Chi.Bio

Mechanical Assembly Guide V1.0 (Complete)

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Overview

In this document we summarise the mechanical assembly of a complete Chi.Bio setup, assuming it is being made by the end user. There are a number of approaches to assembly of the PCBs: You can have PCBs fabricated (cheaply using a company such as PCBWay) and then solder the components on yourself, or you can pay a company to do the PCB fabrication and assembly (i.e. they do the soldering). This will cost more, but will also save a lot of tedious soldering. If all PCBs have been assembled then you can skip to Section 2, otherwise read Section 1 for some notes on soldering. For more information on building Chi.Bio including schematics, see `https://chi.bio/hardware/`.

Contents

1 Notes on Soldering

This section assumes all PCBs have been already fabricated, and the user is in possession of all electronic components and hardware required, as outlined on `https://chi.bio/hardware/`. Tools required for soldering are a fine (recommend flat tip) soldering iron, solder, solder wick, tweezers, optical microscope to inspect joints (a cheap 20 USD USB miscroscope is perfect), wire cutters, wire strippers, heat shrink, heat plate. With these tools each PCB's bill of materials can be cross-referenced with the labels on each board to see what component attaches where. Note, this process is tricky and tedious, and will be qutie challenging for somebody who has not done much/any soldering before. Consequently we generally recommend paying for pre-assembled PCBs if at all possible. It may be worthwhile showing the pictures of the PCBs to an electronics lab/technician at your university prior to starting to see whether they have any advice. Pointers for the soldering process:

- Many items are not orientation-dependent (i.e. resistors, capacitors, inductors), others are orientation-dependent but due to asymmetric footprints the orientation is obvious. In other cases (most chips, LEDs, diode) you need to ensure that a component is soldered in the correct orientation. All component footprints are labelled with a dot or "1" at pin 1. To figure out which pin is "1" on a particular component look at the datasheet (found by searching its part number on Digikey), or take a look at the high resolution photos included with the schematics of each board.

- Generally the best process for soldering small components (i.e. resistors) is to put solder onto one of their pads, then (holding the component in one hand with tweezers, and the soldering iron in the other) attach it to this pad. Then add solder to the components other pad/s. Ensure that you then check that a good connection has been made at each pad using your microscope.

- Soldering chips with close-packed connections can be quite difficult. My favoured method is to put a bit of solder on one pad, connect the chip in the correct orientation, "flood" all pins with solder (i.e. allowing them to make shortcircuits), then remove excess solder using solder wick. There are many guides for hand-soldering of surface mount electronics online (e.g. here).

- The spectrometer and 7-colour LED both have pads which are only accessible on the underside of the item. In my opinion the easiest way to solder these in place is to put solder on all the pads on their PCB, position the chip on top of the pads, place onto a laboratory heat plate (e.g. a standard stirrer/shaker used for biology/chemistry) and turn it on to ∼250 °C. Wait for heat to transfer through the PCB until you see the solder melt and the component settle into place, then remove it from the heat plate. Make sure you have two sets of tweezers for this process as you will need one to remove the PCB from the heat plate (hot!) and another to position the component if it moves out of alignment. Also, make sure you remove the PCB as soon as it seems the solder has melted, as pumping too much heat into a chip can break it internally.

- The easiest way to solder micro-USB connectors is to put a small amount of solder down on their five PCB pads (i.e. those that attach to the data lines), then position the connector and sequentially push the connecting wire down onto its pad with your soldering iron. Then check that connections are good using a microscope. Then, solder the connector's three "legs" to the reverse side of the board (to attach it firmly in place).

- Some pads/pins connect directly to a large copper ground plane, which means quite a lot of heat is required to get the solder to bond the component properly (as it will take a lot of heat to heat up the large thermally-connected copper region). This (along with short-circuits between neighbouring pins) is the primary mistake that you may pick up when inspecting the boards under a microscope.

2 Mechanical Assembly

These mechanical assembly instructions start at the point at which all PCBs have been fabricated and assembled. The tools required are pliers, wire cutters, screw drivers, and super glue. Once all components are ready (and this document has been read carefully), the subsequent steps can be completed in approximately 30 minutes.

2.1 Main Reactor Assembly

Required materials for this section are all PCBs used in main Chi.Bio device (outlined in the PCB List spreadsheet), and all items listed in the Additional Materials spreadsheet.

2.1.1 Stirring Fan

We commence by assembling the stirring fan/magnets, depicted in Fig. 1. As illustrated in Fig. 1a, the magnets should ideally positioned such that their centroids (blue) coincide with the centre of the raised plastic "plateau" of the stirring fan (red). Magnets should be glued in opposite directions, such that one magnet has its "north" pole upward and the other its "south". An effective approach to gluing the magnets is illustrated in Fig. 1b: One magnet is glued into place by holding it with a finger (at the green marked location), and then glue applied to the magnet/plastic interface at each side (orange marked locations). The first magnet glued should be given some minutes to dry before the second is attached. Once both magnets are attached additional glue can be applied (e.g. where the assembler's finger was previously) to secure them further. We have found that a standard fast-drying super-glue is ideal for this step (and for the lens attachment, Section 2.1.2). A 3D printed magnet gluing guide which can be used to precisely position the magnets for gluing is provided as an .STL file (GlueGuide.STL) in the hardware files for Chi.Bio.

