

Appendix 3: IBL protocol for setting up the behavioral training rig

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The latest version of this protocol can be found [on Figshare via this specific link](#).

All IBL protocols cited in the article can be found [on Figshare via this master link](#).

The latest version of the CAD models and technical drawings for the manufactured rig parts can be found [here](#).

The latest version of the whole rig CAD assembly can be found [here](#).

Please cite the associated article when using any of these materials and protocols:

The International Brain Laboratory et al. (2020) *Standardized and reproducible measurement of decision-making in mice*. bioRxiv, 909838. <https://doi.org/10.1101/2020.01.17.909838>



Appendix 3: IBL protocol for setting up the behavioral training rig

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Introduction

This document gives instructions on how to build and set up a standardised version of the steering wheel rig to probe mouse behavior, introduced by the Cortex Lab (<https://www.ucl.ac.uk/cortexlab/tools/wheel>, Burgess et al. (2017)). The goal is to make it easy for other laboratories, including those forming the [International Brain Laboratory](https://www.internationalbrainlab.com), to replicate the task and extend it in various directions. This document gives instructions for building hardware and setting up software such a standardised version.

The standardised version mostly relies on materials that can be bought off the shelf, or ordered online based on 3D drawings. A detailed list of the components can be found in the section **Components lists**.

For more information about ordering the components bundled as a set, please see our website <https://www.internationalbrainlab.com/resources> for the most updated details.

Hardware

Apparatus

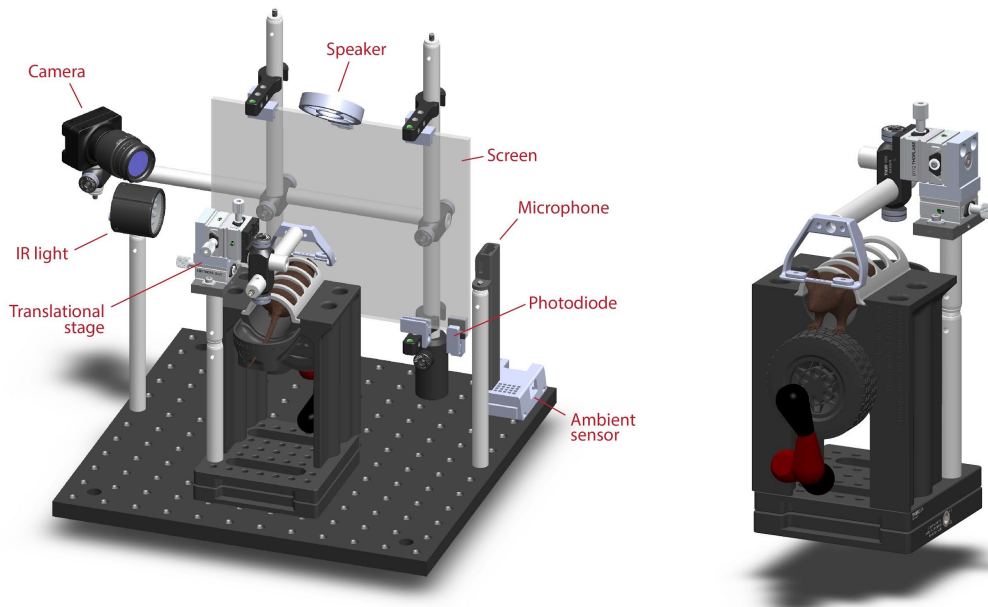
The apparatus was designed to train head-fixed mice on the steering-wheel task and acquire behavioral data. This setup is not used to perform electrophysiological recording of brain activity.

All the material used for the rig can be found in the Appendix section **Components lists**. Briefly, the setup comprises :

- an iPad screen, with a Fresnel lense and polarising filter
- a detachable, magnetic mouse holder, comprising:
 - a steering wheel
 - a water-delivery system
 - a head-fixation assembly, comprising a translational stage to adjust the animal's position
- various sensors:
 - a microphone
 - an ambient sensor, measuring:
 - air humidity
 - temperature
- a camera and an infrared light source
- a sound module



- a [Sanworks](#) Bpod state machine and PC as main controller



The *Standard* behavioral rig. **Left:** CAD rendering of the whole setup, with apparatus labelled. **Right:** CAD rendering of the mouse holder.

A 3D rendered video of the behavioral training rig CAD model can be found on Figshare: <https://doi.org/10.6084/m9.figshare.13042574>

Dimensions of the standardised behavioral rig:

- height: 32.3cm
- depth: 30cm
- width: 39cm
 - Note: there is some variability in the width (+/- 1.5cm), depending on the camera placement during setup.

Apparatus wiring connections

Apparatus connected to Bpod		
Port type	Port no	Item connected
TTL I/O	In1	Frame2TTL
	In2	Sound card Ch2 Camera (Green, Black2)



Behavior Port	Port 1	Port interface board
Module	Port 1	Rotary encoder module
Module	Port 2	Ambient Sensor
USB	USB	Behavior PC
Power	Power	12V power supply

Apparatus connected to other modules		
Module type	Port no	Item connected
Port interface board	Port 1 (Valve)	Valve (both wires)
	Port 1 (GND , S)	Camera (Purple, Black1)
Rotary encoder module	+5V	Rotary encoder (Brown)
	A	Rotary encoder (Green)
	B	Rotary encoder (Grey)
	GND	Rotary encoder (White)
	Z	Rotary encoder (Blue if present)
	State Machine	Bpod
Sound module	Out1 -	Speaker -
	Out1 +	Speaker +
	Ch2	Bpod TTL I/O 2 + Camera (Green)
	Ch2 gnd	Bpod TTL I/O 2 - Camera (Black2)
	Power	12V power supply
	Audio In	PC sound card (headphones)

Apparatus connected to the PC

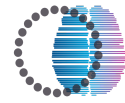


Port type	Port no	Item connected
Graphics card	1	Display Monitor
	2	Rig Screen
PC sound card	headphones	Sound module
USB Port	any	Camera
USB Port	any	Microphone
USB Port	any	Frame2TTL
USB Port	any	Bpod
USB Port	any	Rotary Encoder Module

Task definition

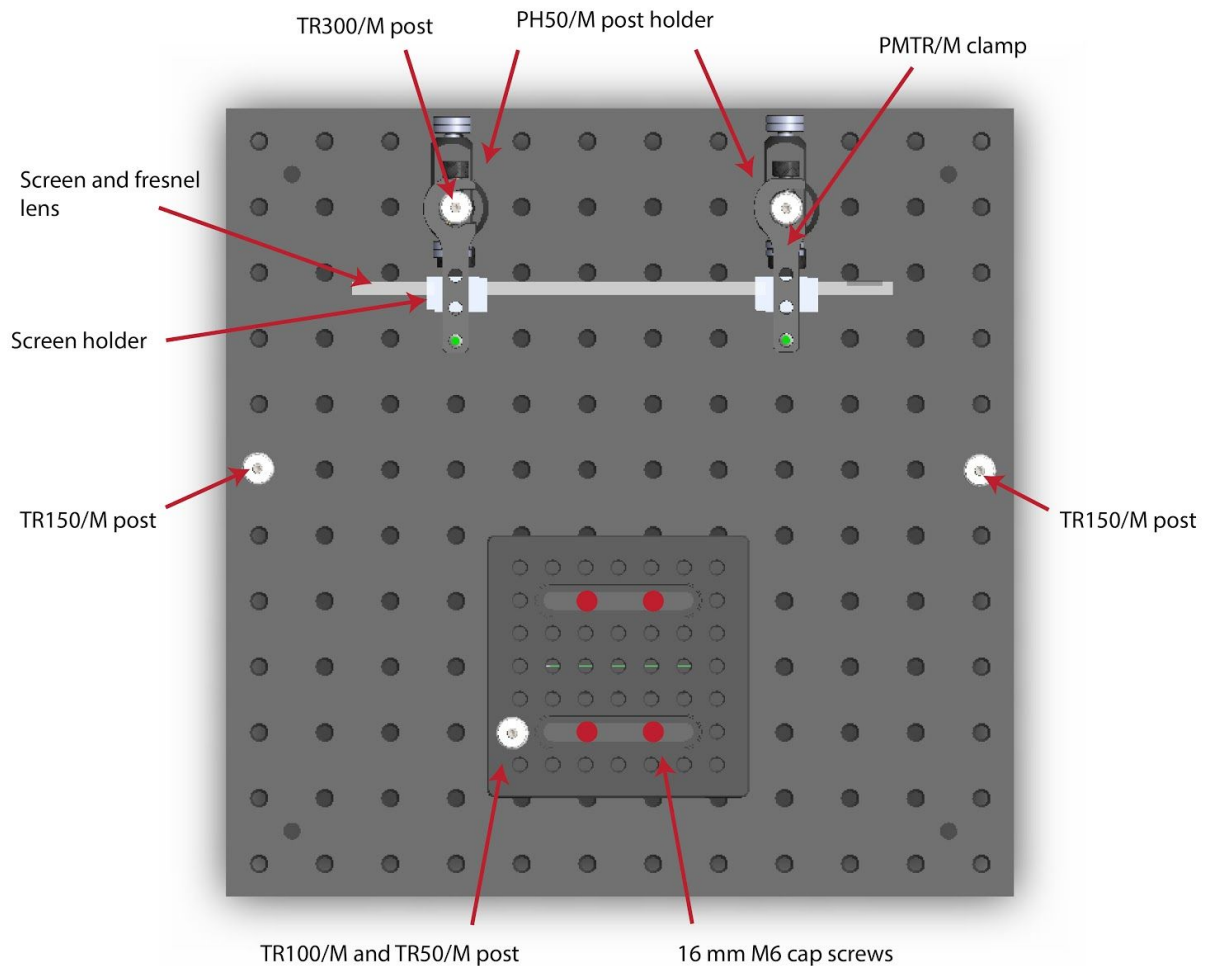
A steering wheel is placed under the front paws of a head-fixed mouse, and the wheel's rotation is coupled to the horizontal position of a visual stimulus on the screen. Turning the wheel left or right moves the stimulus left or right. The mouse is then trained to decide whether a stimulus appears on its left or its right. Using the wheel, the mouse indicates its choice by moving the stimulus to the center. A correct decision is rewarded with a drop of water and short intertrial interval, while an incorrect decision is penalized with a longer timeout and auditory noise.

For further information on the task, see International Brain Laboratory (2020) Appendix 2: IBL protocol for mice training.

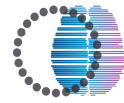


Frame and components

The setup itself comprises an iPad screen installed on two posts, a mouse holder with a steering wheel encoder and head-fixation assembly, and a water-delivery system. Here we describe the assembly of the frame required to hold these and other components together.



Rig footprint diagram. The steering-wheel setup is contained entirely within a frame made of Thorlabs components, all seated on a 300mm x 300mm aluminium breadboard (MB3030/M). Components can be secured to the breadboard using 16mm M6 cap screws. The screen/Fresnel assemblies are seated between four grooved screws on clamps (two bottom, two top) that are attached to 300mm posts. The mouse itself is seated on a 3D-printed holder (not shown) that attaches to a magnetic plate in the center of the frame.



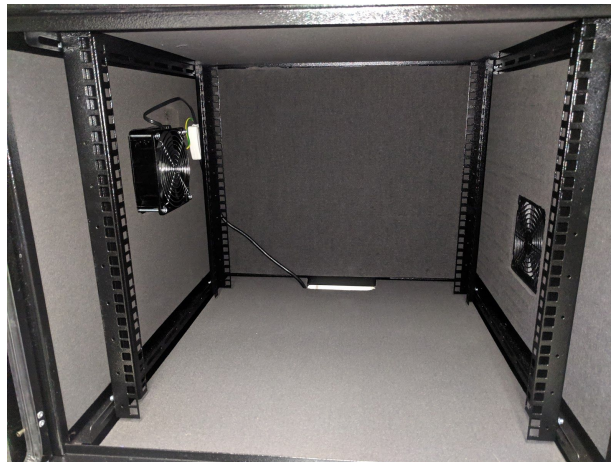
1. Enclosure box

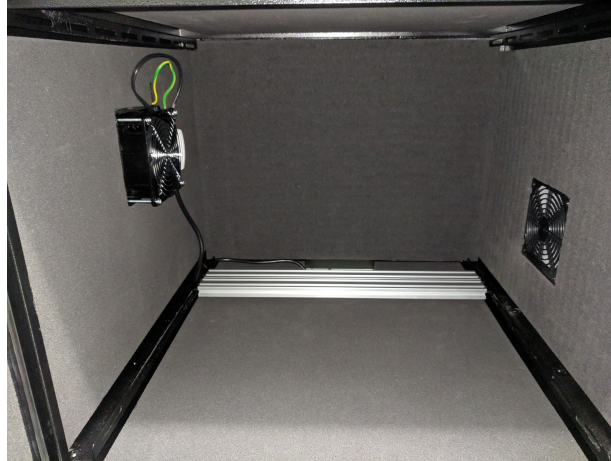
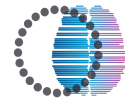
The rig will be placed in an acoustic enclosure box, if using the IBL standard Orion acoustic enclosure, follow step one. If using a separate sound proof enclosure, proceed to step 2. If using a different enclosure, it is recommended that a fan is used to maintain a cool temperature in the box as the hardware produces a significant amount of heat over a training session.

1.1. Preparing the box

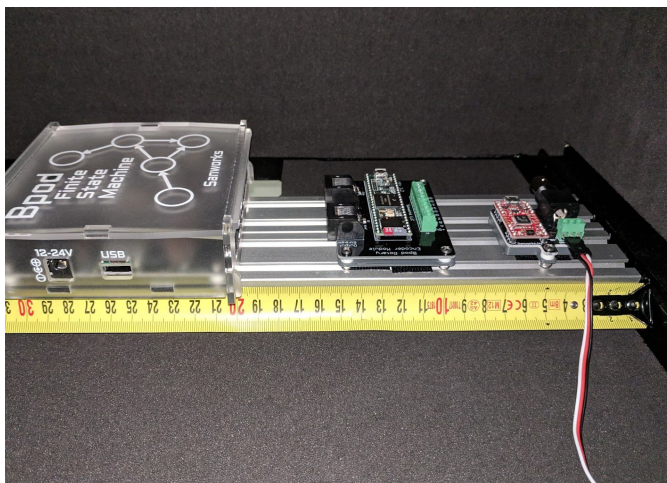
Note: The original design of the box is for the cable hole to be at the top, and the ventilator with power supply to be on the right hand side. You can however choose to reverse the side of the box (placing it upside down) like in the images below. The door can also be removed and flipped if desired.

- 1.2. Remove the four vertical rail posts by unscrewing them.
- 1.3. Attach the white fan component to the side of the fan using velcro tape if it came loose during shipping.
- 1.4. Position two 40x510 mm rails in the back of the box using four M5 screws (hex cap screws are easiest) on either side. The screw which is the closest towards you should be in the third to last slot in the side guides. The other three screws should be in the second to last slot in the side guides.

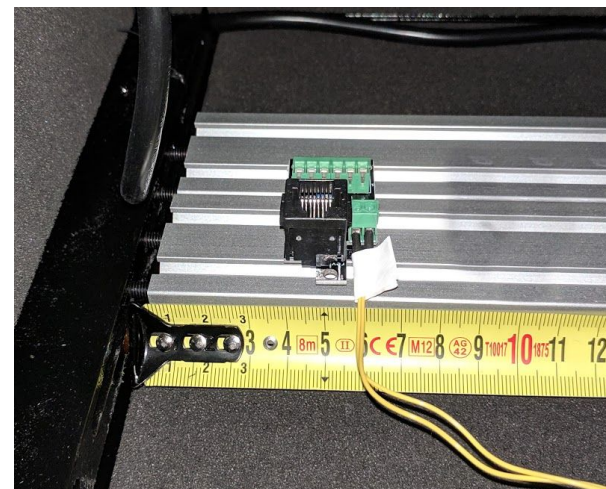




- 1.5. Place the Bpod in the center of the rail platform with the power and USB input facing towards you.
- 1.6. Attach the other components to the rails at the position shown in the pictures below.

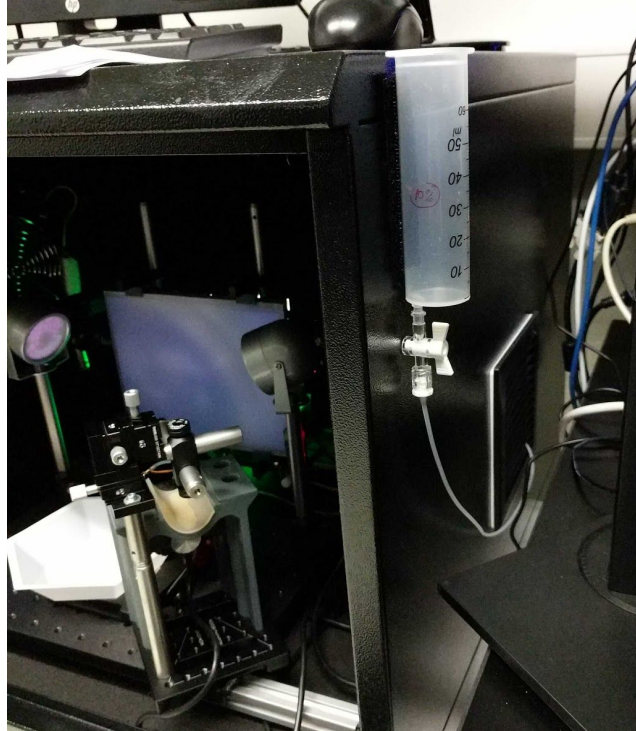
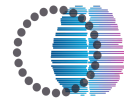


Bpod, Rotary encoder module, and Frame2TTL module



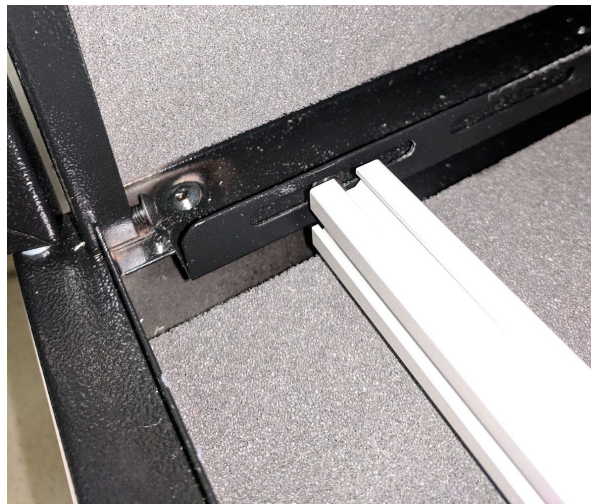
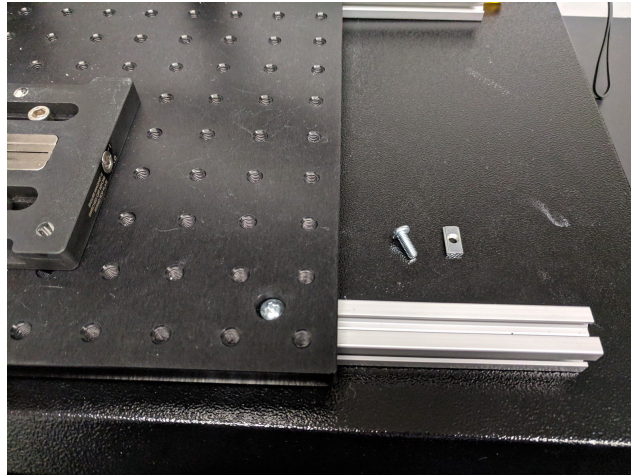
Valve and camera module

- 1.7. Use a piece of velcro tape to attach the water reservoir on the outside of the box as shown.
- 1.8. Use a screwdriver or other pointy object to puncture a hole in the **vent** (square grid opposite to the ventilator with power supply) and feed the tubing through that.
 - 1.8.1. Note: in the picture below, the box was placed upside down, hence the vent is on the right hand side.



Place the rails and breadboard in the enclosure box.

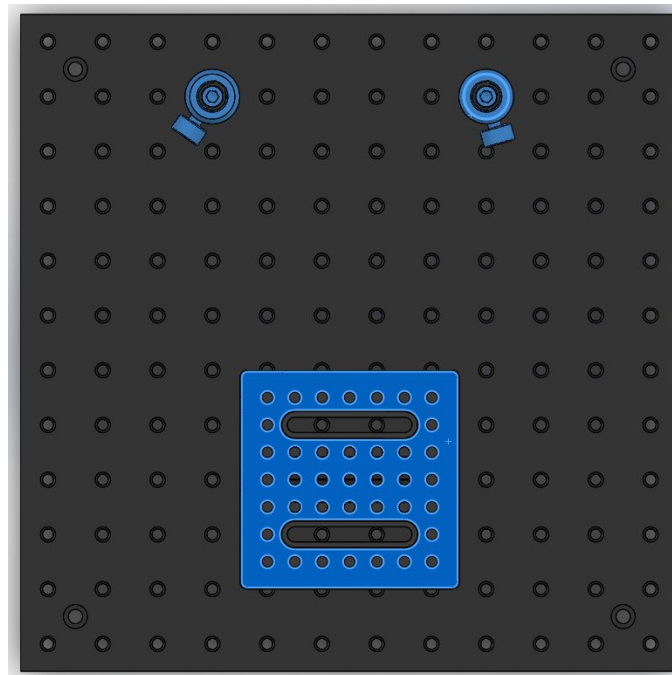
- 1.9. Put two M5 self-aligning roll-in T-nuts into each of two 200mm rails . Attach the rails to the side guides with M5 screws. The rail which is the closest towards you should be in the first slot in the side guides. The rail which is further from you should be in the fifth slot in the side guides.
- 1.10. Place the baseplate of the rig on the two 200mm rails and attach using M5 screws (phillips head screws are easiest) placed through the untapped corner holes of the baseplate into the roll-in T-nuts (below, right). Place the baseplate in the center such that on both sides the rail sticks out equally far (10.1 cm).
- 1.11. **Continue with the build, preparing each segment outside the box** but mounting it onto the main breadboard in the rig. Make sure you keep enough space for cables to be semi-organized in the back of the box - a headlamp can help see behind the screen.



2. Assembling the frame

The frame is composed chiefly of Thorlabs components and 3D printed parts.

- 2.1. Attach the magnetic base (KB1M/M) to the breadboard (MB3030/M) as shown in the footprint diagram using four 16mm M6 cap screws in the sliding slots.
- 2.2. Screw a 16mm M6 cap screw through the bottom of the two PH50/M post holders.
- 2.3. Attach each post holder (PH50/M) to the breadboard (MB3030/M).
- 2.4. Attach the magnetic plate (KB1M/M) to the breadboard.



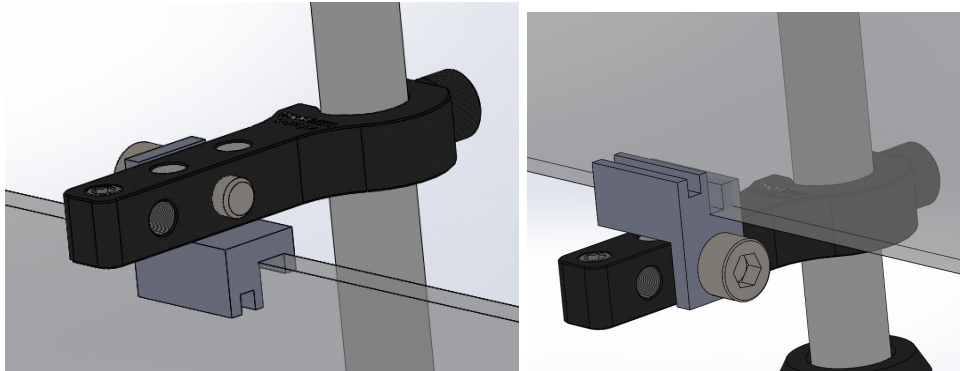
Note: If you have purchased the Sanworks assembled kit, you may skip to step 2.13

- 2.5. On each of two TR300/M posts, slide the small 3d printed spacer (1cm) over the post holder and secure a PMTR/M clamp on top of that.
- 2.6. Slide the larger 3d printed spacer onto each pole above the PMTR/M.
- 2.7. Slide a RA90/M over each post to the top of the spacers for later attachment of the video camera (should be 15.5 cm from the top of the two posts).
- 2.8. Put a TR300/M post through the two RA90/M's with the screw end sticking out towards the left of the screen (when facing the screen). Feed the pole all the way through.
- 2.9. Place an SWC/M 3.5 cm from the end of the TR300/M post. Angle the rotating clamp such that the indicator stripe is between the second and the third stripe.

