Installation Procedure for Autonomous In-Cage Behavioral Training Device for Small Animals

I. PCB Circuit Board Welding and Testing

This section mainly includes two PCB boards (5) located on the left and right of the main circuit board, each consisting of a white LED indicator light and a buzzer; one PCB board (5) located at the top of the main circuit board, consisting of an RGB LED indicator light and a buzzer; and one main circuit board (9).

1. Welding and Installation of Three Buzzer PCB Boards:

1.1 **Resistance Welding:** Use chip resistors to weld one 10R resistor to the corresponding position on the left and right buzzer PCB boards. Similarly, weld two 30R resistors and one 120R resistor to the top buzzer PCB board.

1.2 **LED Indicator Light Welding:** During welding, ensure to select the welding contacts according to the notch indications on the PCB board. Weld one white LED indicator light to each of the left and right buzzer PCB boards, and one RGB LED indicator light to the top buzzer board.

1.3 **Buzzer Welding:** Weld one buzzer to each of the three buzzer PCB boards. Ensure that the buzzer is flush with the PCB board.

1.4 **Terminal Block Welding:** Weld one 3-port terminal block to each of the left and right buzzer PCB boards, and one 5-port terminal block to the top buzzer PCB board. Note that the terminal blocks should be welded to the back of other components with the ports facing outwards.

2. Welding and Installation of Main Circuit Board:

2.1 **Resistance Welding:** Weld two 10kΩ chip resistors to the corresponding indicated positions on the front of the main circuit board.

2.2 **Microprocessor Welding:** First, weld two corresponding-length slots to the indicated position for the microprocessor on the main circuit board. Ensure that the slots are installed flush with the main circuit board. Then, weld pins to the microprocessor shield board to install the microprocessor module onto the slots. This installation design ensures that the microprocessor module can be reused.

2.3 **HX711 Module Welding:** This module processes data obtained from the weighing module to obtain the weight of the small animal. First, connect a 4+6 pin to the module. Then, weld it directly to the indicated position on the main circuit board.

2.4 **MPR121 Module Welding:** This module detects which reward spout the small animal triggers. Since only relatively simple functions are needed, only the first four pins on the left end of the module need to be welded, according to the indications on the main circuit board.

2.5 **WiFi Module Welding:** Weld a base and proceed with normal welding according to the

indications on the main circuit board. Afterward, install the WiFi module.

2.6 **Rocker Switch and Power Plug Welding:** Perform normal welding according to the indications on the main circuit board. During the welding of the rocker switch, its pins can be cut short to facilitate the welding process. Ensure that the rocker switch does not protrude from the PCB board.

2.7 **Micro Solid-State Relay Welding:** On the main circuit board, locate the Solid_DO1 and Solid_DO2 indications (i.e., the ports on the first row), and weld two micro solid-state relays, which are related components of the peristaltic pump drive circuit. During welding, pay attention to distinguishing the current input and output pins of the micro solid-state relay. Simply remember that the side of the component with model specifications should face inward towards the main circuit board.

2.8 **Toggle Switch Welding:** Normally weld two toggle switches on the indicated positions on the main circuit board to control whether water supply is controlled by the microprocessor. Their positions do not require distinction between positive and negative.

2.9 **RESET Pin Header Welding:** During welding, reverse the two pins onto the main circuit board, with the longer end on the front of the main circuit board. Additionally, after welding, use a jumper cap to electrically connect the two pins.

2.10 **Terminal Block Welding:** The terminal blocks on the main circuit board are welded in two locations. Weld two 8-port terminal blocks at the top ends of the main circuit board (note that these two 8-port terminal blocks are welded to the two ends of the top side of the main circuit board, with the middle two 8-port slots left empty). Weld four 4-port terminal blocks at the bottom end of the main circuit board. During welding, also ensure that the ports face outwards.

2.11 **Voltage Conversion Module:** A 12V to 5V voltage conversion module onto the designated position on the back of the main circuit board. Be mindful to distinguish the four voltage input and output ports of the module and solder them onto the specified contacts on the main circuit board according to the indications.

3. Testing
3.1 Basic Hardware Testing
3.1.1 Voltage Conversion Testing: Connect the power supply first and use a multimeter to test if the voltage input and output of the voltage conversion module on the main circuit board are 12V and 5V respectively. Proceed to the next step if the test is passed; otherwise, check the circuit and soldering issues.

3.1.2 Microprocessor Board Voltage Testing: Test if there are 5V and 3.3V on the VIN pin and 3V pin of the microprocessor board respectively. Move to the next step after completion of the test.