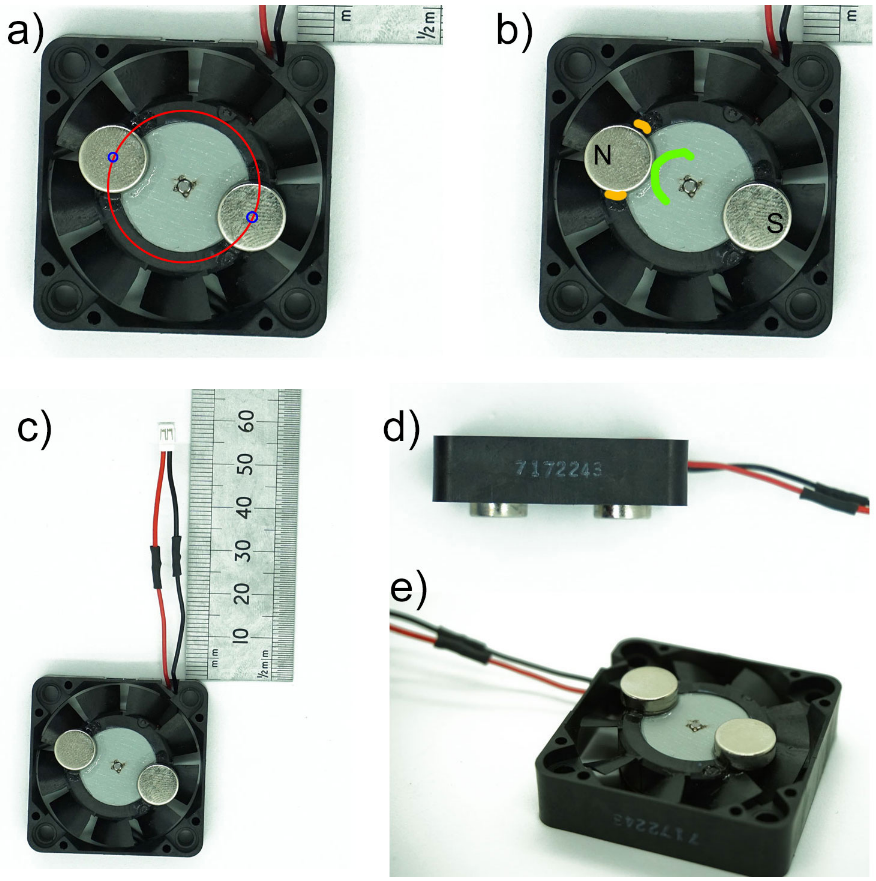

Figure 1: Stirring Magnet Assembly. a) Positioning of magnets on the outer edge of the fan's motor. b) Place finger in location marked green, and apply glue in orange locations to secure magnet. Ensure magnets are oriented with opposite north/south polarity. c-e) Assembled stirring fan.

2.1.2 Lens

We now attach the lens to the Chi.Bio side PCB. The first step in this process is to trim two small plastic tabs on the underside of the lens (blue arror, Fig. 2a). This figure illustrates what the initial lens looks like (Fig. 2a), and what it should look like after these tabs have been cut off (Fig. 2b). Trimming of these tabs is necessary as otherwise it is not possible to get the Lens flush with the LED (when assembled the LED is positioned approximately where the red square is in Fig. 2c). Cutting of these plastic tabs can be done quite crudely; the only requirement is that they be reduced in height by approximately 1mm. I find that this is easily done using wire cutters or similar. You could probably also file/sand them off, though this would likely take longer.

When these tabs are removed it is then possible to glue the lens to the LED on the side PCB. Before applying glue it is worthwhile practicing putting the LED in place atop the LED, which will demonstrate that the plastic tabs have been cut sufficiently and that it is oriented correctly. The white plastic circle printed on the PCB indicates the intended position of the lens. In general it is difficult to attach the lens off-centre, as it will not sit flush on the LED unless placed in the correct location. Ensure that it sits as close to the PCB as illustrated in Fig. 3c below (there should be a gap of $\sim$ 1mm between the bottom of the LED's black sticky pad and the PCB). Once ready, the lens is attached permanently by applying four small dots of glue to the LED (easier than applying glue to the lens!) where indicated in green in Fig. 3a, which correspond to the locations indicated in green in Fig. 2c. With the glue in place, the lens is then placed atop the LED, and held for a $\sim$ 10 seconds to let the glue dry. We have found that (as in Section 2.1.1) a standard fast-drying super-glue is ideal for this step, since it is non-conductive, and does not dry opaque.

