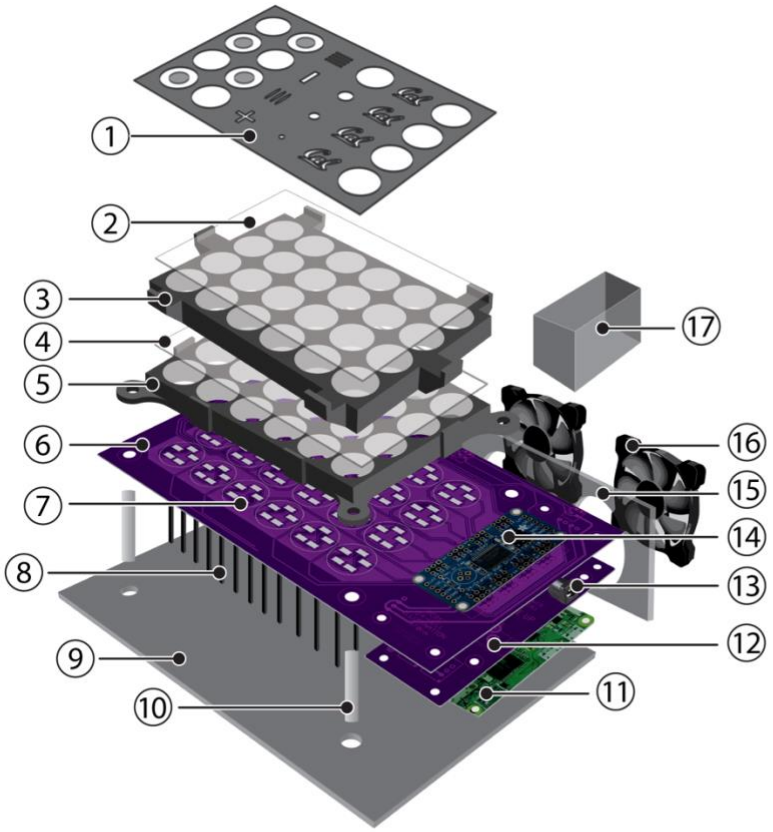
BEFORE YOU BEGIN

A. Parts of the LAVA board



1. Photomask
2. Diffuser (top)
3. Light guide (top)
4. Diffuser (bottom)
5. Light guide (bottom)
6. PCB-1
7. LED
8. Heatsink
9. Base
10. Round standoff
11. Raspberry Pi Zero W
12. PCB-2
13. Power connector
14. LED driver (TLC5947)
15. Fan holder
16. Fans
17. LED driver cover

Note: the 24-well and 96-well LAVA boards are identical EXCEPT for parts ③, ⑤, and ⑥

B. Equipment

1. Standard soldering tools (soldering iron, solder, flux)

2. Wire cutter

3. Wire stripper

4. Hot plate or reflow oven*

5. Philips head screwdriver
6. Mini flathead screwdriver
7. Tweezers
8. Scissors
9. Superglue
10. Laser cutter**
11. 3D printer***
12. Dye cutter (for photomask manufacturing) ****

* Hot plate is used for reflow soldering. A reflow oven can also be used.

** Any laser cutter capable of cutting 12 x 12 x ¼" acrylic sheets is sufficient. Parts can also be outsourced to a laser cutting service.

*** Any 3D printer capable of printing black PLA or ABS parts with at least 6 x 6 x 6" bed size is sufficient. No support material required. Parts can also be outsourced to a 3D printing service.

**** Any dye cutter capable of cutting adhesive vinyl is sufficient, but feature size and cut quality is variable between cutters and should be tested

C. Materials

Refer to bill of materials for details

Custom orders:

- Printed circuit boards (PCB-1, PCB-2, parts 6 & 12). We provide both EAGLE and Gerber files for all PCBs. These parts can be ordered at your preferred PCB manufacturer. We recommend OSH Park, www.oshpark.com
    - Silk screen masks are very helpful during reflow soldering. We recommend ordering a silk screen mask for PCB-1 from your preferred PCB manufacturer or OSH Stencils, www.oshstencils.com

- 3D-printed light guides (parts 3 & 5). We provide STL files for these components, which can be printed on any extrusion-based 3D printer (ex. Ultimaker 3, uPrint, etc) out of ***black*** PLA or ABS. No support material is required.

- Laser-cut components (parts 9, 15, & 17) should be cut out of 0.118" (3 mm) thick acrylic. We provide AI files for these components.

- Custom photomasks can be cut from adhesive vinyl using a dye cutter. We provide an AI file with sample photomasks. Alternatively, custom photomasks can be laser-plotted from mylar using a photomask print service. We recommend Fine Line Imaging, www.fineline-imaging.com

D. Miscellaneous notes

- Power supply (PSU):

  Choice of correct power supply is critical for proper LAVA board operation. Please see bill of materials for suggested PSU to use with blue CLM1B Cree LEDs. For use with other LEDs, perform the following calculation to determine PSU voltage:

  Minimum PSU voltage (24-well board) = 5 x V_f

  Minimum PSU voltage (96-well board) = 4 x V_f

  where V_f is the forward voltage of a single LED (usually 2-5V).

