PULSE TANK

BY RAFAEL LOZANO-HEMMER

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GENERAL IMPORTANT INFORMATION

This short section must be read for proper operation.

PULSE TANK (2008)

BY RAFAEL LOZANO-HEMMER

Technique

Heart rate sensors, solenoids, ripple tank, projector, computer.

Description

Pulse Tank is an interactive installation where the heart rates of members of the public are detected by sensors and converted into water waves in a ripple tank. A light show is created by the resulting waves and their interaction.

Operation

Please refer to <u>*Appendix I - Installation*</u> *for detailed system information and wiring diagram. For each tank:*

1. Turn on the power to all other electronics: sensor stands and ethernet switch.

2. Turn on the computer by pressing on its power button for half a second. The projector will turn on automatically when it receives a signal from the computer

3. After the computer powers up and the desktop is visible, it takes about two minutes before the Pulse Tank software will start up automatically.

4. At this point, only the projector's light should be illuminating the water tank.

5. To shutdown the artwork, a simple press on the computer's power button for a maximum of half a second should launch a proper computer and artwork shutdown.

***** The computer could be set with power options in the Operating System to automate the turn On/Off sequences. Another technique would be to have the projector's operating hours scheduled automatically through the projectors' internal scheduler. *****

General Artwork Behaviours

For the hand plate sensor:

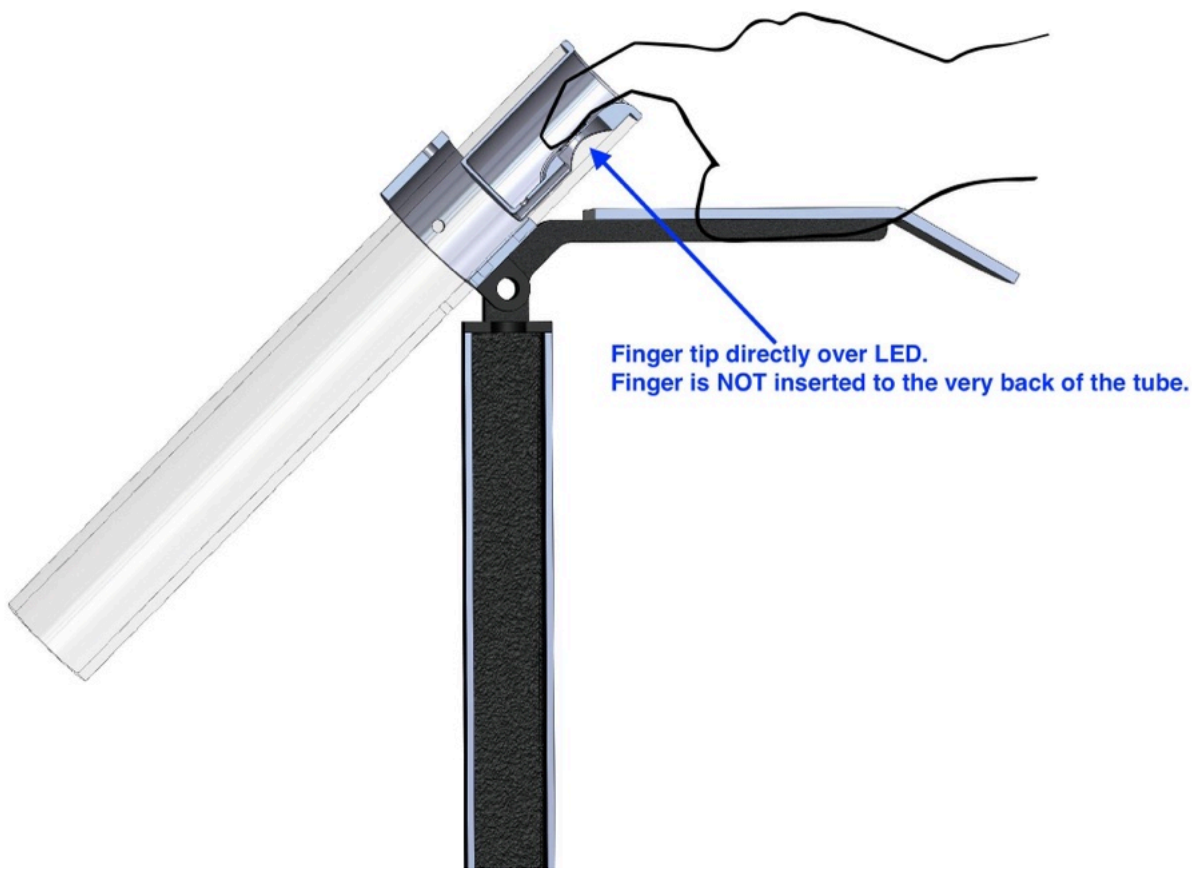
During normal operation, visitors should place both of their hands on the hand sensor plate. After a few seconds, water waves will be produced accordingly, until the participants' hands are lifted off the plates.

For the finger sensor:

During normal operation, visitors should insert one of their fingers into the finger sensor tube. More specifically, the participant places their fingertip on the small indentation felt in the middle of the tube; a green LED is visible inside the finger sensor, and the participants' fingertip should be placed right on top of this LED.

Participants should not hover their finger above the LED, but rather touch it gently. Pressing down is not ideal as the blood flow in the finger will be restricted and the sensor will not be able to measure or detect a reliable heart rate.

The below diagram illustrates the proper placement of a participant's finger in the tube.



Maintenance

Please wipe any smudges off the stainless steel hand plates, metal finger plates, acrylic finger tubes, and black metal sensor stands. Do not use a damp or wet cloth as this will disrupt the electronics embedded in the hand plate or finger tube.

Also, do not use alcohol-based cleaning products, especially on the black finger sensor tube, as this might remove some of the paint (which is acrylic-based).

Water stains may develop on the plastic covers of the solenoids and along the long acrylic square tubes over time. Gently wipe these off.

Check the inside of the finger tubes to ensure visitors did not leave objects or debris inside them.

The water in the tank needs to be filtered regularly to remove dust and particles. Please place the three water filter pumps inside the tank every night and let them run until morning. Additionally, you might need to vacuum out the particles that have sunken to the bottom of the tank. See the photos below for the proper placement of the filters.

Filter pumps

Filter placement

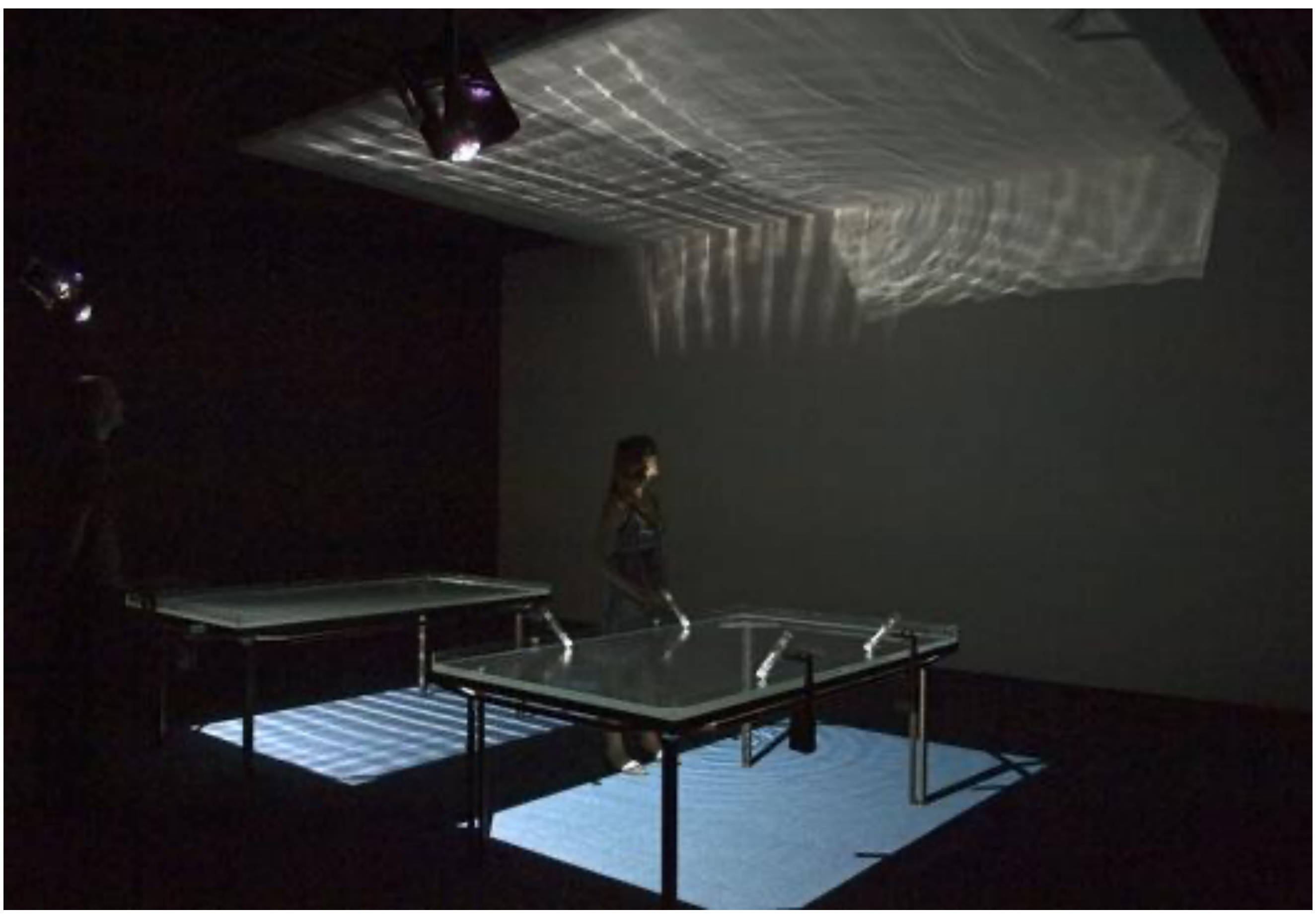
Regularly check that all the components of the sensor stands and the solenoid actuators are not loose and do not rattle. Consult the troubleshooting section for instructions on re-tightening the components.

If you notice calcium building up on the tank, empty the tank using a water safe shop vacuum then wipe it down with vinegar or a small amount of dawn dish soap with a sponge and hot water (do NOT use steel wool or any coarse sponge that could damage the tank). Make sure there is no soap residue leftover before filling the tank or bubbles will be difficult to remove.

Placement Instructions

The artwork comes in two versions: Version 1 is a 4-foot-by-8-foot plexiglass tank that sits upon a table structure and Version 2 is a large metal tank which sits directly on the floor.

Version 1:



Version 1: Plexiglass tanks on table

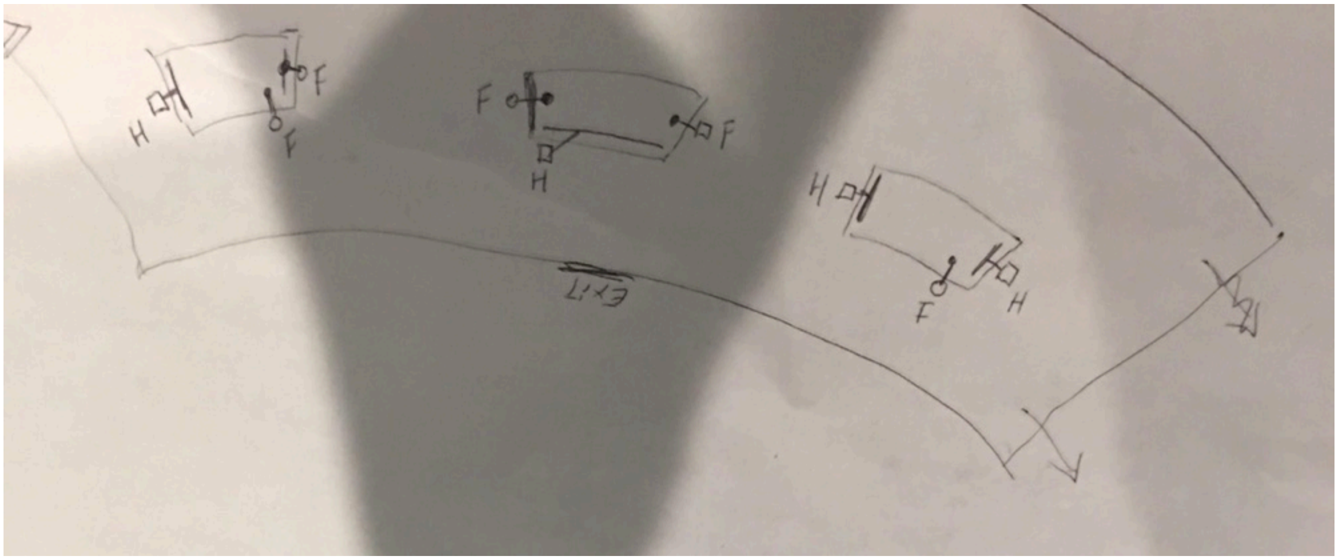
Version 2:

Version 2: metal tanks directly on the floor (Hirshhorn Museum, 2018).

For Version 2, a projector with an ultra-short throw lens is mounted close to the tank: the goal is to have the projector as close as possible to the tank, while being protected from water splashes, in order to have a higher brightness and avoid a maximum of shadows create by people between the projector and the tank..

Heart rate sensors are placed around each side of the tanks, except the side opposed to the projector side.

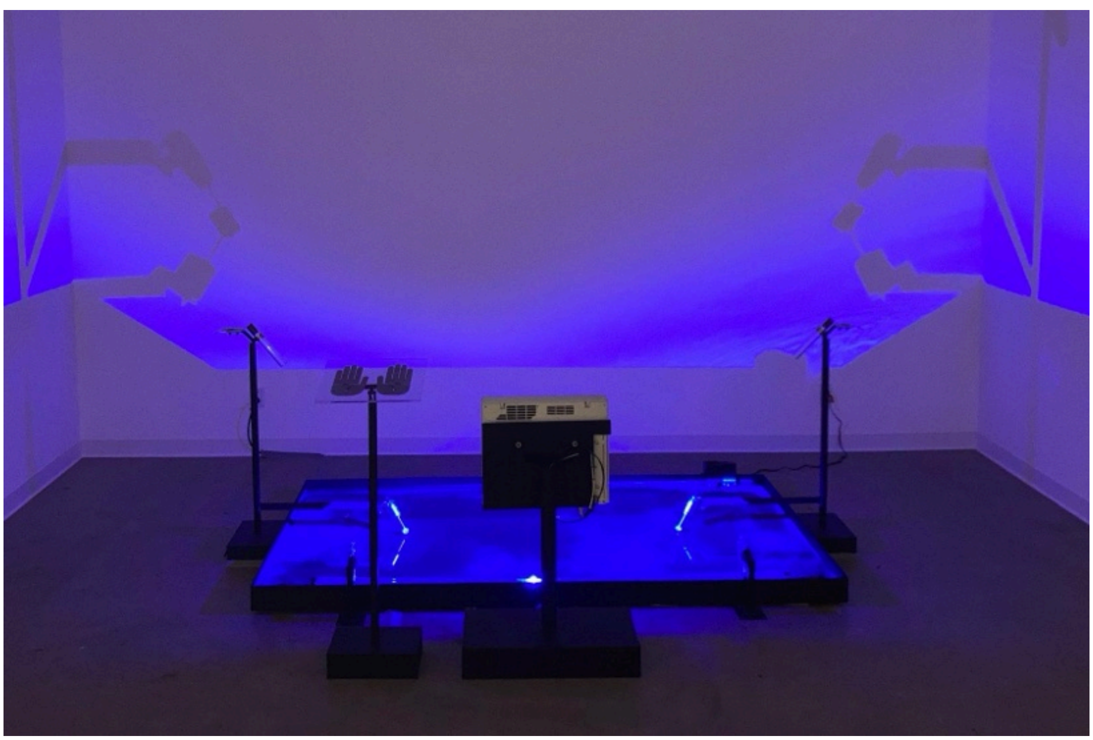
The following sketch shows the placement of the sensors around three tanks, at a recent iteration of Pulse Tank at the Hirshhorn Museum.



All sensor stands are typically 42 cm away from the edges of the tanks. The sensor stands located along the shorter sides of the tanks are centred along that edge, and the sensor stands located along the long sides of the tank are positioned closer to corners, about 70 cm away from a corner.

The standalone solenoids base plates were installed to be exactly at the edge of the tank, giving enough distance between the stand's body and the tank.

In a smaller tank version, the projector stand would be centered to the tank, but distance from the tank would vary. The finger sensor stands would be using a longer arm to get the solenoid over the tank, and the sensor's base would be installed 1 cm away from the edge.



DETAILED TECHNICAL INFORMATION

Normal Software Operation

When the computer first starts up, it takes about two minutes before the **PulseTank.app** software automatically starts. If for some reason the app does not start up or is exited, wait for one minute. A watchdog script will automatically notice that the app stopped running and will restart it again.

PulseTank.app Icon

When the software starts up, all that will be visible is the light mapped onto the position of the water tank, as shown below. No other projector light should be visible outside of the tank's perimeter.

The app then sends the preset settings to the connected pulse sensors over an ethernet network connection and then waits for the sensor's input.

Projected light mask

Manual Software Calibration

Keyboard Shortcuts:

Pressing key **g** will make the GUI appear and hide. Upon hiding the GUI, its settings will be saved.
Pressing key **d** will make the heart rate graphs and other information appear.
Pressing key **f** will toggle the app between fullscreen and window mode.

The app can be used to map the projector light onto the position of the tank and to change the presets for each heart rate sensor stand.

Calibrate Light Mapping:

The software allows for three different masks to be drawn, but only one mask will be used at this point in the calibration. The mask is defined by a set of points; most of the time, it's a polygon marked by four points. The amount of points can be changed via the **point amount** slider.