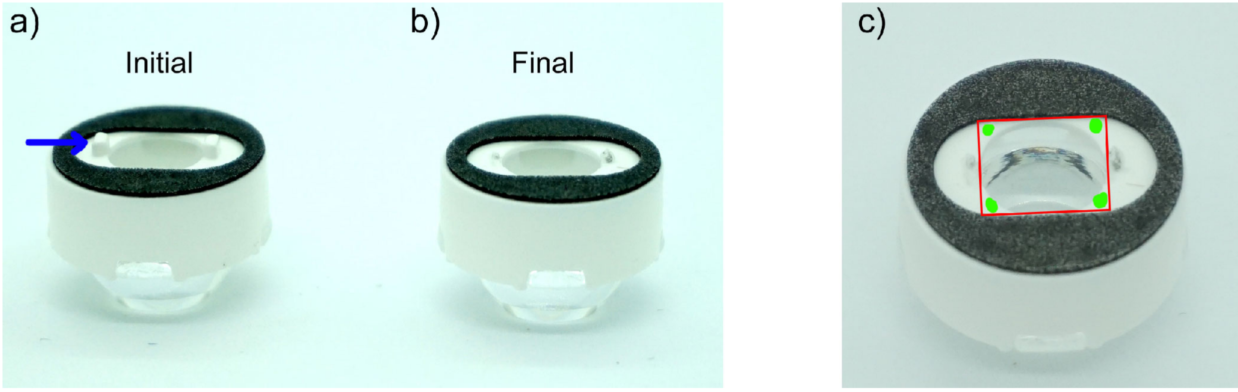

Figure 2: a) Initial off-the-shelf lens. b) Lens with plastic tabs trimmed. c) LED (red) positioning. Green spots indicate where glue will contact the lens, though it is easier to apply glue to the LED rather than the lens.

Try to use glue sparingly to prevent obscuring of the LED.

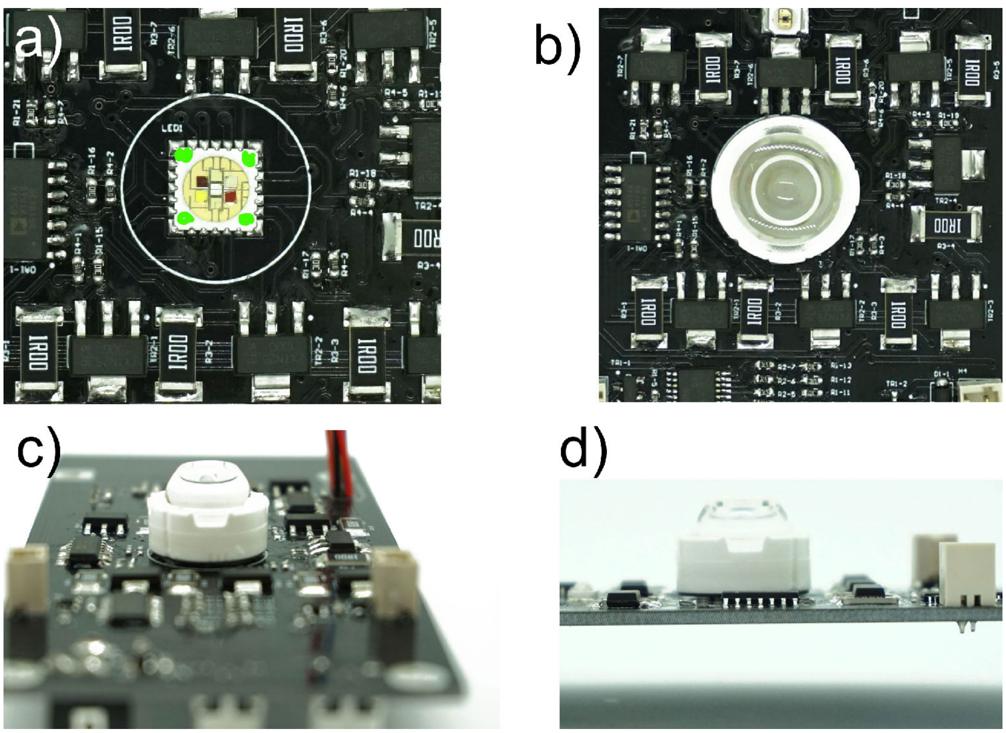

Figure 3: a) LED without lens, small dots of super glue should be added to the locations indicated in green. b-d) The lens when attached correctly to the PCB.

2.1.3 Sensor Aperture

The SensorAperture is attached to the SensorBreakoutAS7341 PCB after (or before) it has been attached to the LaserMeasure board. The SensorAperture is used to define the spectrometer's field of view, and its position therefore represents a tradeoff between concentrating measurement on only what is directly in front of the spectrometer, and limiting the total amount of light incident upon the spectrometer. The distance between sensor and aperture can be adjusted by adding additional washers between the Sensor aperture and the spectrometer PCB, as illustrated in Fig. 4. If maximum light collection is desired a larger hole could be drilled in SensorAperture.