  Minimum PSU output current should be 1A. ***IMPORTANT*** Beware that if PSU output voltage is more than 1-2V greater than the calculated voltage above, the TLC5947 may overheat. Always test PSU by running LAVA board with selected PSU for > 10 min and check that TLC5947 chip does not become hot.

- Optional resistor on TLC5947 board:

The default power output of the TLC5947 chip is 15mA. Each LAVA board LED thus receives 15 mA current and voltage equal to V_f. If your optogenetic application requires high illumination intensities, an optional resistor can be added to the TLC5947 board to increase power output to 30 mA per channel.

See the TLC5847 datasheet and Adafruit link for more details:
https://www.ti.com/lit/ds/symlink/tlc5947.pdf

https://www.adafruit.com/product/1429

For example, to set current output to 30 mA per channel, solder an additional 3.3K ohm through-hole resistor onto TLC5947 board

PROTOCOL

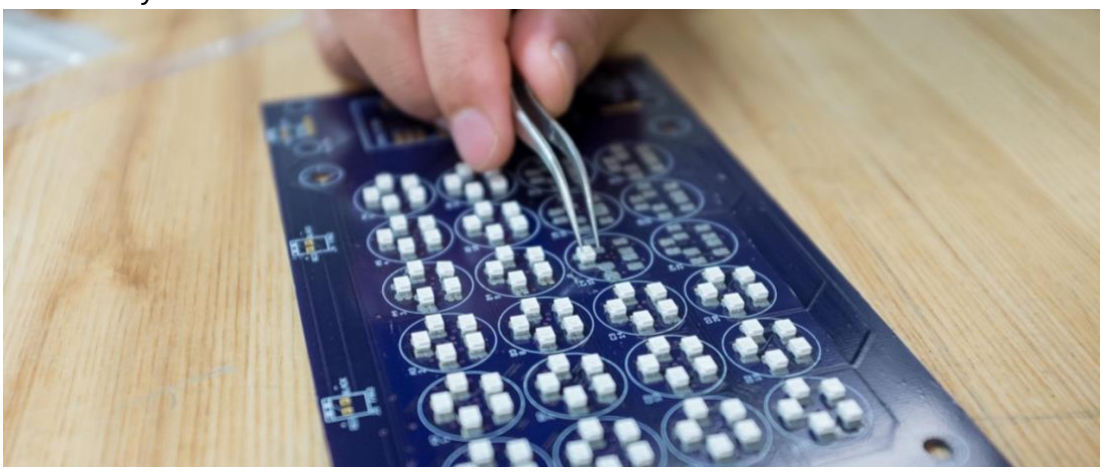
STEP 1: Solder LEDs onto PCB-1 using reflow soldering

Reflow soldering is a fast and simple way to attach surface-mount components to a circuit board. In brief, a paste (called reflow solder paste) is applied to the copper pads on PCB-1. The LEDs are placed on top of the paste, and the board is heated on a hot plate to melt and solidify the solder. We recommend the following guide as a reference: https://www.build-electronic-circuits.com/reflow-soldering/

1. Using the solder mask, apply solder paste only to the grid pattern of copper pads on PCB-1, as indicated below

2. With tweezers, place surface-mount LEDs onto pads in the correct orientation (angled notch indicating *anode* must be on top left)

   IMPORTANT If using LEDs other than specified, they must be package PLCC-4 or PLCC-2 and placed in the correct orientation (anode left, cathode right, see **Fig. 1-2**). We highly recommend testing with one LED prior to reflow of entire PCB-1 to ensure proper orientation. Note that notch indicator standards vary between manufacturers.



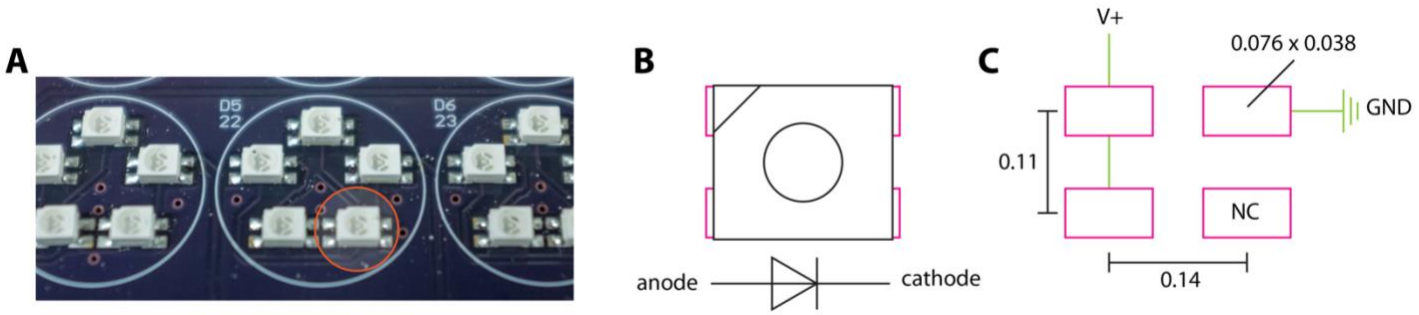
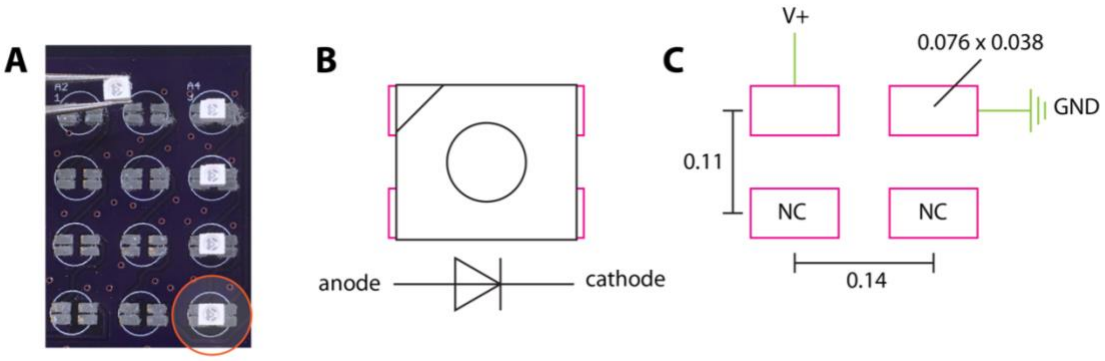


