DEVICE FABRICATION AND ASSEMBLY: MOTOR ARRAY

The device container is made of acrylic sheets (¼ and ½ inch) laser cut to fit 12 motors (**Supplementary Figure 1A**, CAD files for configurations of 2, 4, 6, 8, 10, and 12 motors are available in the Supplemental Materials). The original design of the top sheet has spaces for 12 motors in 2 rows of 6, but the number of motors can be customized to fit desired needs and incubator space requirements. Motor spacers (**Supplementary Figure 1B**) are 3D-printed from polylactic acid (PLA) filament on a fused deposition modeling (FDM) 3D printer and are necessary to mount the motors at the correct distance from the acrylic top sheet that accommodates the 6mm motor coupler and an M4 hex head bolt (**Supplementary Figure 1B**). One motor spacer has dual function as a mount for a hall effect sensor used to detect motor revolutions for rpm calculations (**Supplementary Figure 1C**).

To fabricate the structural components of the motor and frame, follow the instructions below:

1. Laser cut the top and bottom device panels from ¼ inch acrylic sheets using the CAD design of your choosing (2-12 motors)
2. Laser cut the front and back device panels from ½ inch acrylic sheets
3. Print motor spacers (1-11) and hall effect sensor mount spacer (**Supplementary Figure 1C**) from PLA on an FDM 3D printer.
4. Connect the 6mm brass coupler to the D-shaped shaft of the motor and secure it in place with the provided M4 set screws. (**Supplementary Figure 1B**).
5. Add Loctite into the top of the brass coupler before screwing in the M4 hex bolt. (The Loctite prevents the bolt from coming undone).
6. Place a motor spacer over the hex bolt and insert M3x30mm flat head machine screws in the holes provided on the top sheet to secure it directly to the motor below.
7. Repeat steps 1-3 for (n-1) number of motors as required for your device needs.

   *Note: the positive/negative motor electrical connections should be installed in the same orientation such that all the positive connections are on the same side of the device. This facilitates easy wiring later (***Supplementary Figure *1D**).*

8. For the dual-purpose motor spacer, place a 2x3mm magnet over the metal set screw in the side of the brass coupler and secure the hall effect sensor along the track. The sensor should be close enough to the magnet to trigger the switch (indicated by a lit bulb), but far enough away not to interrupt the motor rotation or dislodge the magnet while in motion.
9. Once the magnet and sensor are in place, repeat step 3 for the dual-purpose motor.
10. Once all motors are assembled on the top sheet, flip device over and wire polarity of motors in parallel according to diagram (**Supplementary Figure 1D**).
11. Back, front, and bottom panels can now be assembled:
    a. Drill holes for 2 M3 x 12mm screws into the top and bottom of both ½ acrylic back and front panels.
    b. Drill holes for 2 M3 x 6mm screws on either side of the front panel. (These will be used to secure the control panel later).
    c. Attach the top plate with the wired motors to both front and back panels using 4 M3 x 12mm screws.
    d. Attach the bottom plate to both front and back panels using 4 M3 x 12mm screws.

12. Bend 3mm flat wire using pliers into shape to make the tension arms (**Supplementary Figure 1E)** and insert into the slots in the front/back panels and hook into the slots provided at either end of the top motor plate (**Figure 1B/ Supplementary Figure 1A**).

DEVICE FABRICATION AND ASSEMBLY: CONTROL PANEL & POWER SUPPLY

The device control panel is 3D-printed PLA casing that houses the internal electronic components. The control panel creates an interface between the software programmed into the Arduino Nano and the hardware (LCD screen, button, motors, and hall effect sensor). Instructions on the printing and assembly of the control panel and power supply can be found below:

1. Print the control panel (**Supplementary Figure 2A**) casing in PLA on an FDM 3D printer.
2. Wire the electrical components using jumper wires and electrical wire according to the wiring diagram (**Supplementary Figure 2B**) in this suggested order:
    a. Screen (connected to the Arduino Nano and grounded on the button bread board)
    b. Buttons (fitted to bread board and connected to Arduino Nano)
    c. Relay module (connected to the Arduino Nano, the motors, and the variable voltage power supply)
    d. Hall effect sensor (connected to the Arduino Nano and grounded on the button board)
    e. Arduino Nano (connected to all other components and its own power supply)

    Note: The diagram shows two separate power supplies for the motors (variable voltage) and Arduino Nano because it is not recommended to subject the Arduino Nano to variable voltage. The quick disconnect terminal adapters are an optional feature if the user would prefer easy disconnect of the device from the power sources for ease of transport.