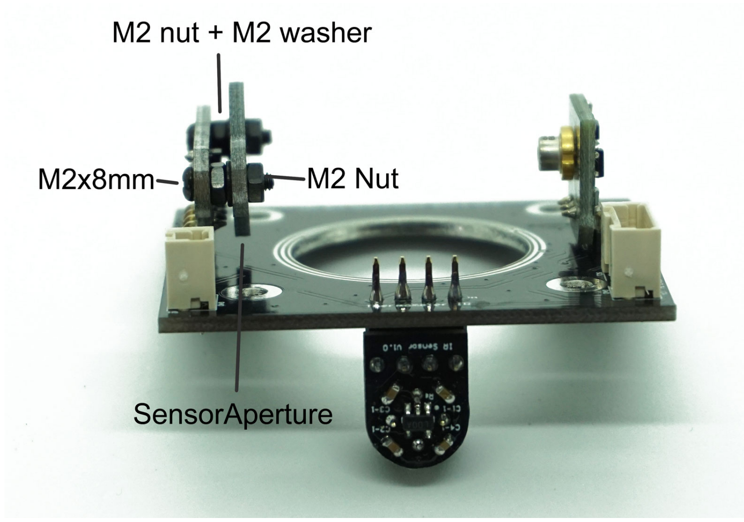

Figure 4: LaserMeasure assembled with SensorAperture, using M2 screws, nuts and washers. Additional nuts/washers can be added to change the spectrometer's field of view.

2.1.4 Main Stack

We now have all components necessary to assemble the device's main internal structure. In Fig. 5 this is summarised, for a full list of fixing components (including the PCB spacers, nuts, screws, washers), see the "Additional Materials" spreadsheet.

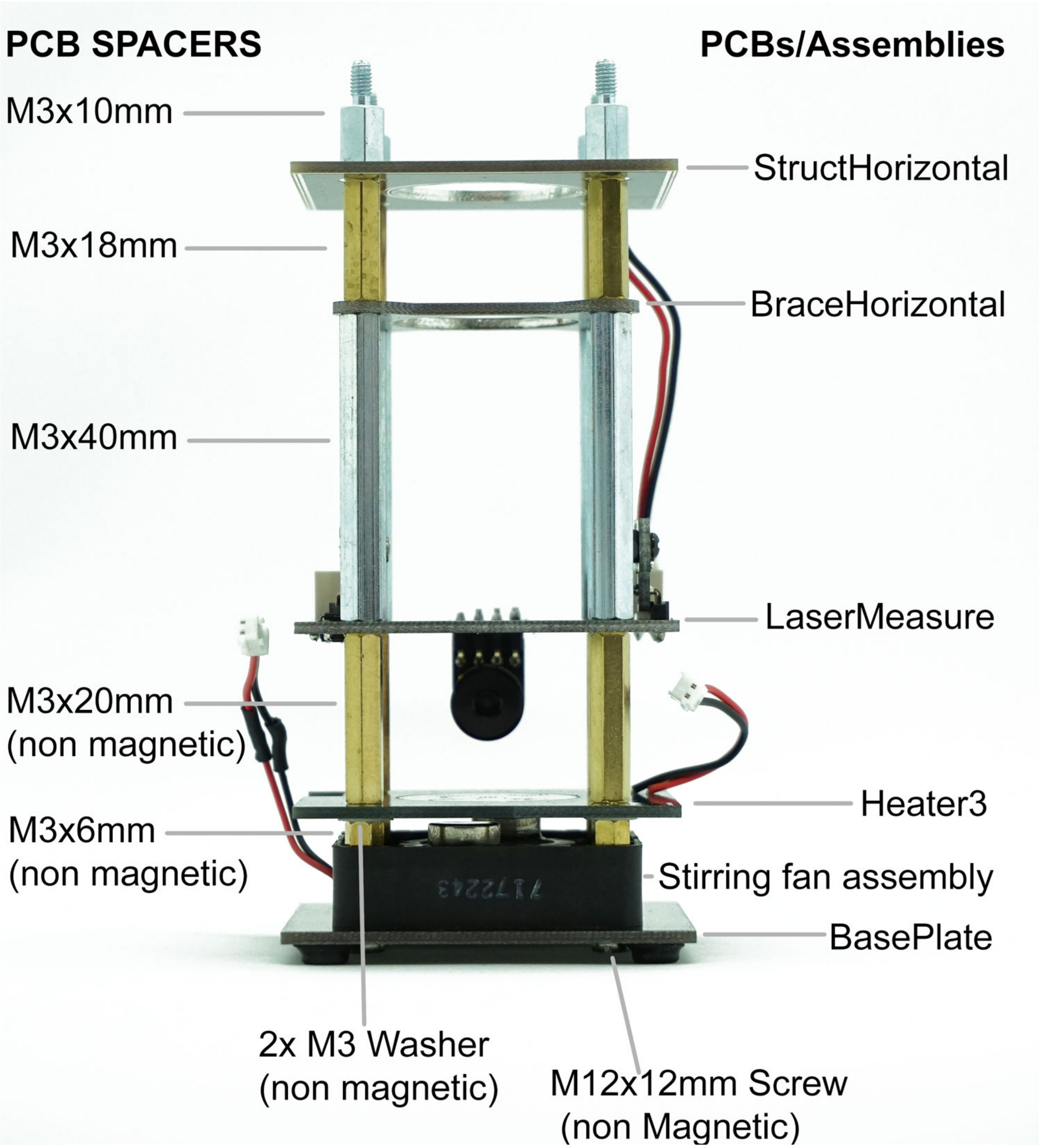

Figure 5: Internal structure, illustrating each spacer/screw (left) and PCB (right). Non magnetic PCB spacers/washers are required at the bottom of the device as too much magnetic material in this area can stall the stirring motor.

