of how to use the Sidekick with another software, an example of connecting through Putty is given in the project's repository.

Step 2: Calibrating the Plate Map, and setting the Purge Location

Before doing anything with the Sidekick, first set up the plate map and a purge location. Setting a plate map is important for locational accuracy, as slight variations in assembly may differ from the preloaded map for a standard 96-well plate. To calibrate the Sidekick, load a 96-well SBS microplate into the tray. Then type the command: "remap" (return) and follow the prompts. You can remap as many times as you wish.

The purge location is any arbitrary place that you can use to purge the pump lines and dump excess liquid. The Sidekick has been designed with a tray to accommodate small waste vials, but you can easily set up a purge location elsewhere. To set up a purge location, type the command: "set purge" (return) then follow the prompts. The purge location can always be reset.

Once the purge location has been set, and the plate map recalibrated, your Sidekick is now ready to dispense to a plate. Before dispensing from a pump, clear the air from the lines. This can be done by directing the Sidekick to dispense to the purge location, "p1 purge 1000" or with the "manual purge" command. Repeat this process after leaving liquid in the lines for an extended period, or to clean the lines after changing liquids.

6.2 Command Library:

Dispensing and Moving:

A dispense command should be a single line indicating three things:

1. The desired pump to dispense from: "p1"
2. The desired location to dispense to. This can be a well location, or the purge vial location: "a8" or "purge"
3. The desired volume in microliters to dispense: "200"

For example, a command dispensing 200 µL from pump 1 into well H3 would look like this:

"p1 h3 200"

A movement command should be a single line indicating two things:

1. The desired pump to move: "p1"

2. The desired location to move to: “a8” or “purge”

For example, a command moving pump 1 into well H3 would look like this:

“p1 h3”

Things to note:

- All commands are case insensitive (e.g., "p1” and “P1” are identical).
- Volume is given in microliters and rounded to the nearest 10 µL increment.

Command List:

Initialize: Homes the armature against the limit switches. Use if the Sidekick has bumped against something and skipped steps.
Hardware check: Runs through all the hardware to validate that everything has been wired correctly. Use after wiring the Sidekick, or for troubleshooting.
Free move: Allows the user to freely move the armature.
Sleep: De-energizes the motors, allowing the armature to move freely.
Wake: Re-energizes the motors so that the armature can move again. Use after the “sleep” command.
Return home: Returns the armature to the home location.
Manual purge: Used to purge the liquid lines. Use after swapping reagents, or for cleaning the lines.
Remap: Used to calibrate a new plate. Use if swapping in a plate with different well locations.
Set purge: Sets the purge location. Use if changing the location of the purge tray/vial.

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