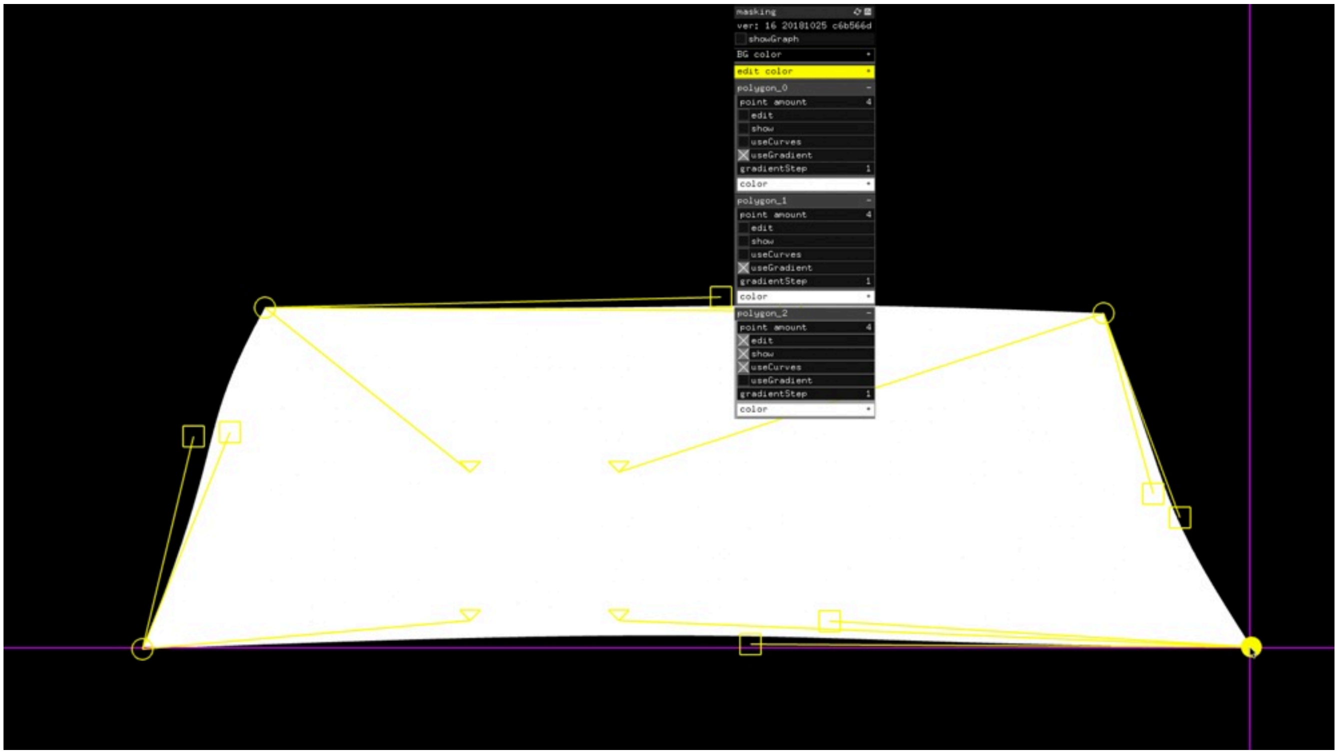
The light should be mapped to line up with the bottom corners of the tank. I.e the projected light doesn't intrude on the edges of the tank. At Les Atelier 3333 the light should be mapped to line up with the acrylic bar that reacts to the hand sensor on one of the long edges of the tank. Note: The projector stand is 44.25cm to the tank, at the lowest height on the projector stand, at a right angle.

Additionally, you can choose both to make the line between each point curved and to have a colour gradient from black to white.

Each point has four controllers associated with it:

A circle: which if moved changes the position of the mask's point.
Two squares: which define the bezier curve shape between this point and the next.
A triangle: which defines the endpoint of the black to white gradient.

Consult the following photo illustrating this masking function, with curve effect.

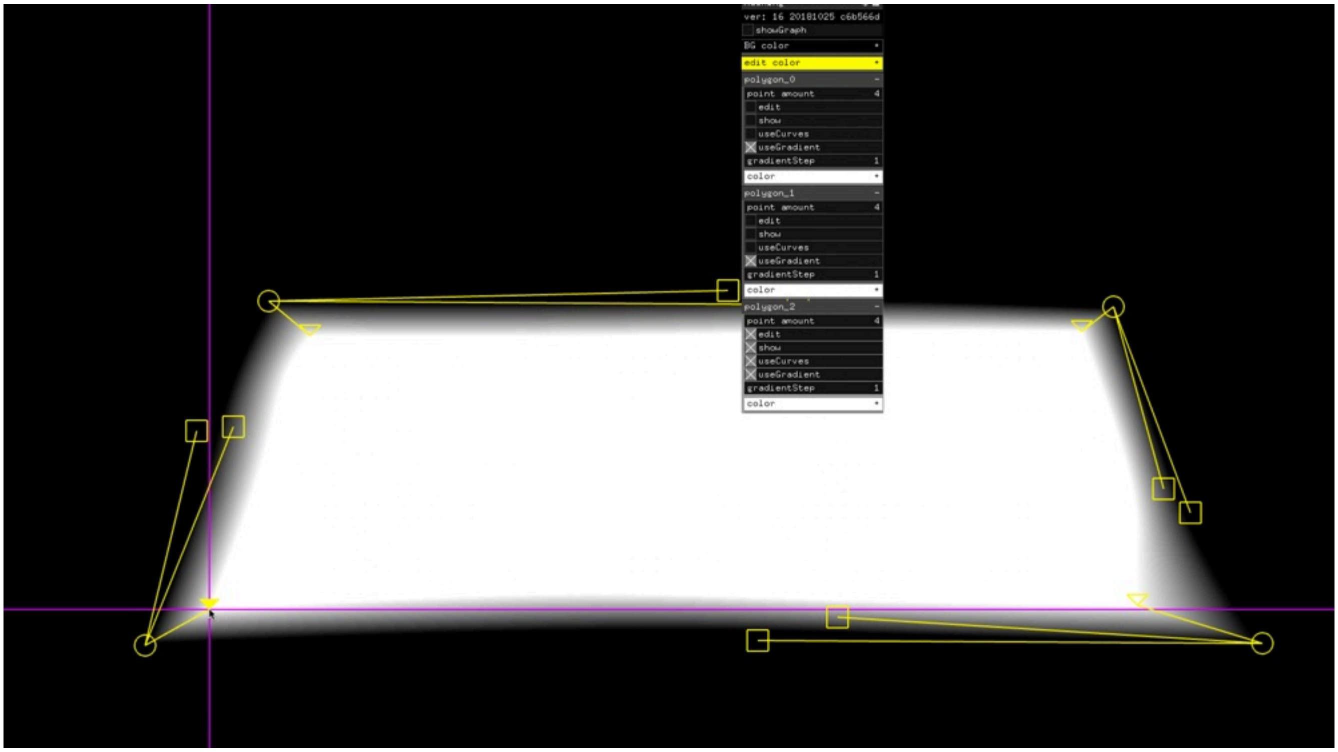


Masking in edit mode with curve effect

If you want to edit any of the three polygon masks you need to enable the **edit** and the **show** GUI elements. This will reveal the control handles mentioned above.

Now you can decide to use **useCurves** and/or the **useGradient** effects.

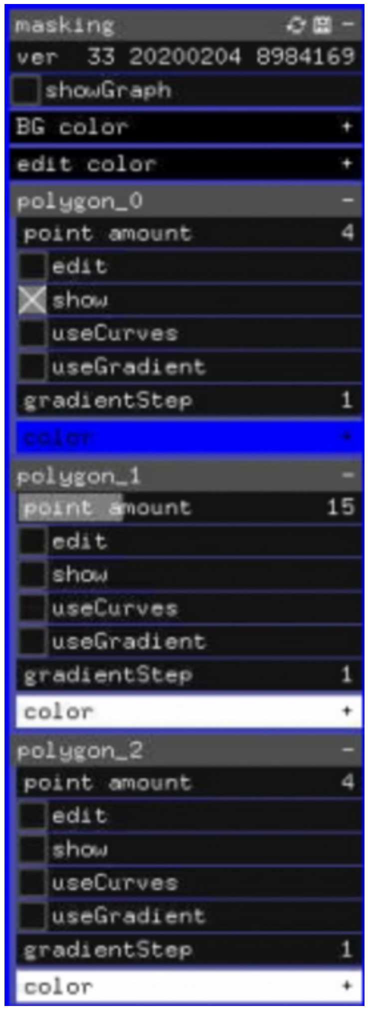
Because editing the gradient effect can be taxing on the computer, you can decide to lower the gradient resolution via the **gradientStep** slider. This will make the computer react better to your handle position changes. Just make sure to set the **gradientStep** slider back to **1** before disabling editing.



Masking in edit mode with gradient effect

When in edit mode, cross hair lines are drawn in the mouse cursor position, making it easier to find the cursor position.

When you get close to any of the controller handles, they will become highlighted, which means they can now be dragged to a new location.



Ver: a number is automatically generated every time a new version of the code gets submitted to git

BG color: should be **0,0,0** = black

Edit color: helps making the control handles more visible in different light settings.

Point amount: defines how many points are used to describe a shape.

Edit: shows control handles.

Show: needs to be selected if you want to see the shape and if you want to edit it too.

useCurves: creates bezier curves between two points.

useGradient: feathers edges.

gradientStep: reduces the amount of gradient steps.

Color: sets the color of the masking shape.

Calibrate Sensor Settings:

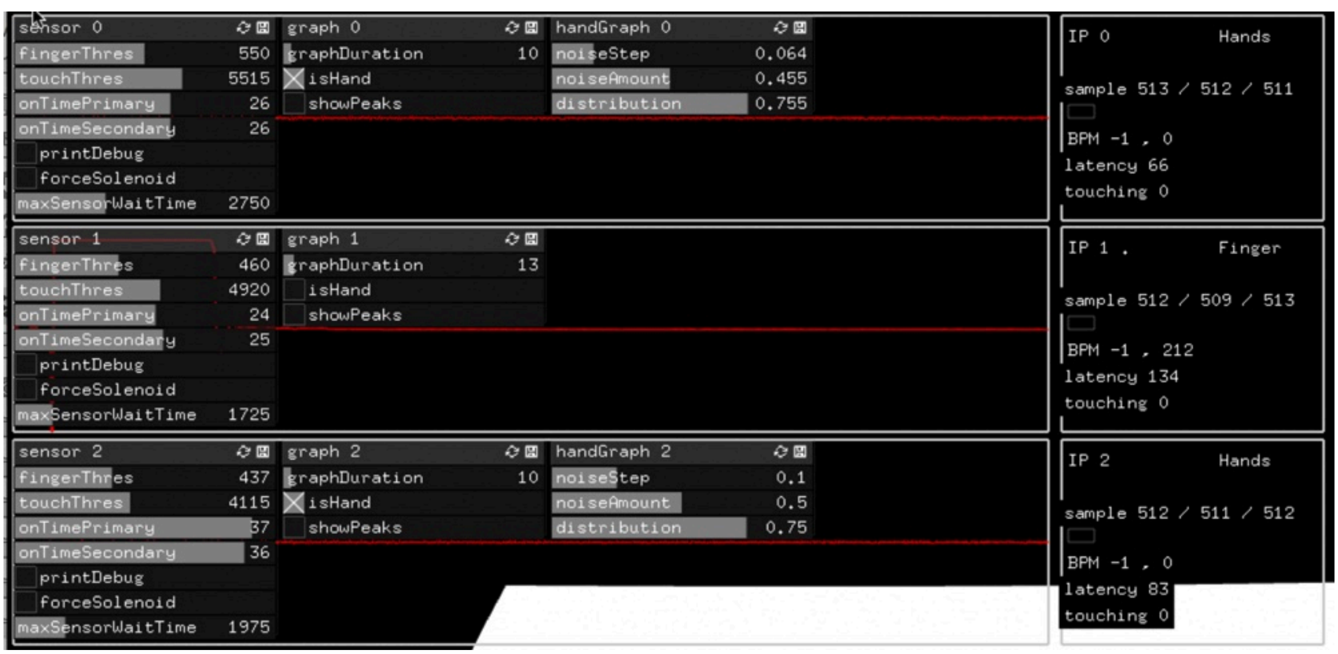
To reveal the GUI elements for the heart rate sensor, you need to press key **d** and key **g**. Pressing only key **d** will show the line graphs. Only pressing key **g** will show the masking GUI.

Each sensor has a line graph, an information box, and one to three GUI blocks associated with it.

Each information shows:

- Last number of sensor **IP** address;
- A small blinking **dot** beside the IP address, which indicates successful communication with the sensor stand;
- The words **Hands** or **Finger**. The sensor stand sends this label to the software. If there is a communication problem you might see **???** instead;
- **Sample** shows the analog voltage readings from the heart rate sensor. The minimum, current and maximum reading as displayed;
- **BPM** displays the results of two different BPM measuring algorithms. The app picks one of the two BPM readings: the one closest to 73 BPM. If a reading is outside of the predefined 40 - 120 BPM range, then the default value of 73 BPM will be used instead;
- **latency** is the amount of time since the last BPM reading was received;
- **touching** is either **0** or **1**. As soon as a visitor touches the sensor, a **0** should change to **1**.

In the graph window, the red line draws the current analog voltage reading. The blue and yellow lines show the peak and trough values used to measure BPM.



GUI elements for heart rate settings, line graph and information boxes

Sensor:

fingerThres: only affects the finger sensor and not the hand sensor. This value should be a bit lower than the average sample value. This is needed to successfully find the peaks and trough in the sample data.

touchThresh: only affects the finger sensor. The black plastic inside the finger tube that houses the green LED and heart rate pulse sensor is capacitive touch sensitive. As soon as a person touches the black plastic, the capacity value read by the micro controller increases. **touchThresh** needs to be set just below the value that is considered a non-touch. To find the best setting, enable **printDebug**. Now, the live capacity touch reading will be displayed beside the word **touching** in the *information* box. If, for example, the finger actuator pulses without anyone touching it, then the **touchThresh** needs to be adjusted to a higher value.

onTimePrimary: Defines for how many milliseconds power is being sent to the solenoid actuator, for the first beat of the heart beats double beat.

onTimeSecondary: Defines (in milliseconds) the power being sent to the solenoid actuator.

printDebug: If enabled, it tells the microcontroller to send additional information to the app which then gets printed in the information box. Also, additional information is sent out via the micro controllers USB serial port. This helps during debugging, when the microcontroller is connected via USB to a computer and a serial Terminal is opened (we use the Arduino IDE.)

forceSolenoid: This forces the solenoid to perform one single pulse at the length defined by **onTimePrimary**.

maxSensorWaitTime: It takes the hand and finger sensor four to six seconds to get a good heart beat reading. However, we do not want visitors waiting this long. As soon as a touch is detected, we wait for n milliseconds and then use the default 73 BPM to pulse the actuator. As soon as a new reading is received, we switch to it.

Graph: Shows the heart rate measurements coming in from the hand sensors and live readings from the finger sensors.

graphDuration: Defines how fast the graph is moving (from right to left.)

isHand: This is set automatically according to the reading received from the microcontroller.

showPeaks: Determines whether the peaks and troughs are displayed.

handGraph: Since the hand sensor only provides BPM readings and no sample data, we fake the hand graph with the below perlin noise settings. This has no effect on the solenoid actuation.

noiseStep: Increases the step distance in the generated noise used to simulate sensor readings during testing.

noiseAmount: Increases the amount of the generated noise used to simulate sensor readings during testing.

distribution: Increases the distribution in the generated noise used to simulate sensor readings during testing.

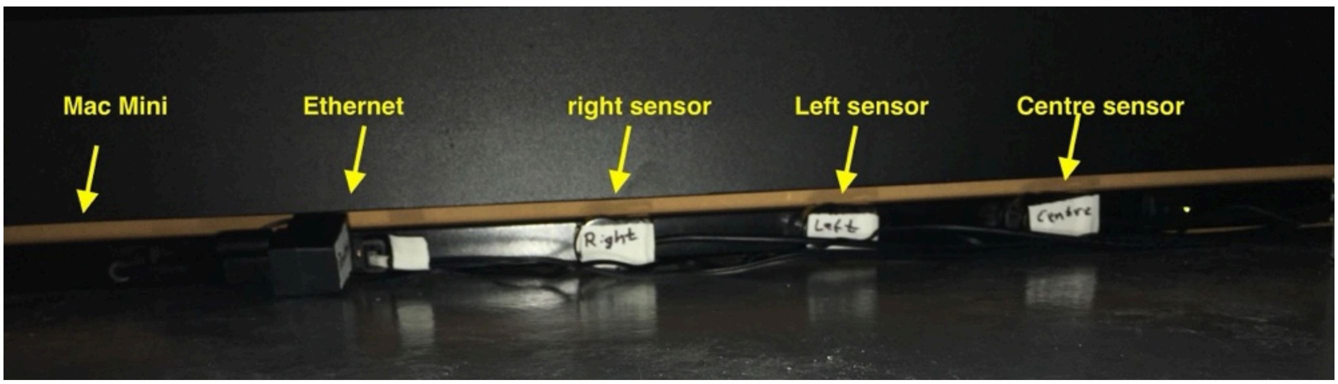
Remote Access to Artwork's Computer

There is a software installed on the computer running this artwork that allows the studio to connect remotely to the artwork. This feature is helpful when you require assistance from the studio, as we can remotely connect to it, do a quick inspection, and do a debugging session of your components, if needed. In order to enable this feature, the computer has to be connected to the internet at all times. Depending on the computer's operating system (Windows 7/8/10, OSX), the procedure to set the computer online will vary. Please look online for tutorials, if necessary.

Preliminary Troubleshooting Steps

To quickly fix any minor problem, first try unplugging the related power plug.

Each tank has a long power strip under the back edge with five devices plugged in: Mac mini, ethernet switch (if in use), left sensor stand, centre sensor stand, and right sensor stand. The sensor stand plugs are labelled. Simply unplug and replug the related sensor stand and plug to restart the microcontroller inside the sensor stand. Note this power bar might be hidden in the projector's stand and cables could be mounted with Wago connectors to ease the disconnections and connections: in that case, please turn off the computer with the keyboard first, then unplug the powerbar's input plug to achieve the same result.



The solenoid on the finger sensor stand is constantly pulsing.