Figure 1. Orientation of LED placement on 24-well PCB-1. A) Image of soldered PCB-1 for 24-well LAVA board using blue CLM1B Cree LEDs. Anode marking must face top left. Each well is illuminated with a cluster of 5 LEDs connected in series. Single LED circled in red. B) Schematic of a single LED denoting proper orientation. C) Schematic of solder pad placement on 24-well PCB-1. All dimensions are in inches.

Figure 2. Orientation of LED placement on 96-well PCB-1. A) Image of LEDs being placed on



PCB-1 for 96-well LAVA board using blue CLM1B Cree LEDs. Anode marking must face top left. Each well is illuminated with 1 LED, and each column of 4 LEDs is connected in series (ex. wells A4, B4, C4, D4 are connected in series). Single LED circled in red. B) Schematic of a single LED denoting proper orientation. C) Schematic of solder pad placement on 96-well PCB-1. All dimensions are in inches.

3. Place PCB-1 onto hot plate and heat on maximum temperature for 2-5 min. Once you notice the solder paste turn a metallic in color, wait an additional 1-2 min. Carefully take board off hot plate (it is HOT) and let cool at room temperature for 5-10 min.
4. Clean the solder mask with a paper towel and save for future use

STEP 2: Solder through-hole components using standard soldering

The placement location for all remaining through-hole components is marked on PCB-1 and PCB-2. The component outline indicates the side (PCB top vs. bottom) onto which the component should be *physically placed*. The leads of the component pass through the matching holes, and the component is soldered on the opposite side from which it is physically placed. While soldering, make sure that each component is flush with the PCB.

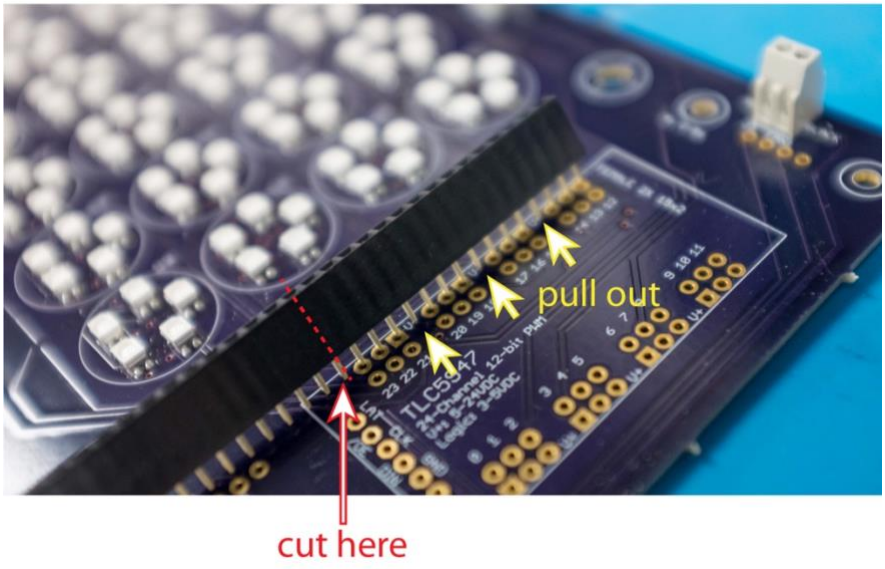
If a component is accidentally soldered in the wrong orientation, it should be removed with de-soldering braid or a solder sucker and re-soldered correctly. We recommend this Sparkfun guide as a reference for soldering techniques: https://learn.sparkfun.com/tutorials/how-to-solder-through-hole-soldering/all