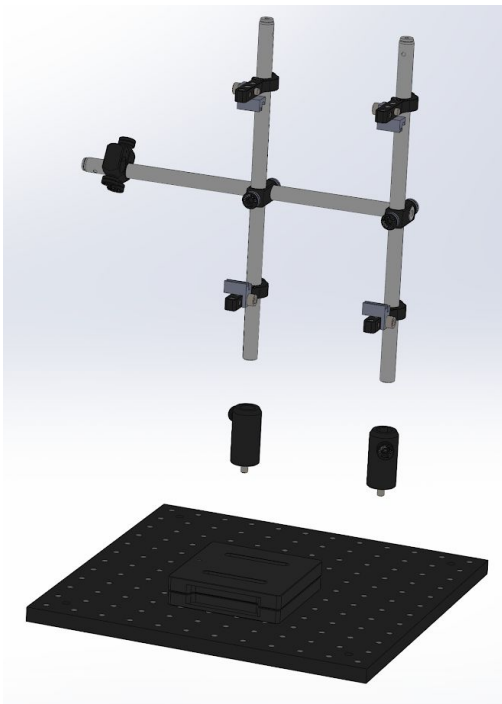


- 2.10. Secure another PMTR/M clamp ~20cm above the lower clamps.
- 2.11. On each of the two lower PMTR/M clamps, use a 12mm M6 screw to connect the lower screen mount (with a slightly narrower ridge) into the side tap closest to the post. The higher ridge/smaller notch should be farther from the posts.
- 2.12. On each of the two higher PMTR/M clamps, use a 12mm M6 screw to connect

the remaining two mounts (the upper screen mounts) to the tap closest to the post. Again the larger notch should be facing the posts.



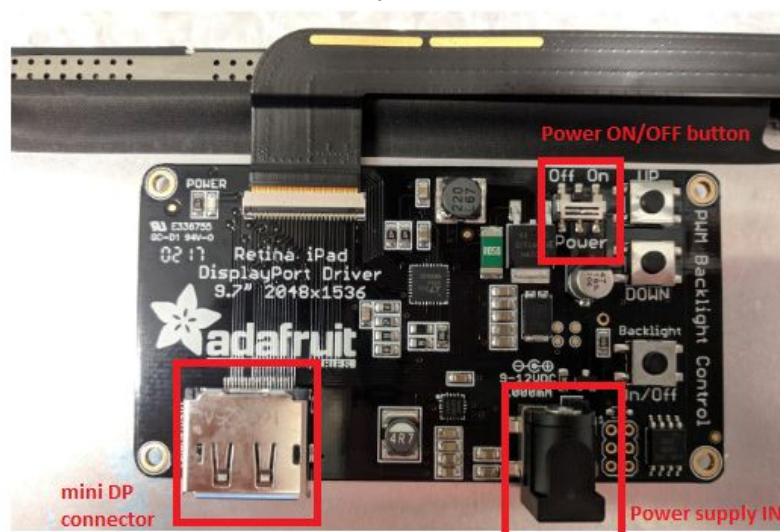
- 2.13. Place a 1cm 3d printed spacer on the bottom of each of two TR300/M posts.
- 2.14. Insert and secure the TR300/M posts into each of the post holders on the breadboard with the tapered end that has the small set screw sticking out pointed upwards.
- 2.15. Ensure that the bottom component clamp on each side is touching the spacer.
- 2.16. When attaching the magnetic base, make sure the magnetic switch is on the right hand side of the setup when facing the screen.
 - 2.16.1. Set the magnetic switch to be in the middle of 0 - 1 .





3. Assembling the screen

- 3.1. Keep the protective plastic film on the screen until attaching the fresnel lens.
- 3.2. On a soft surface, turn the iPad over so that the back is facing up and the input cable is running along the top.
- 3.3. Check that the cable input on the driver board has its locking mechanism (black plastic bar) pressed up. Cut a piece of Velcro covering 80% of the width of the driver board, and attach it securely to the back of the driver board.
- 3.4. Carefully connect a driver board to the input cable. There will be ~1mm of gold contacts left visible. DO NOT FORCE THE CABLE.
 - 3.4.1. This attachment is the source of many screen problems, handle gently and ensure the ribbon cable is fully seated.



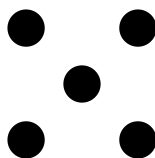
- 3.5. Attach the driver to the back of the screen with Velcro, ensuring the cable is not bending or shearing.
- 3.6. Check that the driver board switch is set to 'OFF'.
- 3.7. Slide the iPad screen onto the larger slit of the lower 3D printed mount. The driver board should be at the top of the screen on the back.
- 3.8. Carefully remove the plastic protective film from the iPad screen.
- 3.9. Slide the Fresnel lens into the front ridge of the lower screen mount, aligning the lens with the screen. The rough side of the lens should face towards the screen.
- 3.10. Center the screen and fresnel lens. When the screen is centered, there should be 3mm between the upper-right screen holder and the screen edge, and 3.3mm between the upper left screen holder and the screen edge. Use the landmarks in the photos below to assist with alignment.
- 3.11. To adjust screen brightness intensity, use a **polarising filter**.

Note: this step needs to be done [once the software has been installed and the screen display properly configured](#).

 - 3.11.1. Set the screen background to grey.
 - 3.11.2. Use a lux meter to measure the brightness of the screen in the four

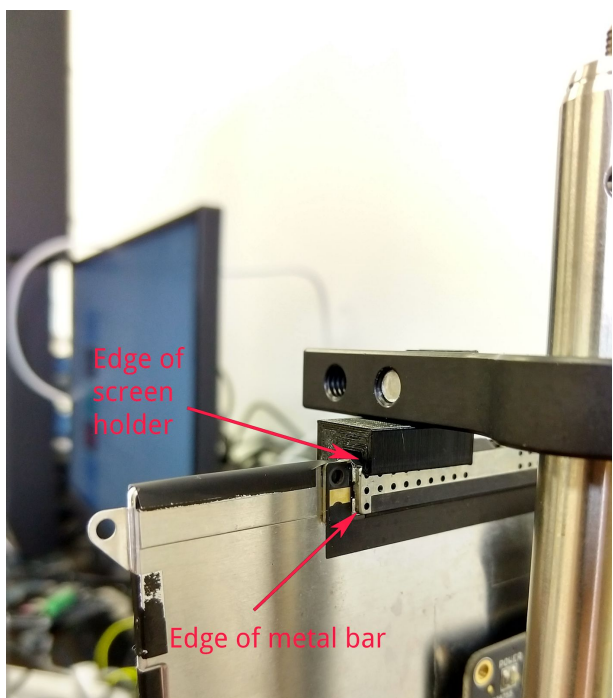


corners and the center in a quincunx shape. These readings will vary but should not be outside of the range of 50-60 lux after placing the polarizing filter (see below).

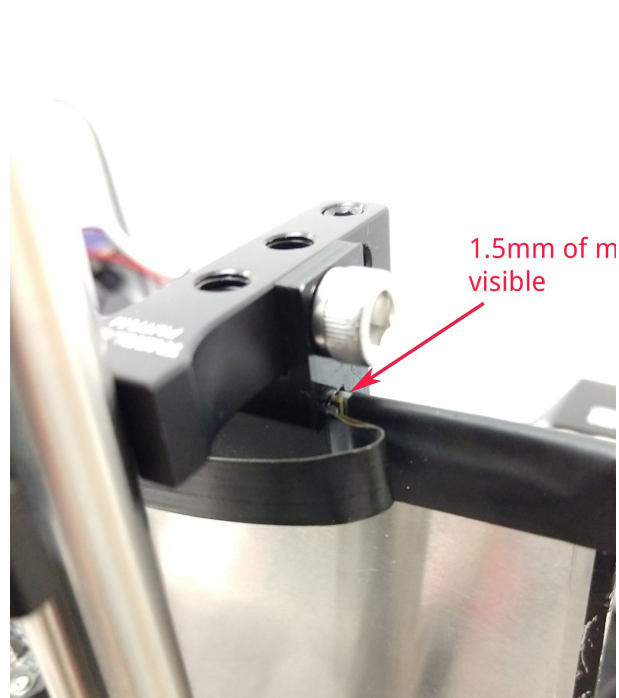


Quincunx shape:

- 3.11.3. Using a full sheet of polarizing filter, place it over the gray screen and rotate to make the screen brighter or dimmer. Using a lux meter, find an orientation that yields **50-60 lux** across the screen.
- 3.11.4. Once this orientation is found, trace the top of the screen on the polarizing filter to keep that same angle when cutting the filter.
- 3.11.5. To cut the filter, place the long edge of the fresnel lens along the line you traced on the filter, and trace the outline of the fresnel lens on the filter. Cut the filter to this size using a razor or scissors.
- 3.11.6. Place the cut filter between the screen and Fresnel lens film and re-center the screen as instructed above.



Right screen holder alignment (Right as viewed from front). The 3D-printed screen holder should be aligned precisely with the end of the perforated metal bar on the screen's back.

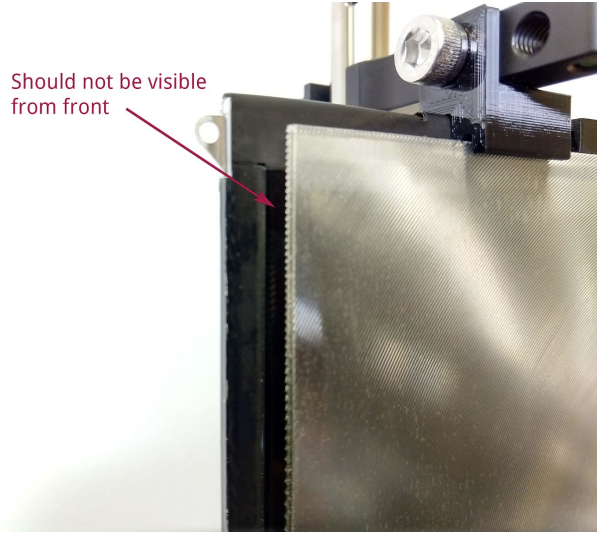


Left screen holder alignment (Left as viewed from front). When the right screen holder is aligned (see other panel), you should see approx. 1.5mm of metal visible between the left 3D-printed screen holder and the screen's black coating.

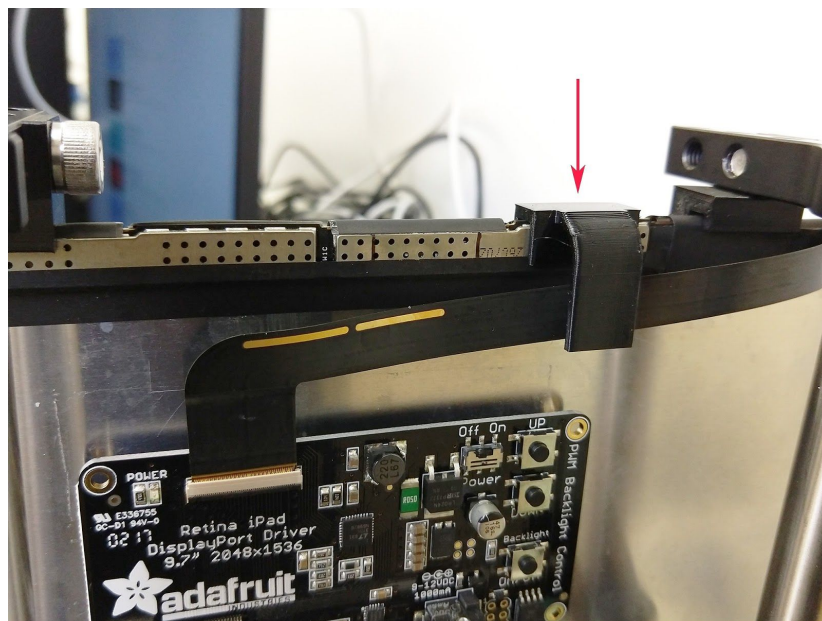


- 3.12. With the screen aligned in the screen holders, shift the fresnel lens laterally until it covers the screen. Note that the screen has asymmetric bezels - the left side bezel as viewed from the front is slightly larger than the right bezel. When properly aligned, only the bezel should be visible from the front (no LCD, see below).

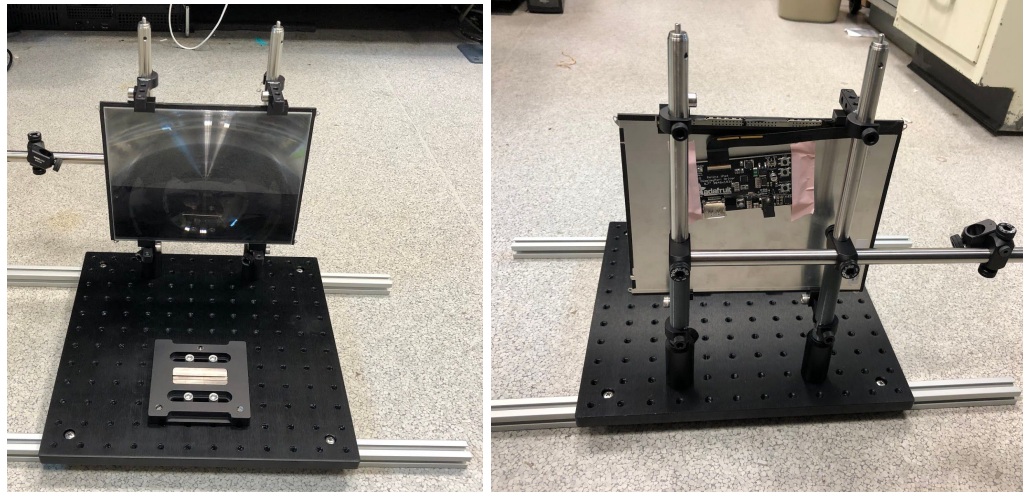
Should not be visible
from front



- 3.13. Firmly secure the screen and lens position by tightening the thumbscrews of the top two screen holders while pressing downwards on the screen and lens.
- 3.14. Press the screen clip onto the top of the screen as shown below, to help keep the flat video cable close to the screen:



Your assembly should look like this:



- 3.15. Once the screen is firmly in place and all connection points are secured tightly to the breadboard, plug in the **9V** AC power cable to the Power supply IN of the adafruit driver board.
 - 3.15.1. Put the power strip in an easily accessible place outside the rig, and plug the screen into that one - that way, the screen can easily be turned off at night to avoid heating up (and without having to reach for the small on/off switch on the back of the driver board).
 - 3.15.2. Toggle the small On/Off switch to the on position to ensure there is some screen output. Press the small “up” button repeatedly to ensure the maximum screen output level. If there is no change in luminance when switched on, check that the ribbon cable is fully connected.
- 3.16. Plug the Display port connector of the screen into mini display port slot 2 on the video card of the behavior PC.

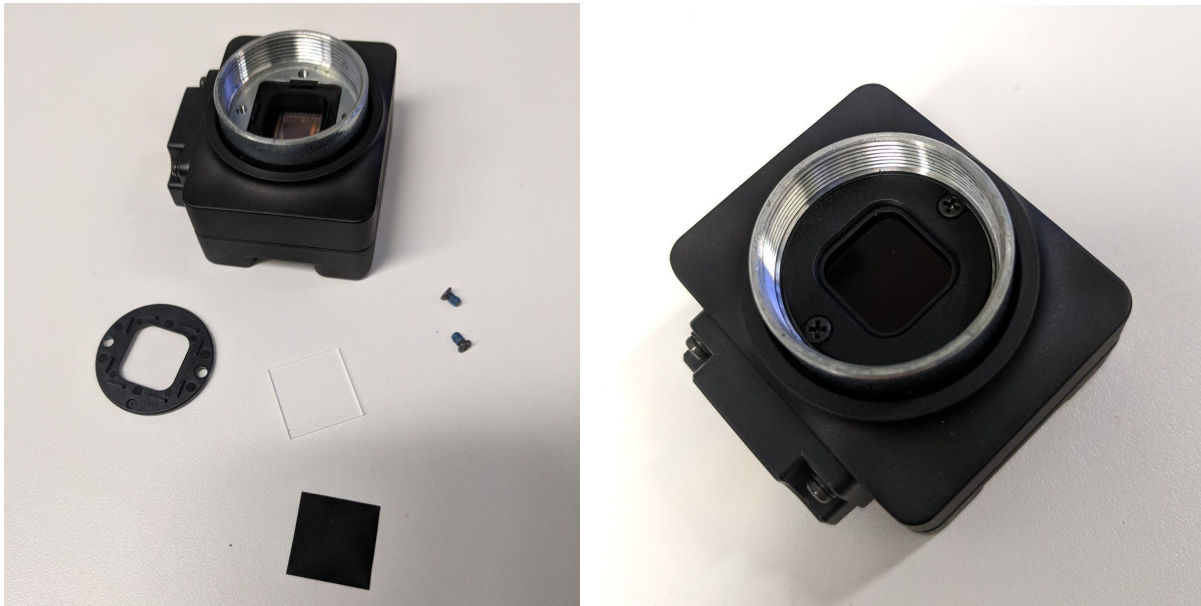
4. Assembling the video camera setup

***Note:** The behavioral setup is equipped with an Chameleon3 infrared camera and an infrared (IR) light source. **If purchased through Sanworks you may proceed to step 4.6** , the Chameleon3 camera is already equipped with an IR pass filter and a tripod mount. Sanworks also places an opaque piece of plastic in front of the IR light source LEDs to diffuse the light.*

- 4.1. The Chameleon3 camera needs to be equipped with an IR pass filter, remove the front of the camera using a small screwdriver. Remove the glass that's in the camera and replace it with a square of the IR pass filter that you cut from the



large sheet.



4.2. The IR light needs an opaque piece of plastic in front of the LEDs to diffuse the light.

4.2.1. Some models of the IR light source have a removable glass front. If this is the case: unscrew the cap of the IR light source and remove the ring inside using a pair of pliers (see picture below). Remove the glass that's in front of the LEDs. Put the glass on a plastic weighing boat and trace the outline with a marker.



- 4.2.2. Other models do not have a removable glass front, and do not have a visible ring inside. If this is the case: 3D print a circle of the same diameter (IR light template). Put this printed circle on a plastic weighing boat and trace the outline with a marker (see images below)



- 4.2.3. For both models: Cut out the circle from the plastic and put it in front of the LEDs and screw the cap back on.

- 4.3. Ensure the camera holding post is properly configured as in steps 2.7-2.9.
4.4. Attach the lens to the camera with two rings (black ring: CML05 and golden ring: CMSP100) in between.
4.5. Screw the tripod adapter (FLIR ACC-01-0003) to the underside of the camera see Note below for which side is the bottom.





- 4.6. Attach the tripod adaptor to a TR30/M post using a 20mm M6 set screw (EU/UK) or a thorlabs AP25E6M 1/4" 20/M6 adapter screw (US).
- 4.7. Keep the lens cap on until you are configuring the camera software to protect the lens.
- 4.8. Connect GPIO cable to the camera, this cable will later be connected to the PC.

Note: Make sure you mount the pole like is shown on the picture below. When facing the camera, the blue cable should be on the right hand side and the pole at the bottom.



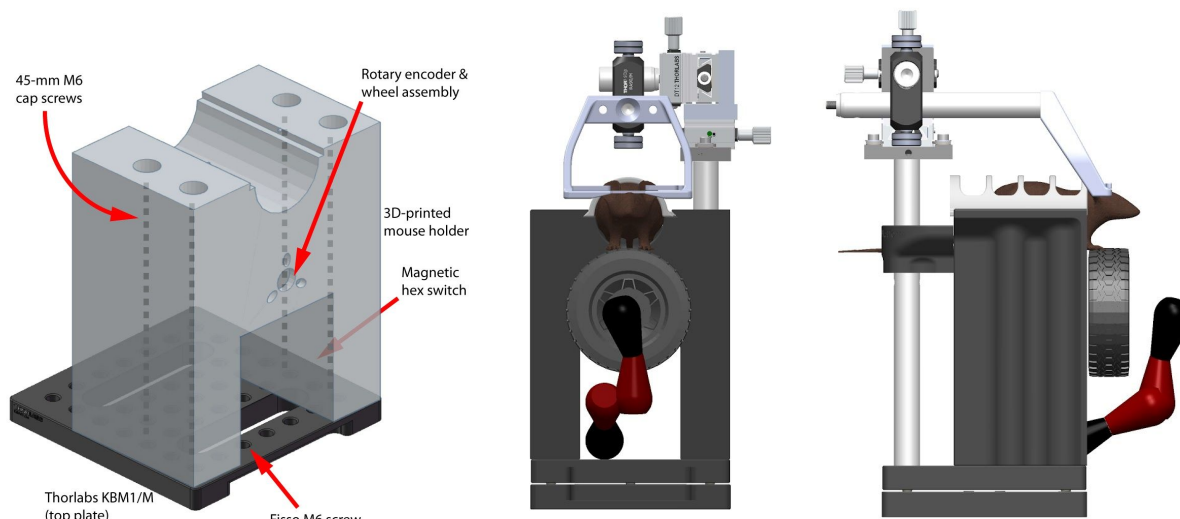
- 4.9. Placing the IR lamp:
 - 4.9.1. Place a TR150/M post in the seventh hole from the front on the leftmost row of the breadboard as indicated in the footprint diagram with a 20 mm M6 set screw.
 - 4.9.2. Attach the IR illuminator to the post with an M4 thumb screw. Note: it may be easier to unscrew the lamp head from its base, so as to screw that base onto the post first.
You will be asked to move the IR lamp head direction when setting up the camera.
 - 4.9.3. Power the IR lamp using a 12V / 1.5 Amp (2 Amp will also work) wall adapter.

5. Assembling the mouse holder

*The mouse holder comprises seating for the mouse, a steering wheel/encoder assembly, an articulated arm for delivering water rewards, and a head-fixation assembly. **Note:** if*



you purchased the assembled kit through Sanworks, skip to step 6.



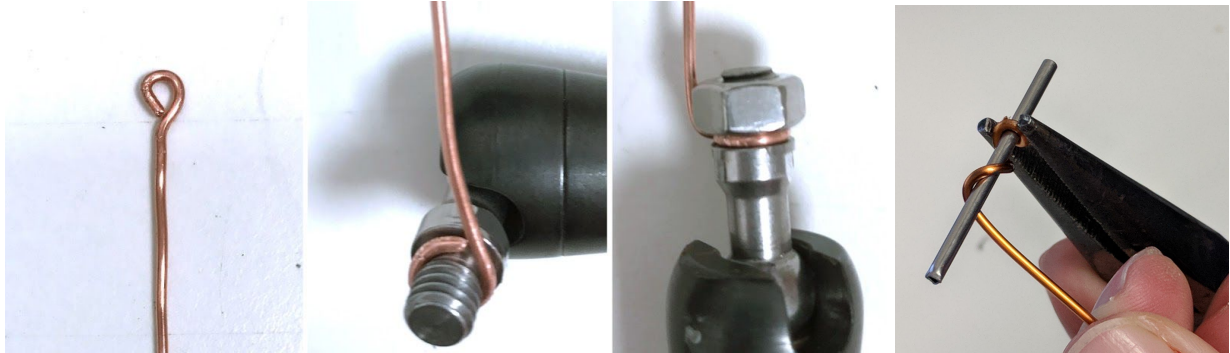
The mouse holder assembly. Left: The mouse holder, seen from the front, shows the center bore that will accommodate the wheel assembly, as well as key attachment points to the KBM1/M breadboard. Center: The front of the holder shows the attachment point for the Fisso arm. Right: The side of the holder shows the attachment point for the head-fixation assembly.