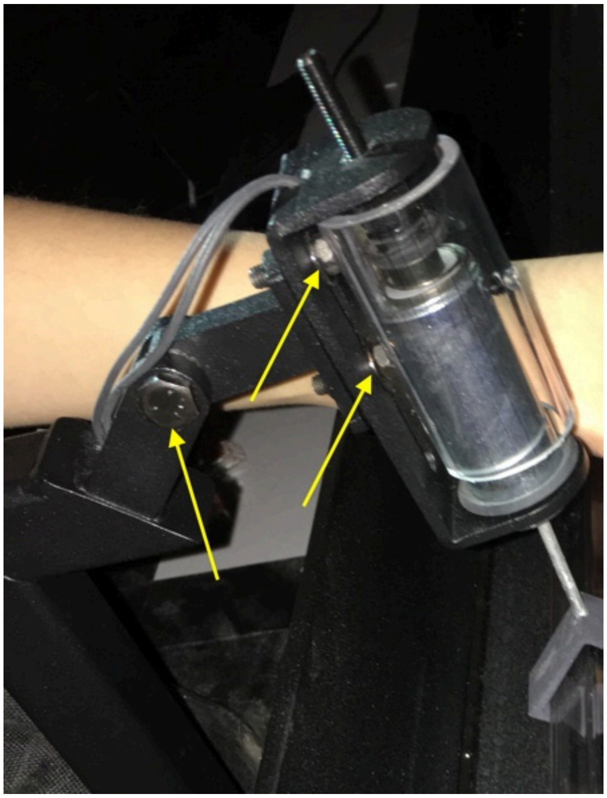
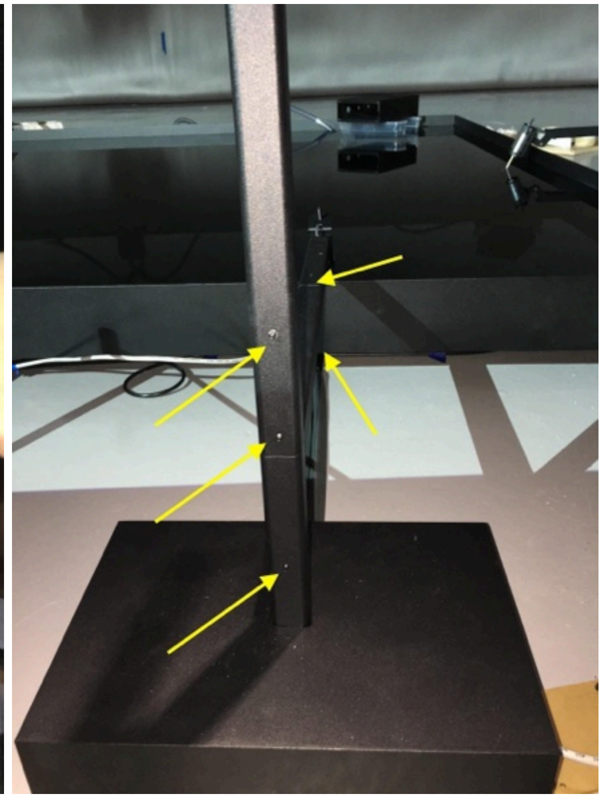
First, try to cycle the power for the related sensor stand as mentioned above.

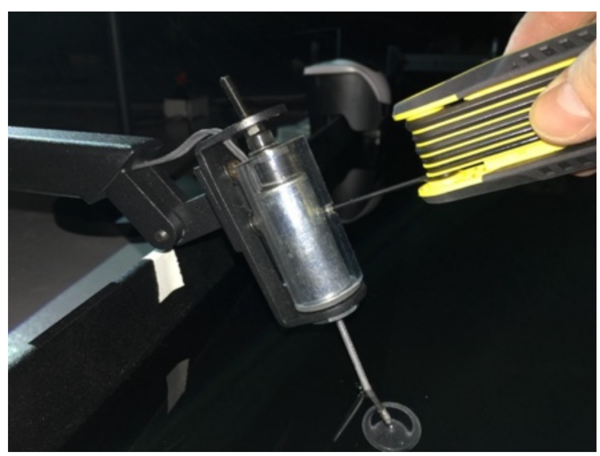
Most likely, the capacity touch threshold needs to be adjusted. Open the GUI and check the **touchThresh** value. It might need to be set to a higher value.

Check for objects inside the finger tube and remove them.

I hear a rattling sound when the solenoids are pulsing.

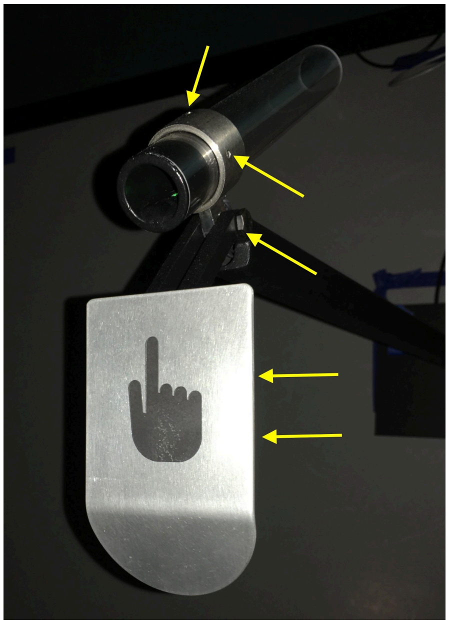
Ensure that all the following set screws and nuts are tightened properly.

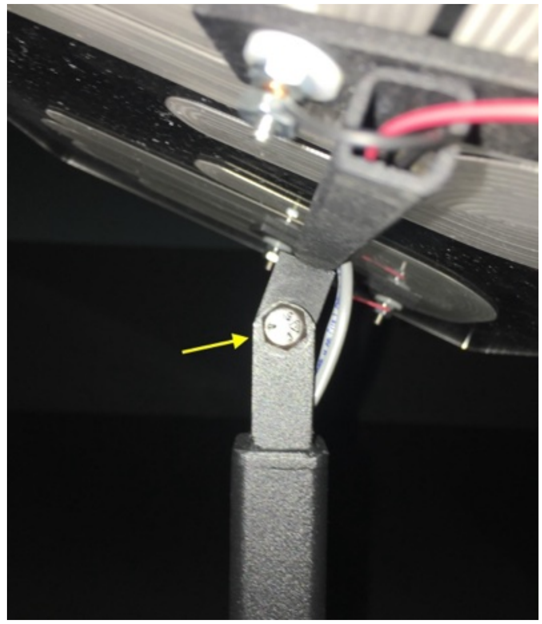





The hand plate or finger tube are wobbly.

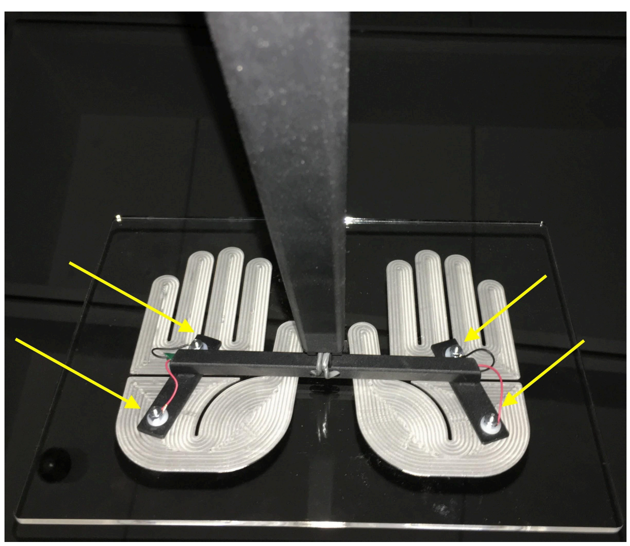
Check that all the set screws and the neck screw are tightened properly.





The hand sensors are not reacting to participants or are pretty erratic.

Check that the four wires running to the stainless steel fingers and palms are connected, as indicated below. These nuts should be firm in place, to have a good electrical contact.



Check that the PCB is still receiving 12VDC power. Are the LEDs on the PCB on? If not, the VDC power supply is not connected correctly.

Check that the left and right hand plate connectors are connected properly to the Polar Heart Rate PCB.

Check that the solenoid connectors are attached well. Press the solenoid button on the main PCB to force power to the solenoid. This will tell you if all the connections between the SSR relay and the solenoid are working well.

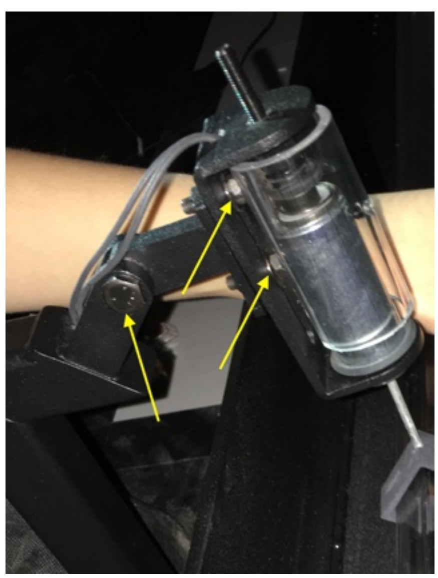
Check if the touch-sensing LED changes its blinking pattern when the hand plates are touched. If the blinking patterns do not change, then try changing the Polar Heart Rate PCB with a new one.

The finger sensor is not reacting.

The capacity touch threshold may need to be adjusted, as it might be set to too high a value. Open the GUI and check the **touchThresh** value.

The finger solenoid makes a loud, clogging sound.

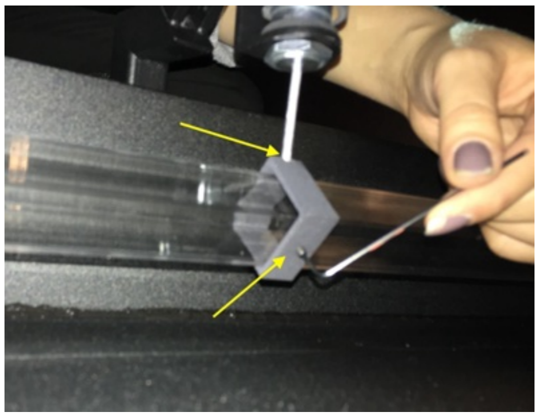
The acrylic ball at the tip of the solenoid plunger might be hitting the bottom of the tank, creating a noise. If so, the neck of the solenoid bracket may have gotten loose. Also, check to see if the two nuts and bolts holding the U-bracket in place are loose. Tighten them accordingly.



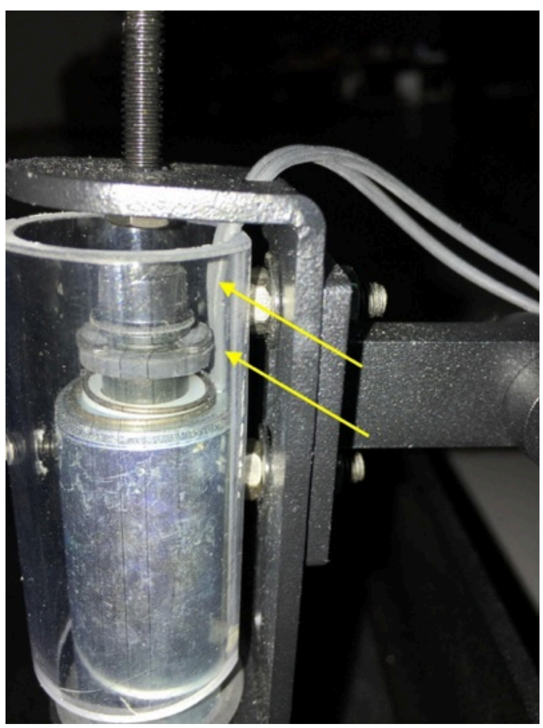
All the electronics and the connections seem fine, but the solenoid is not moving.

The plunger may be bent to the point of not being able to retreat or exit the solenoid body.

Or, the plastic square bracket attaching the plunger to the square tube may be putting a bending force on the plunger. You may loosen the plunger from the square bracket by unscrewing it a bit. If a set screw is on the square bracket provided to you, you may also loosen it.



Or, perhaps the plunger spring shaved some of the insulation off of the solenoid wires and the bare wire is now exposed. Contact the studio for guidance on how best to fix this issue.



Cursor is showing in the app

Open and close the GUI by pressing the ‘G’ key to hide the cursor. If this issue persists and the cursor is visible on app startup, download the Cursorcerer app, this will make the cursor disappear after a set amount of time of inactivity. Depending on the operating system’s version and the software version, there might be other solutions to deploy.

Troubleshooting Assistance

Prior to contacting the Antimodular Studio with a problem about your artwork, please ensure that you went through the preliminary troubleshooting steps outlined in the previous section.

The troubleshooting process will vary depending on the problem. In order to make the process easier, it is recommended that you collect and send the following information to the studio:

- Date and time when the problem first happened;
- Description of the problem;
- Actions taken so far and conclusions;
- Detailed photographs (or videos) displaying the problem;
- Detailed photographs (or videos) of the suspected faulty component;
- Detailed photographs (or videos) of the whole artwork and its surroundings;
- Personnel involved.

Support (Contact Us)

If you would like support for the piece, please feel free to call Lozano-Hemmer's studio in Canada:

Antimodular Research
4462 rue Saint-Denis
Montréal, Québec, Canada
H2J 2L1
Tel 1-514-597-0917
info@antimodular.com
www.antimodular.com

APPENDIX I - INSTALLATION

Description of Components

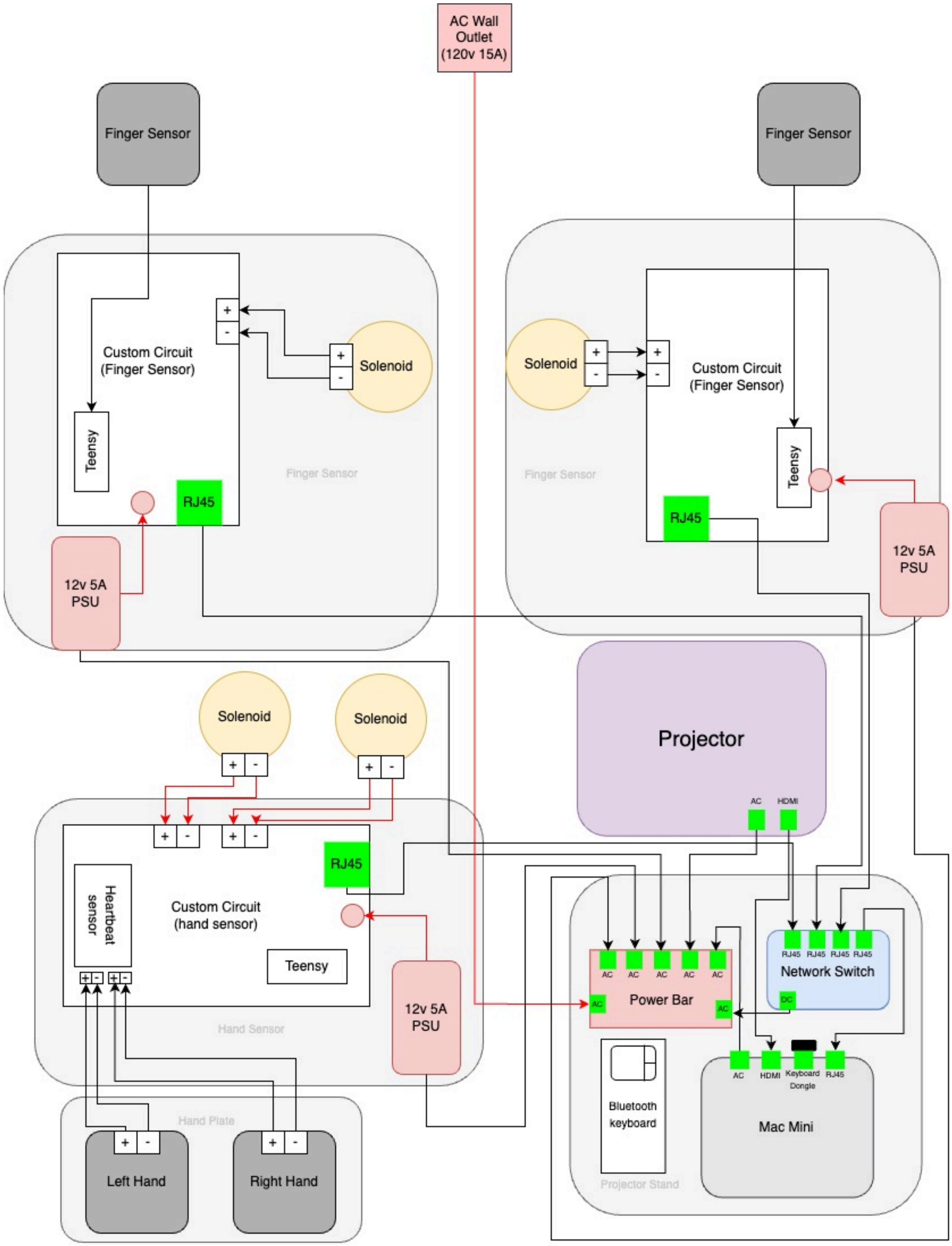
This artwork requires the following components:

Component	Description
Sensor's base	The base is present in both the custom finger sensor and custom hand plate sensor. This includes a T base, a rectangular box, and the main electronics for the sensors and the black plexi sides.
Sensor's PCB	Each sensor has a printed circuit board secured to an acrylic sheet alongside the power supply and labeled according to which stand it belongs in. The PCB reads the sensor's input and relays it to the computer over the network. The PCB is seating a Teensy and a Polar heart rate sensor. Each PCB is powered by a power supply also secured to the acrylic sheet.
Finger sensor stand - upper part (sensor)	The top part of the finger sensor's station, with sign plate and acrylic tube finger sensor.
Finger sensor	The acrylic tube assembly in which the interactors will insert their finger to record a pulse.
Finger sensor stand - lower part (solenoid)	The lower part of the custom finger sensor hosting the solenoid and acrylic ball that creates the ripples on the water surface.
Hand sensor stand	Has a custom hand acrylic plate with metal hand sensor cutouts.
Stand-alone solenoids	For the hand sensor, two solenoids are used, on mounts separated from the sensor stand. They are coupled with a long acrylic rectangular tube, to create linear ripples on the water surface.
Stand-alone solenoids acrylic tube support	This is a custom 3D printed component used to securely hold the acrylic tube in place.
Ethernet cables	The ethernet cables connect each of the sensors to the network switch and the computer to the network switch.

Metal base and mount for projector	Used to hold the projector securely in place. The base hosts the computer, the network switch and the power bar that powers every sensor and component from this single location.
Projector	Used to project light onto the tank, which will be reflected on the surrounding wall(s) and ceiling.
Metal grill	Used for mounting items inside the projector stand, preventing water leaks to reach the electronics too easily.
Computer	Apple MacMini running the software that controls the whole artwork rendition and receives and transmits signals from / to the sensors.
Video cable	Connects the computer to the projector. Might be coupled with a video adapter.
Network Switch	Allows communication between the computer and the sensors.
Water Tank	Contains the water into which the solenoids are dipping in.
Filter	Used to filter the water and clean the tank.