The first step in this assembly is to attach the stirring fan assembly to a BasePlate PCB, as illustrated in Fig. 6. Self-adhesive rubber feet are attached to the underside of the device to stabilise it during operation. This assembly is then completed by attaching the fan using M3x12mm screws, M3x6mm male-female PCB spacers, and two non-magnetic washers on each pillar. It is important that these components are non-magnetic to prevent the stirring fan from stalling.

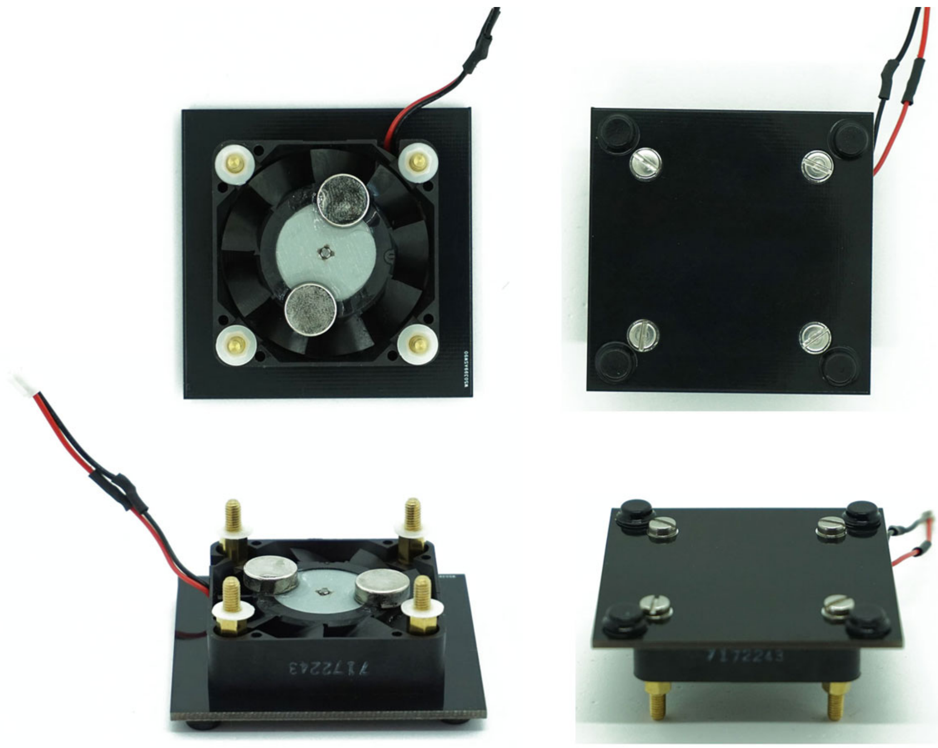

Figure 6: Base assembly.

Next, the device's structure can be assembled in the order pictured in Fig. 7. It is generally sufficient to tighten each screw/spacer by hand; do not over tighten as this may make it difficult to disassemble the device later if needed. Ensure that the orientation of the LaserMeasure PCB relative to that of the Heater/stirring assembly is correct (e.g. as in Fig. 7e).

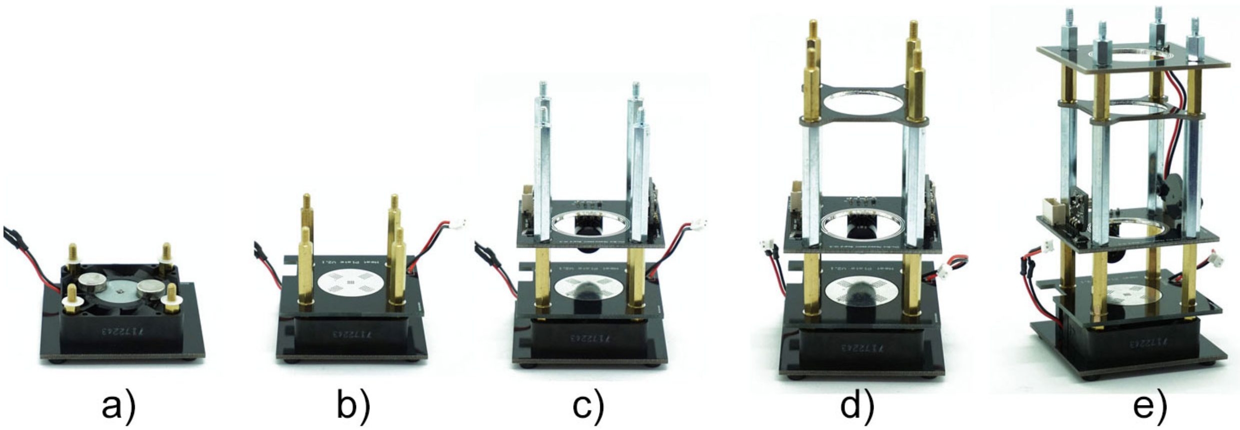

Figure 7: Order of structure assembly. Components used are identified in Fig. 5 and summarised in "Additional Materials" spreadsheet.