- 5.1. 3D-print the (a) mouse holder, (b) mouse cover, and (c) wheel coupler designs. Make sure to order from Shapeways and use the material specifications listed.
- 5.2. Connect the wheel coupler to the shaft of the rotary encoder. It should attach securely with a strong push.
- 5.3. Feed the rotary encoder through the large center bore on the front plate of the mouse holder, so that the coupler is facing outward and the encoder body is housed on the underside of the mouse holder. The encoder cable should be oriented downward.
- 5.4. Feed three 5-mm M3 cap screws (SH3M5) through the small bores on the front plate of the mouse holder, and then screw them into the threaded holes on the face of the encoder.
- 5.5. To the top plate of the two-piece KBM1/M kinematic breadboard, attach the larger Fisso articulated arm to the front center hole (row 1, hole 3) of the KBM1/M, and secure tightly with an adjustable wrench.
- 5.6. Connect the 3D-printed mouse holder to the KBM1/M top plate using four 45-mm M6 cap screws, as shown in the diagram above. The two front screws will be in row 1 (holes 1 and 7) and the two back screws will be in row 3 (holes 1 and 7).
- 5.7. Once the mouse holder is in position, assemble the LEGO wheel and hub, then gently secure it to the front cross of the coupler. There should be 1-2 mm of space between the wheel and the front face of the mouse holder. Spin the wheel to ensure it moves freely with no resistance.
- 5.8. Connect a TR50/M post to a TR100/M post with a 20-mm M4 set screw (remove the set screw in one of the two posts, and use the set screw in the other post to connect the two posts). This option yields a 150 mm long post (vertical post seen in the pictures; good length to position the xyz controller) with M6 taps on both

sides (used to connect to both the KBM1/M top plate and the DT12B/M piece of the xyz controller).

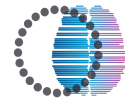
- 5.9. With a 20-mm M6 set screw, attach the composed post to the KBM1/M top plate at row 6, hole 7.
- 5.10. Use an M4 cap screw to attach the DT12B/M piece of the xyz controller to the composed x post, **positioned orthogonally in relation to the KBM1/M top plate.**
- 5.11. Connect the DT12XYZ dovetail translational stage to the DT12B/M piece.
- 5.12. Using an M4 set screw, attach a TR30/M post to the DT12XYZ translation stage.
- 5.13. Attach the RA90/M right-angle clamp to the TR30/M post, so that it is centered in relation to the mouse holder, with the second post bore pointed down.
- 5.14. Attach the headplate holder to the base of the TR100/M post with a 16-mm M6 cap screw.
- 5.15. Feed the holder/post assembly through the open bore of the RA90/M, so that the front of the holder reaches the midline of the LEGO wheel. Secure the RA90/M thumb screw.
- 5.16. Insert the two M3 thumb screws top-down into the headplate holder. These are to secure the animal's headplate.

6. *Assembling the water-reward system*



Making a spout guide. Use a length of 16AWG copper wire to extend the reach of the Fisso arm and enable water delivery to the mouse.

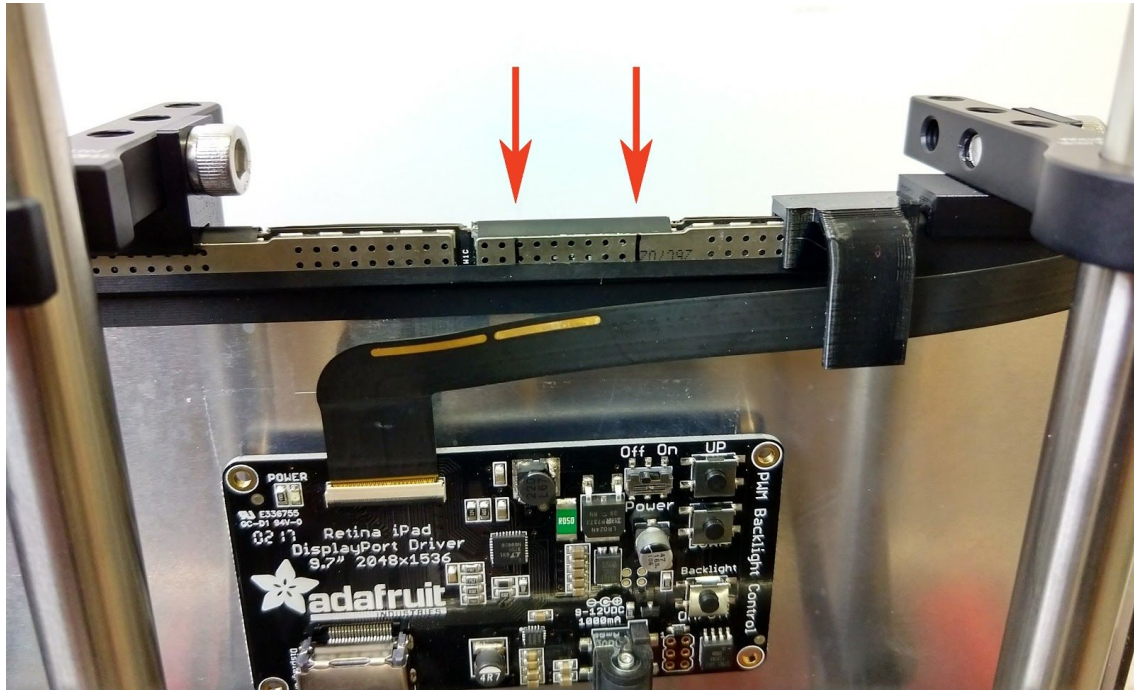
- 6.1. To make a spout guide, first cut an 8-cm length of copper wire. Using needle-nose pliers, wrap the end into a 2-mm-diameter loop, then bend it to a right angle.
- 6.2. Wrap the other end of the wire around the free M6 screw shaft of the Fisso arm, and secure with an M6 hex nut.
- 6.3. Bend the spout guide so that it extends the length of the Fisso arm toward the top of the steering wheel.
- 6.4. Remove the tubing that comes with the pinch valve and replace it with a single 100 cm long piece of tubing, place the pinch valve halfway the 100cm tube.
- 6.5. Insert a short steel tube (component part: Steel tube, Microgroup, 316H15RW) into the valve end to avoid mice chewing on the tube.
- 6.6. Feed the tubing along the back of the Fisso arm and through the 2-mm loop, and adjust the tubing so ~5 mm extends. Gently secure the tubing to the Fisso with a piece of laboratory tape.
- 6.7. Adjust the Fisso arm and spout guide so that the tube tip is centered in the bore of the mouse holder. Make sure the Fisso does not obstruct wheel movement.
- 6.8. Put the pinch valve on a stack of post-its or something else (round of lab tape) that absorbs a bit of the sound - placing it directly on the breadboard will resonate and make a very loud noise when the valve opens.
- 6.9. Use a 65mm x 55mm rectangle of silicone rubber sheeting to line the bore where the mouse will be seated (if you see that the rubber sheet is sliding, use poster putty or tape to fix it in place). This adds a bit of padding for comfort, and can be washed with soap & warm water between sessions.



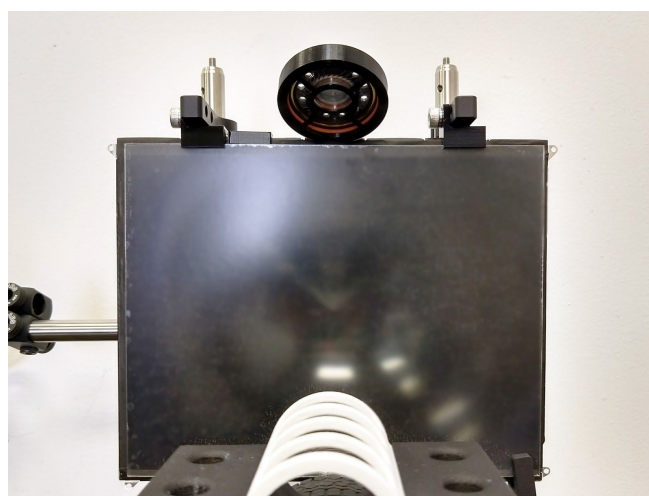
7. Installing the speaker

The speaker is necessary to transmit simple task-related sounds, like beeps and white noise.

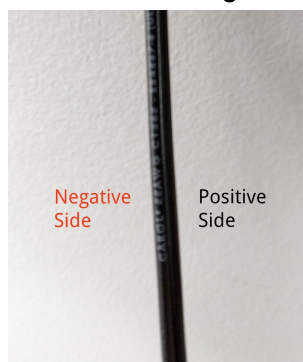
- 7.1. Find or make the two marks on the back of the screen as shown below. They are centered at 10.4cm from the screen edge.



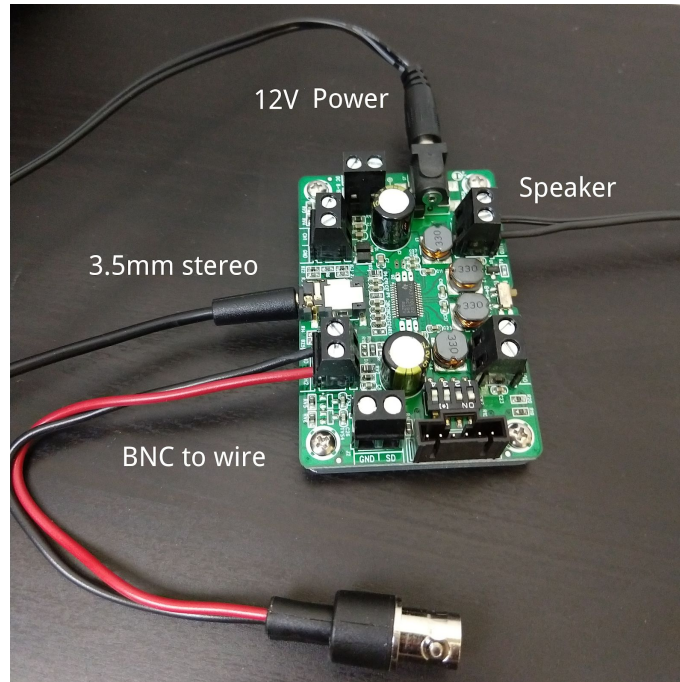
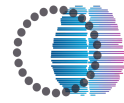
- 7.2. Taking care to avoid touching the flat screen cable, and avoiding the fresnel lens, mount the speaker evenly between the two marks. Make sure that the top of the screen goes all the way into the speaker mount, and that both sides of the mount are even with the screen edge.
- 7.3. Tighten the set screw. When you feel the screw touch the screen, it is safe to turn the screw an additional $\frac{1}{4}$ turn to fix the speaker in place. **To protect the screen, do not exceed $\frac{1}{4}$ turn.**
- 7.4. The speaker should now appear as shown below:



- 7.5. One of the two speaker wires has white writing on it. This is the negative wire:



- 7.6. Connect the speaker, **12V** power adapter, 3.5mm stereo cable and BNC-to-wire adapter to the audio amplifier board as shown below. Make sure to observe polarity of the speaker and BNC connector (black is negative):



- 7.7. Connect one side of the 0.3m (1ft) BNC cable onto the BNC to wire adapter, and connect the other side onto the port of the state machine labeled 'TTL I/O, In2'.
- 7.8. Connect the far side of the 3.5mm stereo cable to the 'Headphones' jack on the PC sound card at the back of the computer (make sure you plug it into the correct port otherwise no sound will be output).



- 7.9. Open an Internet browser and play [this video](#). You should hear sound from the speaker.
- 7.10. If this does not work, see the **Troubleshooting** section at the end of this document.

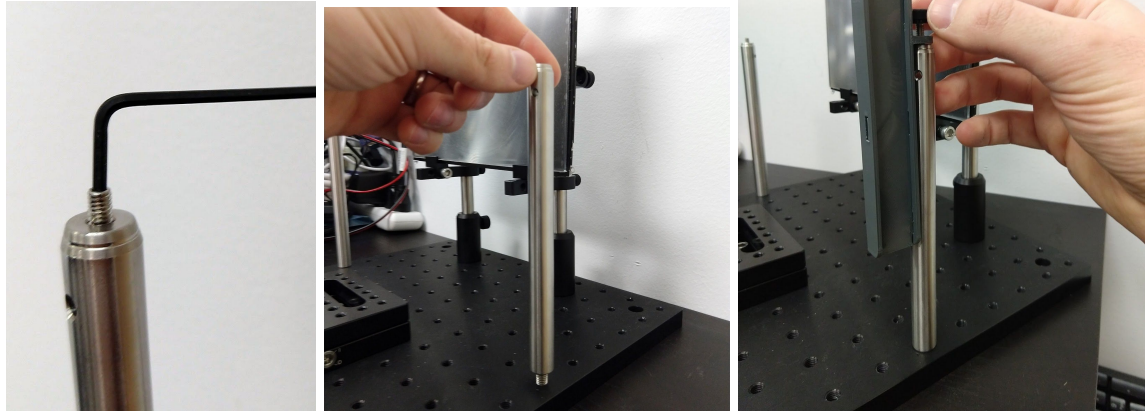
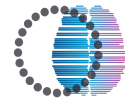
8. Installing the microphone

The microphone is used to record ambient sound and ultrasonic vocalizations from mice.

- 8.1. **If you received the microphone from Sanworks**, proceed to step 8.2 below as the microphone comes already assembled.
- If you received the microphone from Dodotronic**, you have to take the microphone out of its silver enclosure and place it into a 3D printed case.
- 8.1.1. Unscrew the black ring and remove the rubber covering on the other side (as below, left picture).
 - 8.1.2. Push the black plastic case from the USB connector side (as shown below on the middle picture).
 - 8.1.3. Once you have removed the circuit board from the silver enclosure, unscrew the phillips head screws that hold the board down (you have to pull off the black foams space filler too).
 - 8.1.4. Detach the board from the black plastic casing.
 - 8.1.5. There are two white switches on the board - make sure they're both in the 'Down' position (as opposed to "ON" labelled on the board).
 - 8.1.6. The board can now be snapped into the 3D-printed case ([ME101__MikeEnclosure_Top](#) and [ME102__MikeEnclosure_Bottom](#)), no hardware required.



- 8.2. If you haven't yet installed the TR150/M post (as shown in the 'Rig Footprint Diagram' above).
- 8.2.1. Remove the M4 set screw from the top of a TR/150M Thorlabs post using a 2mm hex wrench.
 - 8.2.2. Install the TR150/M post with an M6 x 20mm set screw into the breadboard at the position shown in the diagram, mirroring the IR light.
- 8.3. Connect the microphone to the PC with the USB A to B-mini cable.
- 8.4. Mount the microphone on top of the post, with the body of the microphone oriented towards the rear of the breadboard (as shown below). Secure the microphone with an M4 x 12mm thumb screw.



Connecting Bpod

The Bpod coordinates the input and output signals for most elements of the rig.

1. Connect the computer and power supply

- 1.1. With a microUSB-USB cable, connect Bpod's USB port to the PCs. On Bpod 0.8, make sure this is 'USB' and not 'P' - on the newer Bpod system, there is only one USB connection.
- 1.2. Plug the state machine adapter (which came in the box) into its power supply, and in an electrical socket.

Note: The Bpod's lights will turn on if it is only connected to the computer via USB, but not to a power supply, however the valve will not be able to open. The Bpod must be plugged both into the PC and its power source.

2. Connect the water-reward system

Before troubleshooting, always power off the valve system by unplugging the power supply (ethernet) directly.

- 2.1. Connect the two yellow grounds from the pinch valve to the Port Interface board in the two ports labeled 'VALVE'.
- 2.2. Plug port interface board into the Bpod state machine behavior port/port 1 (*not* 'serial port'/'module') using an ethernet cable.

3. Connect the camera



The camera is connected to other devices through a JST GPIO connector (a white adaptor with coloured cables).

The general purpose of each pin of the GPIO connector can be found in the table below.

General Purpose Input/Output (GPIO)

Diagram	Color	Pin	Function	Description
	Red	1	V _{EXT}	Allows the camera to be powered externally 5 - 24 VDC
	Black	2	GND	Ground for Input/Output, V _{EXT} , +3.3 V pins
	White	3	+3.3 V	Power external circuitry fused at 150 mA maximum
	Green	4	GPIO3 / Line3	Input/Output
	Purple	5	GPIO2 / Line2	Input/Output
	Black	6	GND	Ground for Input/Output, V _{EXT} , +3.3 V pins
	Brown	7	OPTO_GND	Ground for opto-isolated IO pins
	Orange	8	OPTO_OUT / Line1	Opto-isolated output
	Yellow	9	OPTO_IN / Line0	Opto-isolated input

For more information on camera power, see [Powering the Camera](#).

Source: [Chameleon3 technical reference manual](#)

The table below displays which ports are used in the setup:

Source device	Pin	Connected device
JST GPIO connector	2 (Black ; GND)	Valve module (GND)
	5 (Purple ; GPIO2)	Valve module (Signal 'S')
	6 (Black ; GND)	Sound TTL (GND)
	4 (Green; GPIO3)	Sound TTL (Signal)

- 3.1. **Connect** the GPIO connector from the **camera** to the same port interface board as the **pinch valve** in the ports 'GND' and 'S'.



- 3.1.1. Connect (see also image below):

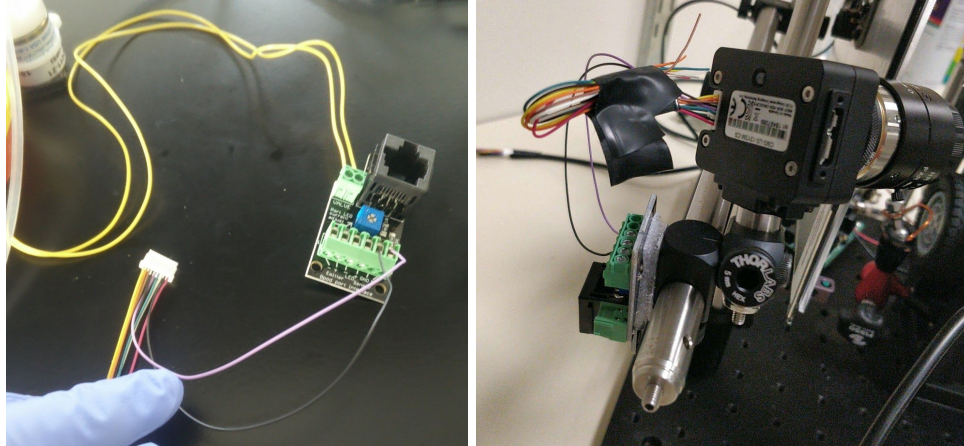
- 3.1.1.1. The valve ground ('GND') to pin 2 of the GPIO connector ('GND', black).
- 3.1.1.2. The valve signal ('S') to pin 5 of the GPIO connector ('GPIO2',

purple).

Note: The cables from the camera connector are rather short (see picture below). You can add length by soldering an extra cable to each connector cable.

Note 2: you can attach the port interface board to the back of the camera holder with velcro, instead of lengthening the cables.

Note 3: Do **not** attach to the camera as it heats up and will melt most adhesives off.



3.2. Connect the GPIO connector from the **camera** to the **sound module** output.

Material needed:

- 1 x BNC cable
- 1 x BNC splitter

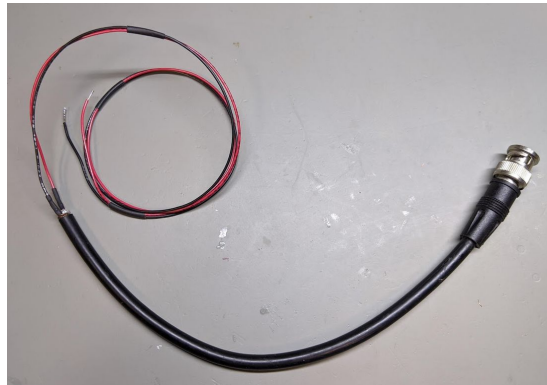


- 2 x thin wires with different colors (preferably black and red)

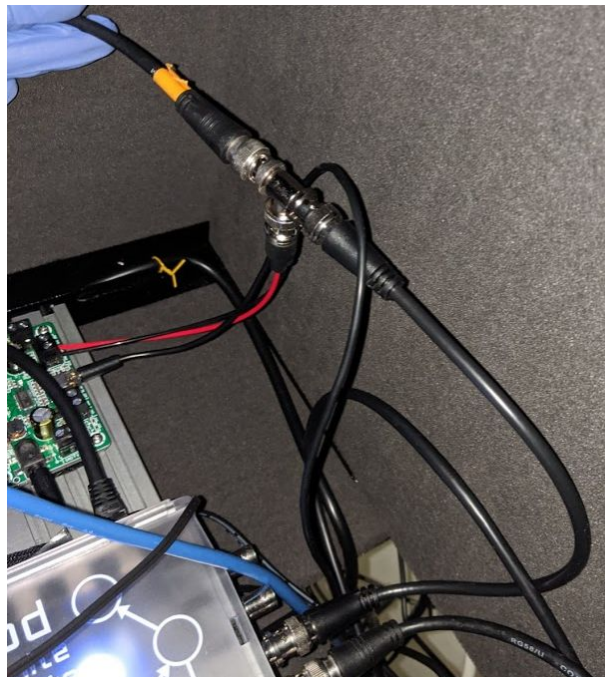
3.2.1. Create a BNC-to-wires cable

3.2.1.1. Cut a BNC cable in half.

3.2.1.2. Solder one of the wires (red) to the signal of the BNC cable and the other (black) to the ground.

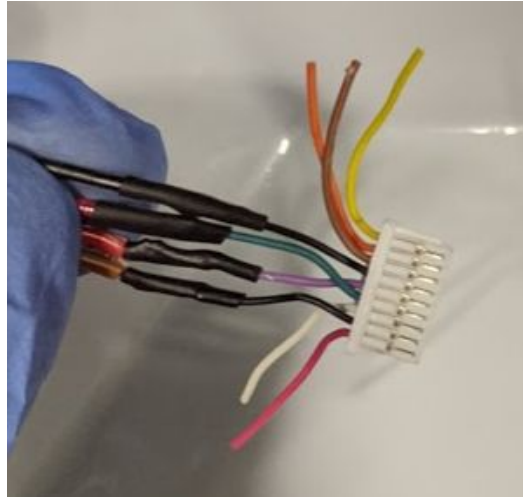


- 3.2.2. Split the output of the sound module using the BNC splitter, and attach to it the BNC part of the BNC-to-wires cable you made.



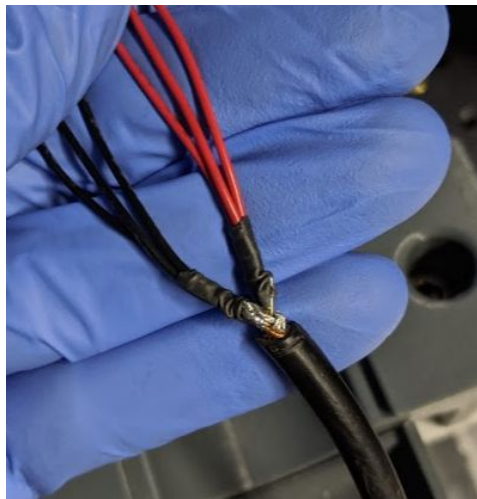
- 3.2.3. Solder the signal wire (**red**) of the BNC-to-wires cable to the pin 4 of the GPIO connector ('GPIO3', **green**).
- 3.2.4. Solder the ground wire (**black**) of the BNC-to-wires cable to the pin 6 of the GPIO connector ('GND', **black**).

Note that the purple and the other black wire of the GPIO connector are already in use.