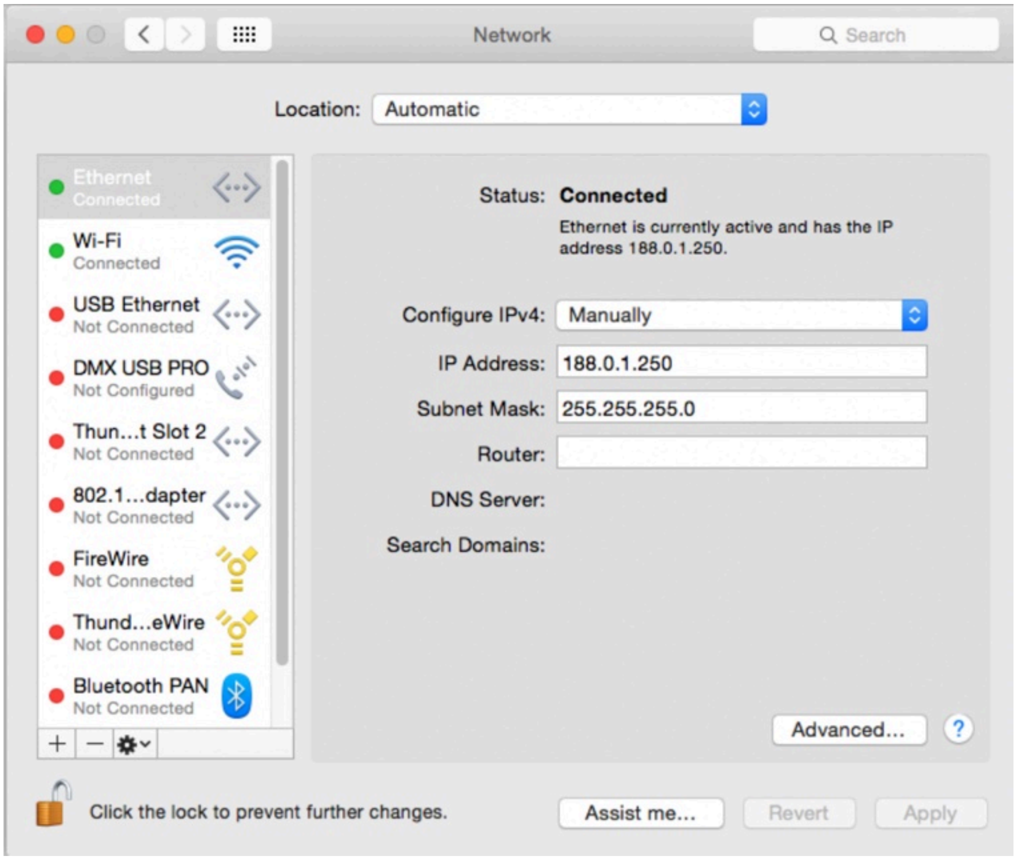
Wiring Diagrams and Connections

In order for the piece to run properly, the computer should be connected according to the following wiring diagrams.


AC Wall Outlet (120v 15A)
Finger Sensor
Finger Sensor
Custom Circuit (Finger Sensor)
Solenoid
Teensy
RJ45
12v 5A PSU
Finger Sensor
Custom Circuit (Finger Sensor)
Solenoid
Teensy
RJ45
12v 5A PSU
Finger Sensor
Projector
AC
HDMI
Solenoid
Solenoid
Custom Circuit (hand sensor)
Heartbeat sensor
Teensy
RJ45
12v 5A PSU
Hand Sensor
Hand Plate
Left Hand
Right Hand
Power Bar
AC
Network Switch
RJ45
DC
Bluetooth keyboard
Mac Mini
HDMI
Keyboard Dongle
Projector Stand

Network Connections

The computer's Ethernet network settings need to be configured to the following:



The sensors are set to IP addresses on the same network:

IP: 188.0.1.XXX

Subnet : 255.255.255.0

APPENDIX II - TECHNICAL DATA SHEETS

Sensor Bases

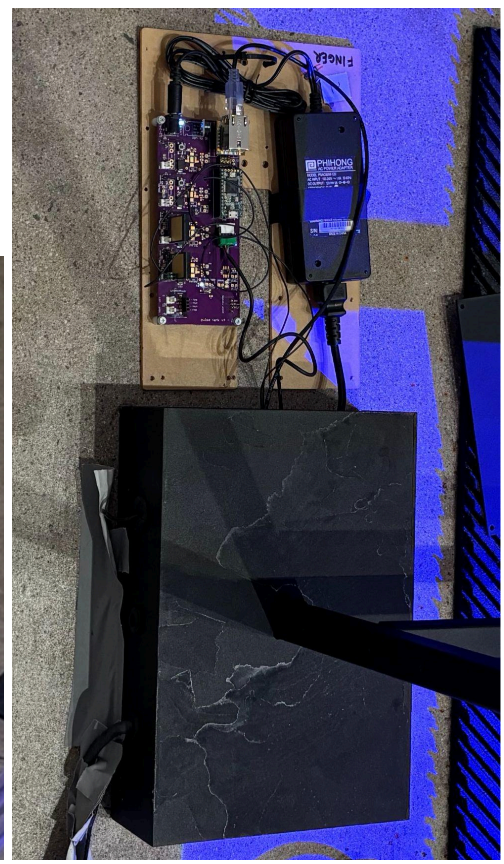
Sensor bases consist of three main elements: T base, the rectangular box that slips around the T base and the black plexi sides. This includes:

- A T base to be screwed to the ground in final position (note to not use double sided tape in future installations);

- A rectangular box, containing the following elements:
  - the sensor's PCB;
  - a power supply 12V/5A;
  - holes are drilled in the box to let power and network cabling out;
  - grommets are used to fill these holes, preventing water leaking onto electronics.

- Black plexi sides provided with screws, allowing to close the boxes, once the assembly of the bases is completed.

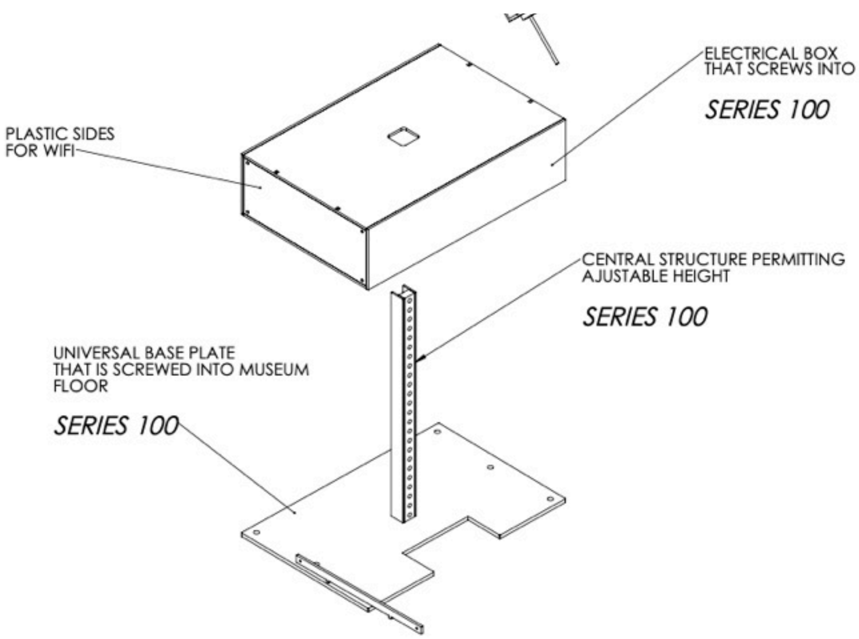
Sensor base - Assembled



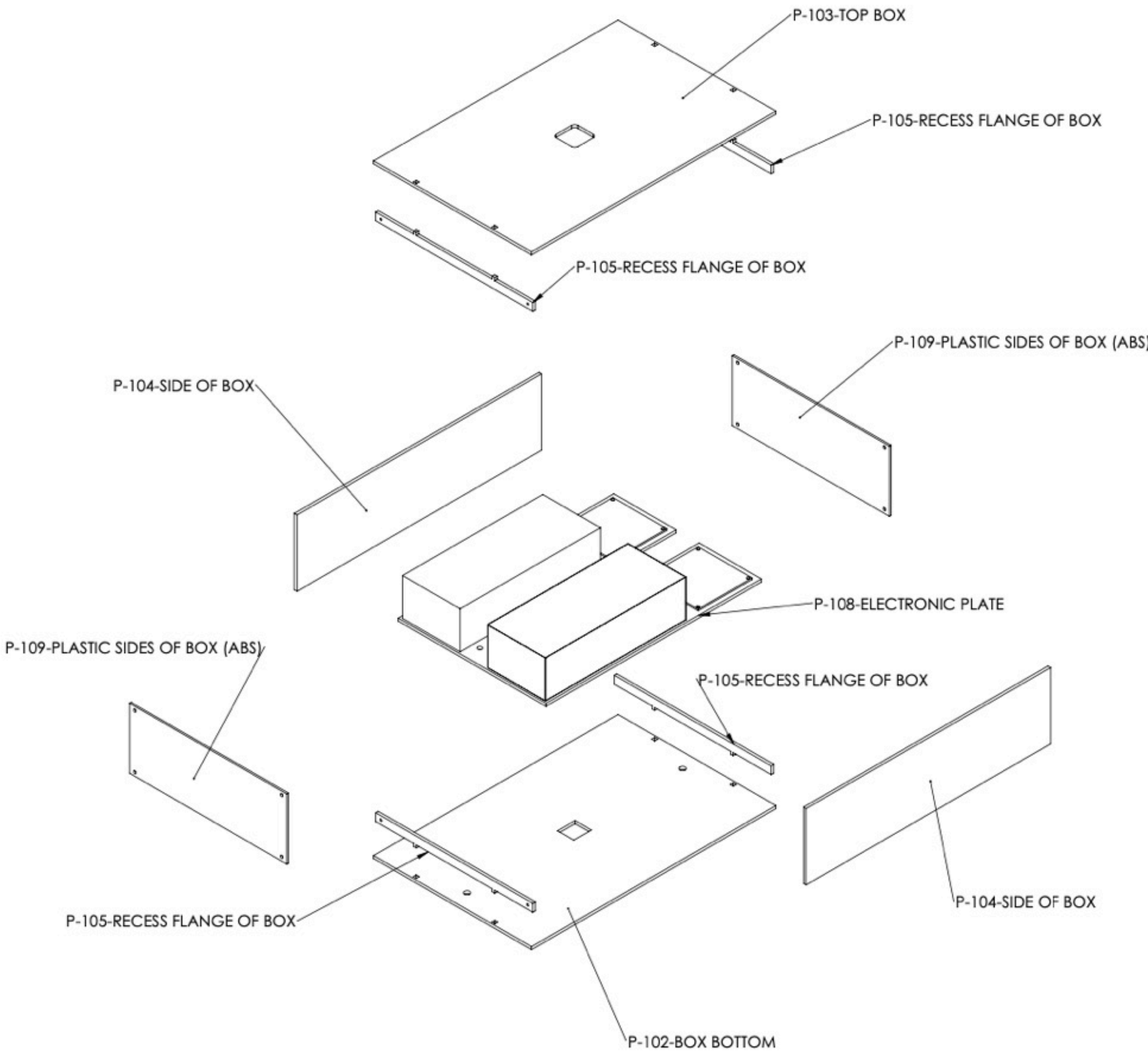
Embedded components

T base (no glue or tape should be used)

Black Plexi side



Box and T Base assembly



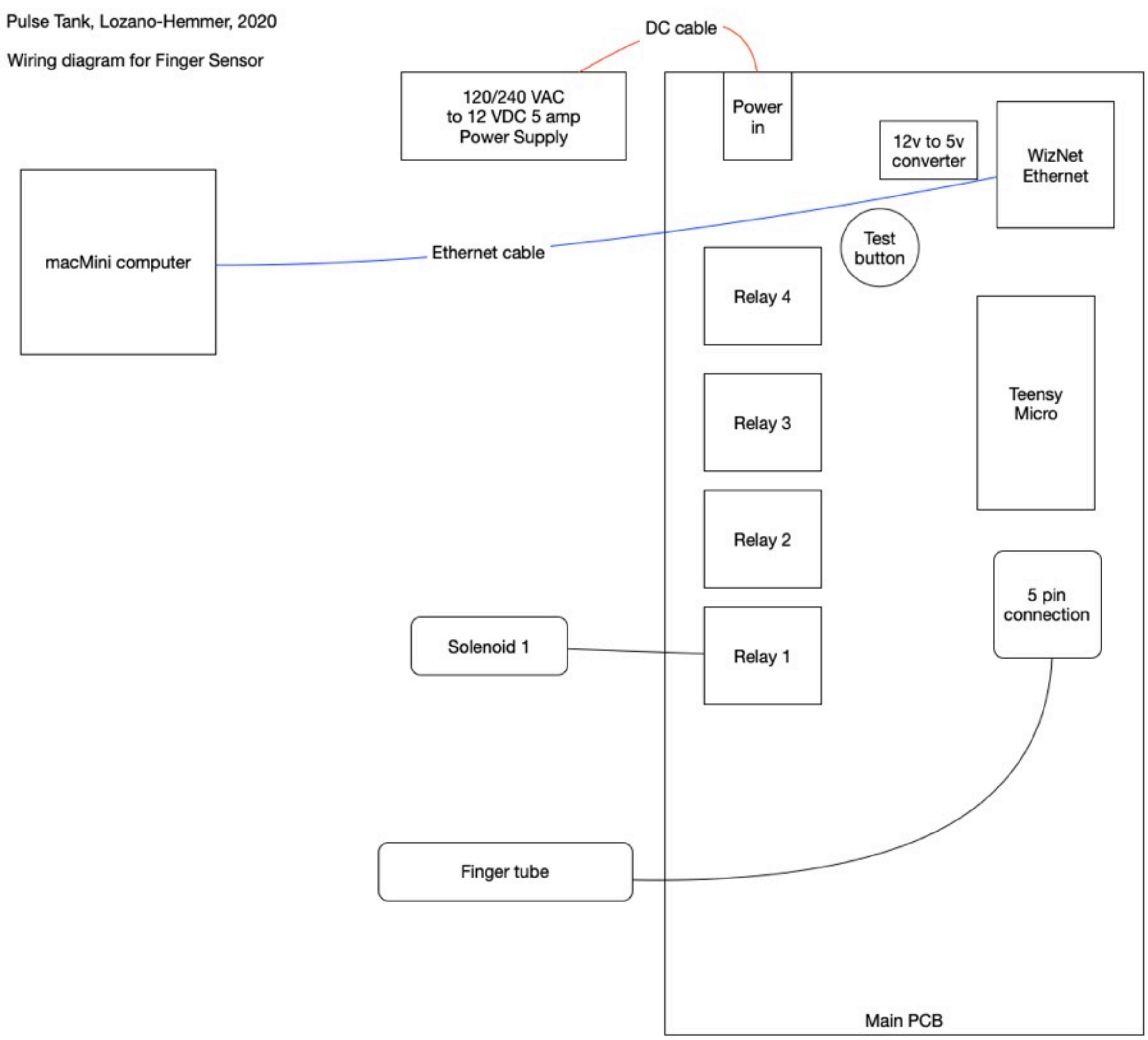
Components and assembly of the box

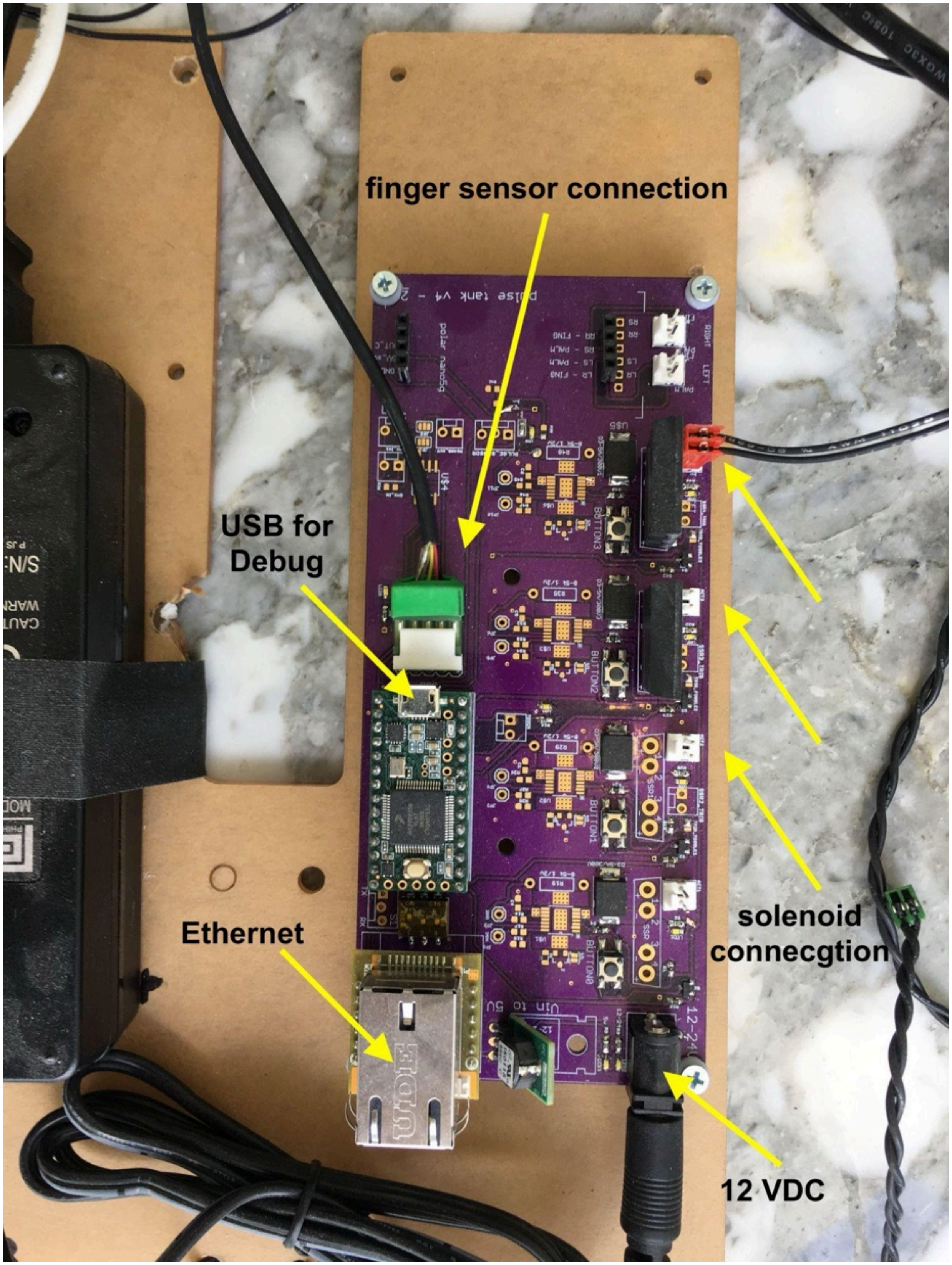
Sensor's electronics

All sensors will have the same electronics embedded inside the sensor's base: the main PCB, a Teensy board, a Polar heart rate sensor. All these are powered by an AC-DC power supply.

Finger Sensor's PCB

The finger sensor collects information from the pulse sensor in the tube, uses the teensy to process it and connects to the network switch in order to send information back to the software running on the computer. This manual shows the "Pulse Tank v4" version of this PCB.