A. Solder the following electrical components onto PCB-1, ensuring proper orientation:

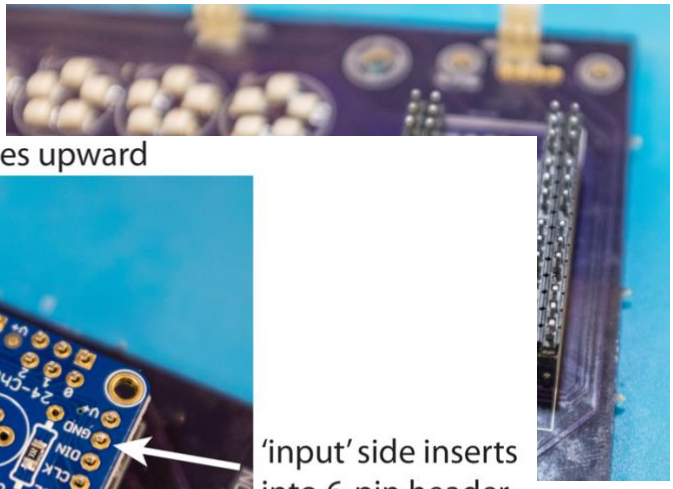
1. Fan terminal blocks (x3), with wire opening facing outward, as shown below.

2. LED driver (TLC5947)

   First, solder female headers onto PCB-1. You will need x4 15-pin headers and x1 6-pin header. To match the hole pattern, you will need to gently pull out every 4th pin from the headers with plyers, as marked below.

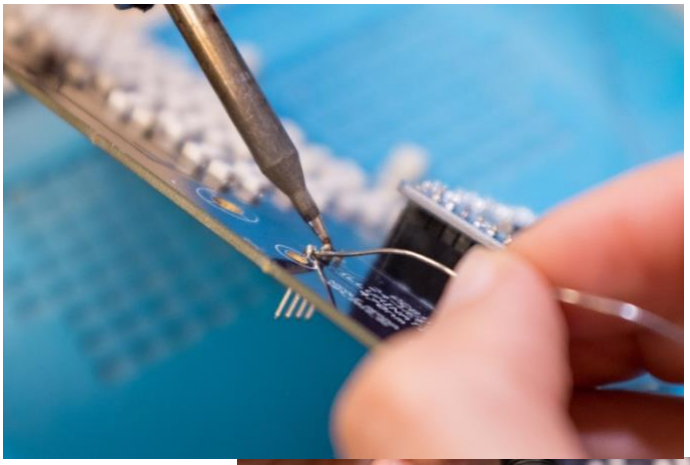


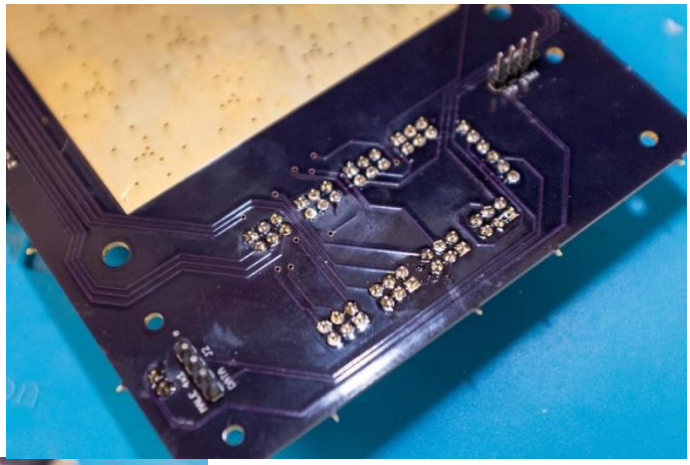
Then, prepare male headers with every 4th pin similarly removed. Insert male headers into female header (side with the longer pin inserts into female header).

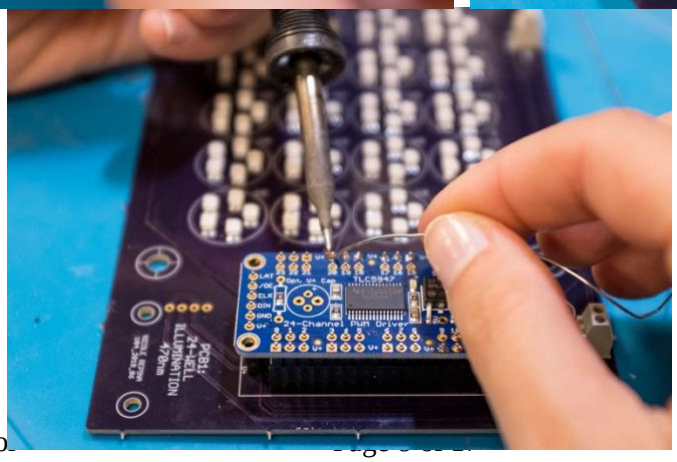


Place TLC5947 through these male headers and solder the leads.
*****IMPORTANT***** take care to ensure proper orientation of TLC4957 chip as indicated below.