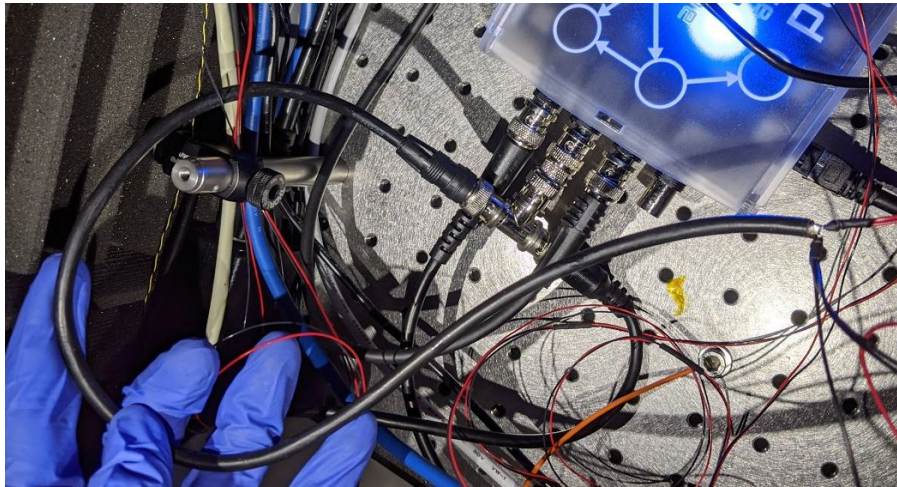
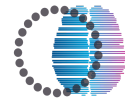


Note: **If your rig uses more than 1 camera, the signal has to be split into as many wires as there are cameras.** This is the case for the IBL Neuropixels Electrophysiology recording rig (design to be published), where 3 cameras are used. Instructions below are specific to this recording rig. Please skip the instructions below if you are installing the standard training rig.

- 3.2.5. Make a BNC-to-wires cable as above, but split the signal and ground into three wires.



- 3.2.6. Split the input into In2 of the BPod with the BNC splitter and connect the BNC-to-wires cable to it

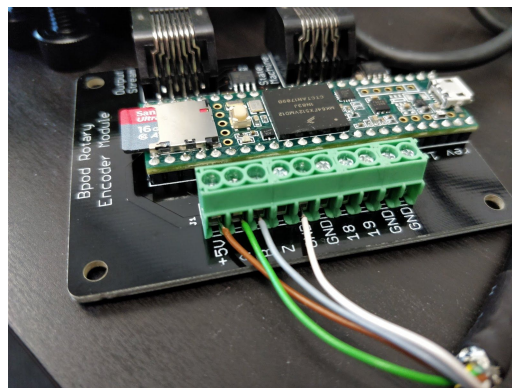


- 3.2.7. Solder the three signal and ground wires onto the GPIO connectors of the three cameras as before (1 pair of wires per connector).

4. **Connect the rotary encoder module**

The rotary encoder module is necessary for recording the wheel movements made by the mouse.

- 4.1. Isolate the gray, green, brown, and white wires in the cable output of the rotary encoder.
- 4.2. Connect the wires to the Bpod rotary encoder: brown to 5V+, green to A, grey to B, blue (if present) to Z and white to GND by inserting the exposed wire into the correct DAQ socket and securing it with a 2-mm flathead screwdriver until tight.



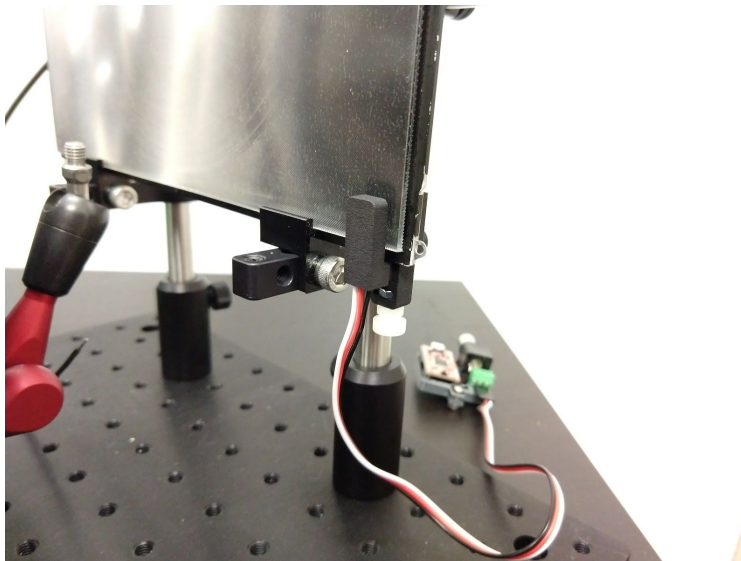
- 4.3. Plug the rotary encoder module into the PC using a microUSB-USB cable.
- 4.4. Connect the 'state machine' output to port 1 of Bpod modules using an ethernet cable. (Note: this is **not** the same port 1 as above, key word here: MODULE)
- 4.5. In Windows Device Manager, under 'Ports (COM & LPT)', find 'USB Serial Device COMX', where X is the number of the COMport. Note this down for the software install.

- 4.5.1. If already installed, in pyBpod, go to Tools -> Rotary encoder module. Type COMX in the Serial Port Window. Check 'Stream data', click 'Start reading', and confirm that the reader gives output when you turn the rotary encoder around.

5. Connect the photodiode (frame2TTL)

The frame2TTL records when the screen updates to a new frame by detecting brightness changes of a flickering square in the bottom right corner of the screen during a task.

- 5.1. IBL Frame2TTL comes with a customized clip to fit on the iPad screen and an IR filter to block incoming light from the IR light in the rig.
- 5.2. Clip to the right lower corner of the screen, where a white/black square will flash at every screen refresh.
- 5.3. Later, when you run the task, make sure the Frame2TTL covers the whole flashing square.



- 5.4. Connect the Frame2TTL module board to a USB port on the computer using a USB - microUSB cable.
- 5.5. Connect a male/male BNC cable from Frame2TTL to the Bpod state machine connector labeled "TTL I/O In1".

6. Connect the environmental sensor

The ambient sensor records the temperature, humidity, and air pressure in the rig while a task is running.

- 6.1. Connect the ambient sensor to a Bpod module port #2 using an ethernet cable as shown below.

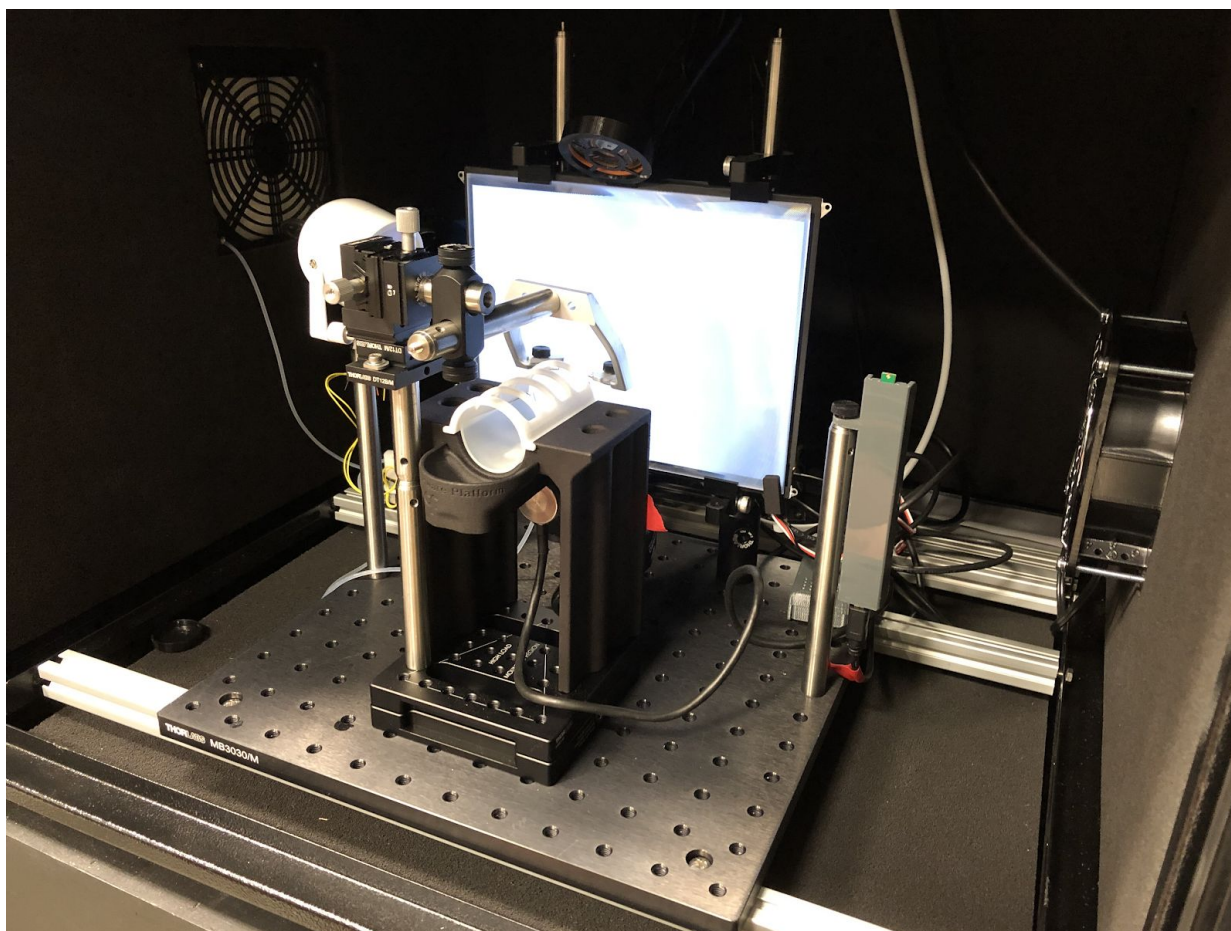


- 6.2. Do **not** connect the ambient sensor to the computer with a USB cable.
- 6.3. Place the ambient sensor in the far right corner of the base breadboard with Velcro tape.



Finished product

Congratulations! You have built the hardware for an IBL rig! Your finished product should look something like this:



Your next step is to get everything working by installing and configuring the software that controls the IBL rig, see **Software** section below.

Software

- **General**

- ***Introduction***

The IBL rig software is run through [pybpod](#), a python implementation of the open-source software for controlling a [Sanworks](#) Bpod; and [Bonsai](#) an open-source visual reactive programming language ([Lopes et al., 2015](#)). The Python language replaces the previous Bpod standard of MATLAB, reducing the cost barrier for use of Bpod and further reducing reliance on closed-source products in neuroscience. Those softwares run on a Lenovo PC, called the “Behavior PC”.

Please note that the rig software, data acquisition, extraction and transfer pipeline currently do not work without the Ayx database. The IBL is working on new software developments that would allow for the rig software, data acquisition and extraction to be run locally without the need for the Alyx database.

Instructions on setting up the Alyx database for your lab can be found on [GitHub](#) and more details on its usage and description can be found in the [documentation](#) and in the International Brain Laboratory (2019), Appendix 5: IBL Alyx User Guide.

- ***How to find COM ports***

- Go to Device Manager on Windows.
- Unplug and replug the USB cable onto the PC and see what COM port disappears and reappears (after plugging it in for the first time, it may take a few seconds to appear under COMports).
- For each rig, list the COMports associated with the State Machine, Rotary encoder, Frame2TTL and Ohaus scale.

- **Behavior PC - graphics and video cards setup**

The “stimulus computer” controls stimulus display and water delivery, and acquires the mouse’s movements on the steering wheel and the output of a photodiode to synchronize stimulus output with other measurements. It runs Windows 10. The computer should be connected to the network, ideally through a high-speed connection (not WiFi).

Sanworks LLC will have pre-installed the following video and sound cards, and associated drivers:

- Video card: NVIDIA Quadro P600
- Sound card: ASUS Xonar AE

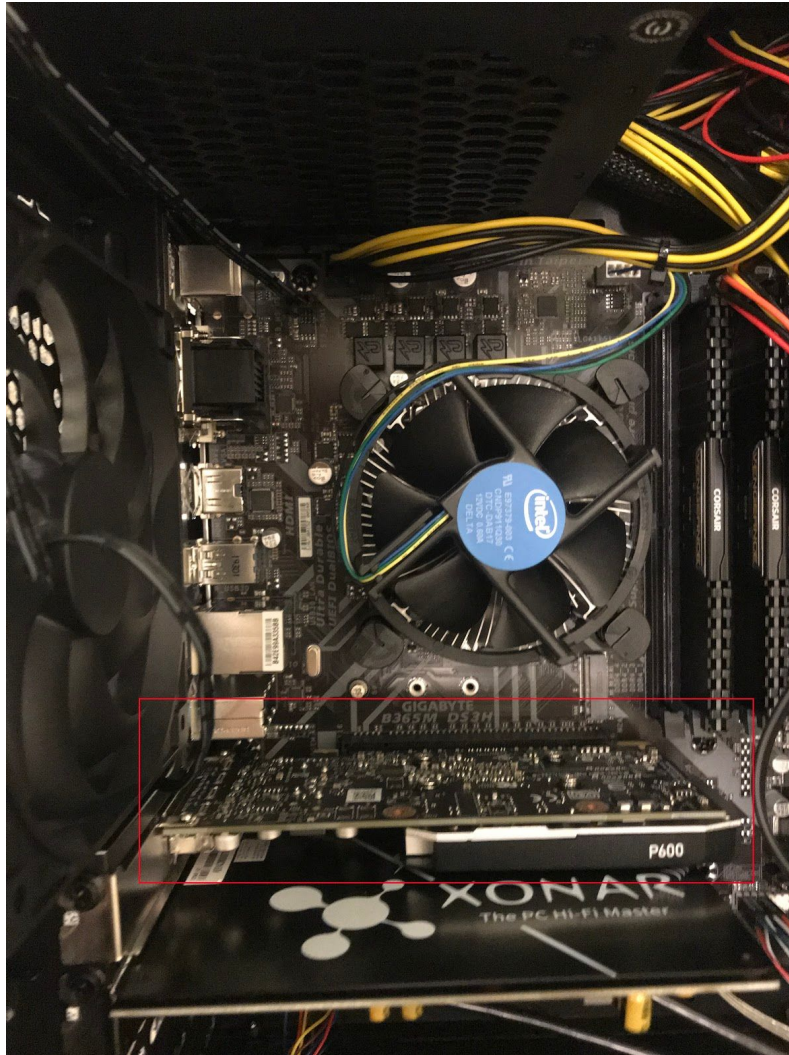
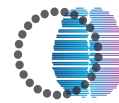
If purchased through Sanworks, you have all the required cards and softwares installed; proceed to the section **Screen Setup**.

- **Installing the video card**

The required video card is the NVIDIA Quadro P600. This card drives the main display monitor and the iPad screen. This is a typical installation that would apply to any card for a Windows machine; if you are not familiar with the process, detailed instructions are below.

Install hardware

1. Ensure your main monitor is connected to the onboard graphics card.
2. If you are removing a currently installed graphics card, open 'Device Manager' and check the 'Display adapters' drill-down menu for the current graphics card.
3. Double-click the graphics device: under the 'Driver' tab, select 'Uninstall' to remove any drivers associated with the current card.
4. After powering down and unplugging the computer, open the case and install the NVIDIA Quadro P600 in the PCI slot (see below, red outline). If you are replacing an existing card, remove it and replace it with the P600.
 - a. If the NVIDIA card is in the PC and you uninstalled the Intel onboard driver it does not give visual output over VGA on the motherboard anymore, you should from then on only use the ports on the video card.



Install software

1. Power up the computer and open 'Device Manager' and check that the 'Display adapters' drill-down menu shows a new object: 'Microsoft Basic Display Adapter,' or similar.
2. Via your browser, [find and download](#), then install, an appropriate driver for your new card
 - a. Use the latest version to date, e.g.

Quadro Desktop/Quadro Notebook Driver Release 450	R450 U3 (452.06)	August 18, 2020
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File name:

452.06-quadro-grid-desktop-notebook-win10-64bit-international-whql.exe

At the time of publication, IBL used the version 411.81.



DOWNLOAD DRIVERS

NVIDIA Driver Downloads

NVIDIA > Download Drivers > Advanced Driver Search

Advanced Driver Search

Product Type:

Product Series:

Product:

Operating System:

Windows Driver Type:

Language:

Recommended/Beta:

SEARCH

3. Back in Device Manager, check that 'Microsoft Basic Display Adapter' has changed to the name of your GPU ('NVIDIA Quadro P600').
4. Restart the computer for changes to take effect.
5. Migrate the main display monitor to an NVS graphics card port using a suitable mini-DisplayPort cable, and confirm that you have visual output.

○ **Installing the sound card**

The speaker is necessary to transmit simple task-related sounds, like beeps and white noise. It is driven by an ASUS Xonar AE sound card that has to be manually placed inside the computer.

Install hardware

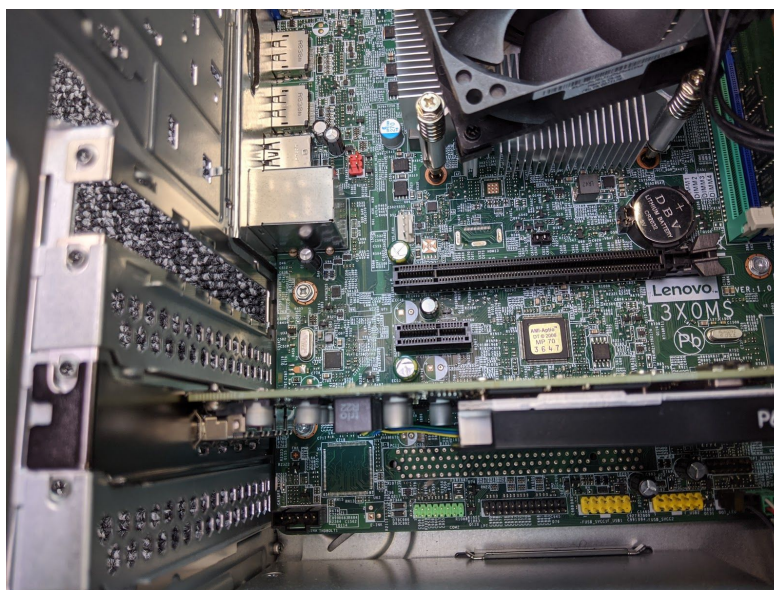
1. Remove the PC cover and open the PCI card retaining clip as shown below:



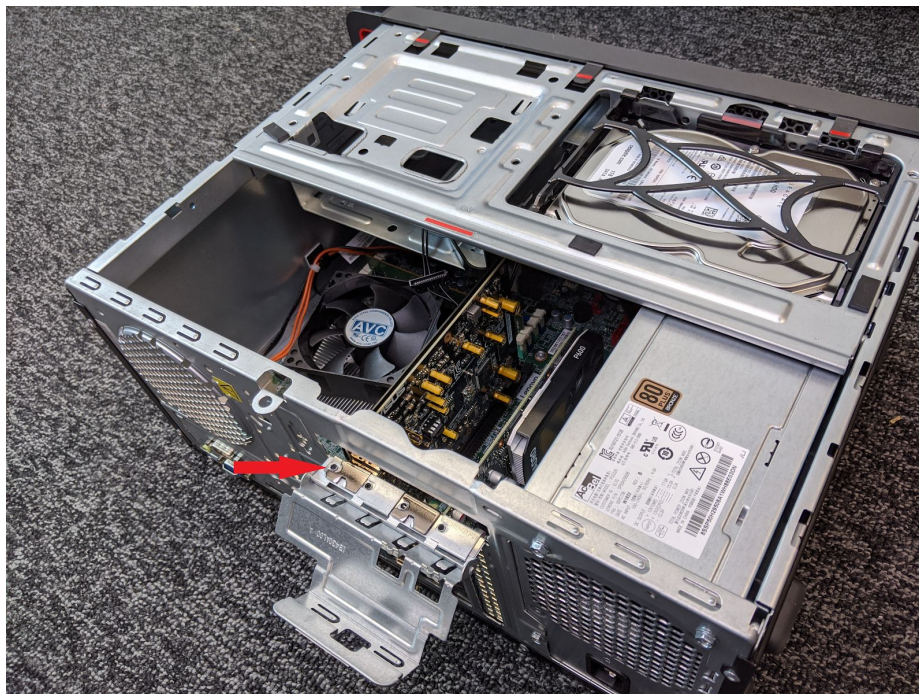
2. The sound card fits into the long 16x PCI express slot directly above the Lenovo logo as



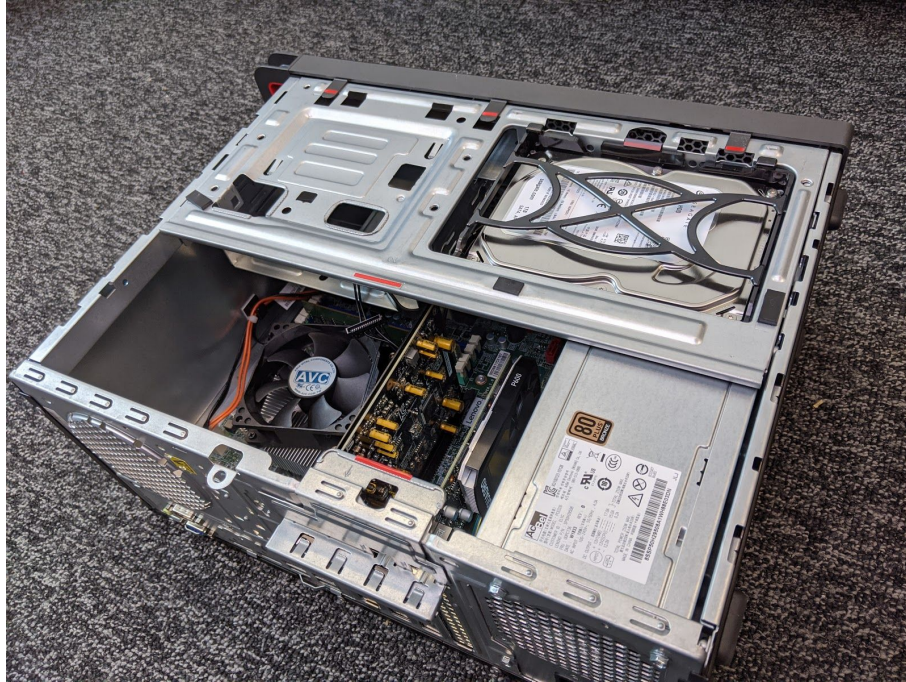
shown below:



3. Press the card into the front part of the PCI express slot (it will not take up all positions). The card is seated correctly if the U-shaped groove in the faceplate rests evenly surrounding the raised metal circle on the chassis (red arrow below)



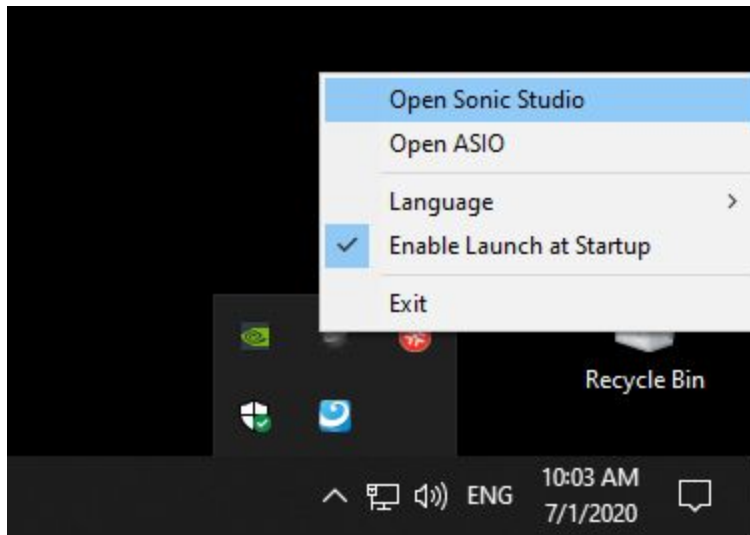
4. Close the PCI card retaining clip as shown below. Then, place the cover back on the PC.