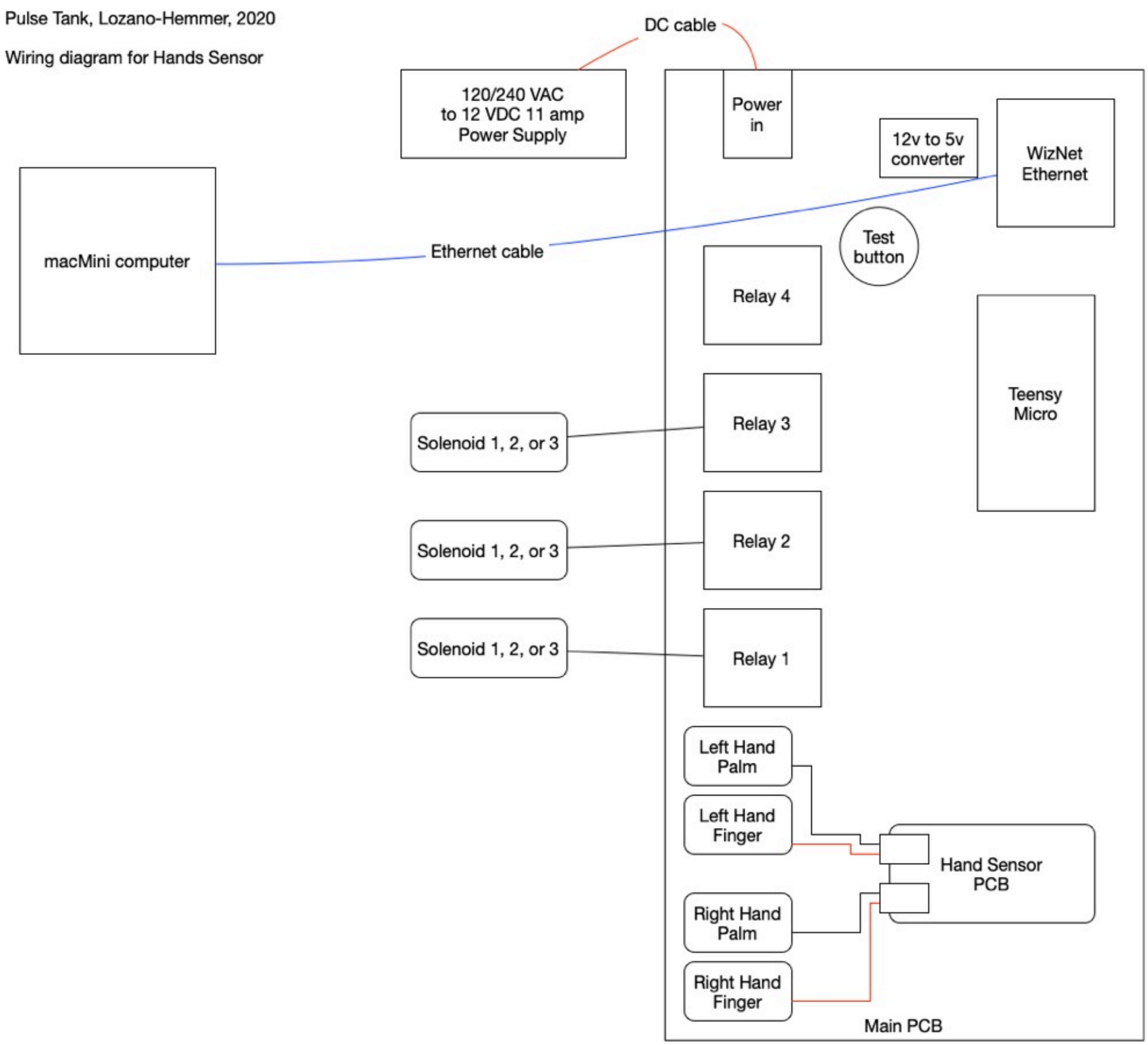


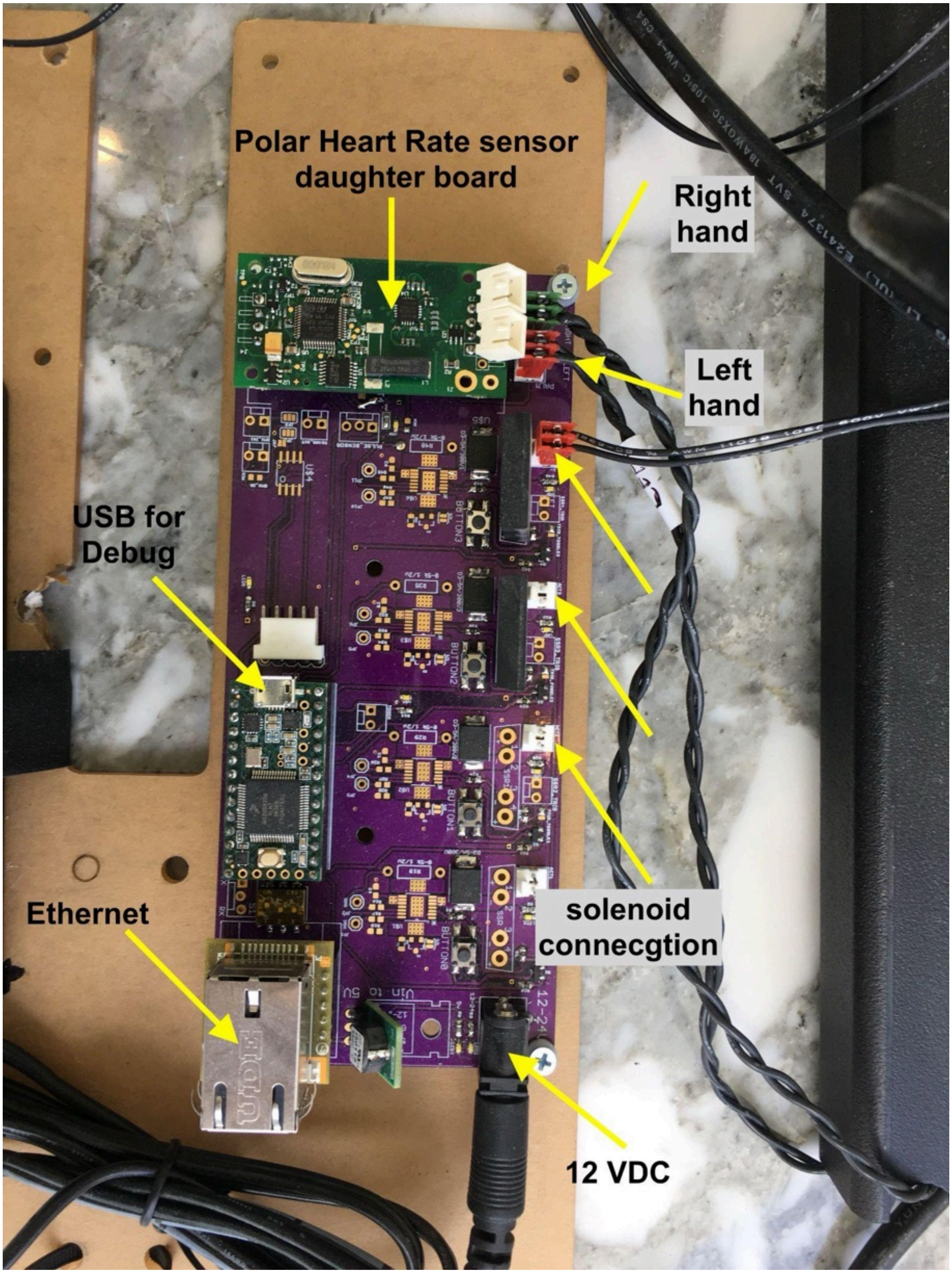


finger sensor connection
USB for Debug
Ethernet
solenoid connecgtion
12 VDC

Hand Sensor's PCB

The hand sensor collects information from the electrical pulses detected in the hand plate. It then sends that information to the Polar sensor on the board. Then it uses the teensy to process it and connects to the network switch in order to send information back to the software running on the computer. This manual shows the "Pulse Tank v4" version of this PCB.



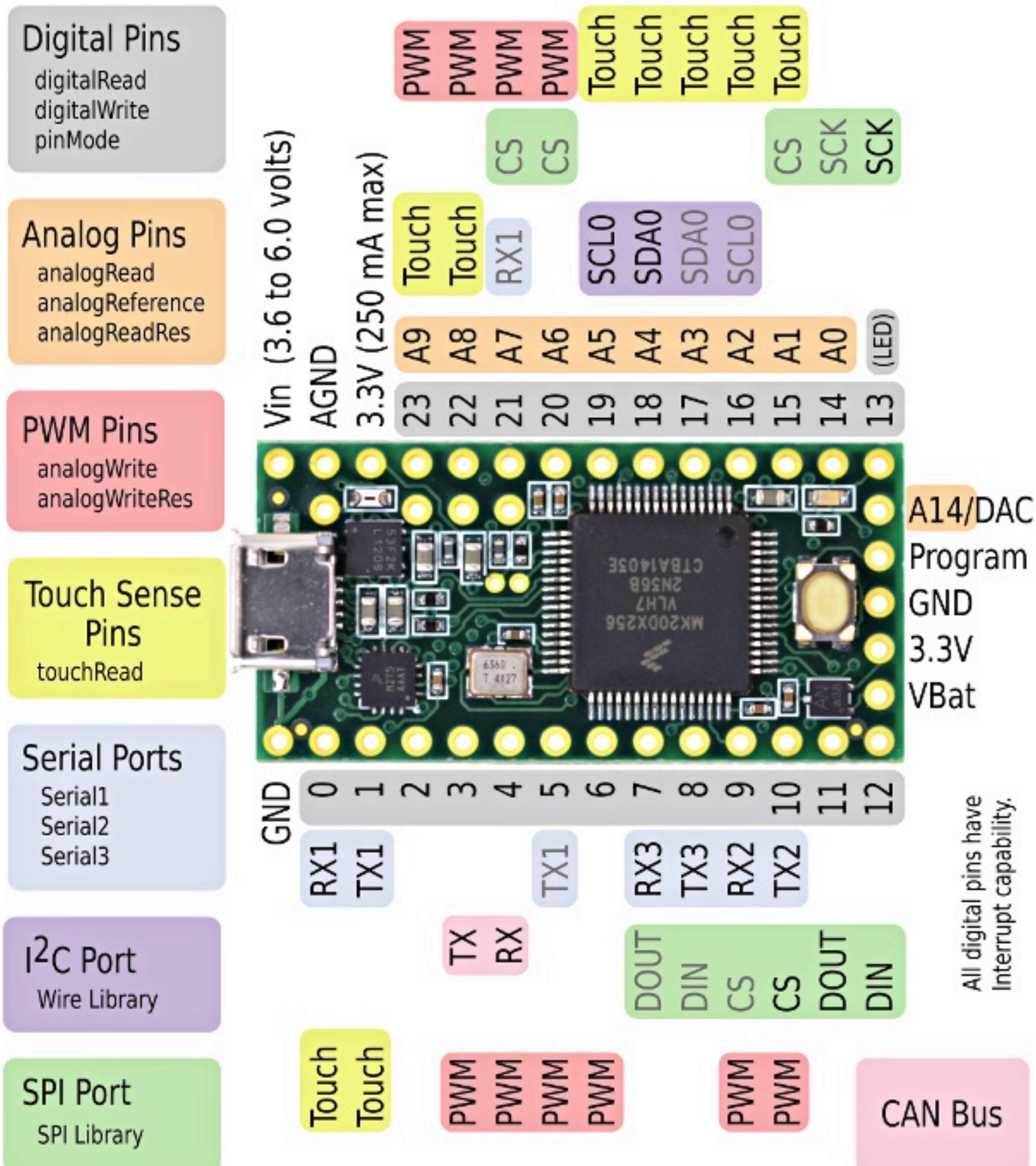

Polar Heart Rate sensor
daughter board
Right
hand
Left
hand
USB for
Debug
Ethernet
solenoid
connecgtion
12 VDC

Teensy

The Teensy is used to process the sensor's input. So far, only version 3.2 has been used.

Technical Specifications:

- 5v power draw
- 32 bit ARM Cortex-M4 72MHz CPU (M4 = DSP extensions)
- 256K Flash Memory, 64K RAM, 2K EEPROM
- 3 UARTs (serial ports)
- Touch Sensor Inputs

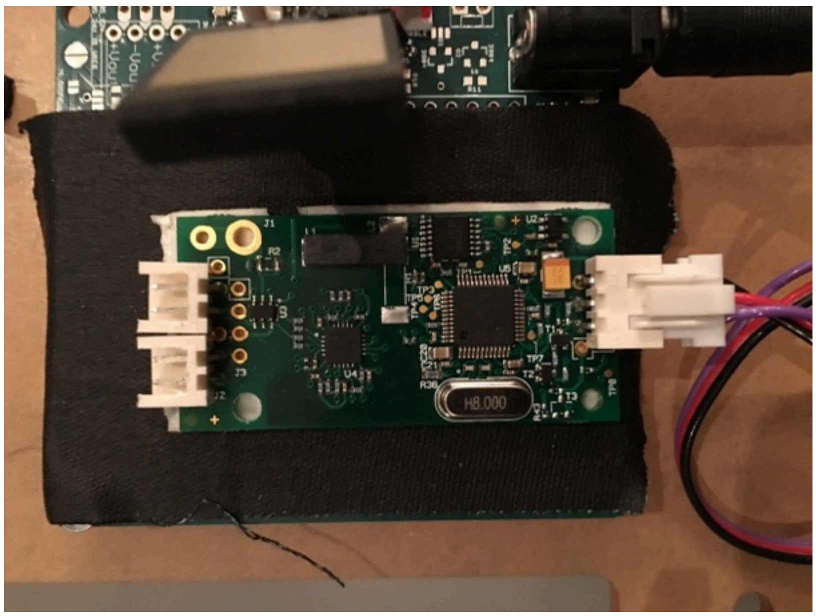


Digital Pins
digitalRead
digitalWrite
pinMode
Analog Pins
analogRead
analogReference
analogReadRes
PWM Pins
analogWrite
analogWriteRes
Touch Sense Pins
touchRead
Serial Ports
Serial1
Serial2
Serial3
I2C Port
Wire Library
SPI Port
SPI Library
Vin (3.6 to 6.0 volts)
AGND
3.3V (250 mA max)
23 22 21 20 19 18 17 16 15 14 13
A9 A8 A7 A6 A5 A4 A3 A2 A1 A0
(LED)
Touch Touch
RX1
SCL0 SDA0 SDA0 SCL0
CS CS
CS SCK SCK
PWM PWM PWM PWM
Touch Touch Touch Touch Touch
A14/DAC
Program
GND
3.3V
VBat
GND
0 1 2 3 4 5 6 7 8 9 10 11 12
RX1 TX1
TX1
RX3 TX3 RX2 TX2
TX RX
DOUT DIN CS CS DOUT DIN
Touch Touch
PWM PWM PWM PWM
PWM PWM
CAN Bus
All digital pins have Interrupt capability.

Polar Heart Rate Sensor

In the hand sensor version, a Polar heart rate sensor is added to the PCB to read the heart rate from the interactor's hand leaned on the hand plate's contact points.

The model in use is the Nano 5G PSL20 (SKU: 9405 2951.01).



Power Supply

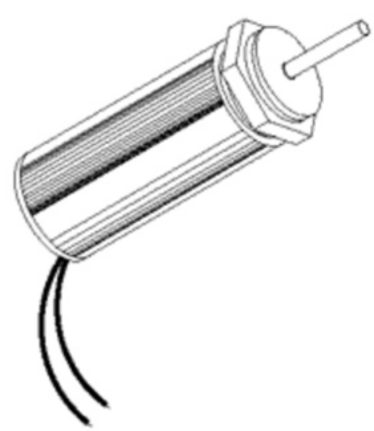
The power supplies for all three of the sensors are strapped in place next to them on an acrylic board as seen in the image below. Each board requires 12v and 5A

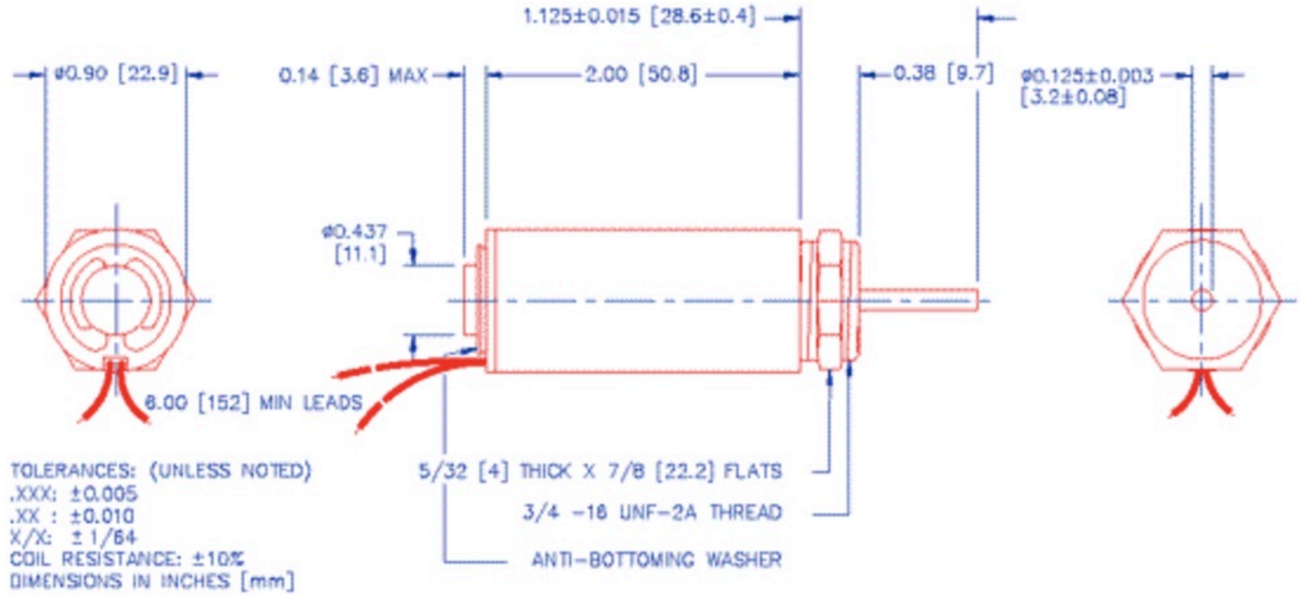
Solenoids

For both finger and hand sensors, the piece uses solenoids as actuators, to dip into the water. The finger sensor's solenoid will be equipped with an acrylic ball screwed in at the tip, while the hand sensor's solenoids will be equipped with a 3D printed support bracket holding an acrylic tube.