3. Power and data transfer headers (x2 4-pin male headers). Ensure correct placement:

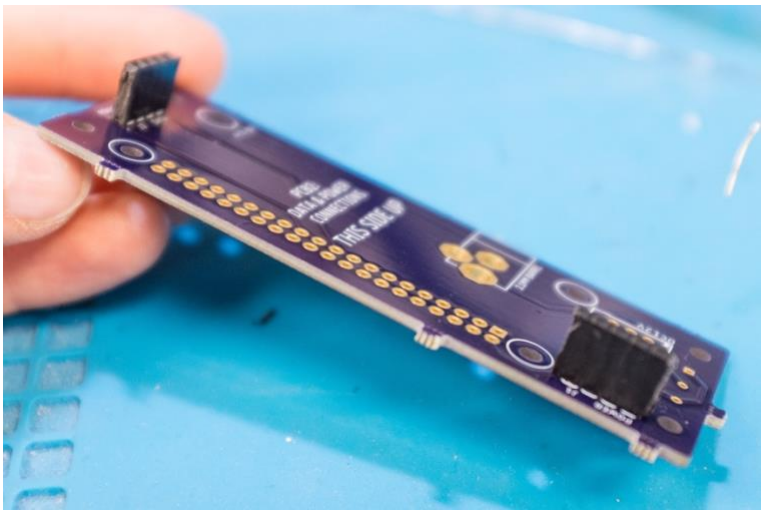




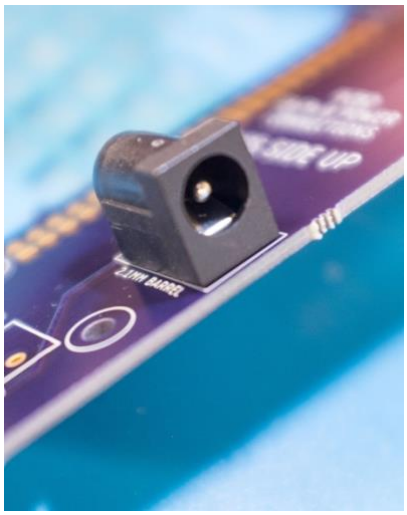


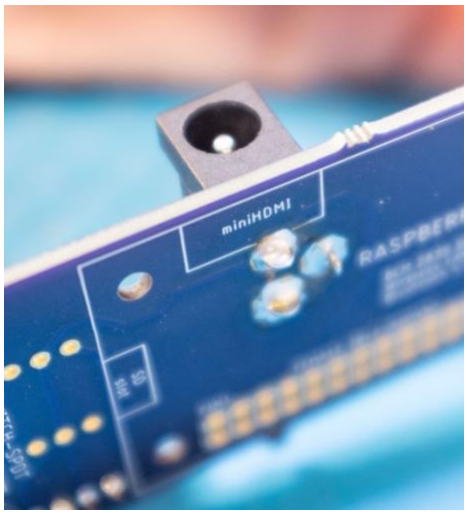
B. Solder the following electrical components onto PCB-2, ensuring proper orientation:

1. Power and data transfer headers (x2 4-pin female headers)

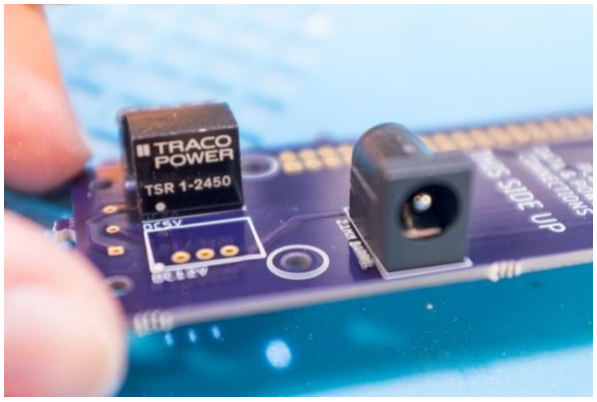


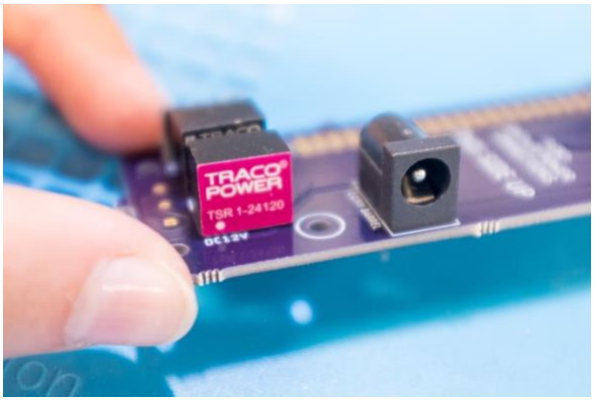
2. DC barrel plug connector





3. 5V and 12V voltage regulators (TRACO power). Ensure polarity indicator (dot) lines up with indicator dot on PCB-2.