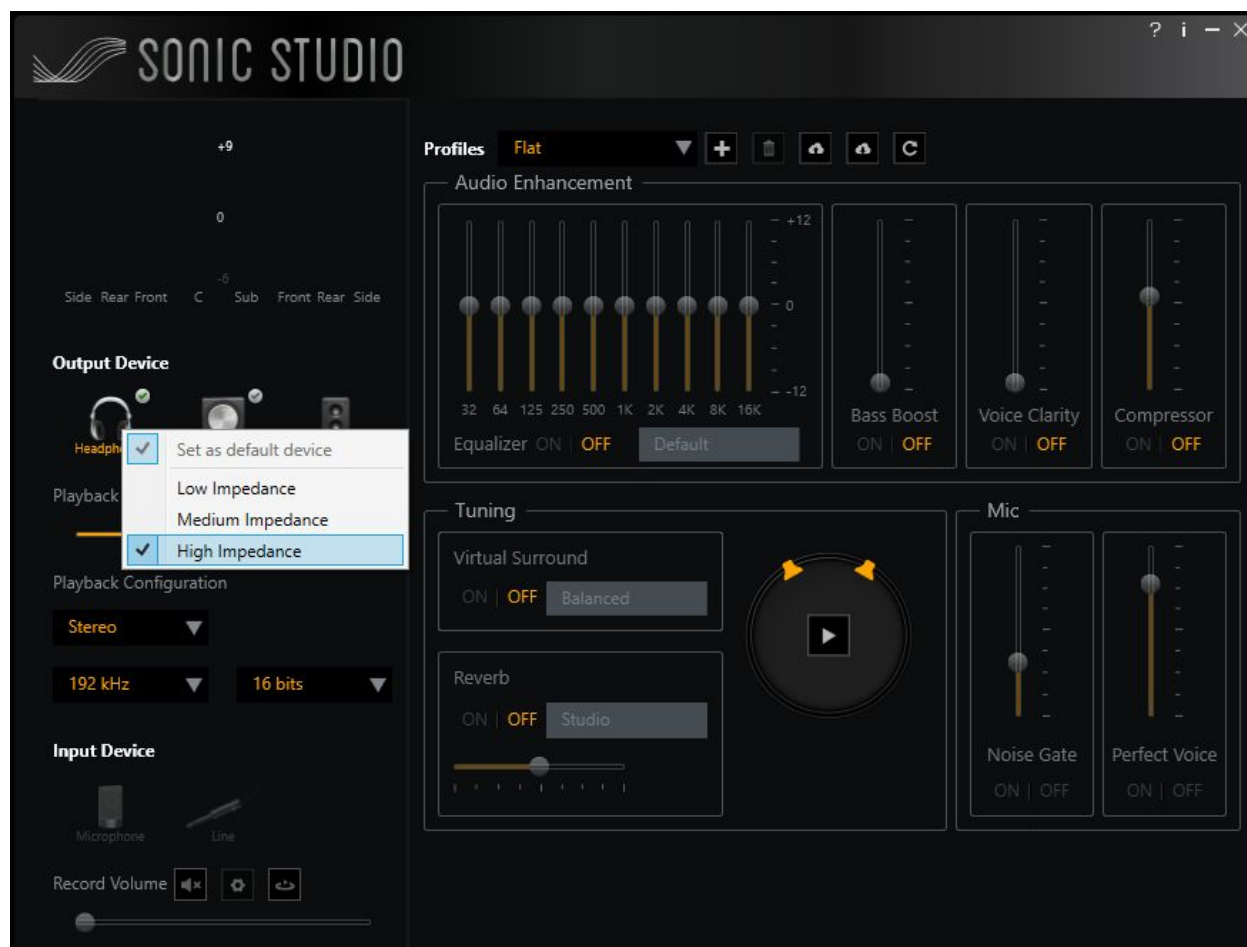
After installing both the video and sound cards, take the cables and wrap them together so they do not touch the motherboard. Tape them to the steel side of the casing with lab tape.

Install software

1. Download and install the ASUS Xonar AE driver from [here](#). Select the Windows 10 64-bit version.
2. Install the driver software using all default settings during the install
3. Once the PC restarts, you should see a new black icon in the system tray. Right-click the icon and select 'Open Sonic Studio'



4. In Sonic Studio,
 - a. Under 'Profiles' select 'Flat'.
 - b. Under 'Output Device' double-click the 'Headphones' icon to select it
 - c. Right-click the headphones icon, and select 'High Impedance'
 - d. Set 'Playback Configuration' to: Stereo, 192kHz, 16 bits



- Under 'Playback Volume' click the 'Gear' icon to configure. Set the left channel level to '20' and the right channel level to '100'.



6. Under 'Profiles', press the '+' button to create a new profile for these settings. Name the profile 'IBL' and click OK.

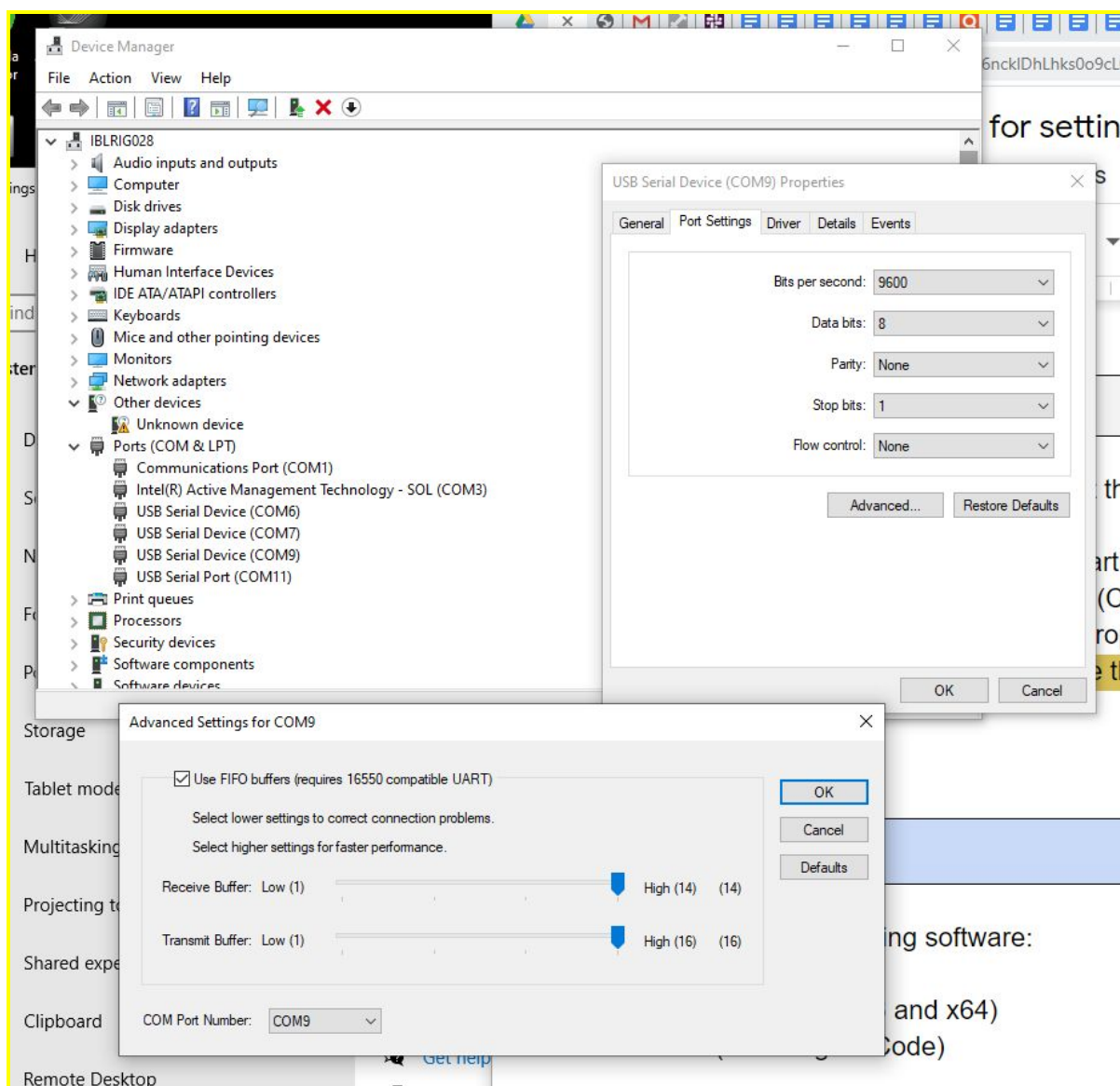




You can now close Sonic Studio.

○ **Other computer settings**

- In Power settings, choose 'performance optimized' so that the PC never goes to sleep. The display can go to sleep after 1 hour of inactivity.
- Set the USB communication latency to 1ms (explanatory article [here](#)).
 - Find the USB driver under Device Manager (Ports (COM & LPT))
 - Right click on USB Serial Port (COM) and select Properties
 - Go to Port Settings, click on Advanced and change the Latency Time (ms) to 1
 - Click OK



● Software Installation

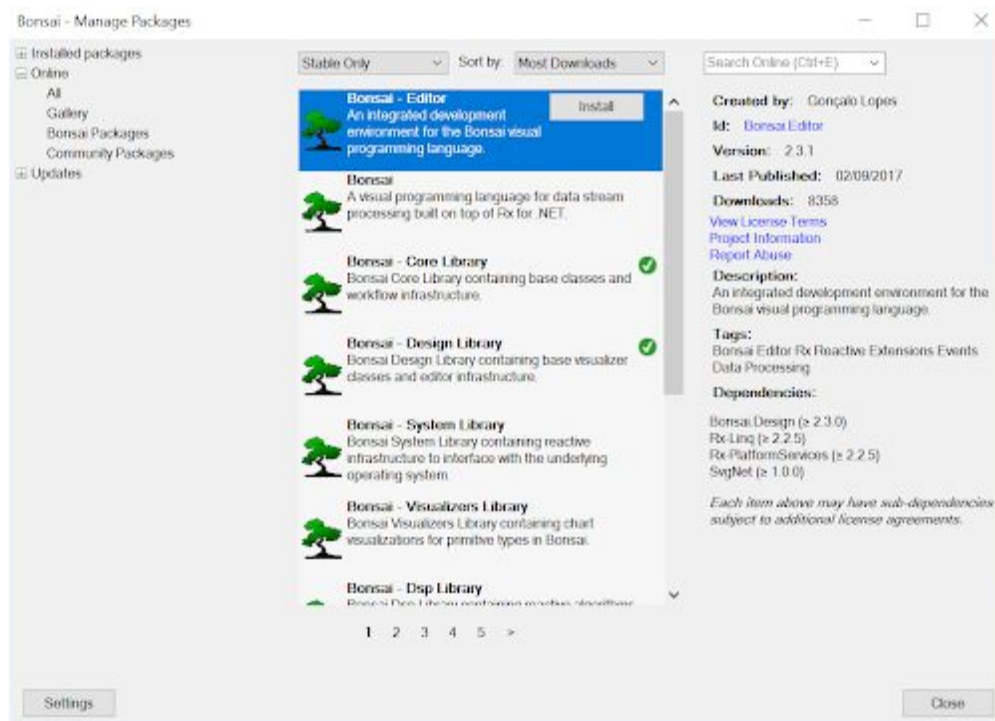
Sanworks LLC will have pre-installed the following software:

- Bonsai dependencies
- FlyCap2Viewer (both x86 and x64)
- Anaconda (including VSCode)
- Git
- iblrig via Git Clone
 (<https://github.com/int-brain-lab/iblrig.git>)
- Video card driver (NVIDIA)
- Sound card driver (Sonic Studio)

You will not need to *install* any further software, but you will need to *setup* some of them. If purchased through Sanworks, you have all required software installed, proceed to the section **Screen Setup**.

Later, if you want to **update** software, see section **Update the software**.

- If not done whilst installing the video card into the PC, download and install the driver for the NVIDIA P600 video card (411.81-quadro-grid-desktop-notebook-win10-64bit-international-whql.exe or a later version).
- If not done whilst installing the sound card into the PC, download and install the driver for the Xonar sound card (XonarAE_Setup_1.1.17.exe).
- [Download](#) and install the Bonsai executable. At date of publication the rig uses the version Bonsai2.5.1.exe .
 - Click **Install**
 - Click **Launch**
 - Click **I accept**

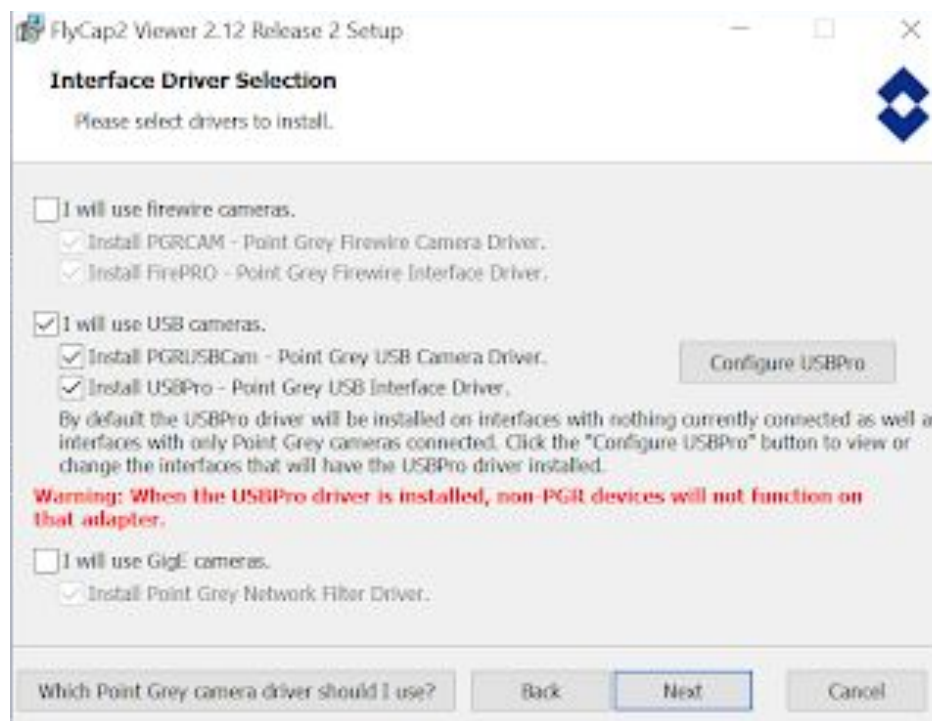


You should now see the Bonsai Package manager (picture above). You do not need to install any packages manually. Click **Close**

- Download and install the 64 bit (FlyCap2Viewer_2.12.3.2_x64.exe) and the 32 bit (FlyCap2Viewer_2.12.3.2_x86.exe) drivers for FlyCap. These executable files cannot be distributed openly, but can be accessed via the camera manufacturer [website](#) once a camera is purchased.

■ **x86 :**

- Click **Install**
- Click **Next / I accept - Next / Next**
- Install for **Anyone who uses this computer / Next**
- Interface Driver Selection : Select **I will use USB cameras (all)**, ignore the warning



- Click to confirm / **Next / Install**
- Click **OK**

■ **x64 :**

- Note: if you get the following error message, make sure you finish and close the x86 installation program before launching the x64 exe:



- Click **Install**
- Click **Next / I accept - Next / Next**
- Install for **Anyone who uses this computer / Next**
- Interface Driver Selection : Select **I will use USB cameras (all)**, ignore the warning
- Click to confirm / **Next / Install**
- Click **OK**

- Download and install [Anaconda for Windows](#). Use the latest version.
- When prompted by the Anaconda installer, install VSCode (if error pops up, press **ignore** button). Check that VScode is installed.
- Open an Anaconda command prompt and input the following commands:
 - When prompted to install Bonsai input Yes (y).

```
conda install git
cd C:\
git clone https://github.com/int-brain-lab/iblrig.git
cd iblrig
python install.py
```

● Sound Setup

- Open Sonic studio (Asus xonar AE) by right clicking on the icon (black) in the bottom right notification area of Windows or searching for Asus xonar AE.
- Load the 'Flat' profile (or set all filters to 'OFF') and save the profile with the name 'IBL'.
- Connect the speaker to the headphone jack and right-click the headphones in the interface, select 'high impedance'. This will make your sound card output a TTL up to 3VDC simultaneously to sound production.
- Click the gear icon close to the headphones and set the volume of the left speaker to 20% and the right speaker to 100%.
- Do NOT change the system volume after setting up Sonic Studio.

● Screen Setup

- Make sure the PC screen goes in slot 1 and Ipad screen in slot 2 of the video card from the left of the graphics card (as per the hardware guidelines).
- If the iPad screen is providing a distorted image, see **Troubleshooting** section.
- Set your background color to grey.
 - Set **128, 128, 128** for each RGB channel. Don't use the Windows-provided greys!
 - This is done so that the mouse does not see a change in luminance when Bonsai starts.
- Remove the task bar from the iPad screen (explanatory article [here](#)).
 - Right-click on the Taskbar, 'taskbar settings'.

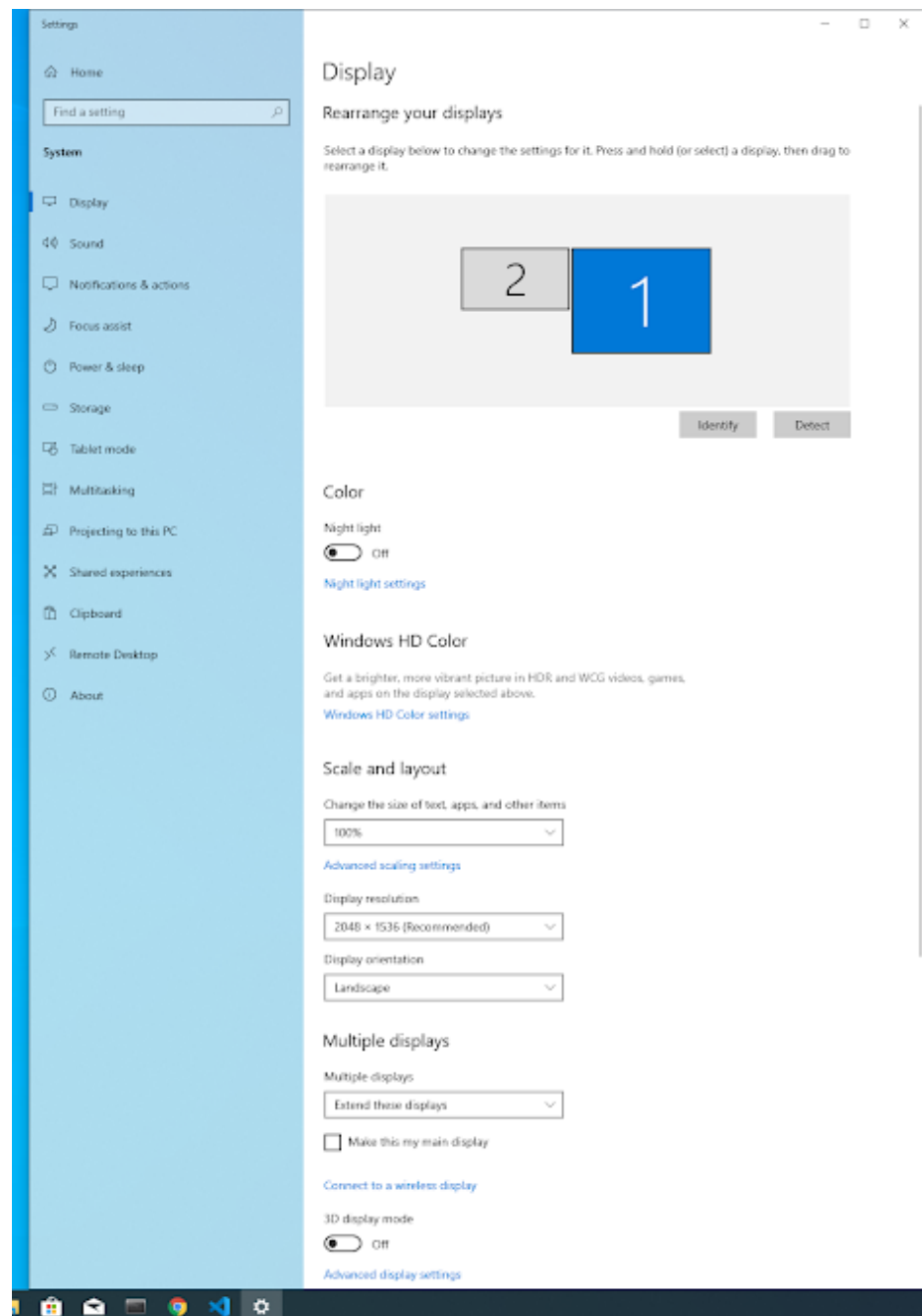


- Under 'Multiple displays', turn "Show taskbar on all displays" off.
- Confirm that the iPad screen is completely grey.

- Go onto Display settings (right click on the desktop background).
- Make sure the iPad screen is screen number 1 and the PC screen is screen number 2.
- Select the PC screen, and tick 'Make this my main display'.
- Set the resolution of the iPad screen to 2048x1536.



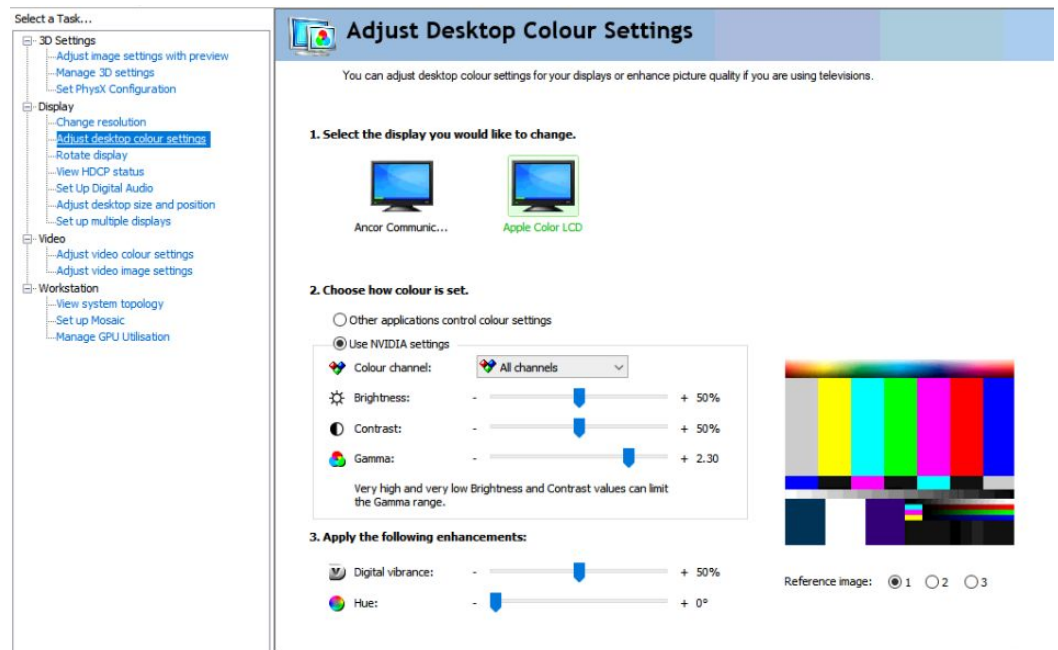
- Set 'change the size of text, apps, and other items' to 100%.



- If you find that the visual stimulus appears on the wrong screen, see the [General software troubleshooting](#) section.
- Calibrate your screen by accessing the “NVIDIA Control Panel” by right clicking on your desktop.
 - Under display select Adjust desktop colour settings.
 - Under **1. Select the display you would like to change** Select Apple Color LCD.



- Under **2. Choose how color is set** Select Use NVIDIA settings set the gamma to 2.35 .



- Go back to the [Screen building section](#), and follow the instructions there to confirm that the luminance is 50-60 lux across the screen.



● Camera Setup

- Open FlyCapture2, a camera should be listed in the Camera list. Select it and press 'Configure Selected'.
 - Uncheck all marks at 'Auto'.
 - Check the two marks at 'On/Off'¹.
 - Set 'Frame Rate' to 30 .
 - Set 'Exposure' to 0.7 .
 - Set 'Shutter Speed' to 10 .
 - Set 'Gain' to 12 .

☒ Absolute Mode

			Auto	On/Off	One Push
Brightness		1.953 %			
Exposure		0.700 EV	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Sharpness		1024			
Hue					
Saturation					
Gamma		1.000			
Iris					
Focus					
Zoom					
Pan					
Tilt					
Shutter		9.998 ms	<input type="checkbox"/>		<input type="checkbox"/>
Gain		11.987 dB	<input type="checkbox"/>		<input type="checkbox"/>
FrameRate		30.016 fps	<input type="checkbox"/>	<input checked="" type="checkbox"/>	

Note: once entered, the numbers will become approximations of the number above - this is fine.

Note: If you're unable to check the 'On/Off' button and the framerate doesn't change, make sure 'Enable/disable trigger' under 'Trigger/strobe control' is **unchecked**.