Specification	Details
Type	Push type
Voltage	12 VDC
Diameter / Length	23mm / 51mm
Mounting method	Threaded front end matching ¾"-16 nut
Internal resistance	1.5 Omhs
Approximate input Power	90 Watts
Plunger type	75mm long aluminum pin, tip threaded with a #6-32 thread.

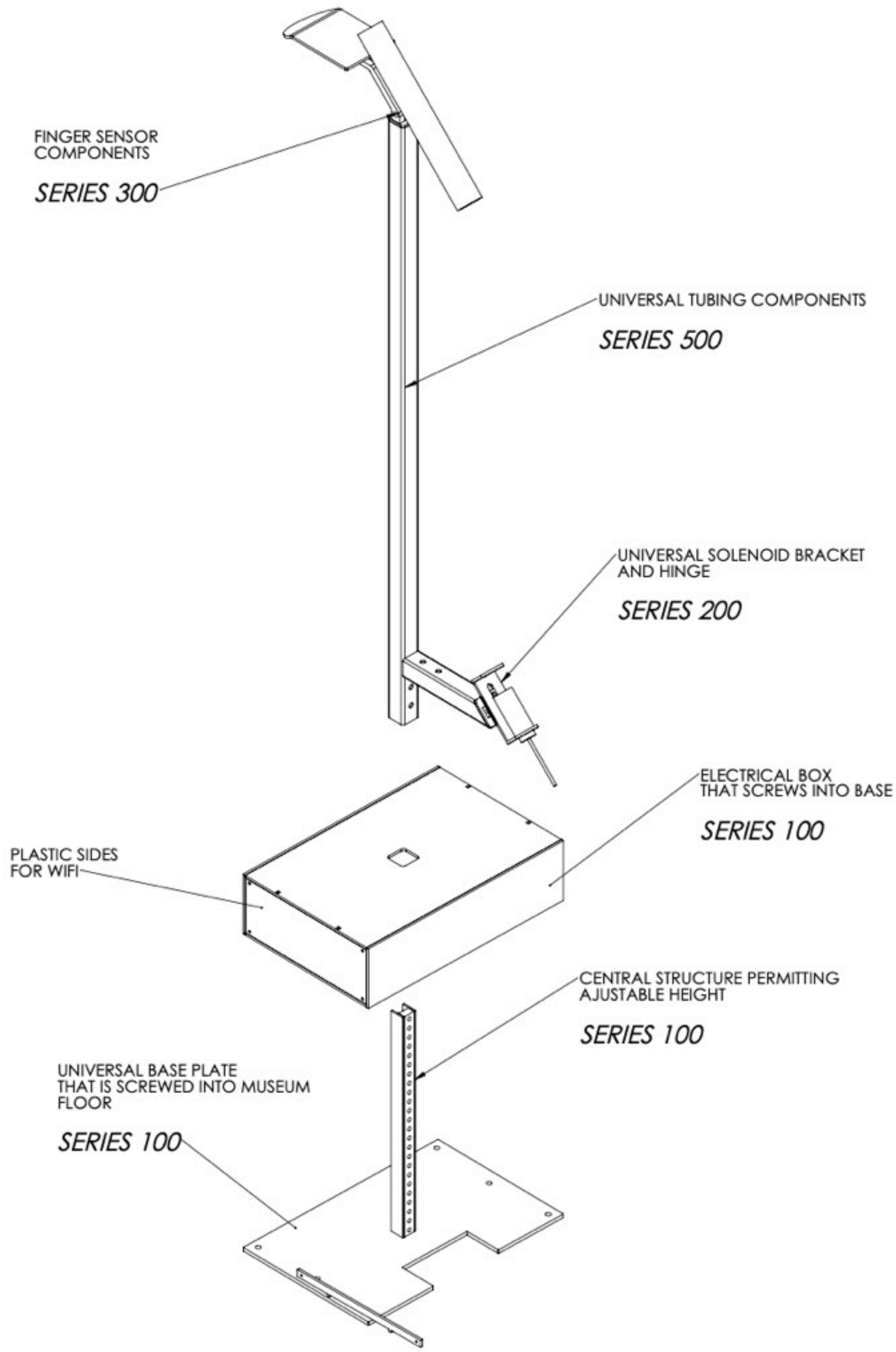
So far, the following model has been used with the work: **SOTUH02305112P.**

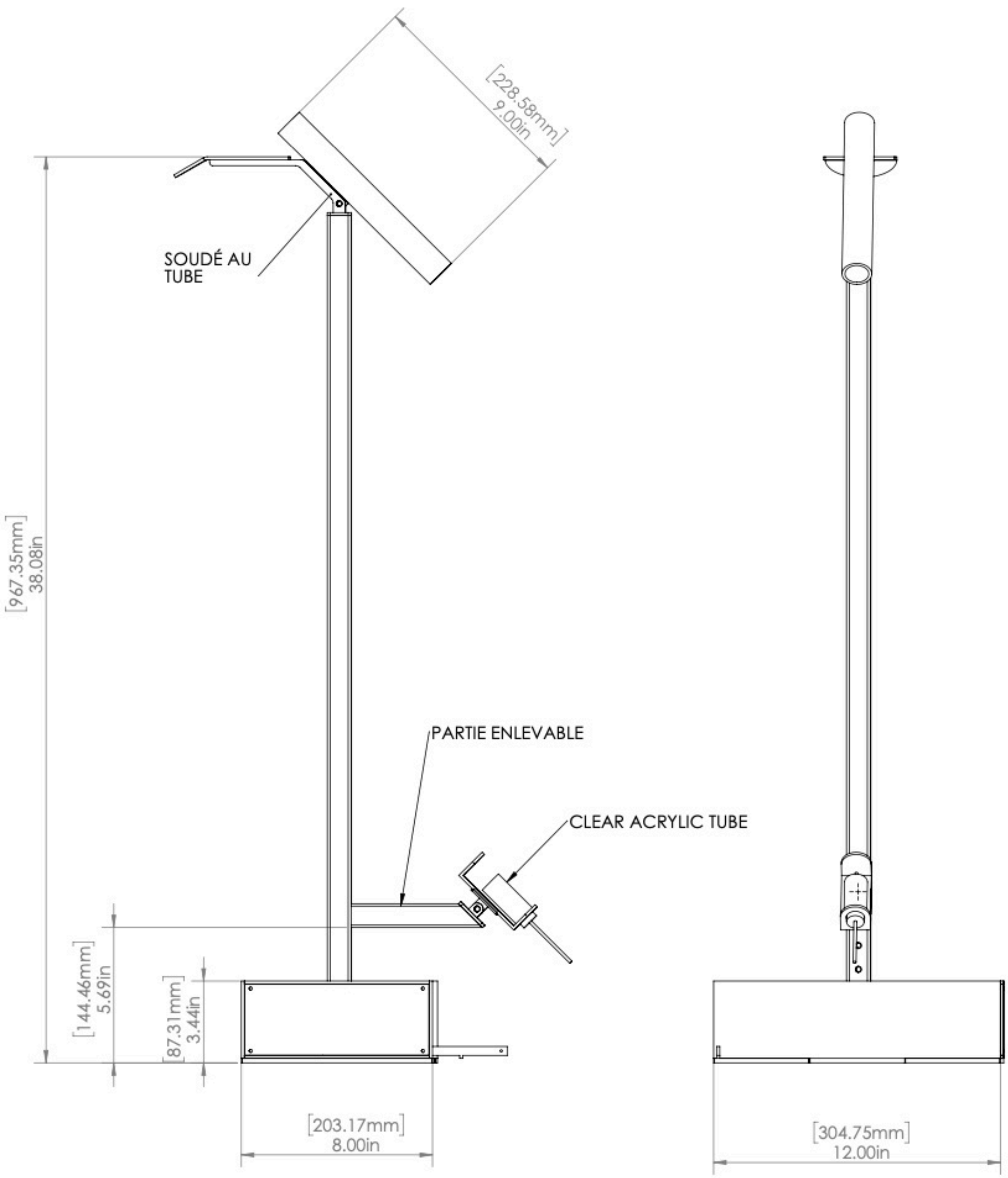



ø0.90 [22.9]
0.14 [3.6] MAX
1.125±0.015 [28.6±0.4]
2.00 [50.8]
0.38 [9.7]
ø0.125±0.003
[3.2±0.08]
ø0.437
[11.1]
6.00 [152] MIN LEADS
5/32 [4] THICK X 7/8 [22.2] FLATS
3/4 -16 UNF-2A THREAD
ANTI-BOTTOMING WASHER
TOLERANCES: (UNLESS NOTED)
.XXX: ±0.005
.XX : ±0.010
X/X: ± 1/64
COIL RESISTANCE: ±10%
DIMENSIONS IN INCHES [mm]

Finger Sensor Stand

The finger sensor stand is assembled on a base (T base, sensor box, electronics): two metal tube parts are used to elevate the sensor (upper part) to the desired height and fish in all electronics cabling required. The stand also hosts a solenoid in the lower part and a sign plate in the upper part.

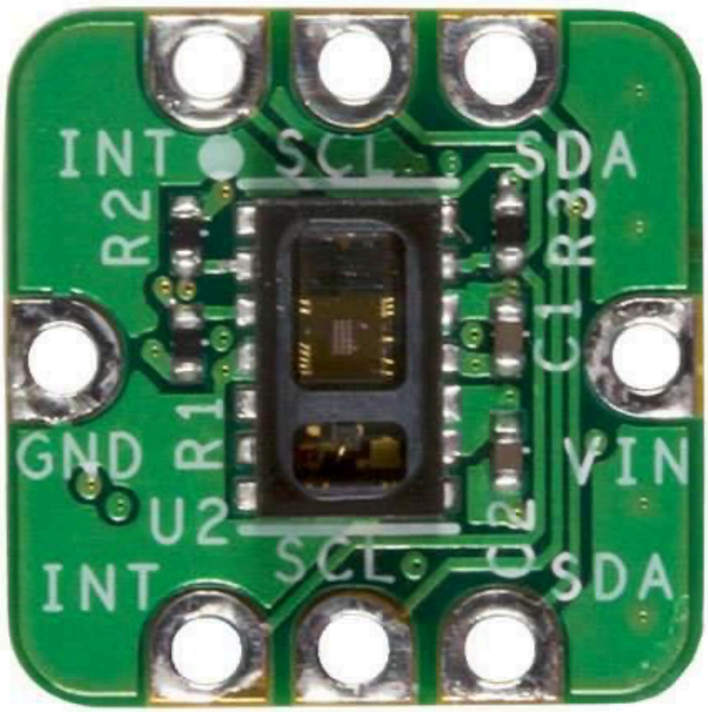



[228.58mm]
9.00in
SOUDÉ AU
TUBE
[967.35mm]
38.08in
PARTIE ENLEVABLE
CLEAR ACRYLIC TUBE
[144.46mm]
5.69in
[87.31mm]
3.44in
[203.17mm]
8.00in
[304.75mm]
12.00in

Finger Sensor - Heart Rate and Pulse-oximetry Sensor

In the finger sensor cylinder, a heart-rate and pulse oximetry monitor is embedded to read the heart rate from the interactor’s finger inserted in the cylinder. The sensor reads through the blood opacity to detect when new blood (lighter, allowing more light through the finger) is fed to the finger.

The model used so far is the MAXREFDES117#.



MAXREFDES117#: HEART-RATE AND PULSE-OXIMETRY MONITOR

The MAXREFDES117# reference design is a low power, optical heart-rate module complete with integrated red and IR LEDs, and a power supply. This tiny board, perfect for wearable projects, may be placed on a finger or earlobe to accurately detect heart rate. This versatile module works with both Arduino and mbed platforms for quick testing, development and system integration. A basic, open-source heart-rate and SpO_2 algorithm is included in the example firmware.

The board features 8 sewing tap pads for attachment and quick electrical connection to a development platform.

As with all Maxim reference designs, the BOM, schematics, layout files, and Gerber files are all available from the Design Resources tab. In addition, boards are available for purchase.

Features

- Optical Heart-Rate Monitor and Pulse Oximetry Solution
- Tiny 12.7mm x 12.7mm (0.5in x 0.5in) Board Size
- Low Power
- Device Drivers
- Free Algorithm
- Example C Source Code For Arduino And mbed Platforms
- Test Data

System Diagram

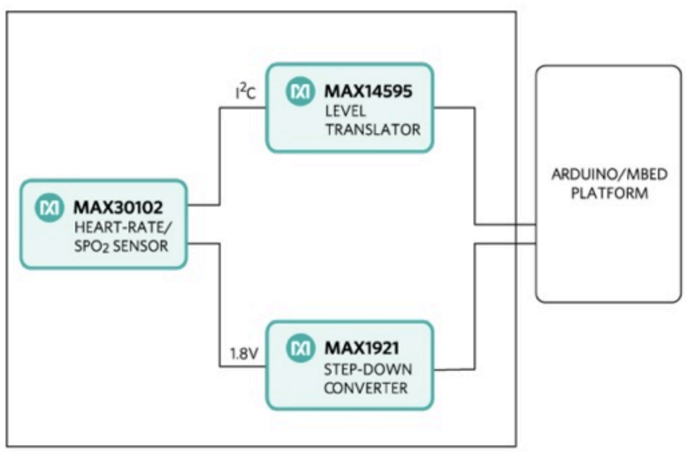


Figure 1. MAXREFDES98# reference design block diagram.

The power requirement is shown in **Table 1**.

Table 1. Power Requirement for the MAXREFDES117# Reference Design

Input Voltage (V)	Input Current (mA, typ)
2V to 5.5V	1.5mA (3.3V input)

Note: Controller board is powered separately

Detailed Description of Firmware

The MAXREFDES117# can be used with virtually any microcontroller that has I^2C interface. The Arduino and mbed example firmware have been tested on the following development platforms:

mbed:

- Maxim Integrated MAX32600MBED#
- Freescale FRDM-K64F
- Freescale FRDM-KL25Z

Arduino:

- Adafruit Flora
- Lilypad USB
- Arduino UNO

Users may read sampled data, calculated heart rate and SpO_2 through a terminal program, allowing analysis on excel or any third-party software. The simple process flow is shown in **Figure 2**.

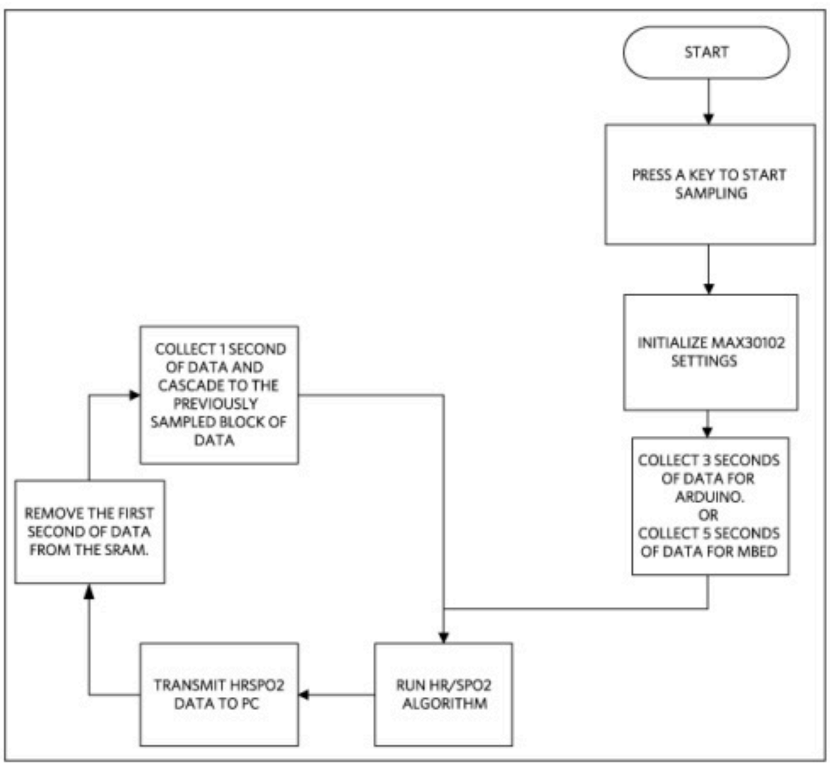


Figure 2. The MAXREFDES117# firmware flowchart.

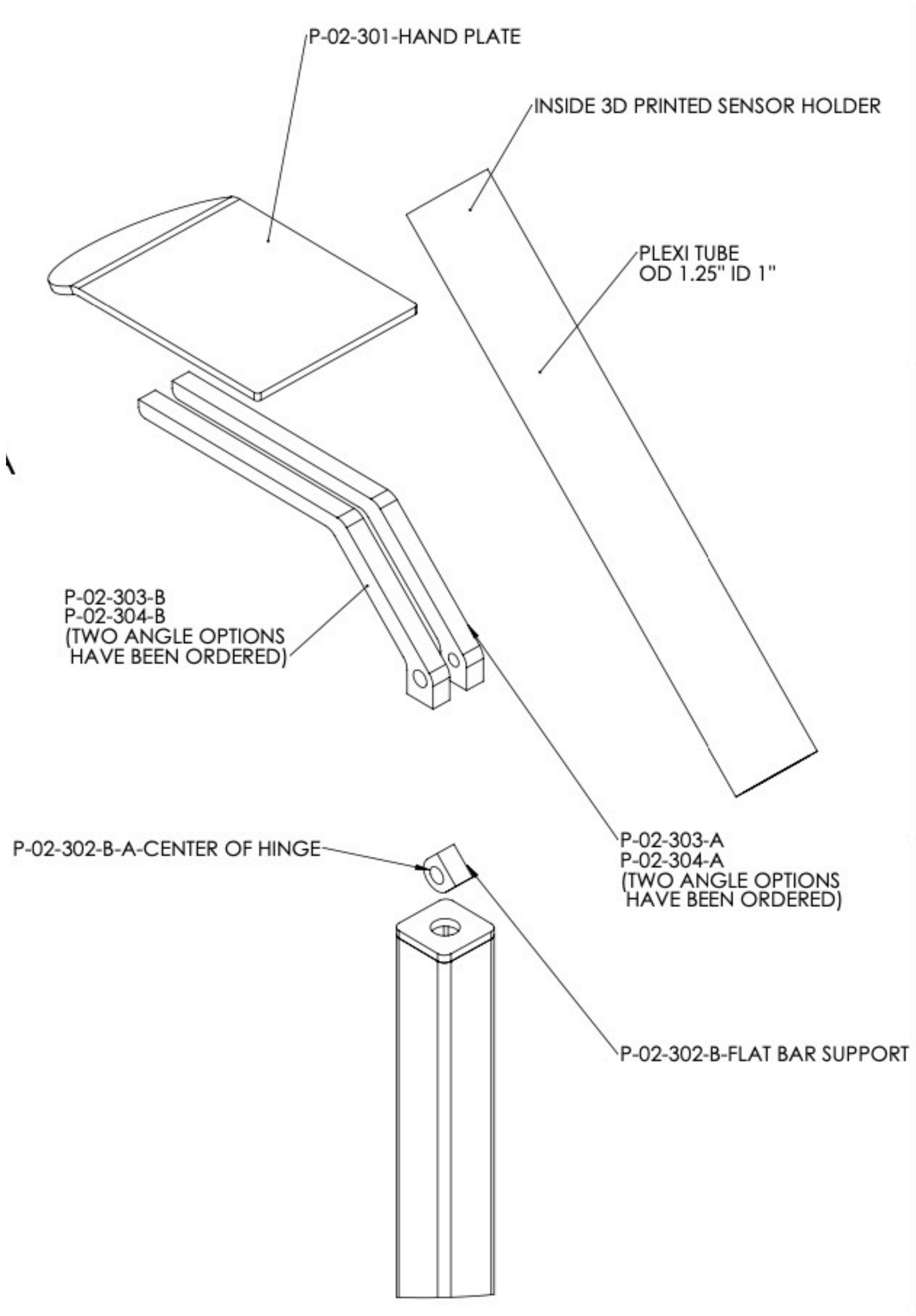
Upper part (sensor)

Participants place a finger into the tube to get the artwork to collect their pulse data. The wires for the sensor are fished through the bottom of the tube and into the base where they connect to the sensor's PCB.