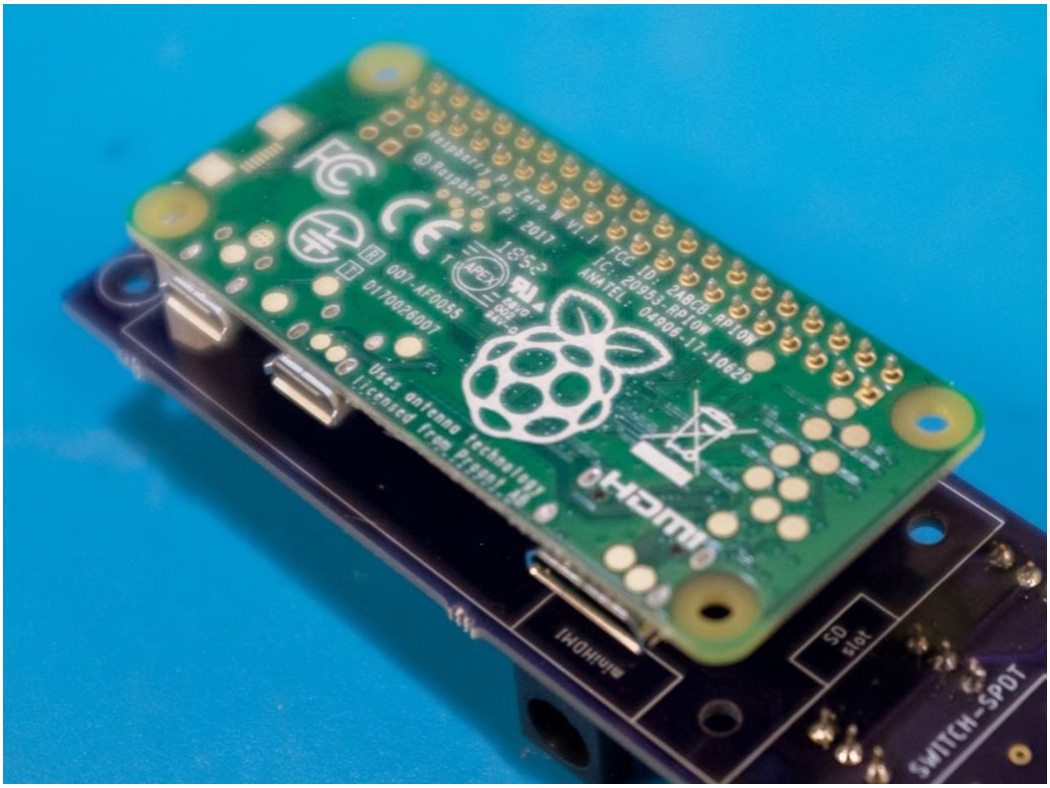




4. Power switch
5. Raspberry Pi Zero W

   First, solder female headers onto PCB-2 (x2 20-pin female headers)

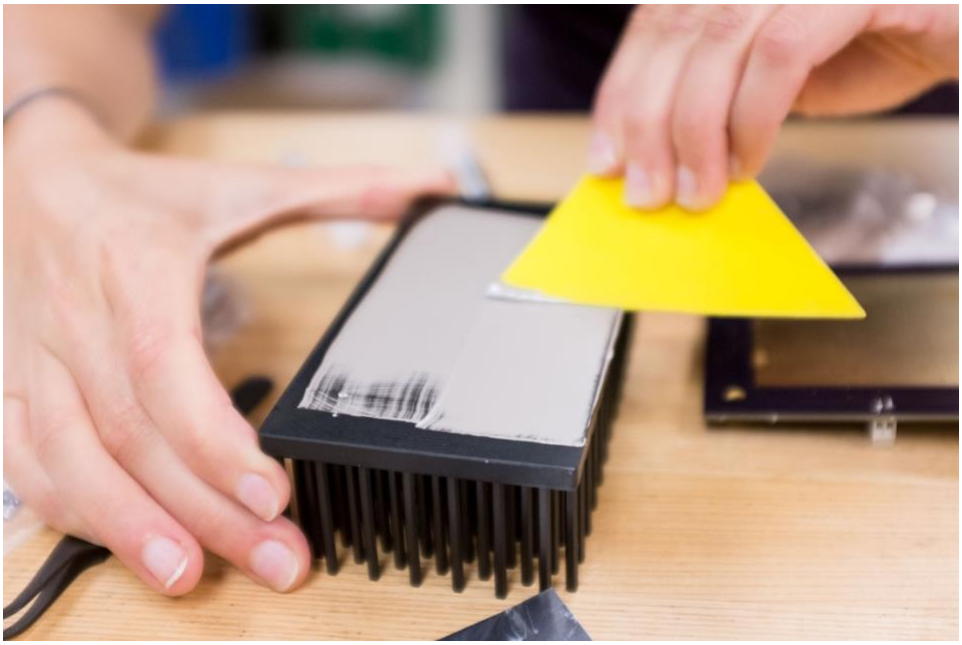
Then, place male headers into the soldered female headers. Place Raspberry Pi through these male headers (ensure proper orientation, as indicated below), and solder the leads.
Tip: place one or two hexagonal standoffs between Pi and PCB-2 to stabilize Pi while soldering.

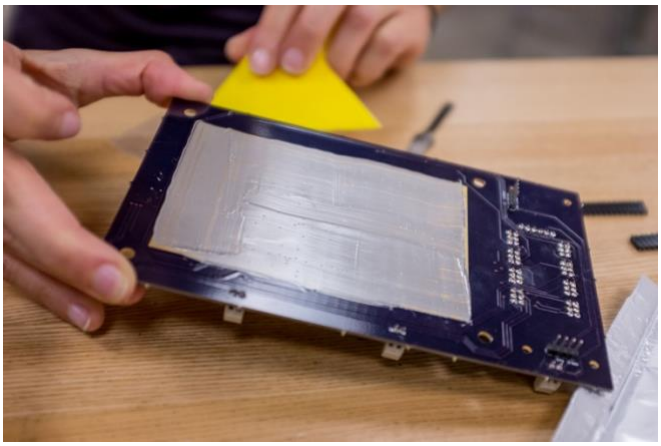


Lastly, secure the Raspberry Pi to PCB-2, and secure PCB-2 to PCB-1, using the hexagonal plastic standoffs (x 8) and 2-56 screws (x 16). Ensure that the corresponding headers mate together between PCB-1 and PCB-2.