The final step in the assembly of Chi.Bio is to attach the vertical sides of the device. This proceeds as illustrated in Fig. 8, and using M3x55mm screws and M3 nuts. The Side PCB (and it's partner SideA) are attached first, after which all internal wires can be connected. Subsequently two SideB PCBs are connected on the remaining two sides (Fig. 7b). Note that the holes used to attach each of the side PCBs are asymmetrical with respect to the outline of the PCBs themself; this allows the four sides to be assembled to make a well-sealed box as shown in Fig. 7c.

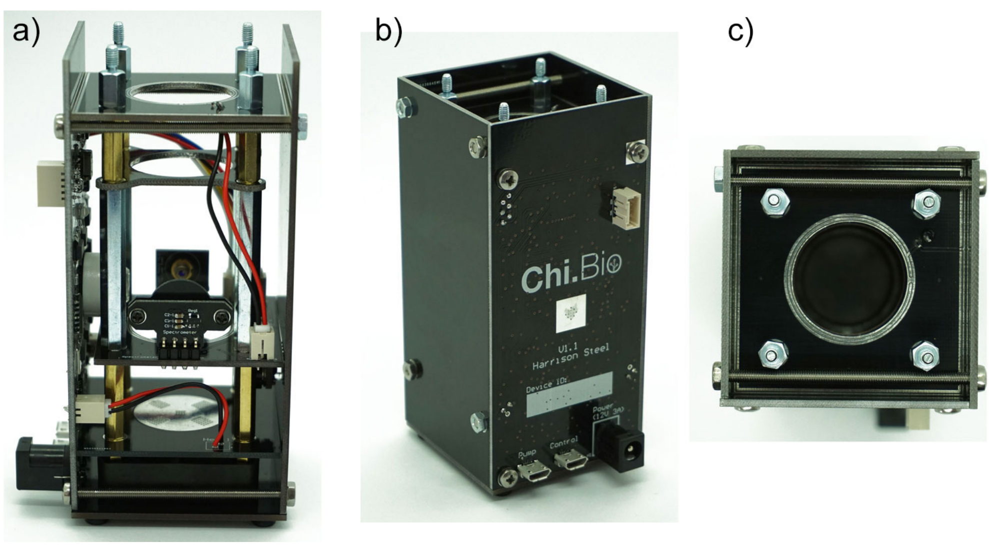

Figure 8: Assembly of Chi.Bio sides, using M3x55mm screws. a) Attaching Side and SideA PCBs, after which all internal wires should be connected. b,c) Attaching two SideB PCBs.

2.1.5 Lid

A lid can be assembled as illustrated in Fig. 9. A rubber M16 washer is used to contact the top of the test tube to provide a soft contact. Note that the TubeCap PCB Pictured here is finished with HASL (Hot Air Solder Levelling). Alternate materials could be used in its place (for example, a non-reactive plastic piece could easily be 3D printed) if desired. Furthermore, this lid could be substituted for one of the many commercially available lids which suit the test tube size used in Chi.Bio. If using a different lid it is important to ensure that sufficient contact force is present between the bottom of the test tube and the device's heat plate to ensure thermal conduction, and to prevent the tube from rotating within the device during stirring. This could be achieved using a standard test tube lid by (for example) running a rubber band over the top to hold it securely.