.

Close up of the finger sensor

Overall view of the finger sensor.


P-02-301-HAND PLATE
INSIDE 3D PRINTED SENSOR HOLDER
PLEXI TUBE
OD 1.25" ID 1"
P-02-303-B
P-02-304-B
(TWO ANGLE OPTIONS
HAVE BEEN ORDERED)
P-02-303-A
P-02-304-A
(TWO ANGLE OPTIONS
HAVE BEEN ORDERED)
P-02-302-B-A-CENTER OF HINGE
P-02-302-B-FLAT BAR SUPPORT

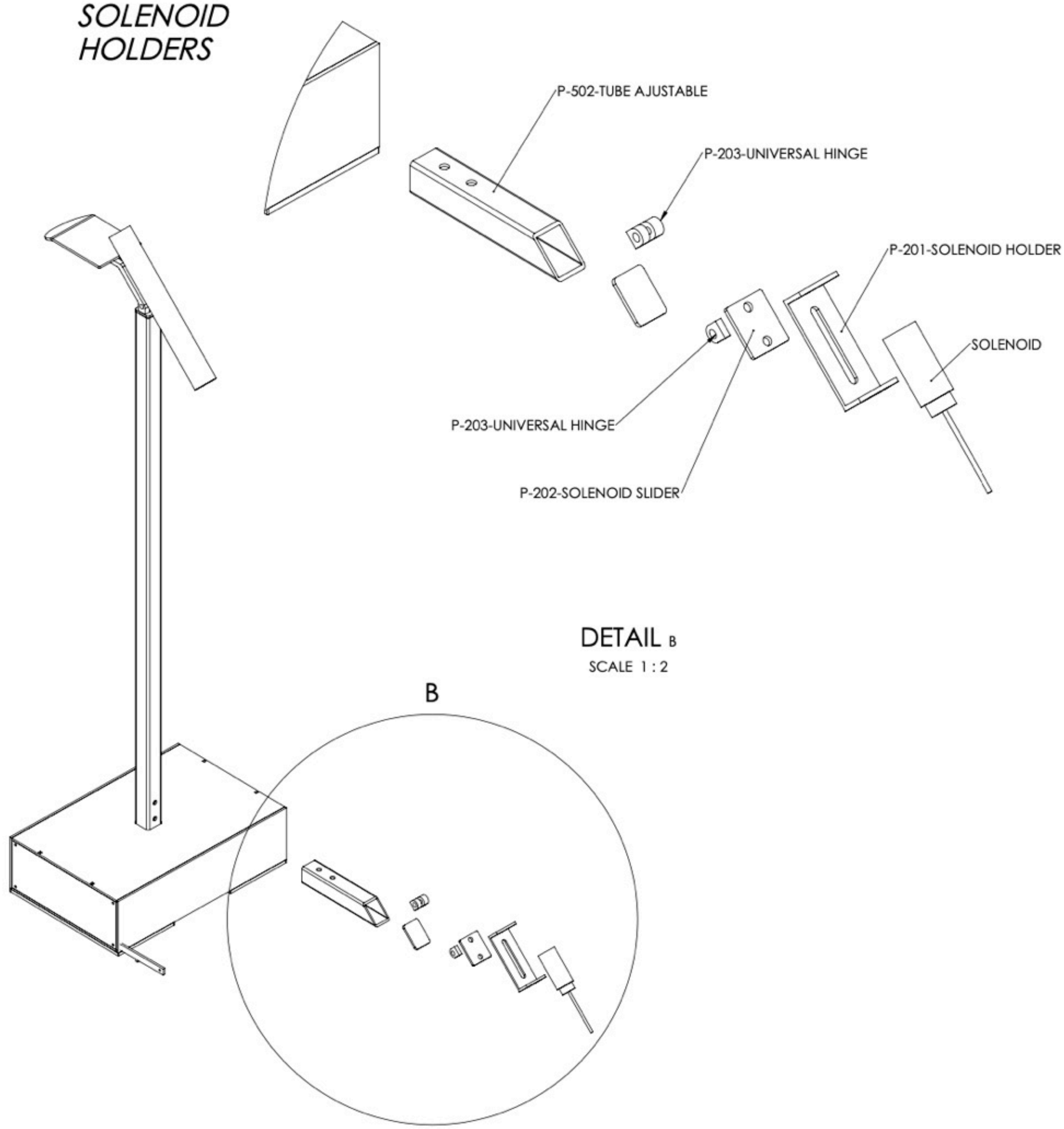
Lower part (solenoid)

The solenoid is attached directly to the metal arm and pushes forward based on the pulse data received from the sensor in the upper part. This creates ripples in the water. The wiring for the solenoid is fished through the end of the bar and into the base where it connects to the PCB. The portion of the arm extending over the tank could have been modified depending on the exhibition's space, to make it longer than following's drawing.

Close up of the solenoid

Overall view of the arm

SERIES 200 SOLENOID HOLDERS



Acrylic Ball

The arm on the lower part of the finger sensor has a solenoid with a clear acrylic ball attached to the end of its aluminium pin. A hole has been drilled in the ball and the acrylic has been tapped to match the solenoid's pin thread. When the ball dips in the water, it creates ripples in the water when the finger sensor is used.

The photos below show the acrylic ball attached to the sensor arm.

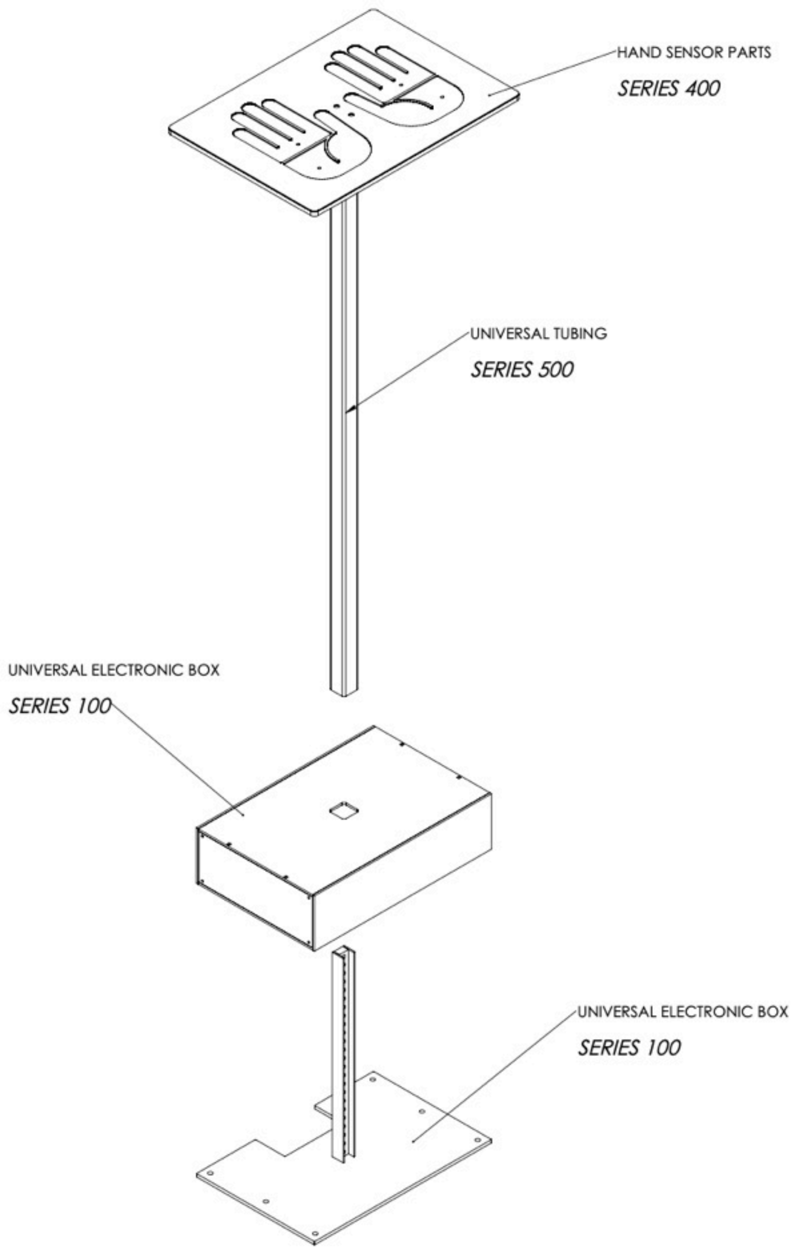
The ball (Scratch and UV resistant Acrylic ball) can be purchased as part number 1383K58 at McMaster-Carr and replacement parts must meet or exceed these specifications.

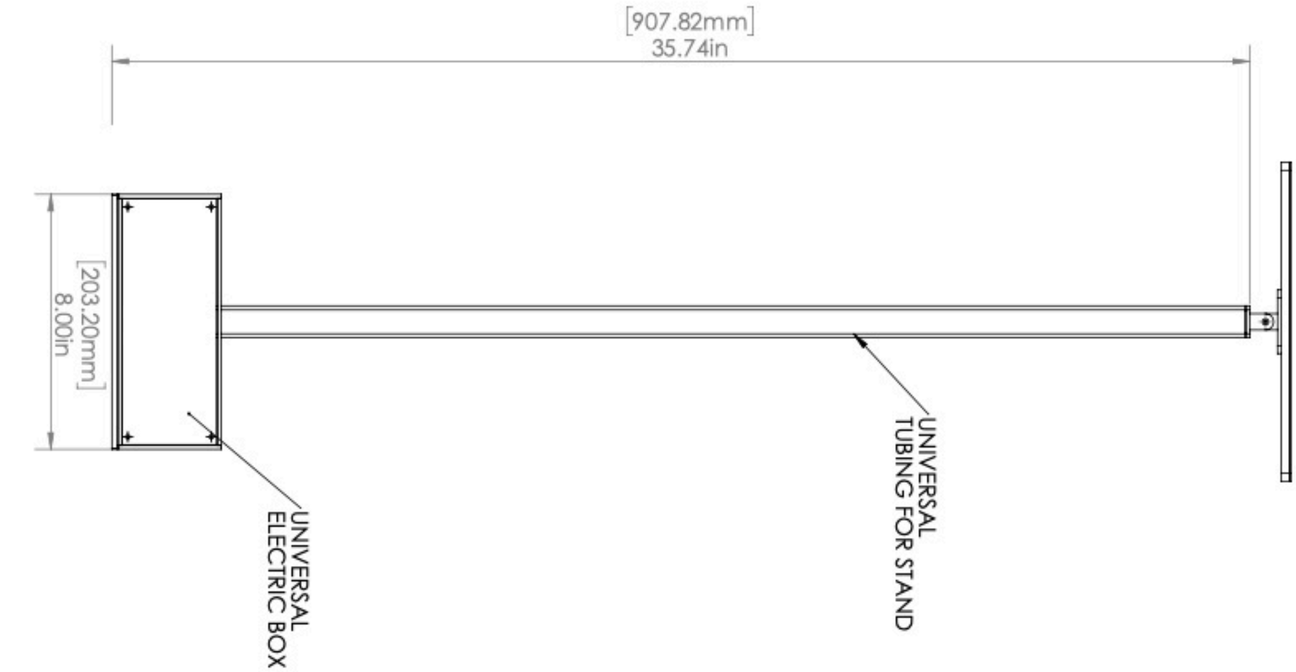
Specification	Description
Diameter	1" +/- a 0.002" tolerance
Clarity	Semi-clear
Material	Acrylic Plastic
Texture	Smooth
Maximum temperature	180° F
Impact Strength	0.040 ft.-lbs/in
Hardness	Rockwell M89-M96 (Hard)
Chemical resistance	Resistant to water, bleach
Useful performance properties	Clear, electrical insulator, high strength, low thermal expansion, slippery, UV resistant, weather resistant

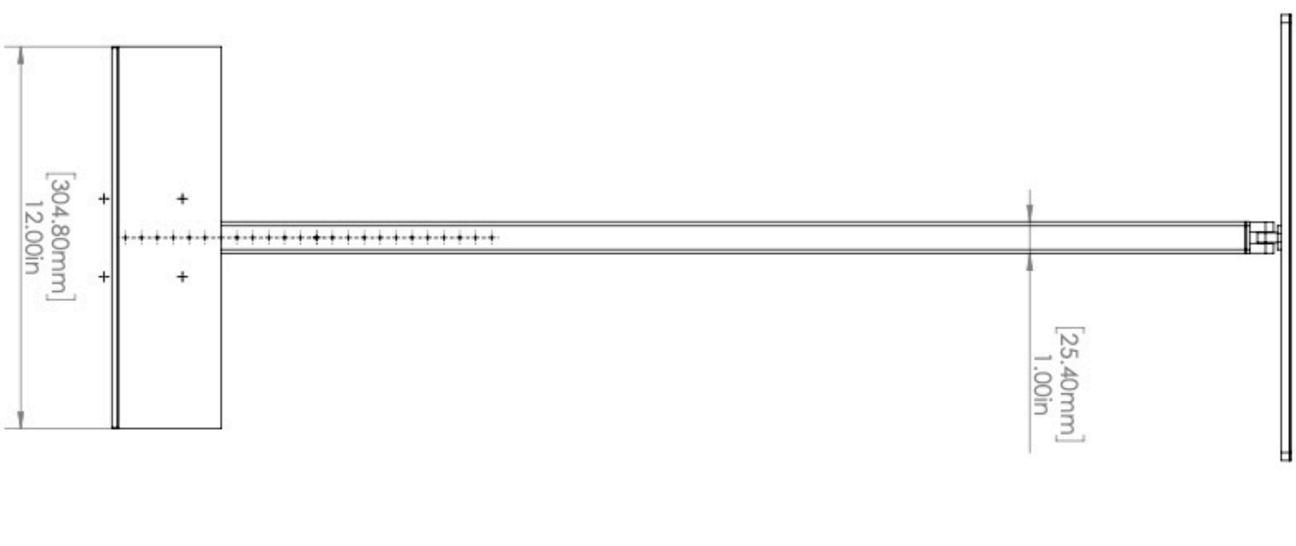
Hand Sensor Stand

Stand

The hand sensor supports a custom acrylic pane with conductively painted hands. The wires from the acrylic plate are fished through the length of the stand and connected to the PCB within its base.

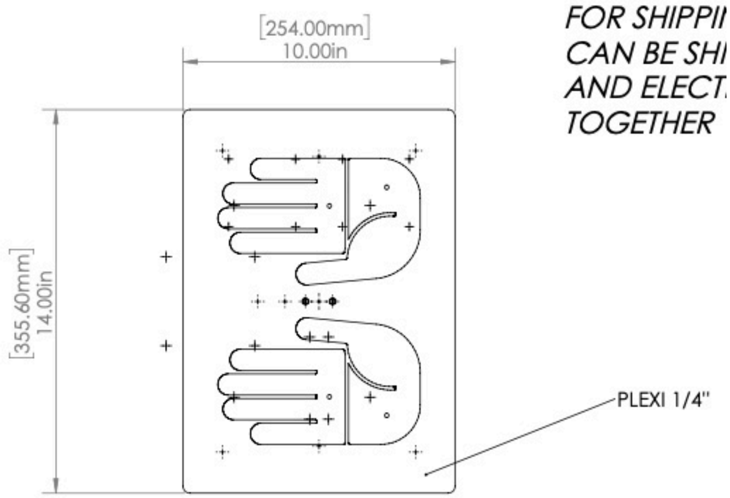


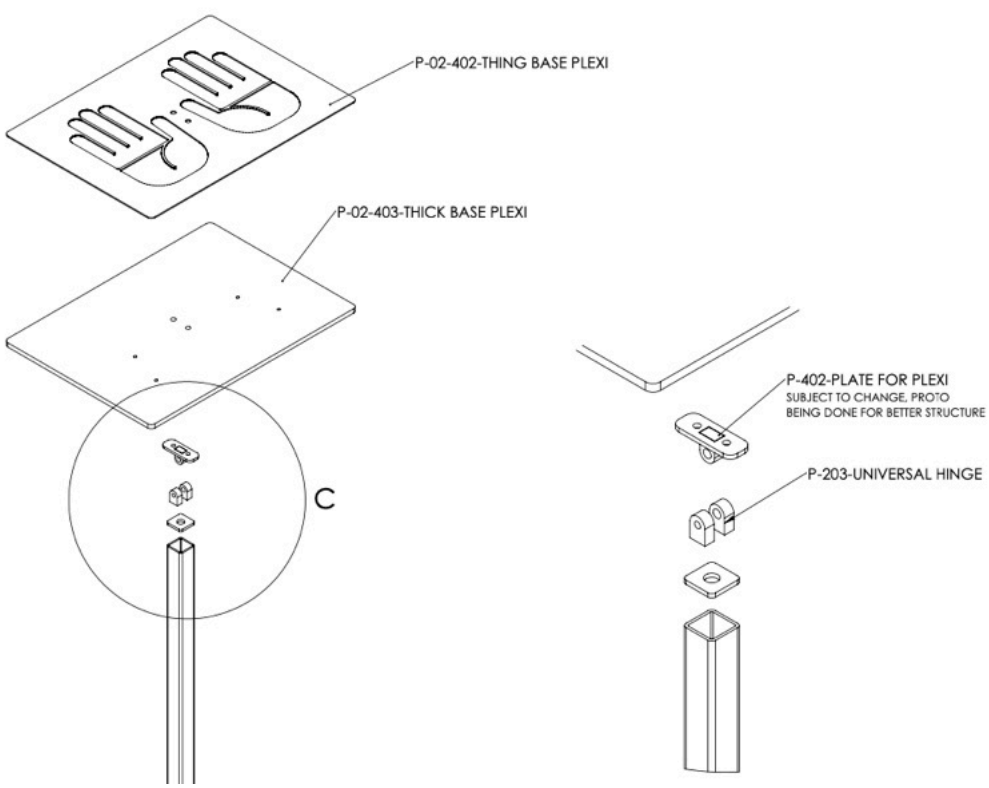

[907.82mm]
35.74in
[203.20mm]
8.00in
UNIVERSAL
TUBING FOR STAND
UNIVERSAL
ELECTRIC BOX


[304.80mm]
12.00in
[25.40mm]
1.00in

Hand plate

The hand plate as seen in the images below is a ¼" thick acrylic pane with hand prints placed on in thin conductive metal. Nuts underneath these plates secure them and transmit data from the heartbeat of the participants to the sensor in the base.