- Select 'Trigger/Strobe' in the menu on the left.
 - Under 'Trigger Control' check 'Enable / disable trigger'.
 - Under 'GPIO 2'
 - check 'Enable strobe for this pin'

¹ After checking Enable trigger in the Trigger Control menu, it is not possible to change anything in this menu anymore. So first, uncheck Enable trigger and set all the values correctly (frame rate etc); then check Enable trigger again. After doing this the values in the first menu will jump to some arbitrary number. But when unchecking Enable trigger (this is what Bonsai does automatically when recording video) the correct values should return.



- set 'Duration' to **10** .
- Set Polarity to **High**
- Under 'Pin Direction Control' set 'GPIO 2' to 'Out' and all the others to 'In'.

Trigger Control	Trigger Delay	Pin Direction Control
<input checked="" type="checkbox"/> Enable / disable trigger Mode: <input type="text" value="0"/> Parameter: <input type="text" value="0"/>	<input type="checkbox"/> Enable / disable delay <input type="text" value="0.0000"/> Min trigger delay: 0.00000s Max trigger delay: 0.00000s	This is usually only used to manually set pins as input without setting them as a trigger source. GPIO 0: <input checked="" type="radio"/> In <input type="radio"/> Out GPIO 1: <input checked="" type="radio"/> In <input type="radio"/> Out GPIO 2: <input type="radio"/> In <input checked="" type="radio"/> Out GPIO 3: <input checked="" type="radio"/> In <input type="radio"/> Out
Trigger Source <input checked="" type="radio"/> GPIO 0 <input type="radio"/> GPIO 1 <input type="radio"/> GPIO 2 <input type="radio"/> GPIO 3 <input type="radio"/> None	Software Trigger <input type="button" value="Fire Software Trigger"/>	
Trigger Polarity <input checked="" type="radio"/> Low <input type="radio"/> High		
Strobe Control		
GPIO 0 <input type="checkbox"/> Enable strobe for this pin Polarity <input type="radio"/> High Delay: <input type="text" value="0.00"/> <input type="radio"/> Low Duration: <input type="text" value="0.00"/>	GPIO 1 <input type="checkbox"/> Enable strobe for this pin Polarity <input checked="" type="radio"/> High Delay: <input type="text" value="0.00"/> <input type="radio"/> Low Duration: <input type="text" value="10.00"/>	
GPIO 2 <input checked="" type="checkbox"/> Enable strobe for this pin Polarity <input checked="" type="radio"/> High Delay: <input type="text" value="0.00"/> <input type="radio"/> Low Duration: <input type="text" value="10.00"/>	GPIO 3 <input type="checkbox"/> Enable strobe for this pin Polarity <input checked="" type="radio"/> High Delay: <input type="text" value="0.00"/> <input type="radio"/> Low Duration: <input type="text" value="10.00"/>	

- Under 'Advanced Camera Settings' check **Timestamp**, **Frame counter** and **GPIO pin state**

Embedded Image Information
Select the frame-specific information to be embedded in the image.

<input checked="" type="checkbox"/> Timestamp	<input type="checkbox"/> White balance
<input type="checkbox"/> Gain	<input checked="" type="checkbox"/> Frame counter
<input type="checkbox"/> Shutter	<input type="checkbox"/> Strobe pattern
<input type="checkbox"/> Brightness	<input checked="" type="checkbox"/> GPIO pin state
<input type="checkbox"/> Exposure	<input type="checkbox"/> ROI position

- Save your settings
 - Select 'Advanced Camera Settings' in the menu on the left.
 - Under 'Memory Channels' set 'Channel' to 1 .
 - Click 'Save'.

Memory Channels

Channel: 1 ▾

Note: Saving to the default memory channel restores the camera to factory defaults.

Save

Restore

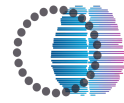
- **PyBpod Setup**

- ***BPod board setup***

- To start the pyBPod interface type the following commands in an Anaconda prompt.
 - Make your life easier by creating a shortcut to the C:\iblrig folder: search for 'Anaconda Prompt' in the task bar, then right-click 'Open file location'. Right-click on the Anaconda Prompt shortcut, 'Properties', and enter C:\iblrig under 'Start in'. Then double-click on the conda prompt, and Pin it to the taskbar for future use: you'll only have to type 'pybpod' to launch.

```
cd C:\iblrig
conda activate iblenv
pybpod
```

- Select the board under 'Bpod boards' in the left hand of the screen.
- Change the field "Box name" into something following this pattern: `_iblrig_labname_behavior_#` , e.g. `_iblrig_mainnenlab_behavior_1`
- The dropdown menu next to 'Serial port' lists all COM ports associated with hardware components. Select a serial port from the dropdown menu and click 'Load board info' (or if you know which COM port it is, choose that one).
- If you get an error select a different port until the list with events fills when you click 'Load board info'.



Box name

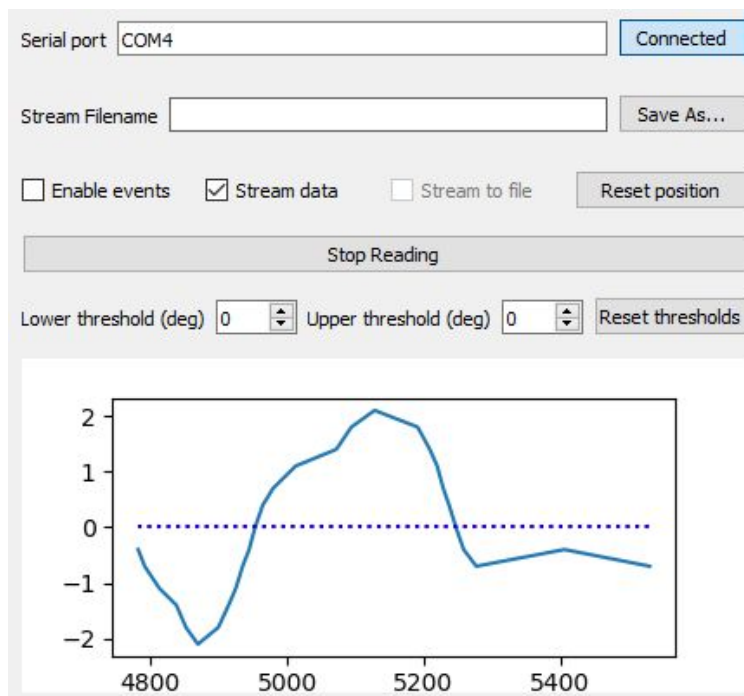
Serial port

Net port

- Once you connect under the 'Load board info' button there are several tabs. Select 'Ports' and make sure the following ports are checked: BNC1, BNC2, and Port1.
- BNC1 will receive the Frame2TTL pulses to synchronize the visual stimulus.
- BNC2 will receive a TTL on sound onset.
- Port1 will receive a TTL every time the camera collects a frame.

○ ***Rotary encoder setup***

- In the bar at the top of the screen click 'Tools' » 'Rotary Encoder'
- In the field next to 'Serial port' type in one of the remaining COM ports listed at point 5.4 and click 'Connect'. If you get an error keep trying other ports.
- Check 'Stream data' and click 'Start Reading'
- Check whether the rotary encoder is working by turning the wheel in the setup



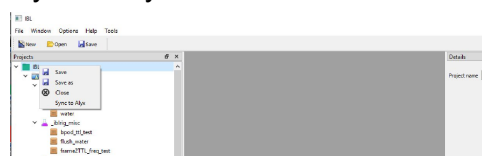
- Note down the COM port (a prompt will ask you for this when you run your first task) and click 'Disconnect' to disconnect

○ **Frame2TTL setup**

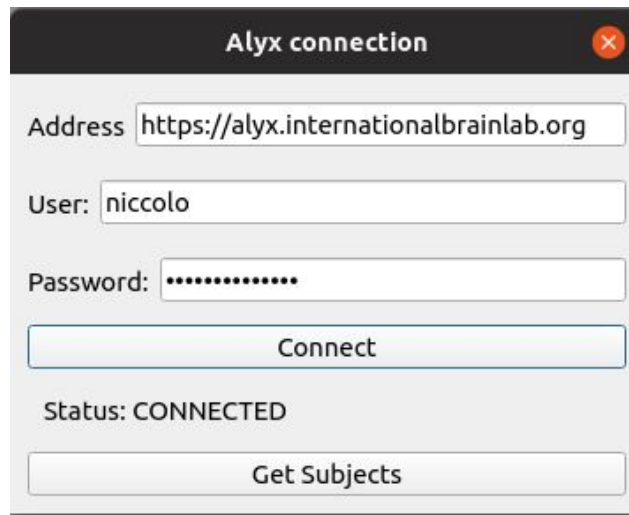
- Install USBTree viewer (UsbTreeView.exe)
- Open USBTree viewer and disconnect and connect the USB cable of the Frame2TTL to find out which COM port belongs to it, note this down (you will also be prompted for this when running your first task)
- If you wish to change your COM ports at any time, you can do this in `iblrig_params\iblrig_params.json`

○ **Alyx module setup**

- If you do not already have an Alyx database set up for your laboratory, follow the instructions on [GitHub](#).
- Right click on the project name in the top left of the window and click 'Sync to Alyx'.



- Input your username and password and click 'Connect'.
 - If you do not have a username, contact your Alyx administrator.
 - Click on 'Get subjects' to retrieve subject information from Alyx.


 A screenshot of a software window titled "Alyx connection" with a close button (X) in the top right corner. The window contains three input fields: "Address" with the text "https://alyx.internationalbrainlab.org", "User:" with the text "niccolo", and "Password:" with masked characters ".....". Below these fields is a "Connect" button. Under the button, the text "Status: CONNECTED" is displayed. At the bottom of the window is a "Get Subjects" button.

- Click 'Save' in the top left corner of the screen.
- Follow the directions [here](#) to use the ONE.setup() method to set your ONE parameters.
 - *Note: the iblenv does not need to be created/activated again as it was already done previously.*
 - Put in your login after "ALYX_LOGIN" and your password at "ALYX_PWD".
 - Make sure the URL is <https://alyx.internationalbrainlab.org> if you are an IBL member, or your own URL if not.
- Save and close the file.
- Log on to Alyx.
 - NOTE: this does not need to be done every time pybpod is opened unless you need to pull new subjects. To run the task daily, you can run under your username locally (see [Run a protocol](#))
- Click on 'Misc' in the top right corner.
- Click 'Lab Locations'.
- Click 'add lab location' in the top right.
- Add a new lab location matching the name of your BPod board.
 - Some information specific to your setup (e.g. Frame2TTL calibration) will be saved here.

● Calibration

○ *Frame2TTL calibration*

- Activate your user, select `calibration_mouse`, and run the `frame2TTL` protocol.
- Make sure that the door to the rig is closed, the IR light is turned on (should be warm to the touch), and that the Frame2TTL is secured tightly to the bottom right corner of the screen.
- If a threshold cannot be recommended, make sure you have the IR shield for the Frame2TTL properly connected.

○ *Water calibration*

- Make sure your scale is connected to the PC via USB

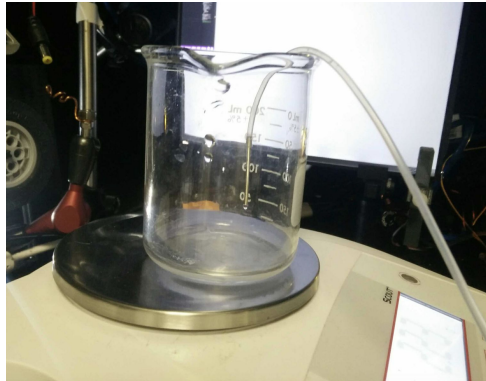


Image reference: [scale\[2\]](#), [cable\[3\]](#).

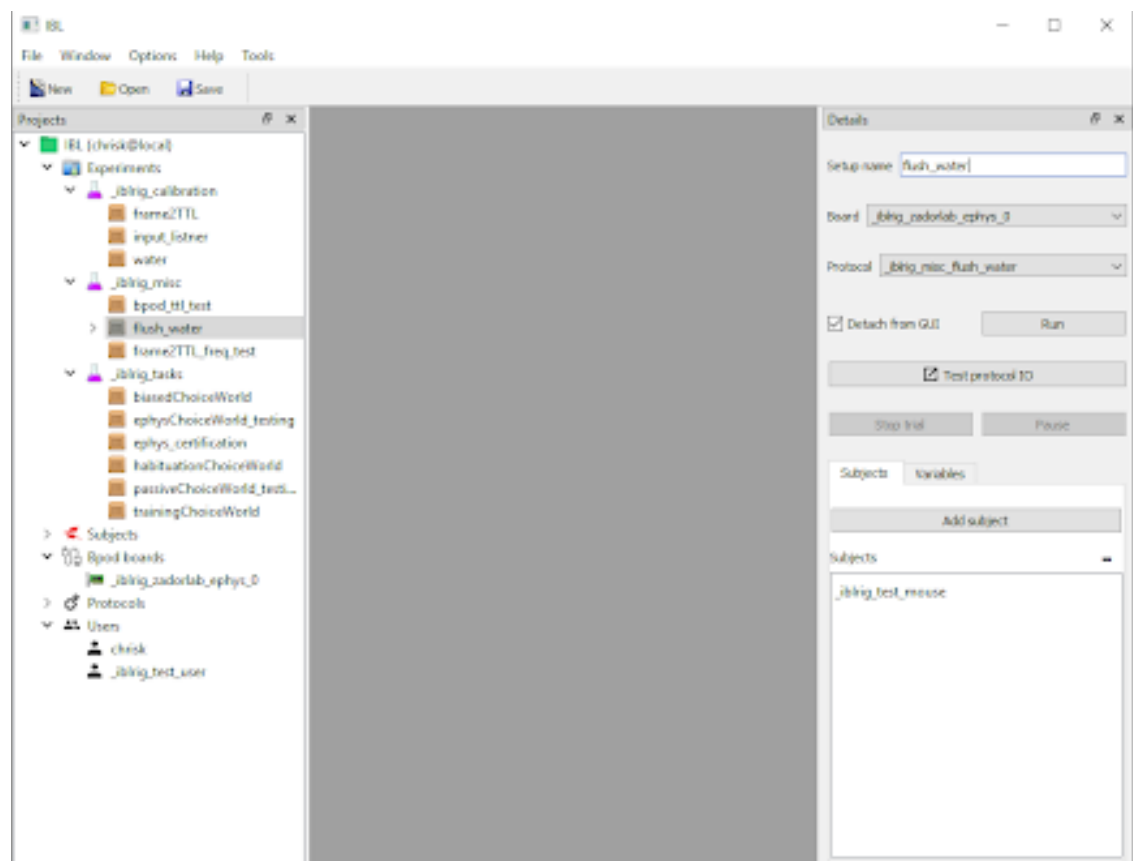
[Alternatively this can be done with a non USB enabled scale with the values entered manually, see below]

- Find the COM port number of the Ohaus scale.
- Edit the number of the COM port in the variable `OA_HUS_SCALE_PORT` in line 11 of `C:\librig_params\IBL\tasks\librig_calibration_water\task_settings.py` file


```
OA_HUS_SCALE_PORT = None # 'COM2' # Set to None for manual weight logging
```
- Make sure the water from the rig can drip into a cup placed on the Ohaus scale. Tare before you begin. The stainless steel tip should not touch the cup, see image below.



- In Pybpod: Flush water > Run.
- Under 'Subjects', select '_iblrig_test_mouse'.
- Under 'iblrig_misc', select 'flush_water' and run -this is done first to make sure nothing obstructs the flow and no air bubbles remain in the tubing. Once water freely flows, stop the 'flush_water' protocol.



- Fill the syringe.
- In Pybpod: run water calibration.
 - Under 'Subjects', select 'iblrig_calibration'.
 - Under 'iblrig_calibration', select and run 'water'.

- In the Anaconda Prompt, you'll see the ETA of the procedure. When completed, an overview figure (PDF) will be saved in
`C:\iblrig_data\Subjects_iblrig_calibration\<<date>\<session_number>\raw_behavior_data_iblrig_calibration_water_curve.pdf`

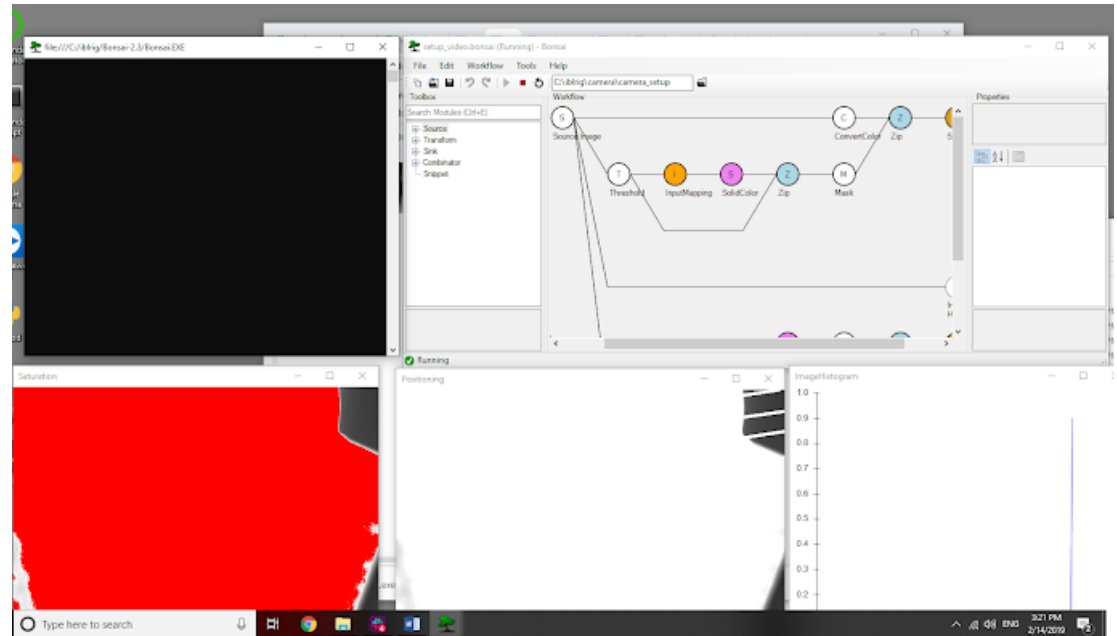
○ Calibrate the camera

Note: This calibration step aims at ensuring the pupil and other body parts tracked by the camera are well visible. This step necessitates a mouse to be placed in the setup.

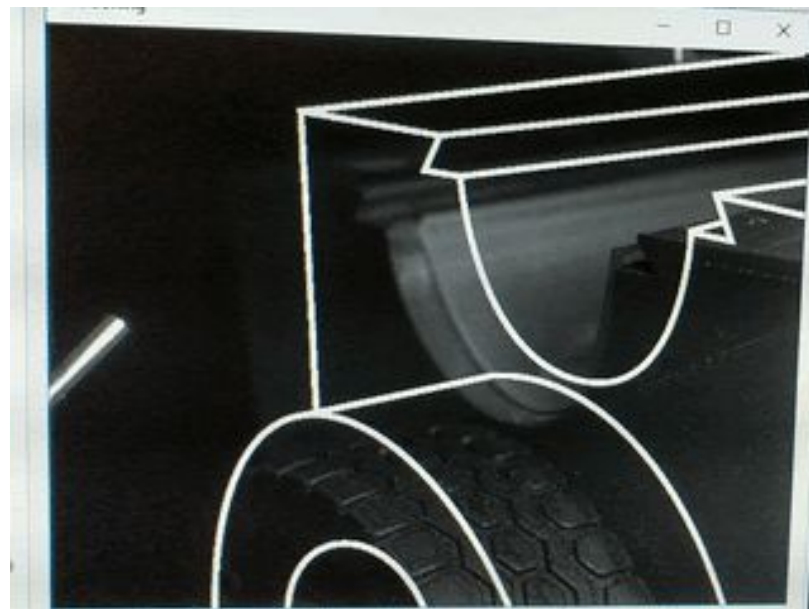
- There are two sliders on the camera lens: one for the focus and one for the aperture. Familiarize yourself with which slider is which.
- The focus slider changes where the camera produces a sharp image (FAR <-> NEAR slider)



- The aperture slider changes the amount of light that comes into the camera (C <-> O slider)
- Run the video setup Bonsai workflow
- Run Bonsai by opening `C:\iblrig\Bonsai-2.3\Bonsai64.exe`
- Open this workflow in Bonsai (File > Open):
`C:\iblrig\devices\camera_setup\setup_video.bonsai`
- Press **Play** (green arrow on top bar of the Bonsai GUI), 3 windows should appear (Saturation, Positioning, ImageHistogram)

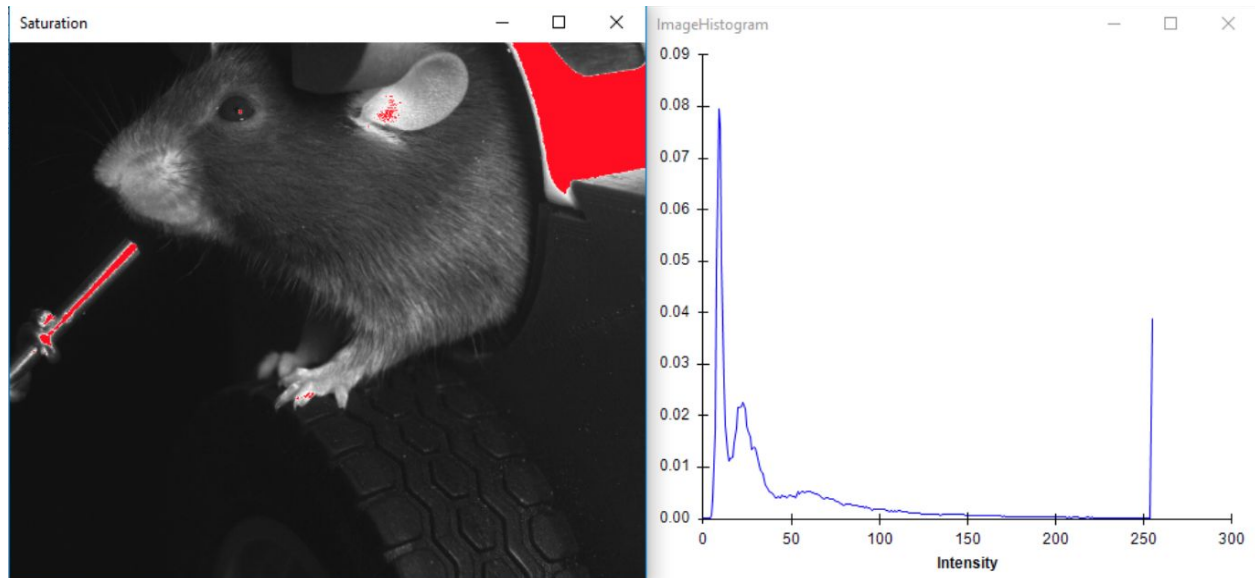


- Position the camera so that the white outlines overlay with the setup in the screen 'Positioning'



- Put a mouse in the setup
- Focus the camera on the eye
- Position the IR light in such a way that the mouse is maximally illuminated
- Close the aperture slider on the camera lens completely by sliding the aperture slider towards 'C' (closed), then open the aperture slowly until you get the following result:
- The red pixels in the 'Saturation' window indicate saturated pixels. Open the aperture slowly until you have a few saturated pixels on the paws and

ear but nothing on the rest of the animal. The spout and the mouse cover can saturate.



- **Hardware connection test**

Launch a test to check the connection between the Bpod and its modules.