3. Mount the screen and colored buttons into the cutouts on the control panel casing and secure using double-sided foam tape.
4. Load software code onto the Arduino Nano:
    a. Install and open the program “Arduino IDE” on a computer (https://www.arduino.cc/en/software).
    b. Connect Arduino Nano into the computer via USB.
    c. Select Arduino Nano from the drop-down menu at the top of the screen.
    d. Open the file “DeviceCode_2023.ino” containing the software code in Arduino IDE.
    e. Load the code onto the connected Arduino Nano by clicking the “Upload” button.
5. Mount the Arduino Nano to the expansion board and secure to the front panel using double-sided foam tape. Ensure that the position of the USB Mini-B port is in line with the cutout on the right side of the control panel (**Supplementary Figure 2A**). This allows users to upload modifications to the software code after assembly is complete.
6. Secure the relay module to the front panel using double-sided foam tape.
7. Ensure that wire connections are tight and secure before placing the control panel cover over the electrical components and securing in place with 2 M3x6mm screws on either side of the front panel.

DEVICE OPERATION

Loading Samples

1. Connect the Arduino Nano to power supply (the LCD screen will light up automatically).
2. Connect the motors to power supply and ensure that the voltage control on the power adapter is turned off (the motors should not be turning).
3. Prepare tissue samples by chopping material to pieces small enough to fit under the rotor in the C Tubes.
4. Ensure proper closure of tubes by rotating cap clockwise until you feel a "click".
5. Install tubes upside down onto motor driven hex bolt heads.
6. Fit the tube holder plate (**Supplementary Figure 1A**) over the D-shaped tube bottoms.
7. Secure tubes to motor plate by latching tension arms into the acrylic plate (**Supplementary Figure 3**).
8. Turn the voltage control on.
9. The device and samples are now ready to run a protocol/program (the motors will begin turning once you have selected a mode or protocol).

Operating Software

The main menu allows you to choose between 3 modes of operation by pushing 1 of 3 colored buttons: Red: Manual, Green: Preset Programs, Blue: Custom Programs, and Yellow: Resets the Arduino Nano and returns you to the main menu. In the software menus, the letter R, G, and B refer to the color button that corresponds to a particular selection (**Supplementary Figure 4**).

R = Red button
G = Green button
B = Blue button

Once a program is selected and the motors are turning, the LCD screen will display calculated RPM values in the bottom right corner (**Supplementary Figure 4**). The speed of the motors can be adjusted to the desired RPMs using the dial to control voltage (**Supplementary Figure 3B**). When running preset and custom programs, the remaining time in the current program is displayed in the top right corner.

In Manual Mode:

- R = Pause (Stops the motors from turning)
- G = Run (Starts the motors)

In Preset Mode:

- R = Up (Cycles through preset program in ascending order #1 to #9)
- G = Down (Cycles through preset program in descending order #9 to #1)
- B = Select and Run (Begins the selected program)

Preset programs may be adjusted by entering values directly into the Arduino IDE software code on a computer and reloading the updated code to the Arduino Nano. To add your own preset programs, go to lines 54-58 in the code. There are 10 "slots" available for preset programs with 3 adjustable components:

1) Duration of forward rotation in seconds
2) Duration of reverse rotation in seconds
3) Number of times to "loop" or repeat steps 1 and 2

In the sample code for preset programs below, each position that is separated by a comma, corresponds to values for an individual preset program up to 10:

```
int favFWD[10] =   {program 1, program 2, program 3, program 4, program 5,
program 6, program 7, program 8, program 9, program 10};
```

In the sample code below, **preset program #1 is coded as follows**:
Step 1. Forward Rotation: **30** seconds
Step 2. Reverse Rotation: **10** seconds
Step 3. Loop Steps 1-2: **4** times

And **preset program #2 is coded as follows**:
Step 1. Forward Rotation: **300** seconds
Step 2. Reverse Rotation: **20** seconds
Step 3. Loop Steps 1-2: **9** times

```
//Index of selected fav/preset and respective arrays of F/R/L values
int curFavNum;
int favFWD[10] =    {30,300,30,20,0,0,0,0,0,9};
int favREV[10] =    {10,20,10,10,0,0,0,0,0,9};
int favLOOPS[10] =  {4,9,2,2,0,0,0,0,0,9};
```

In Custom Mode:
You will move through 3 different menus to dictate to the software the specifications of the protocol you would like to run.

Menu #1: Duration of Forward Rotation

- R = Seconds
- G = Minutes
- B = Select

Menu #2: Duration of Reverse Rotation

- R = Seconds
- G = Minutes
- B = Select

Menu #3: Loop (number of times to repeat Steps 1-2)

- R = Increasing integers
- B = Select and Run (Begin the selected program)

Custom programs are not retained in the device memory but can be programmed as one of the preset programs.