3.2 Program Testing
3.2.1 Program Burning: To ensure that the main circuit board is not powered when burning the

program using a USB, first disconnect the power supply circuit of the microprocessor board. After disconnection, use a multimeter to verify if the power supply circuit is indeed cut off.

3.2.2 Buzzer Board Functional Testing: Connect the wiring of the buzzer PCB board to the ports on the main circuit board following the GND line. Then use the 'test_LED.ino' program to test the LED indicator light control and buzzer punishment function of the three buzzer boards.

3.2.3 WiFi Module Functional Testing: Use the 'test_WiFi.ino' program to test the WiFi transmission and reception functions.

3.2.4 Weight Module Functional Testing: Connect the wires of different colors from the weighing platform sensor to the W (white), G (green), R (red), and K (black) ports on the main circuit board. Then use the 'test_weight.ino' program to test and check the weighing function in the serial monitor.

3.3 Toggle Switch Functional Testing: Connect the peristaltic pumps to the corresponding ports on the main circuit board using 20cm long thick wires. During connection, note that the red wire is positive and the black wire is negative. The connecting ends of the wires should be twisted into one strand without any exposed wires. Connect them to the DO1, DO2, and corresponding GND ports above the main circuit board. DO1 corresponds to the left side for mice, and DO2 corresponds to the right side. The normal test result should be that flipping the toggle switch upwards initiates the operation of the corresponding peristaltic pump.

3.4 Water Pipe Pumping Test: Use a 3mm inner diameter water pipe to extend the water intake pipe to draw water from the water storage tube to the reward nozzle. A small water pipe connector is used for the connection. The connection process can be facilitated by dipping in water.

Each peristaltic pump has an intake pipe and an outlet pipe. To meet the requirements of the water supply system, use a 15cm long water pipe to extend the outlet pipe and a 20cm long water pipe to extend the intake pipe. To ensure that the end of the intake pipe can be placed at the bottom of the water storage tube and stably draw water, drill a 1mm diameter ventilation hole and a 3mm water pipe connector on the water storage tube. After installation, flip the toggle switch to check if water can be drawn from the water storage tube.

3.5 Reward Nozzle Touch Detection Testing: Connect the tail end of each peristaltic pump's outlet pipe to one end of the reward nozzle and use a 15cm long flexible wire to weld one end to a position 20mm away from the outer end of the reward nozzle and the other end to the corresponding reward nozzle touch detection port on the main circuit board. The L port corresponds to the left side for mice, and the R port corresponds to the right side.

Use a 1cm long, 3mm diameter heat-shrink tube to tightly cover the welding point of the reward nozzle for insulation protection. Then, place a 1cm long, 2mm diameter heat-shrink tube at a position 28mm away from the outer end of the reward nozzle, so that only 28mm of the reward nozzle is located outside the autonomous training cage.

After completing the above installation operations, use the 'test_MPR121.ino' test program to conduct a test. The test result should be that when the corresponding reward water spout is touched, the corresponding detection signal will appear in the serial port monitoring window. When the reward water spout is not touched, the detection signal will not be triggered.

3.6 Testing of Rocker Switch: Use the 'test_switch.ino' test program to conduct a test. When the rocker switch is turned on, the *buildin_led* will remain lit continuously. When the rocker switch is turned off, it will blink.

II Bonding Process for Small Animal Habitats

As shown in Figure 1, during the installation of small animal habitats:

1. Inspect the acrylic sheets needed, remove the film on the acrylic sheets, and confirm the type and installation position of the corresponding acrylic sheets.

2. ***Screw thread tapping.*** First, locate the outside of the installation surface through the asymmetric four mounting holes on the main circuit board and make markings. All threads should be tapped from the outside, clockwise for entry and counterclockwise for exit. At the same time, ensure that the threads are tapped vertically. Subsequently, on the front panel of the habitat, use M4 threads to tap eight holes for installing the peristaltic pumps; use M3 to tap four holes for the water storage tube and four holes for installing the 3D-printed mounting plate. On the 3D-printed mounting plate, use M3 to tap four holes for installing the main circuit board and three holes for installing the buzzer PCB board on the side. On the 3D-printed weighing platform support plate, use M3 to tap two holes.

3. ***Install the overall framework of the small animal habitat.*** First, install the base plate and surrounding acrylic sheets. During installation, constantly refer to the model to ensure correct installation. To ensure stability, after aligning the installation positions, first use glue to fix key positions, and after one minute, use a syringe to reinforce all connections.