- Run the protocol `bpod_ttl_test` (under Experiments > `_iblrig_misc`) to make sure frame updates and go tones are properly synchronized (see below section on how to run a protocol). If this runs correctly, the final anaconda prompt output should look as below.



```

2019-10-16 11:13:07.052 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 1981
2019-10-16 11:13:08.09 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 1982
2019-10-16 11:13:08.177 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 1983
2019-10-16 11:13:08.278 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 1984
2019-10-16 11:13:08.483 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 1985
2019-10-16 11:13:08.502 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 1986
2019-10-16 11:13:08.615 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 1987
2019-10-16 11:13:08.825 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 1988
2019-10-16 11:13:08.935 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 1989
2019-10-16 11:13:09.45 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 1990
2019-10-16 11:13:09.170 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 1991
2019-10-16 11:13:09.319 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 1992
2019-10-16 11:13:09.470 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 1993
2019-10-16 11:13:09.619 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 1994
2019-10-16 11:13:09.770 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 1995
2019-10-16 11:13:09.919 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 1996
2019-10-16 11:13:10.70 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 1997
2019-10-16 11:13:10.219 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 1998
2019-10-16 11:13:10.352 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 1999
2019-10-16 11:13:10.485 INFO [ iblrig_misc_bpod_ttl_test.py:81] Starting trial: 2000
2019-10-16 11:13:10.586 INFO [session_params.py:109] Checking...
2019-10-16 11:13:10.689 INFO [session_params.py:133]
=====
TEST PASSED:
=====
Stimulus and tone detected in all trials
=====
main
System.InvalidOperationException: Sequence contains no elements.

```

See Troubleshooting, section ***Bpod_ttl_test failure*** for what to do in case this script fails running.

• Run a Protocol

○ Launch the pyBpod user interface

- From an anaconda prompt, type pybpod
- Select the correct details for the desired Bpod board
- Select the correct user name (experimenter)

Note: PyBpod does not allow you to run a task without a user and a subject.

To "login" as a user you just need to double-click on your user under "users". If your user is not there you can create one by right clicking and editing the name on the right-hand side text box that should have appeared.

○ Run a protocol

- Water and screen calibration protocols, flushing of water and task protocols can be found on the 'Projects' menu (left side of the GUI) under IBL/Experiments.
- To run any of the protocols, click on the protocol and specify the details of the protocol on the 'Details' menu on the right side of the GUI:

- Make sure the correct Bpod board is selected in 'Board' for the experiment to be run;
- Add a subject: click on add subject on 'Subjects' and choose from the list (running a calibration or water flushing protocol also requires specifying a subject - use a mock subject for these);
- The IBL task should be run in detached mode - checkbox to the left of the “run” button.
- Press 'Run' to start the task, calibration or water delivery;
- To stop a protocol press “Stop” and if it does not stop, press “Kill”.
- If you want to adjust something in the rig while a session is running, click "Pause" on the right hand side of the pybpod window, and "Resume" afterwards.

- ***Mouse disengagement warning***

When running the task, computations are done so as to detect when a mouse is disengaged. Criteria can be found in International Brain Laboratory (2020) Appendix 2: IBL protocol for mice training.

The GUI display will change color if a disengagement criterion is reached:

- **Green:** Less than 400 trials in 45 minutes
- **Yellow:** Median response time of latest N = 20 trials > than 5 times the median response time of whole session AND more than 400 trials performed
- **Red:** 90 minutes elapsed since session start

- ***Transfer data to your server PC***

In the IBL, the data acquired on the PC connected to Bpod is then transferred to a local server PC for post-processing and uploading onto the main shared database. For a complete overview of the pipeline, please see International Brain Laboratory et al. (2019) [Data architecture and visualization for a large-scale neuroscience collaboration](#).

If you have a local server PC, proceed to its installation (cf. Appendix material of the Data architecture paper).

- ***Change parameters - Edit the task file***

- Edit the 'task_settings' file if changes in parameters are needed.
 - The 'task_settings' file is located in iblrig_params > IBL > tasks > **the_desired_task_name** > task_settings.
 - For example, for trainingChoiceWorld: https://github.com/int-brain-lab/iblrig/blob/master/tasks/_iblrig_tasks_trainingChoiceWorld/task_settings.py
- To edit general settings, for your rig go to iblrig_params > user_settings
- To edit COM ports go to iblrig_params > .iblrig_params.json

- ***Create a new task from an existing one***

Creating the task

1. The easiest thing to do here is to create a copy the entire folder of an existing task, eg `iblrig_params\IBL\tasks_iblrig_tasks_biasedChoiceWorld` and rename it to the task you want
2. Inside this folder change the name of the task file to match the new name for the folder you created (this should be the name of the task you want to create)
 - a. For simple changes to the task protocol, you should only need to change the task file and the `task_settings` file
3. Copy this folder and paste it into the `iblrig\tasks` folder

Getting your task to appear in the PyBpod Gui

1. Open pyBpod
2. Right click on protocols and select import protocol, navigate to your task file (eg. `iblrig_params\IBL\tasks_iblrig_tasks_biasedChoiceWorld`)
3. Find the task that you based your new task off of in the Protocols list and copy any Post commands from that task to add for your own task
 - a. To add a post command to a task click the + sign by it and under 'Type of Command' select 'Execute a external command', paste what you copied from the original task in the 'external command' box
 - b. You have to do this one command at a time, and I think order can matter here, so add them in the order that they were in on the original protocol
4. To add a 'Setup' Right click on an experiment type (tabs with pink flasks next to them) and select 'add setup'
5. Fill in the name of the experiment you want to run, select your bpod board, and select the protocol you just created. If the protocol is not there, try clicking save then closing and re-opening the gui.
 - a. Check 'Detach from GUI'

This should be sufficient to then select and run your task as any other, if not there is likely some error in your code

• Update the rig software

While the install function assumes nothing, the update function has to run from within the `iblenv` (unless you have git installed system wide). To activate the environment type in an anaconda prompt:

```
(base) C:\iblrig>activate iblenv
```

Then type:

```
(iblenv) C:\iblrig> python update.py
```

This will tell you which version you are on, and ask you if you want to update to the latest version.

For more information on how to update you can use the flags `[-h | -help | ?]` e.g:

```
(base) C:\iblrig>python update.py -h
```




e.g. `python update.py -v 6.4.0` will update to this particular version.

Appendix

Comments and suggestions

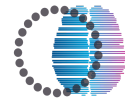
Hardware suggestions

- A glue-on white board sheet can be placed onto the door of each rig.
- To switch the side to which the Orion sound proof box door opens, remove the door by lifting/pushing the tabs on the hinge.
- To make opening and closing the box easier, [3D-printed handles](#) for the Orion box can be made to fit over the key.
- If you are not UK-based and using the Orion box, the fan does not have the proper plug for your outlets. Instead of using an adaptor, open the white box that attaches the fan to its power cable and replace the power cable with an option that matches your outlets.

Note: In the USA, the voltage is lower than the recommended voltage for these fans, but the fan will still run albeit at a lower speed.

Questions and further suggestions

Please send any queries or suggestions to info+behavior@internationalbrainlab.org .



Troubleshooting

Bpod_ttl_test failure

If you cannot run the test `bpod_ttl_test` and obtain an error message such as below:

```
PyBpod
.CALIBRATION_DATE': '2020-10-08', 'IBLRIG_VERSION': None, 'SCREEN_FREQ_TARGET': None, 'SCREEN_FREQ_TEST_STATUS': None, '
SCREEN_FREQ_TEST_DATE': None, 'BPOD_TTL_TEST_STATUS': None, 'BPOD_TTL_TEST_DATE': None} to c:\iblrig_params\iblrig_para
ms.json
2020-10-28 16:53:52.202 INFO [path_helper.py:497] NOT FOUND: PREVIOUS_DATA_FILE
2020-10-28 16:53:52.202 INFO [path_helper.py:497] NOT FOUND: PREVIOUS_SETTINGS_FILE
2020-10-28 16:53:52.202 INFO [path_helper.py:497] NOT FOUND: PREVIOUS_SESSION_PATH
2020-10-28 16:53:52.204 INFO [params.py:135] Writing {'NAME': 'iblrig_hausserlab_behavior_2', 'COM_BPOD': 'COM12',
'COM_ROTARY_ENCODER': 'COM11', 'COM_F2TTL': 'COM10', 'F2TTL_DARK_THRESH': 327.0, 'F2TTL_LIGHT_THRESH': 287.0, 'F2TTL_CAL
IBRATION_DATE': '2020-10-28', 'WATER_CALIBRATION_RANGE': [50.0, 200.0], 'WATER_CALIBRATION_OPEN_TIMES': [50.0, 100.0, 15
0.0, 200.0], 'WATER_CALIBRATION_WEIGHT_PERDROP': [0.9666666666666667, 2.3, 3.9333333333333334, 5.5333333333333332], 'WATER
CALIBRATION_DATE': '2020-10-08', 'IBLRIG_VERSION': None, 'SCREEN_FREQ_TARGET': None, 'SCREEN_FREQ_TEST_STATUS': None, '
SCREEN_FREQ_TEST_DATE': None, 'BPOD_TTL_TEST_STATUS': None, 'BPOD_TTL_TEST_DATE': None} to c:\iblrig_params\iblrig_para
ms.json
2020-10-28 16:53:52.214 INFO [frame2TTL.py:92] Light threshold set to 287.0
2020-10-28 16:53:52.215 INFO [frame2TTL.py:94] Dark threshold set to 327.0
2020-10-28 16:53:52.216 INFO [frame2TTL.py:188] Frame2TTL: Thresholds set.
Traceback (most recent call last):
  File "C:\iblrig_params\IBL\tasks\iblrig_misc_bpod_ttl_test\iblrig_misc_bpod_ttl_test.py", line 49, in <module>
    bonsai_hide_stim = msg.bonsai_hide_stim()
  File "c:\iblrig\iblrig\bpod_helper.py", line 50, in bonsai_hide_stim
    self.rotary_encoder, bonsai_hide_stim, [ord("#"), 1]
  File "c:\users\iblruser\anaconda3\envs\iblenv\lib\site-packages\pybpodapi\bpod\bpod_base.py", line 391, in load_serial_
message
    response = self._bpodcom_load_serial_message(serial_channel, message_ID, serial_message, 1)
  File "c:\users\iblruser\anaconda3\envs\iblenv\lib\site-packages\pybpodapi\bpod\bpod_com_protocol.py", line 487, in _bpod
com_load_serial_message
    message_container = [serial_channel-1, n_messages, message_id, len(serial_message)] + serial_message
TypeError: unsupported operand type(s) for -: 'NoneType' and 'int'
System.InvalidOperationException: Sequence contains no elements.
```

Do the following:

- Try recalibrating the frame2ttl and repeat launching the test.
- If the audio TTL pulses are not detected (shown by error messages such as "missing stimulus sync. pulses" and "missing tone sync pulses" in yellow color), check:
 - in Flycap, that all settings are as suggested above - sometimes there are saving issues.
 - If the problem persists, check the physical connection between the camera, bpod and sound module.
 - Lastly, check if the correct pin on the GPIO cable is connected and chosen in Flycap.



Speaker module

- 1) Confirm the origin of the fault is not the speaker, power or minijack cable.
- 2) Check that the sound module has all switches in the correct position (Fig 1 below):
- 3) Check that all the connections are made in the correct ports (Fig 2 below).

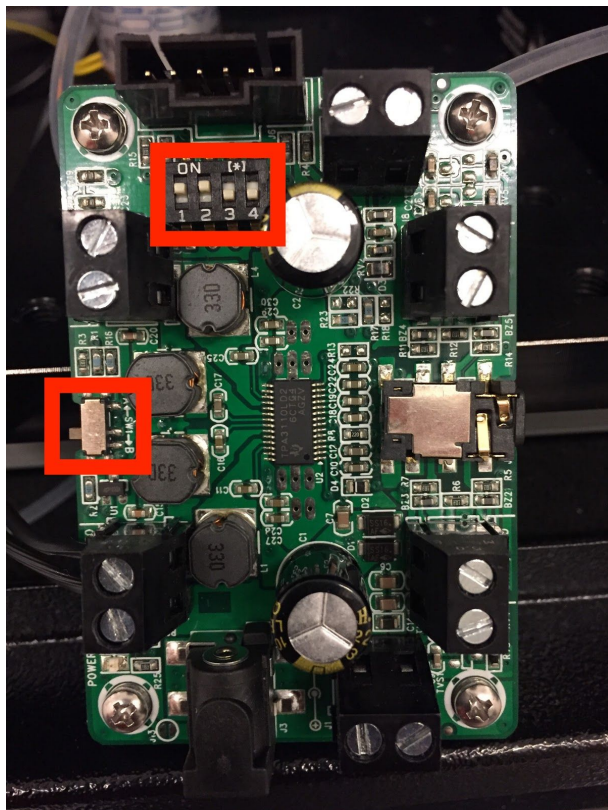


Figure Troubleshooting 1: Sound module switches position.

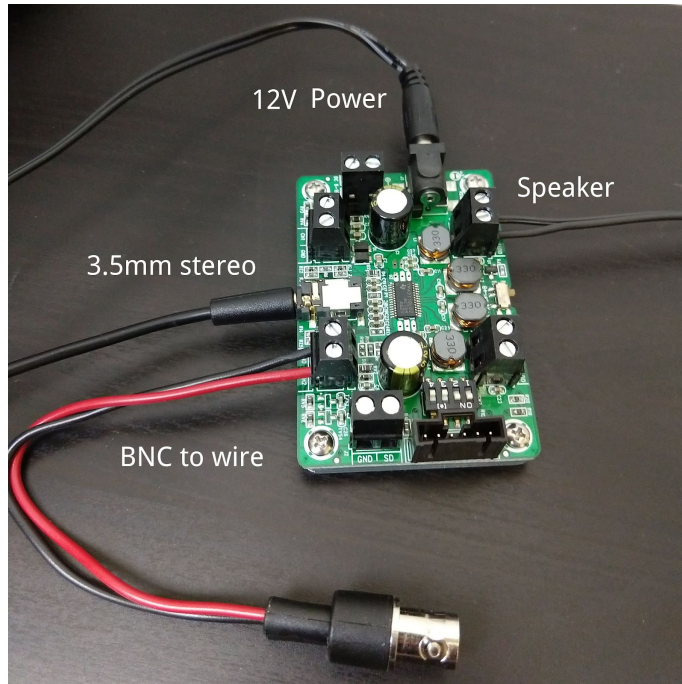


Figure Troubleshooting 2: Sound module connections.

Screen output

- 1) The ribbon cable attaching the screen to the driver board is notoriously finicky. If you are having brightness issues or do not have a signal, try gently repositioning this cable and ensure it is tightly seated in its connection.
- 2) These screens (especially with this cable) can be easily damaged. It is useful to have a backup screen on hand.
- 3) If the Bonsai display is appearing on the PC screen when a task starts, try unplugging the rig screen, rebooting and plugging screen back in. Other variations of screen unplugging and rebooting may also work.
- 4) If your ipad screen looks like the Fig 3 below when you first plug it in, do not worry! This is a common issue and there's a relatively simple fix.

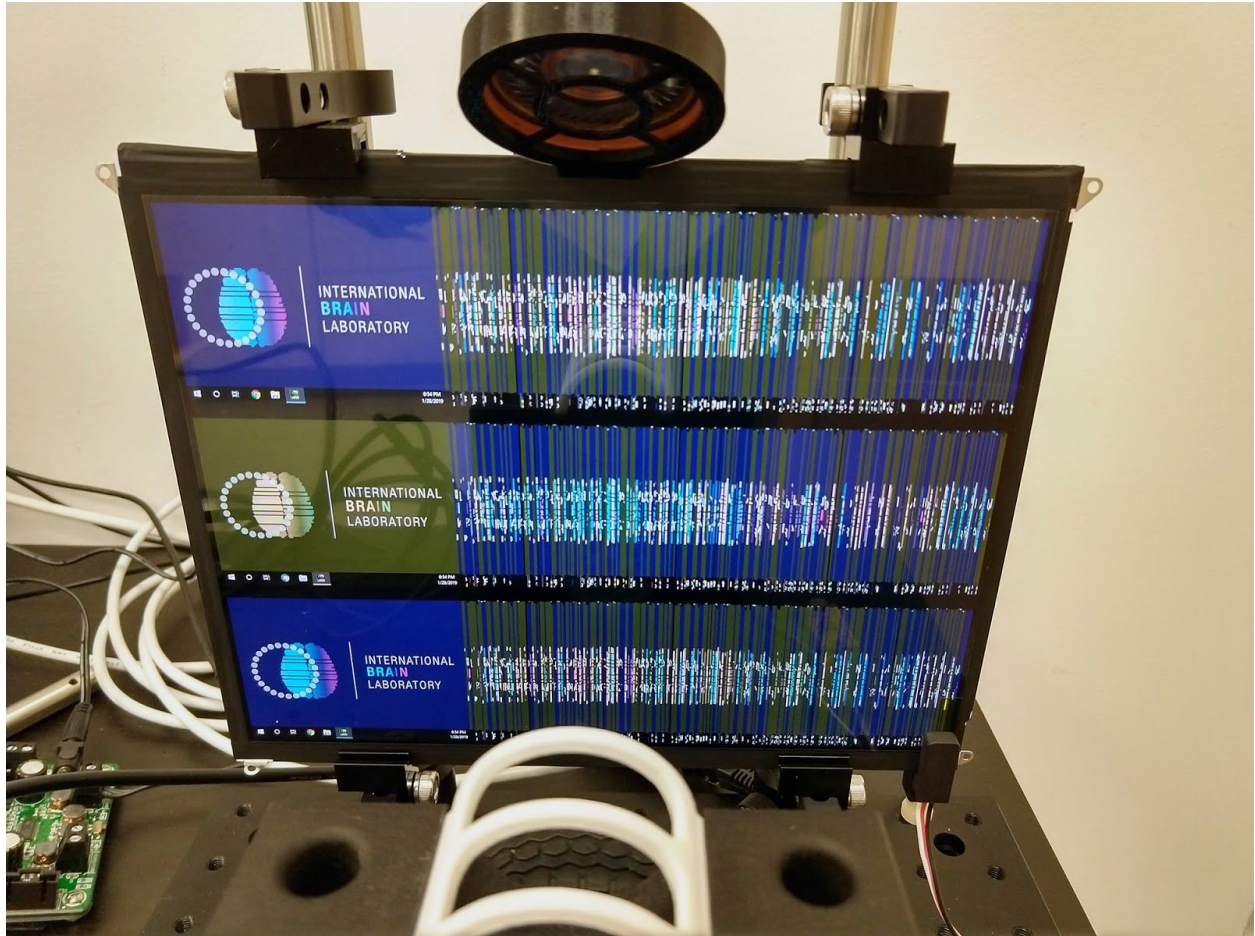
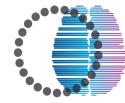


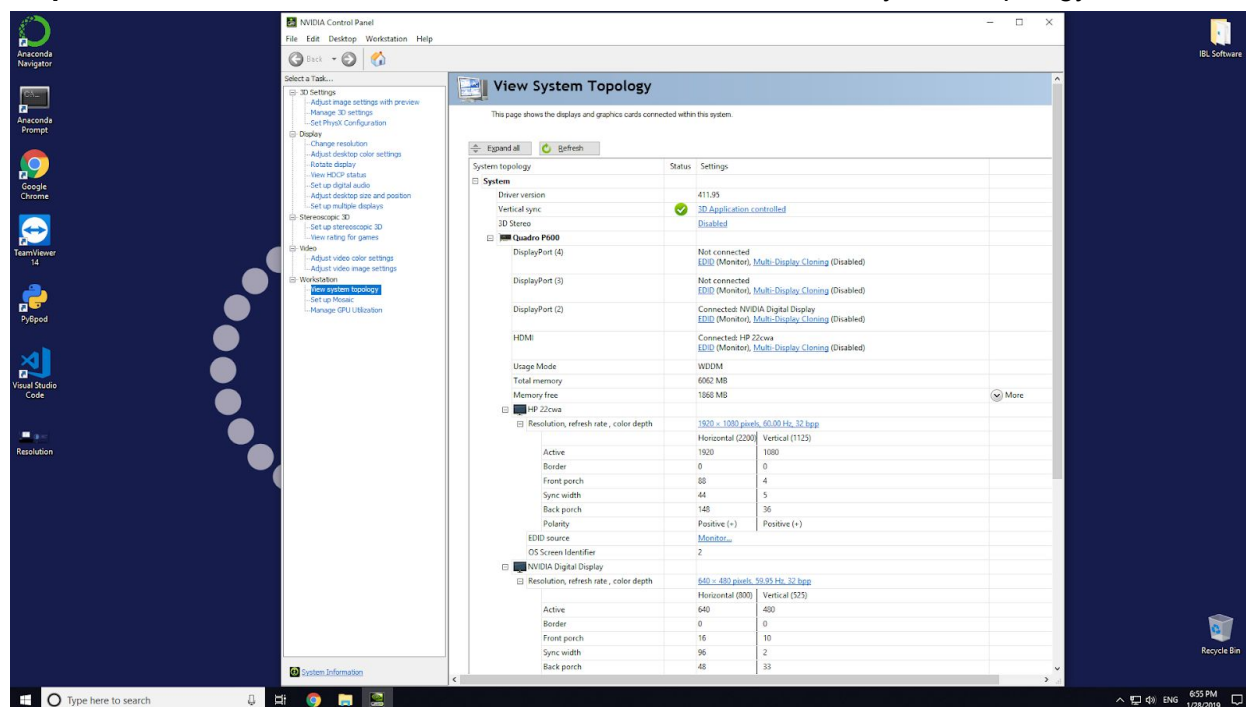
Figure Troubleshooting 3 : Ipad screen displays fuzzy image.

The issue occurs because some of the Adafruit driver boards do not describe themselves properly to the PC. We fix this by pointing the PC to a file with the proper ipad screen description - an EDID file.