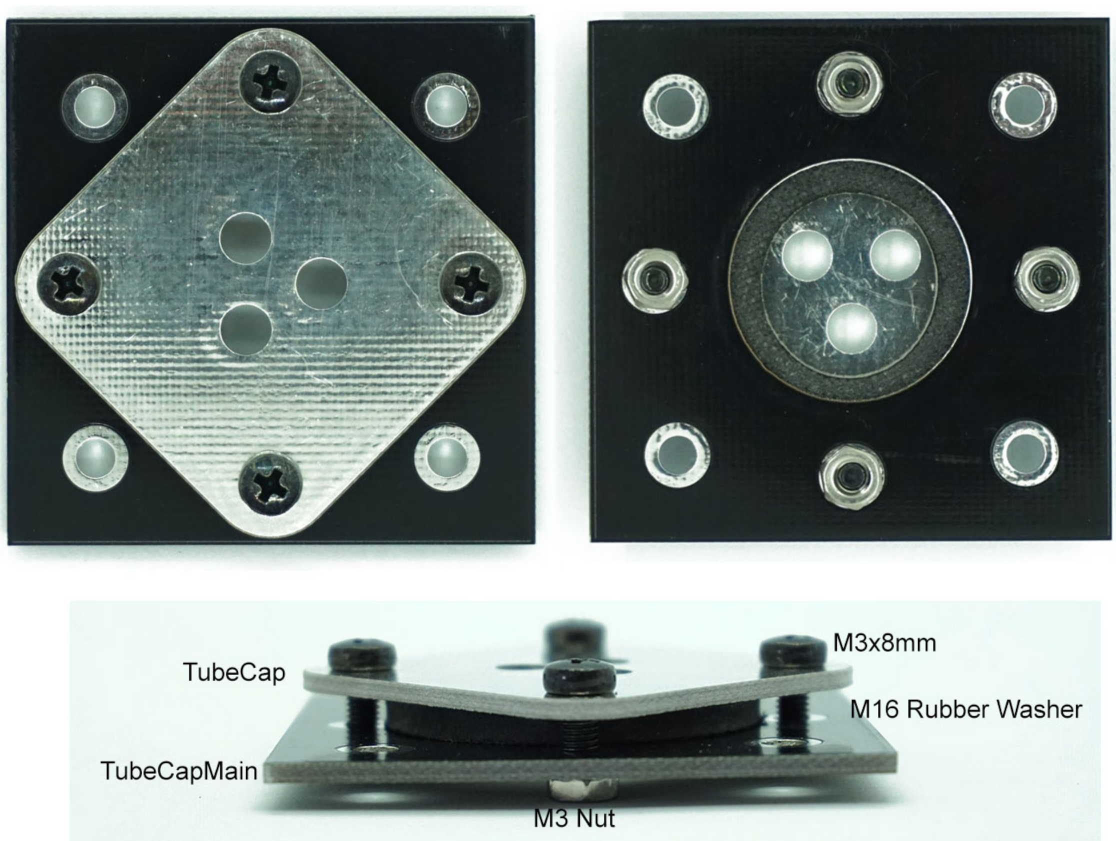

Figure 9: Assembly of the device lid, which employs a M16 rubber washer to contact the top of the reaction chamber.

2.2 Pump Board Assembly

Materials required for assembly of the pump board are listed in the "Additional Materials" spreadsheet. The easiest order to assemble this device is to first insert pumps into the main Pumps PCB, then fix them in place by using PumpClamp and PumpClampSide PCBs as illustrated in Fig. 10b which are in turn fixed to the board via its legs (M3x50mm PCB spacers). The two-wire connectors can then easily be attached to the PCB and their other ends soldered to pump terminals (Fig. 10c). Note that one of the pump terminals is labeled with a (+), and must be connected to the red wire.

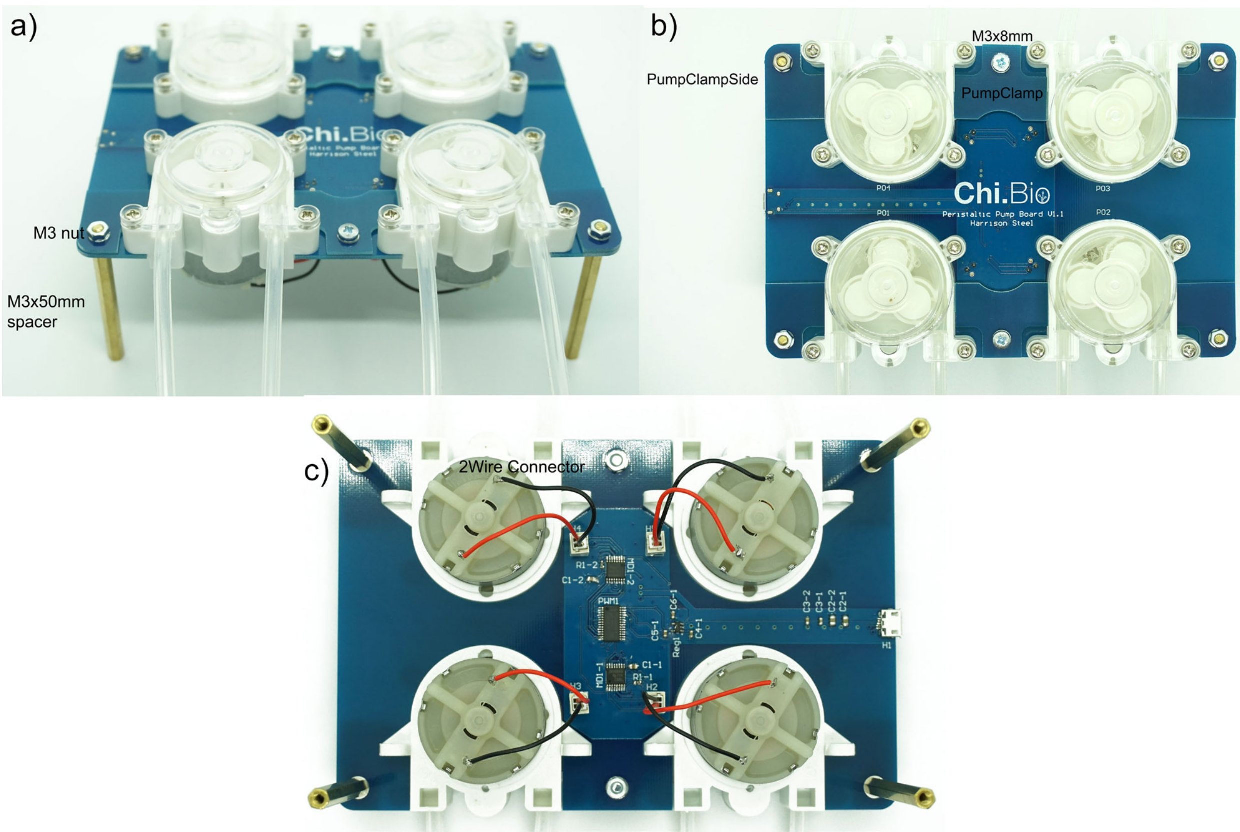

Figure 10: Assembly of the pump PCB, which uses four peristaltic pumps, M3x50mm PCB spacers, M3 nuts, and the PCBs PumpClamp (x2), PumpClampSide (x4), and Pumps (x1). Note that the pump board can be assembled with only two or three pumps, depending on the user's needs.