4. ***Install the drawer part of the small animal habitat.*** Install the drawer part according to the model and the aforementioned method. To ensure that the weighing platform and drawer part do not rub against each other, first install the weighing platform onto the habitat—first check the force direction of the sensor and install one end of the sensor's support onto the weighing platform support plate, and use an M3×12 screw combined with a nut for installation. The main body of the weighing platform and the other end of the sensor are installed together, directly fixed with a nut and an M3×16 screw. During installation, be careful not to apply too much force to the circuit part in the middle of the sensor, and ensure that the entire weighing platform is parallel to the habitat.

At the same time, when installing the drawer part, to ensure that the main body of the drawer is symmetrical, install the outer baffle in coordination with the framework of the small animal habitat. First, install the surrounding baffles and base plate, then ensure symmetrical installation of the outer baffles. Afterward, install the weighing platform using M3×12 screws to check for friction.
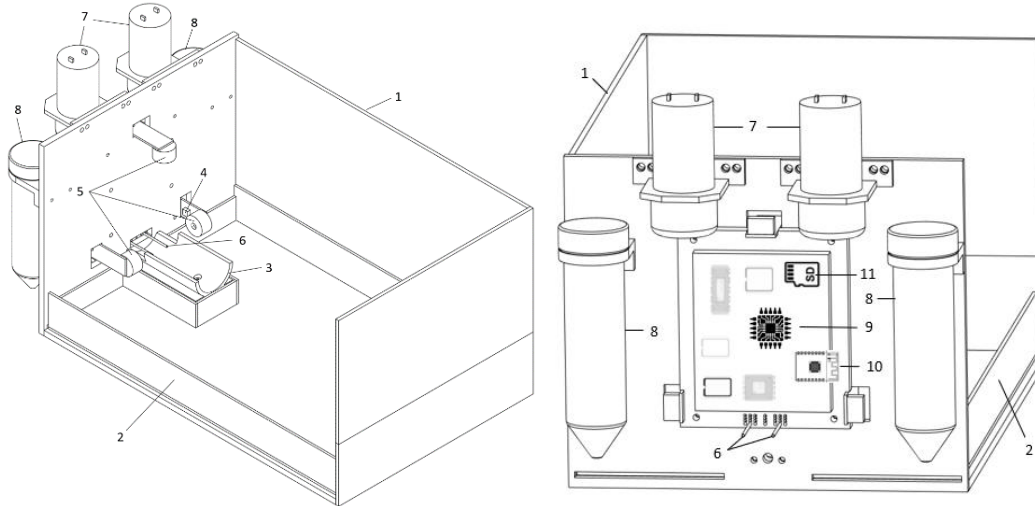
Figure 1

III. Overall Assembly and Testing Process

1. ***Installation of Peristaltic Pumps.*** Install the peristaltic pumps in position (7). Use four M4 screws with eight washers to install the two peristaltic pumps into the corresponding positions. The washers should be placed between the peristaltic pumps and the front panel to reduce the impact of peristaltic pump vibrations on the experiment.

2. ***Installation of Water Storage Tube.*** Install the water storage tube in position (8). First, use four M3×8 screws to install the water storage tube holder to the corresponding position, then place the water storage tube on the holder.

3. ***Installation of Main Circuit Board.*** Install the main circuit board in position (9). First, use four M3×12 screws to install the 3D-printed mounting plate to the corresponding position (note the installation direction). Then, use M3×12 screws to install the main circuit board onto the 3D-printed mounting plate (be careful not to overtighten).

4. ***Installation of Buzzer PCB Board.*** Use M3×5 screws to install the corresponding buzzer PCB boards onto position (5). Among them, the RGB LED indicator buzzer PCB board should be installed on the top, and the rest should be installed on both sides. During the installation process, ensure that the buzzer PCB board is flush with the installation position, and pay attention to installing the buzzer inward.

5. ***Installation of Reward Water Nozzles.*** Install the two reward water nozzles onto position (6). During the installation, pay attention to the symmetry and fixation of the reward water nozzles, ensuring that they can be repositioned while securely fixed in place on the 3D-printed fixing plate. The fixation method can be achieved by thickening the middle part of the water nozzles to pressure-fit them onto the fixing plate.

6. ***Installation of Weighing Platform.*** Install the weighing platform onto position (3). During the installation, be cautious to protect the sensors of the weighing platform from pressures exceeding 300g. Additionally, ensure that there is sufficient clearance between the weighing platform and the internal baffle of the drawer to eliminate the influence of friction on the detection data. This step should be performed in advance before the aforementioned parts.

7. ***Overall Testing.*** Download the '{task}.ino' program for overall training and testing.

After completing the installation, cover the top plate and install the required cameras.