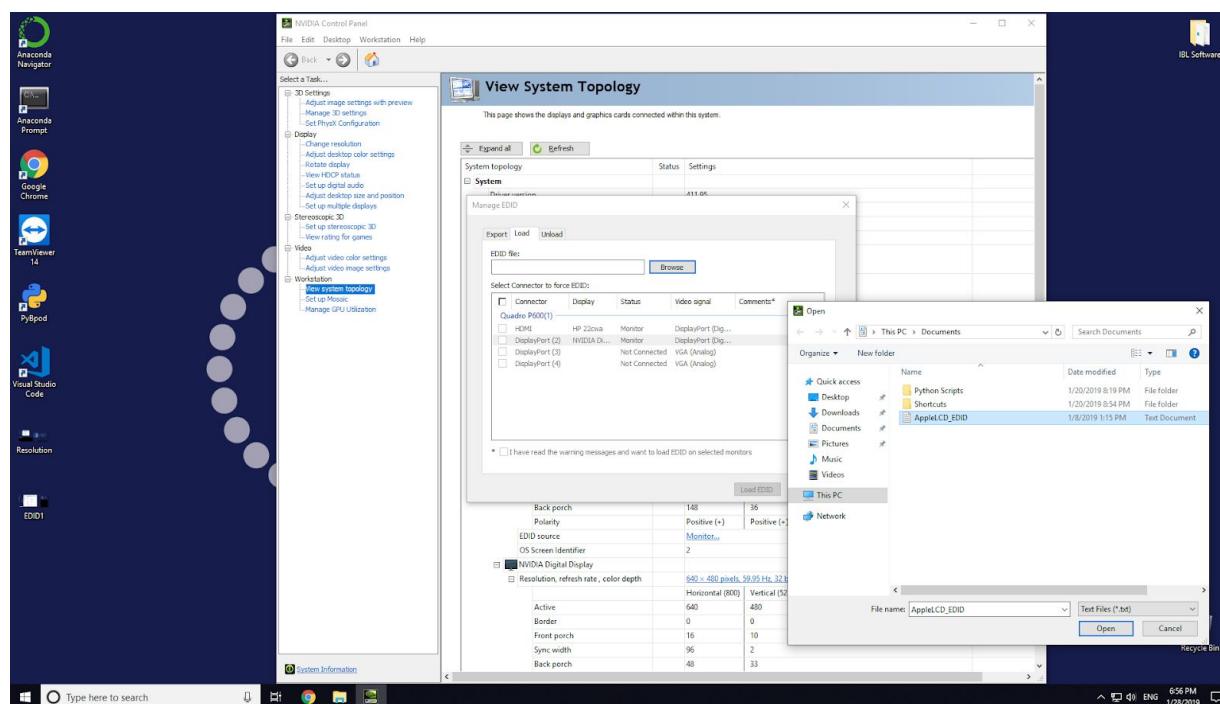
Step 1: On the main PC screen, right-click the green NVidia icon in the quick-launch section of the taskbar, and open the NVidia Control Panel



Step 2: Next, in the 'Select a task' menu on the left, choose 'View System Topology':

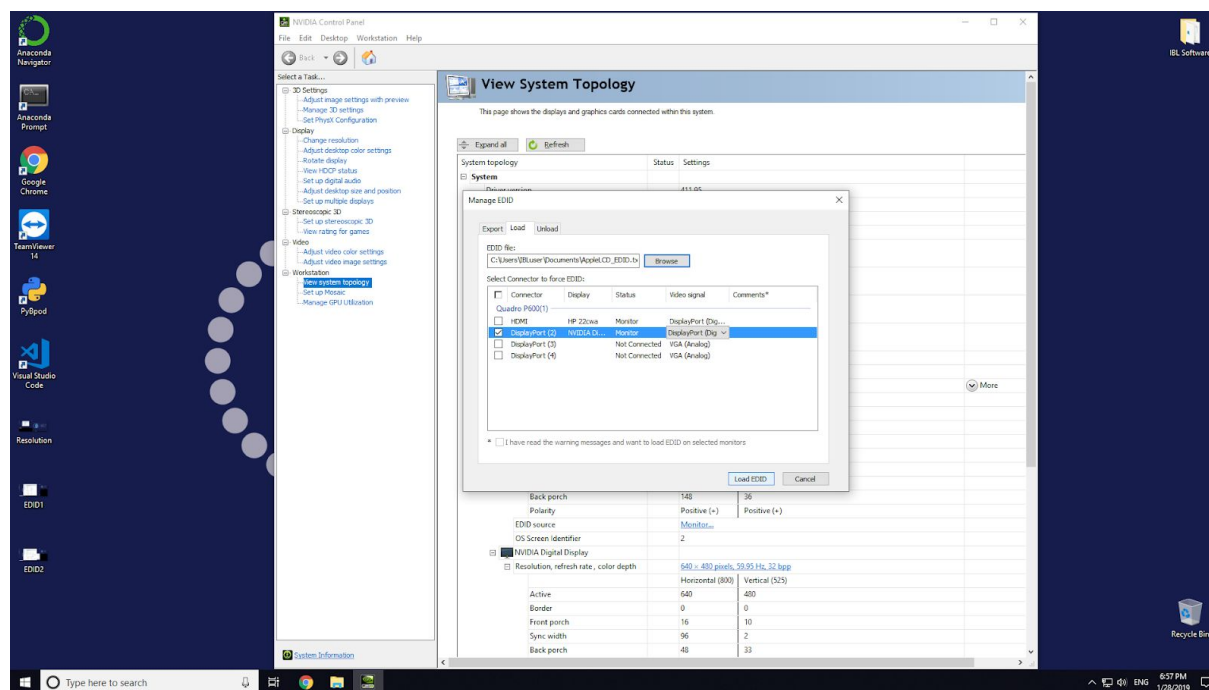


In the 'System' tree, under 'Quadro P600', you should see 'Nvidia Digital Display' on whichever channel the iPad screen is connected to. Under 'EDID Source' you'll see a link that says 'Monitor...'. Click it and you should see a 'Manage EDID' window. Click on the 'Load' tab and browse for a file. From the 'Documents' folder on your desktop, open 'AppleLCD_EDID':



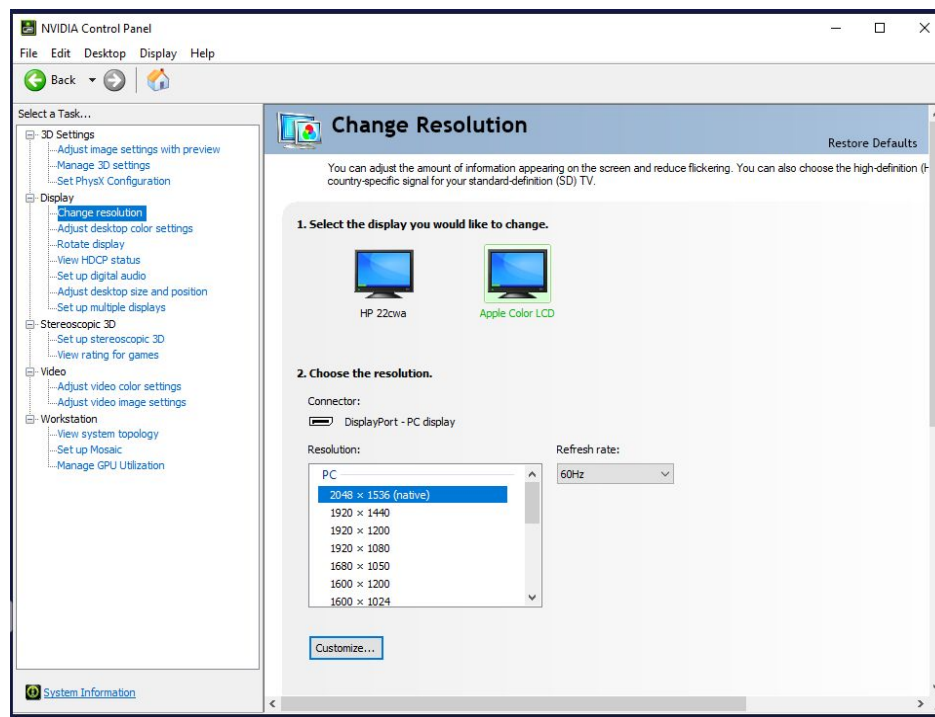


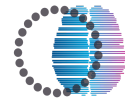
Step 3: Load the EDID. Check the port with 'Nvidia Digital Display' and click 'Load EDID':



The iPad screen should now display a single desktop, but with the wrong resolution

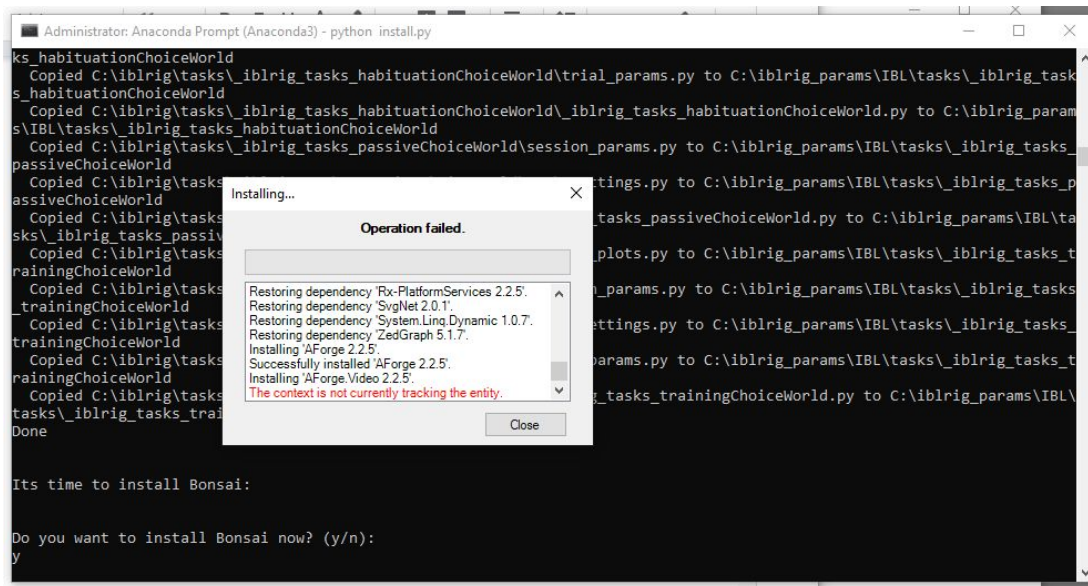
Step 4: Set the resolution. From the 'Select a Task' menu on the left, choose 'Change Resolution'. Select 'Apple Color LCD' and set it to its native resolution: 2048 x 1536





General software troubleshooting

- **When installing Bonsai, it stops with 'Operation Failed'**



- click **close**, it will continue to install. If still not working, delete the Bonsai folder in the C:\iblr/, then run `python update.py -v version_number` again

- **Typing pybpod in an anaconda prompt does not open a pyBpod window:**

- Either navigate to the iblr folder, or setup the starting path: Go to Start and search for "Anaconda Prompt" - right click this and choose "Open File Location", which will open a folder of shortcuts. Right click the "Anaconda Prompt" shortcut, choose "Properties" and you can adjust the starting dir in the "Start in" box. Change this to C:\iblr, and pin the Anaconda Prompt to the Start bar. You can then type 'pybpod' after opening Anaconda prompt, without navigating to the right folder.

- **The Bpod is yellow and the protocol does not start:**

- Select the Bpod board under the header 'Bpod boards' in the left side of the GUI.
 - Press the 'Load board info' button on the 'Details' menu on the right side of the GUI. Select 'Ports' and make sure the correct ports are checked (according to section 6.1 above).
 - Try to run the protocol again.

- **Everything seems fine but the task does not start or end:**

- Go to the Anaconda prompt and press enter.
 - Unplug/replug the USBs connected to the rotary encoder and state machine.

- **The visual stimulus appear on the computer screen instead of on the iPad screen in the rig:**
 - Open `C:\iblrig\visual_stim\GaborIBLTask\Gabor2D.bonsai` in a text editor. Change `<gl:DisplayDevice>` from “Second” to “First” or from “First” to “Second” to match the display number of the iPad.
 - Repeat this for the .bonsai files in all other task folder in `C:\iblrig\visual_stim`. Note that for the habituation task, this is found in `C:\iblrig\visual_stim\GaborHabituationTask\Shaders.config`; here it is listed as `<DisplayDevice>`. You may need to reboot the PC in between tries to get this right.
- **Camera sync error (could not find camera pulses)**
 - Open FlyCap, hit “Configure Selected”, “Trigger/Strobe” and re-check the Enable/Disable Trigger box (see section 5).
- **Visual Sync Error: could not find data on BNC1**
 - Adjust Frame2TTL, ensure it is positioned correctly and detects the pulses
 - Ensure that the frame2ttl calibration returns good thresholds.
 - Run Frame2TTL synchronization.
- **Sound Sync Error: could not find data on BNC2**
 - Ensure the computer volume is not muted. If so, unmute it.
 - Ensure all wires are attached to the proper ports on the sound card, see section 7.6 of the Hardware guide
 - Windows update:
 - Windows update(s) may cause your sound card to stop being recognized by windows, and consequently the card driver cannot be updated/installed.
 - The offending updates currently known as per Asus website are KB4579311 and KB4577671 (you might want to confirm the numbers on your windows machine). Asus has a link explaining the steps here: <https://www.asus.com/support/FAQ/1044486>
 - Uninstall the windows update(s), reinstall latest card driver, and reinstall the windows update(s).
- **General troubleshooting (works for most things if all specific troubleshooting fails):**
 - Close AnacondaPrompt and restart pybpod.
 - If the error mentions one aspect of the hardware and cannot connect (eg. rotary encoder), try unplugging and replugging.
 - Unplug and re-plug all the USBs connecting the BPod to the computer (except for the camera).

- **Water calibration issue**

- Check if “flush water” works
- Check if the COM for the scale is correct
- If they are fine and when running water calibration, bpod crashes (indicates by blue LED turns into green) mid-way (e.g. when you’ve got the first calibration figure but it doesn’t poke you for input of min and max value on the curve). You can try:

- Go to the data folder
(C:/iblrig_data/Subjects/_iblrig_calibration/<date>) and delete the folders there (name such 001, 002, which are the record from your previous run on the same day). Then run the script again.
- Input max and min values directly to
C:\iblrig_params\IBL\tasks_iblrig_calibration_water\task_settings.py



Components lists

CAD models (STL, SLDPART) and technical drawings for the manufactured parts (in dark blue below) can be found on Figshare:

https://figshare.com/articles/A_standardized_and_reproducible_method_to_measure_decision-making_in_mice_CAD_Drawings_for_items_linked_in_appendices_zip/11638362

The whole CAD assembly file of the rig (including non-manufactured parts) can also be found on Figshare:

https://figshare.com/articles/A_standardized_and_reproducible_method_to_measure_decision-making_in_mice_CAD_files_for_behavior_rig/11639973

Main components

Category	QT	Details	SKU	Supplier	Price/U nit	Total	Category total
Rig frame	1	Breadboard	MB3030/M	Thorlabs	€138.00	€138.00	€416.57
	2	Post holders	PH50/M	Thorlabs	€6.93	€13.86	
	3	Posts	300 mm	Thorlabs	€9.74	€29.22	
	2	Posts	150 mm	Thorlabs	€6.47	€12.94	
	2	Posts	100 mm	Thorlabs	€5.34	€10.68	
	1	Posts	50 mm	Thorlabs	€4.72	€4.72	
	2	Posts	30 mm	Thorlabs	€4.67	€9.34	
	4	Component clamp	PMTR/M	Thorlabs	€22.30	€89.20	
	3	Right-angle clamp	RA90/M	Thorlabs	€8.87	€26.61	
	1	Rotating	SWC/M	Thorlabs	€22.00	€22.00	



		clamp						
	2	Screen spacers	10mm, fit over ThorLabs posts, 3D printed - black, versatile plastic, natural finish	SMS102__ScreenMountSpacer_10mm	Shapeways	€8.00	€16.00	
	2	Screen Spacers	72mm, fit over ThorLabs posts, 3D printed - black, versatile plastic, natural finish	SMS101__ScreenMountSpacer_72mm	Shapeways	€7.00	€14.00	
	2	Screen holder top	3D printed - black, versatile plastic, natural finish	SM101__ScreenMount_Top	Shapeways	€7.50	€15.00	
	2	Screen holder bottom	3D printed - black, versatile plastic, natural finish	SM102__ScreenMount_Bottom	Shapeways	€7.50	€15.00	
Mouse holder	1	Incremental rotary encoder	24mm, push-pull, 5V, 1024 PPR	05.2400.1122.1024	Distrelec	€145.00	€145.00	
	1	Mouse holder	3D printed - black, versatile plastic, natural finish	MH201__MouseHolder_PCV2-X	Shapeways	€200.00	€200.00	
	1	Poop tray	3D printed - black, versatile plastic, natural finish	MH202__MouseHolder_PCV2-P_Tray	Shapeways	€25.00	€25.00	
	1	Mouse cover	3D printed - white, versatile plastic, natural finish	MH203__MouseCover_PCV1-X	Shapeways	€20.00	€20.00	
	1	Wheel/encoder coupler	3D printed - black, versatile plastic, natural finish	MH204__WheelCoupler	Shapeways	€5.00	€5.00	
								€1,195.52



	1	LEGO wheel/axle hub		86652 & 32019	BrickLink	€2.00	€2.00	
	1	Magnetic breadboard		KBM1/M	Thorlabs	€266.00	€266.00	
	1	Headplate holder		HPH301__HeadplateHolder_IBL_PCv3_High_Z	Protolabs	€200.00	€200.00	
	2	Headplate holder stopper	CNC machined from aluminium	HPH302__HBar_Holder_Stopper_Locker_PCV4_1	Protolabs	€10.00	€20.00	
	1	Translational stage		DT12XYZ/M	Thorlabs	€280.00	€280.00	
	1	Silicone Rubber Sheet (cut to size)	To place under mouse in holder	840-5541	RS	€32.52	€32.52	
Reward delivery system	1	Pinch valve	1-tube, normally closed, 12V DC	225P011-21	NResearch	€56.30	€56.30	€677.81
	1	Steel tube		316H15RW	Microgroup		€1.00	
	1	Copper wire segment (80mm)	Sold as a spool of 40m length. 80mm required per rig.	70825773	Allied Electronics	€17.20	€17.20	
	1	Articulated arm	Strato XS-13 130 mm with M6 mounts		eBay	€105.00	€105.00	
	1	Syringe	60ml	309652	BD	€0.50	€0.50	
	1	Tubing	1/32" ID x 3/32" OD, 50 ft	WZ-95702-00	Cole Parmer		€1.00	
	1	Luer Lock Fitting		EW-45502-00	Cole Parmer	€12.00	€12.00	
	1	Scale connector	Ohaus 30268984 USB	Ohaus – Mfr # 30268984 – Item #	Cole Palmer	€111.42	€111.42	



			Kit	EW-11015-43				
	1	Scale	Ohaus SPX222 Scout Portable Balance 220 g x 0.01 g	Ohaus – Mfr # SPX222 – Item # EW-11015-29	Cole Palmer	€373.39	€373.39	
Bpod	1	Bpod State Machine		1024	Sanworks	€655.00	€655.00	€1,150.66
	1	Bpod Rotary Encoder Module		1022	Sanworks	€119.00	€119.00	
	1	Bpod Frame2TTL	Request IBL version in order 'special instructions' field	1501	Sanworks	€198.00	€198.00	
	1	Bpod Port Interface		1008	Sanworks	€31.00	€31.00	
	2	CAT5e Cable - 3' (RJ45)		MP-5ERJ45UNNK-003-ND	Digikey	€3.32	€6.64	
	1	CAT5e Cable - 1' (RJ45)		MP-64RJ45UNNK-001-ND	Digikey	€3.02	€3.02	
	2	0.5m BNC Cable		BKCT2942-50-ND	Digikey	€6.50	€13.00	
	1	BNC to wire adapter		314-1394-ND	Digikey	€6.00	€6.00	
	1	Bpod Ambient module		10055	Sanworks	€119.00	€119.00	
Video	1	Camera lens		MVL16M23	Thorlabs	€180.00	€180.00	€570.65
	1	Camera Chameleon 3		CM3-U3-13Y3M-CS	PointGrey FLIR	€300.00	€300.00	



	1	C-mount tube		CML05	Thorlabs	€15.00	€15.00	
	1	C-mount ring		CMSP100	Thorlabs	€6.00	€6.00	
	1	9pins 0.15m GPIO cable JST connector		ACC-01-3013	PointGrey FLIR	€4.00	€4.00	
	1	Tripod adaptors		ACC-01-0003	PointGrey FLIR	€4.00	€4.00	
	1	USB3 cables		ACC-01-2300	PointGrey FLIR	€8.00	€8.00	
	1	IR light source		CM-IR30	CMVision	€10.00	€10.00	
	1	IR pass filter	Polyester 87 Infrared (100x100 mm). Transmission begins above 730 nanometres.	BH #LE8733 • MFR #87P3	LEE via B&H	€18.65	€18.65	
	1	Weighing boats	White plastic, 85x85x24 mm, pack of 500 / cut to the same size as the IR illuminator lens	611-0094	VWR	€1.00	€1.00	
	2	12V, 2A power supply		1470-3166-ND	Digikey	€12.00	€24.00	
	[optional]	IR light template	If IR light front cannot be unscrewed, use this as a template for the weighing boat plastic	IR101__IR_light_template				
Sound	1	Speaker		HPD-40N16PET00-32-ND	Digikey	€6.12	€6.12	€283.84



1	Speaker cable	Spool of 15,240mm. 400 mm required per rig.	C1362-21-50-ND	Digikey	€8.98	€8.98
1	Speaker cable, 3.5mm		TL633-ND	Digikey	€3.55	€3.55
1	Audio Amplifier		668-1621-ND	Digikey	€17.54	€17.54
	Audio amplifier mount	3D printed - black, versatile plastic, natural finish	AAM101__AudioAmp_Mount	Shapeways	€7.00	€7.00
1	DC Converter	SKU is for US part. For UK, use VEL24US120-UK-JA. For EU, use VEL24US120-EU-JA.	1470-3166-ND	Digikey	€11.21	€11.21
1	Speaker mount	3D-printed - black, versatile plastic, natural finish	SpM3__Speaker_Mount_r3_2	Shapeways	€7.00	€7.00
1	Silicone Foam Strip, 15ft, (134mm / spkr)	Used to line 3D-printed speaker mount, so speaker can be press-fit	5109K21	McMaster	€0.44	€0.44
1	Ultrasonic Microphone	USB ultrasonic mic, 200kHz	Ultramic200K	Dodotronic	€200.00	€200.00
1	Ultrasonic Mic USB cable	USB A to B Mini, 2m	AE9929-ND	Digikey	€2.00	€2.00
1	Microphone mount top	3D-printed, black, versatile plastic, natural finish	ME101__MikeEnclosure_Top	Shapeways	€10.00	€10.00



	1	Microphone mount bottom	3D-printed, black, versatile plastic, natural finish	ME102__MikeEnclosure_Bottom	Shapeways	€10.00	€10.00	
Stimulus display	1	iPad 3/4 Retina display	LP097QX1	1751	Adafruit	€100.00	€100.00	€368.67
	1	Qualia bare driver board		1716	Adafruit	€80.00	€80.00	
	1	Mini Display Port-to-DisplayPort cable	2m length	1698	Adafruit	€8.80	€8.80	
	1	9V DC, 1A power supply		1470-3156-ND	Digikey	€12.00	€12.00	
	1	Fresnel lens	Size: 200 x 160 mm, thickness: 2mm, material: PMMA, groove pitch: 0.5mm, focal length: 220mm	BHPA220-2-5	Wuxi Bohai Optics	€16.00	€16.00	
	1	Lux meter	RS PRO ILM01 Light Meter	123-2223	RS	€81.52	€81.52	
	1	Polarising filter	Rosco Polarising Filter lighting gel	730011	www.stagedepot.co.uk	€70.35	€70.35	
Computer	1	PC	- CPU: Intel Core i5-8500 - RAM: 16GB (2x8GB) DDR4 - HD: 1TB, 3.5", SATA3			€500.00	€500.00	€888.80
	1	Graphics card	NVIDIA Quadro P600	Note: If discontinued, IBL recommends using		€200.00	€200.00	



				instead P620				
	1	Sound card	ASUS Xonar AE			€70.00	€70.00	
	1	Monitor	DELL e2016hv			€100.00	€100.00	
	1	Mini Display Port-to-DisplayPort cable	2m length	1698	Adafruit	€8.80	€8.80	
	1	Keyboard and mouse				€10.00	€10.00	
Enclosure box	1	Orion 9U	600 x 600 Acoustic Wall Cabinet	9U	Orion	€301.73	€301.73	€387.68
	[optional]	Orion box door handle	3D printed	OBH1__Orion_box_handle_bar	Shapeways	€12.95	€12.95	
	[optional]	110V fan	Sunon SP103A Fan fitting in Orion 9U (USA voltage compliant)	Link to product	Amazon	€30.00	€30.00	
	2	20x20mm T-slot rail, 51cm, M5 Thread		20-2020	80/20	€8.00	€16.00	
	2	20x40mm T-slot rail, 51cm, M5 Thread		20-2040	80/20	€13.50	€27.00	
Legends	1	Single-time purchase item per laboratory.						
		Material quantity ordered is sufficient to accommodate several rigs.						
							TOTAL	€5,940.20



Screws and bolts

Purpose	QTY	Thread	Head	Length	Material
IR light, microphone and headbar holder post	3	M6	Setscrew	20 mm	Steel
Mouse body holder	4	M6	Cap screw	45 mm	Steel
Camera to post	1	M6	Setscrew	20 mm	Steel
Headbar holder to post	1	M6	Flat head	14 mm	Steel
Screen posts	2	M6	Cap screw	16 mm	Steel
Magnetic base to breadboard	4	M6	Cap screw	16 mm	Steel
Screen holder to component clamp	4	M6	Cap screw	12 mm	Steel
Water delivery to fisso arm	1	M6	Nut	N/A	Steel
Rails in enclosure box	12	M5	Hex bolt	15 mm	Steel
Breadboard to rails	4	M5	Philips pan head	12 mm	Steel
Post-assembly insertion nuts	4	M5	N/A	N/A	Steel
IR light to post	1	M4	Thumb screw	8 mm	Steel
Microphone to post	1	M4	Thumb screw	12 mm	Steel
Wheel to coupler	3	M3	Slotted cheese head	10 mm	Nylon
Rotary encoder to mouse holder	3	M3	Philips pan head	5 mm	Steel
Headbar holder thumbscrews	2	M3	Thumb screw	6 mm	Steel

References

- International Brain Laboratory et al. (2020) [A standardized and reproducible method to measure decision-making in mice](#)
- <https://www.ucl.ac.uk/cortexlab/tools/wheel>
- Burgess et al. (2019) [High-yields methods for accurate two-alternative visual psychophysics in head-fixed mice](#)
- International Brain Laboratory et al. (2019) [Data architecture and visualization for a large-scale neuroscience collaboration](#)