2.3 Control Computer Assembly

The Chi.Bio control computer is assembled by connecting the BeagleBoneBoard PCB to a standard BeagleBone Black microcontroller. This is done with M3 screws (which can be of varying length), to which rubber feet can be attached using M3 nuts if desired (as illustrated in Fig. 12). In general some manner of feet/screws should be employed to prevent the electronics on the underside of the BeagleBone Black from resting directly on a surface/benchtop which could lead to short circuiting.

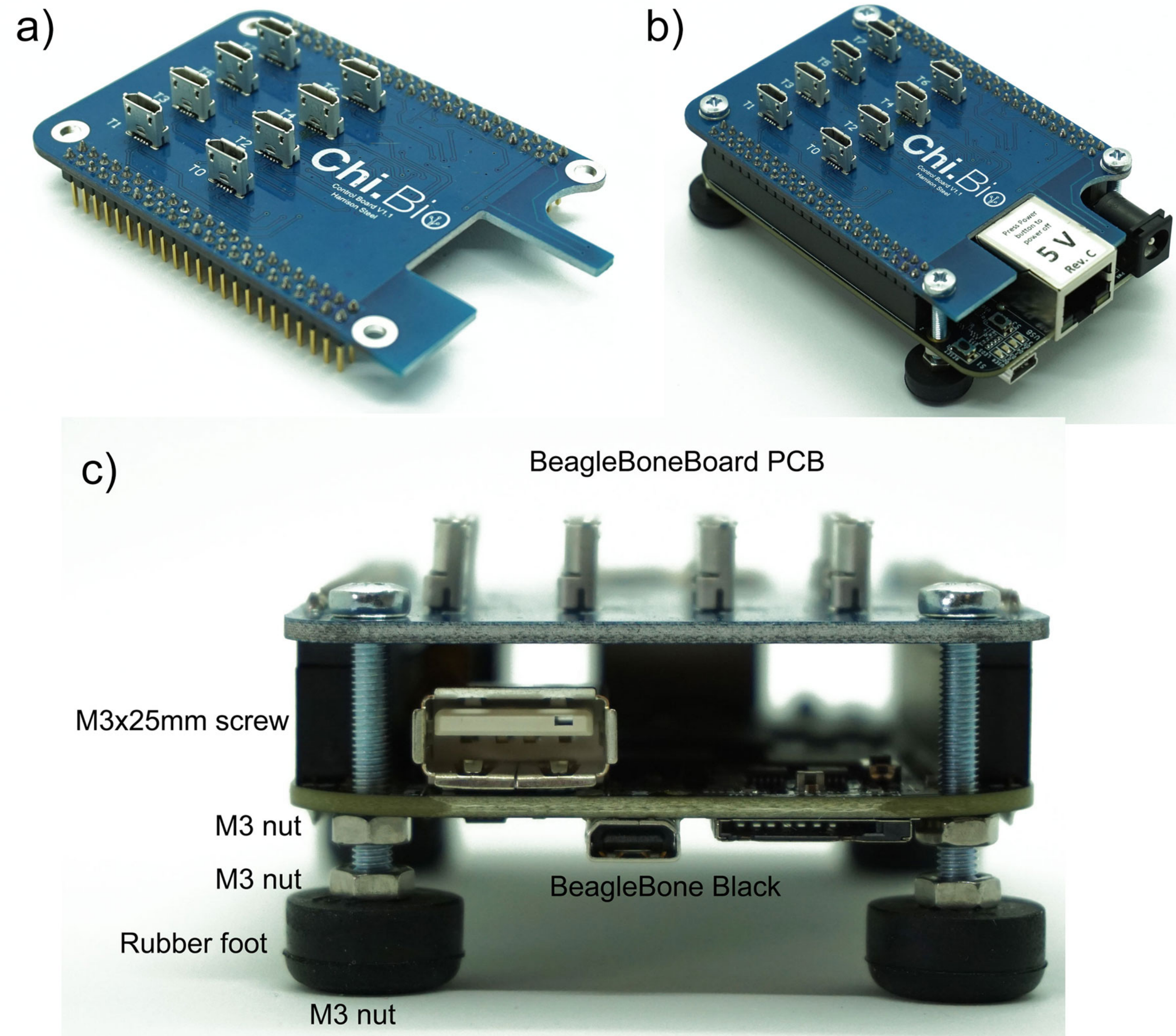

Figure 11: Assembly of the Chi.Bio control computer. a) BeagleBoneBoard PCB designed for Chi.Bio. b) Assembled board with BeagleBone Black microcontroller. c) Diagram of components used in assembly, summarised in the “Additional Materials” spreadsheet.