STEP 3: Attach heat sink

Attach heat sink to PCB-1 bottom using Arctic Silver thermal epoxy. Mix the two epoxy components together, and quickly apply a thin layer to heat sink and bare copper region of PCB-1. Check that no epoxy seeps through vias onto the top surface of PCB-1 (if it does, gently wipe away before it solidifies). Make sure heat sink is centered and wait 1 hr or more to solidify.

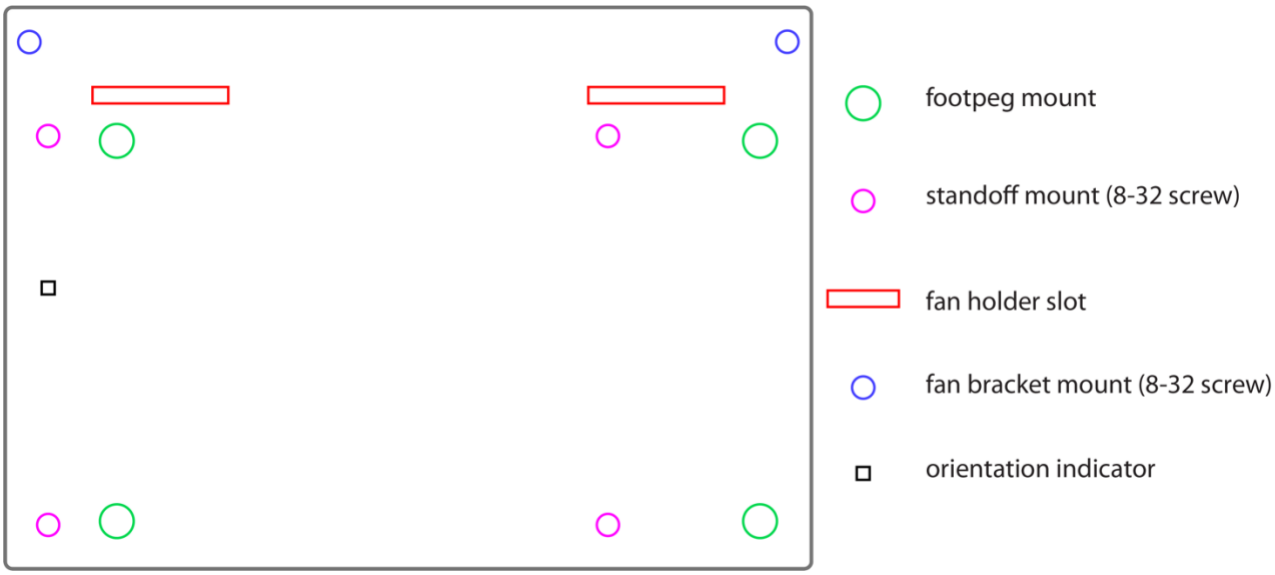




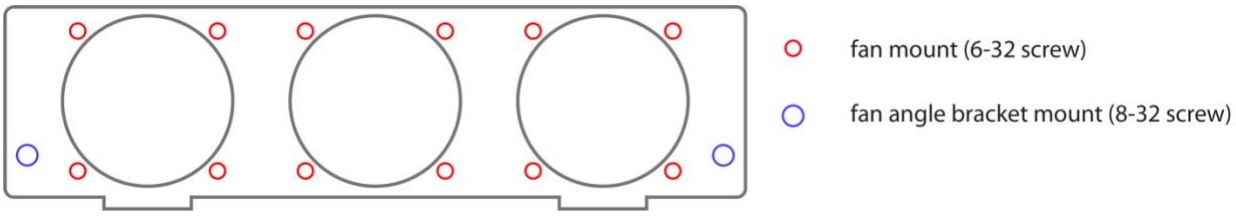
STEP 4: Assemble laser-cut and 3D-printed components

While heat sink cures, laser cut and 3D print components as indicated on page 3.

Schematic of laser-cut base (part 9) is shown below. Note that this part is not symmetric, and square orientation indicator marks left side of base.



Schematic of laser-cut fan holder (part 15) is shown below:



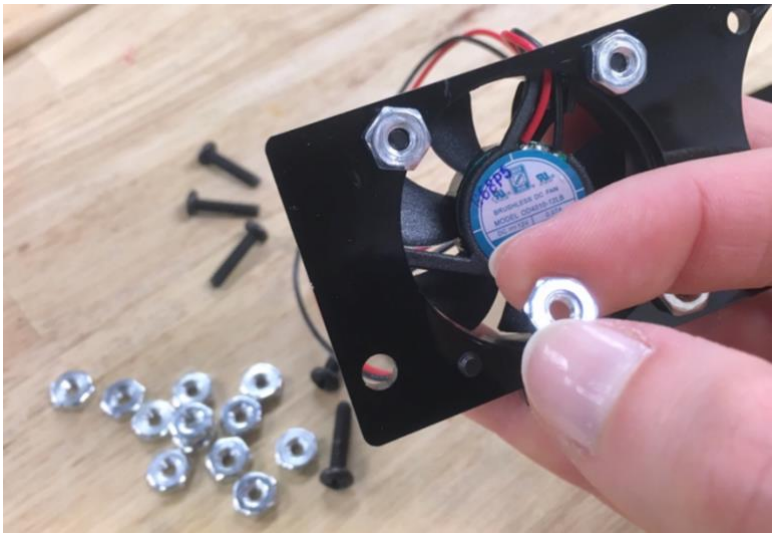
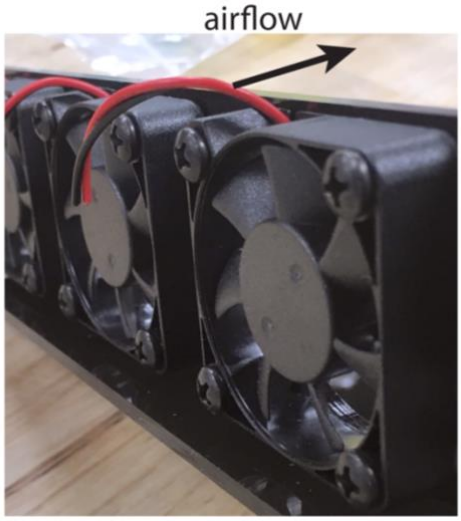
After the parts are fabricated, perform the following steps:

1. Orient base (part 9) so that indicator square faces left. Insert rubber footpegs (x4) into base from bottom, through the 4 larger holes, as shown below.

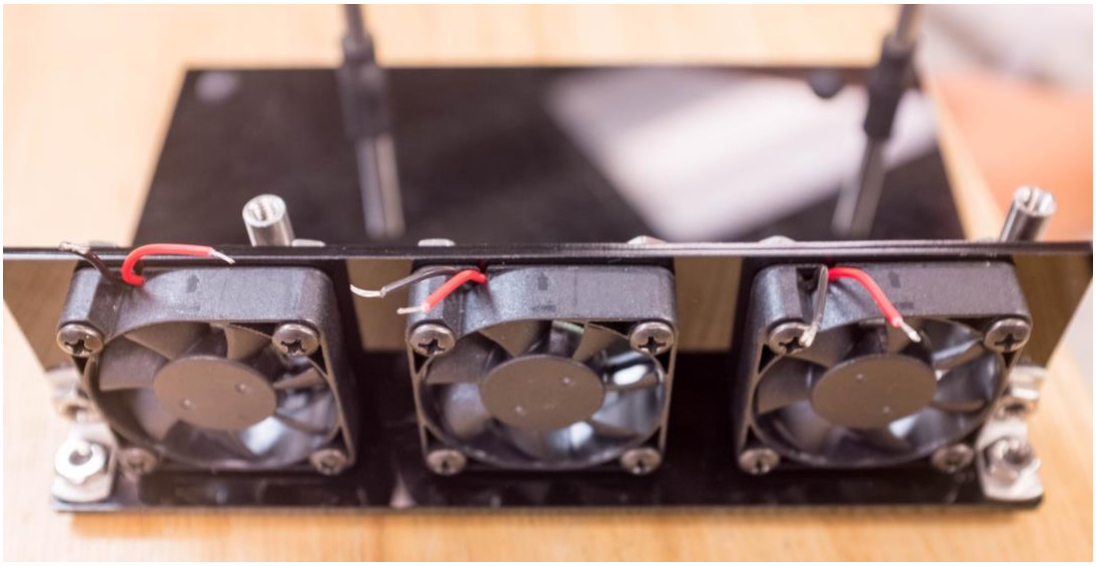

2. Screw vibration-damping mounts (x4) onto base (part 9) using 8-32 screws, through the 4 smaller holes. Then, screw round metal standoffs (x4, part 10) into each vibration-damping mount with an 8-32 setscrew



3. Screw fans (x3, part 16) into fan holder (part 15) using 6-32 screws and nut. Make sure fan airflow arrow points in the correct direction, and wires face upwards, as shown below.

4. Trim fan wires to ~ 0.5” (1.5 cm) in length and use right-angle brackets and 8-32 screws and nut to attach fan holder (part 15) onto base (part 9). With wire strippers, strip the end (~3 mm) of each fan wire.



5. Assemble the walls of the LED driver cover (part 17) using superglue. The cover will be placed on top of the LED driver to prevent accidental shortage.
6. Cut the 80˚ LSD diffuser sheet to match the 3D-printed light guides.

After the heat sink cures, attach the LAVA electronics to the remaining hardware components:

7. Place PCB-1 onto the x4 metal standoffs (part 10). Place bottom light guide (part 5) onto PCB-1, taking care to center it on the wells. Place x4 8-32 screws through the light guide screw holes and screw into standoff, thereby sandwiching PCB-1 in between.
8. Insert fan wires into corresponding terminal block, ensuring correct orientation, and tighten set screw with small flathead screwdriver.

STEP 6: Software control

The next step is to configure the Raspberry Pi and your personal laptop to enable software control. Please follow instructions in *LAVA-userguide.pdf*