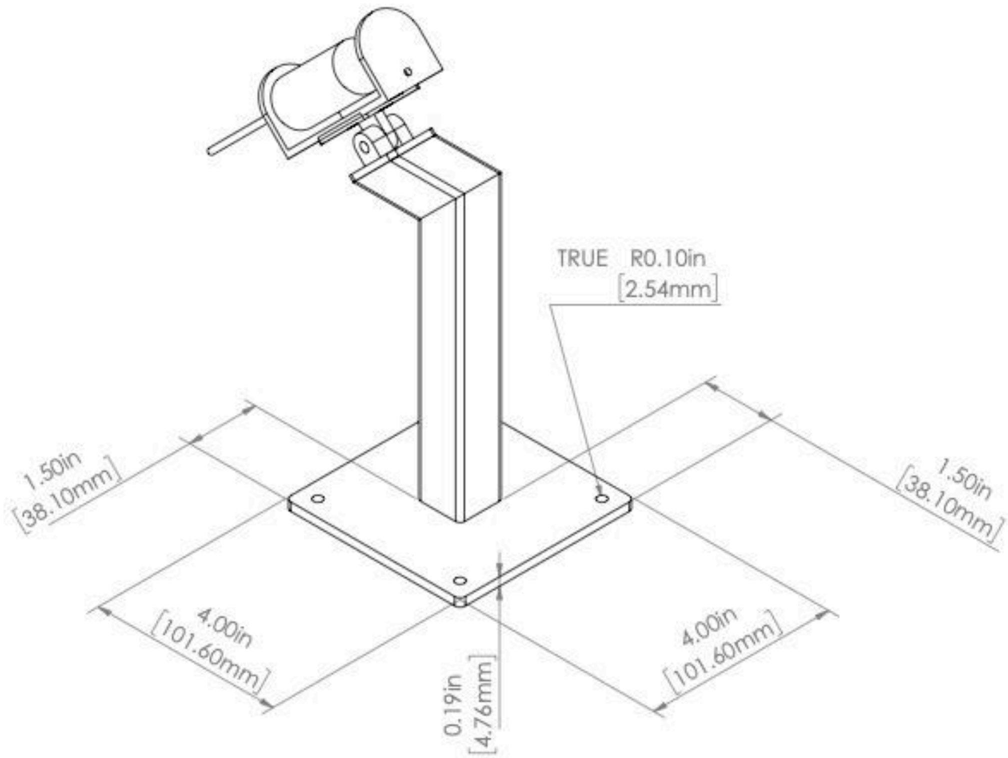


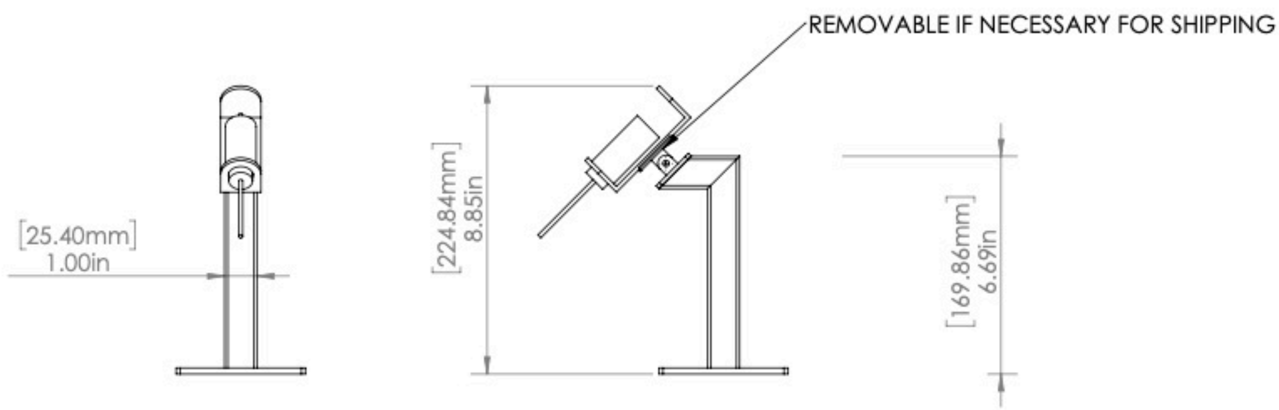


Stand-alone solenoids

The stand alone solenoids must be bolted directly into the floor through their base. Their wires will be connected to the hand plate pcb seated in the base of the hand plate sensor. On the end of their aluminium pins sit custom 3d printed brackets to support the acrylic bar. When a heartbeat is detected they will pulse with it creating waves within the tank.

Stand alone solenoids


TRUE R0.10in
[2.54mm]
1.50in
[38.10mm]
1.50in
[38.10mm]
4.00in
[101.60mm]
4.00in
[101.60mm]
0.19in
[4.76mm]

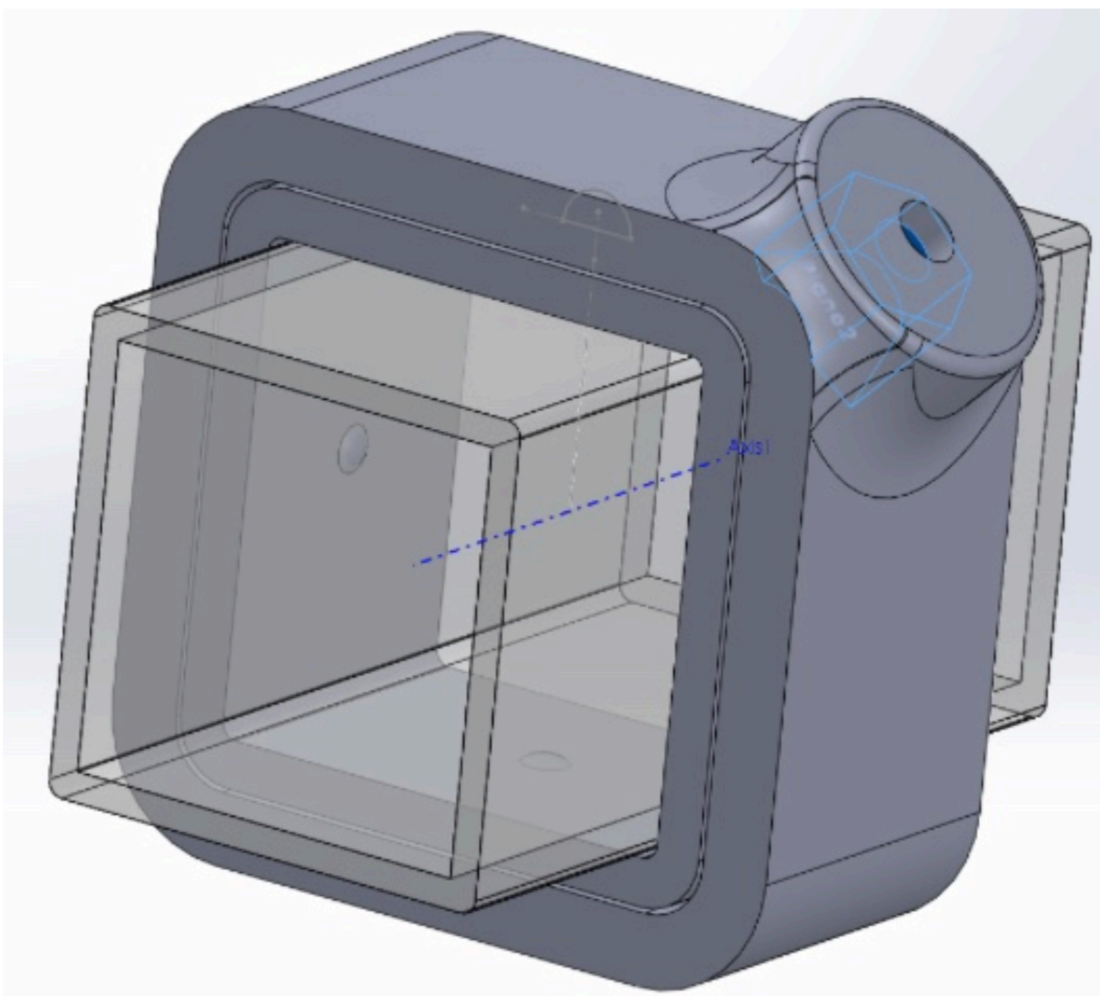

REMOVABLE IF NECESSARY FOR SHIPPING
[25.40mm]
1.00in
[224.84mm]
8.85in
[169.86mm]
6.69in

Acrylic tube support

These have been custom printed by the studio to couple the acrylic bar to the solenoid. When printed in ASA or PLA-CF (carbon fiber reinforced), the bracket should be sturdy enough for the artwork's reaction.

Previous iteration of that bracket was a simple square plastic frame, with a #6-32 thread tapped in the center of a side edge and a set screw in the center of one of said edge's opposite sides.

We improved that part to the following: a version where a #6-32 nut is inset in the assembly (in the outer ring), built for better strength. The inner ring has bumps at the center of all sides (inside and outside) to press on the acrylic bar and into the bracket, making a tight connection without the need of a set screw.



Acrylic Rectangular Tube

The clear acrylic bar (Scratch and UV resistant Acrylic Rectangular Tube) can be purchased as part number 8516K37 at McMaster-Carr and replacement parts must meet or exceed these specifications. The length will vary depending on tank dimensions. The shortest bar used today was 6ft long.

Specification	Description
Wall Thickness	1/16”
Outside Dimensions	72” (L) x 1” (W) x 1” (D)
Clarity	Clear
Material	Acrylic Plastic
Texture	Smooth
Light Transmission	85%
Maximum temperature	180° F
Impact Strength	0.040 ft.-lbs/in.
Hardness	Rockwell M89-M96 (Hard)
Chemical resistance	Resistant to water, bleach
Useful performance properties	Clear, electrical insulator, high strength, low thermal expansion, slippery, UV resistant, weather resistant

The bar is sealed against water using end caps (vinyl snap-in square plug). They can be purchased as part number 7984N13 at McMaster Carr. The ridges seen in the image below are trimmed until the cap fits snugly inside the bar and then is sealed with black waterproof sealant.

Specification	Description
For inside size	0.83"-0.93" x 0.83"-0.93"
Shape	Square
Height	7/16”
Material	Vinyl Plastic
Maximum temperature	350° F
Hardness	Durometer 60A
Color	Black

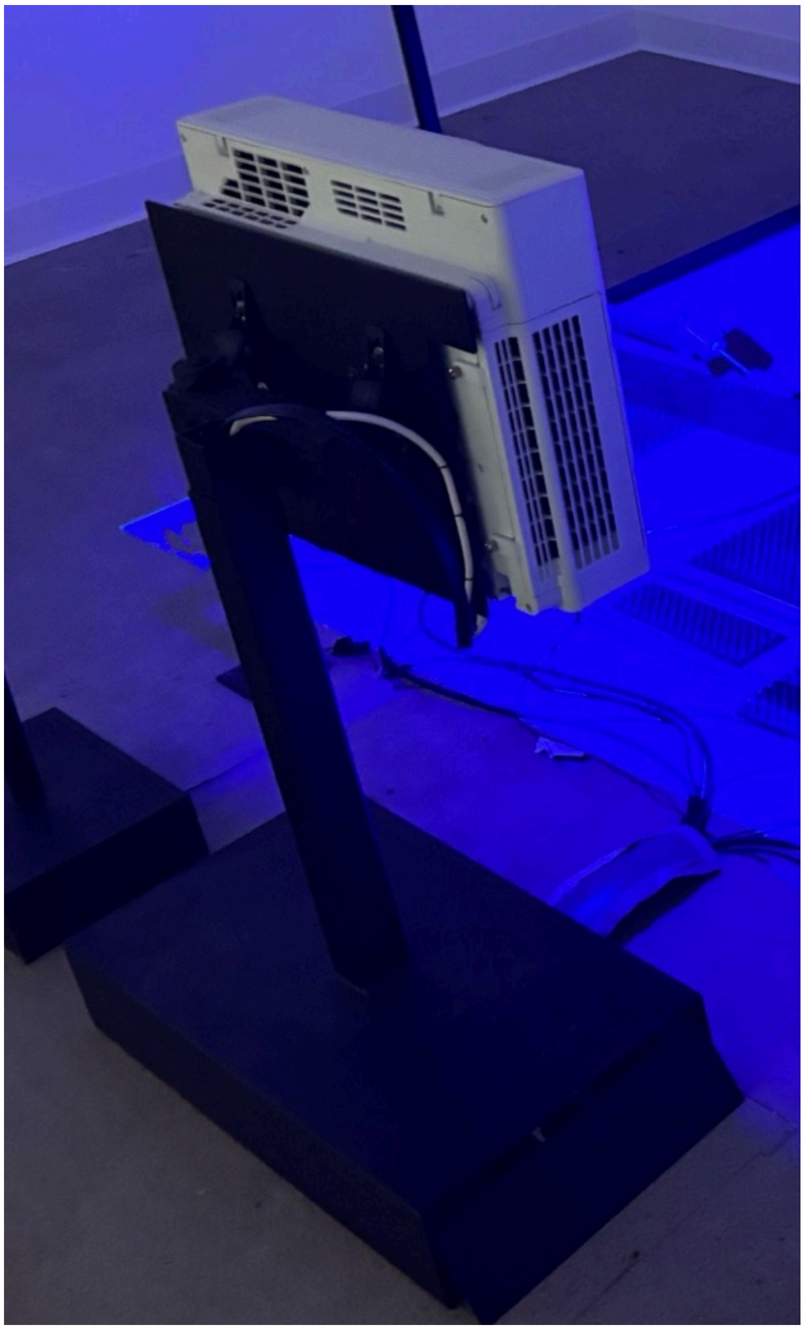
Ethernet cabling

Any regular straight CAT6 ethernet cable would do the work here, as long as the cables are black jacketed to match with the bases and most of the equipment. In case there is any slack in a cable, please coil the extra part and hide it under the tank, while ensuring to not get it pinched between the tank and the floor, or mats).

Replacing the provided cabling with others of different length for an easier cabling management should be feasible, however, it should be tested before final installation.

Projector’s Metal Base and Mount

The projector stand is designed to be screwed into the back of the projector and support it as seen in the image below. The base of the stand is constructed in the same way as the sensor base stands, with a T base and a hollow metal box that allow the power supply and video cabling connected to the projector to be fished through.



Projector Stand

Projector

The projector in use here has been selected for its resolution's form factor (16:9) and its high brightness, as the projector's light should be the only light source in the exhibition's space. Allowing its reflection on surrounding walls to be punchy and the main attraction in the exhibition space.

It is worth noting that consumer market and low-budget projectors are rarely a good solution for this work as any bad color balance or uneven brightness which are usually less noticeable on a regular projection will be emphasized with the reflection of the light and could create some sort of smudge effect or discoloration. A projector with a short throw lens could also create such a problem.

Ideally, the reflected light would be white coloured, daylight - around 4500-5000 Kelvin.

The exhibition's space and tank dimensions would impact the total brightness desired for the projector. A 2.3 metres wide tank would call for a projector of at least 5000 lumens. A 4 metres wide tank would call for a projector of at least 10,000 lumens.

In previous installations, a Christie DHD951-Q projector was used and loved for its light quality, while paired with an ultra-short throw lens (121-127101-XX), in a smaller or darker room.

In another installation, an Epson PowerLite 800F projector was used and the light quality was uneven: in such a scenario, the studio made the call to transform the white light into blue light: a call that only the artist's studio should have the ability to make.

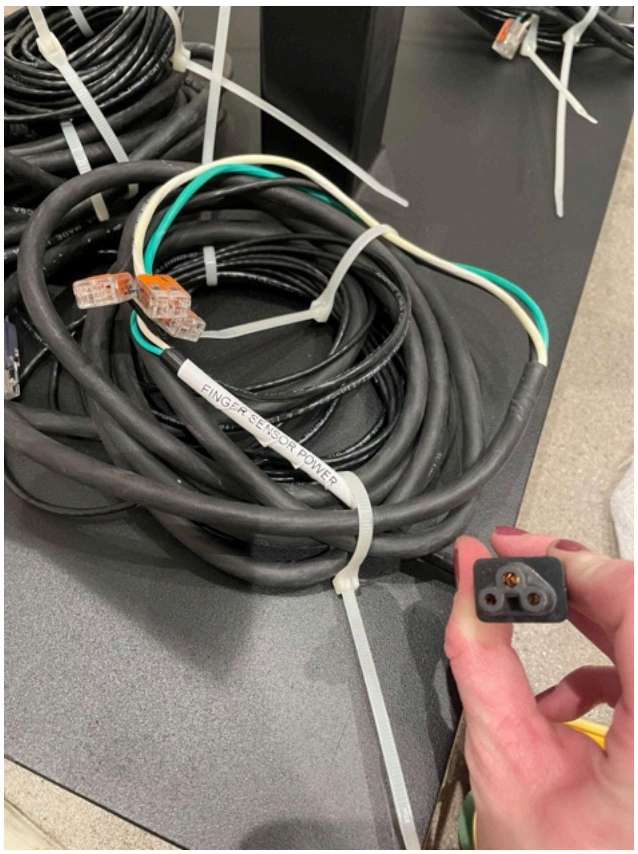
Computer

At the time of writing this manual, the software operating on the computer is coded under openFrameworks' platform. Software version referred to in this manual should be run on an Apple MacMini with a Core2Duo 2.66Ghz processor, a GeForce 320M, 4GB of RAM and 500GB of HDD, running on OSX 10.12.6.

Power Cords

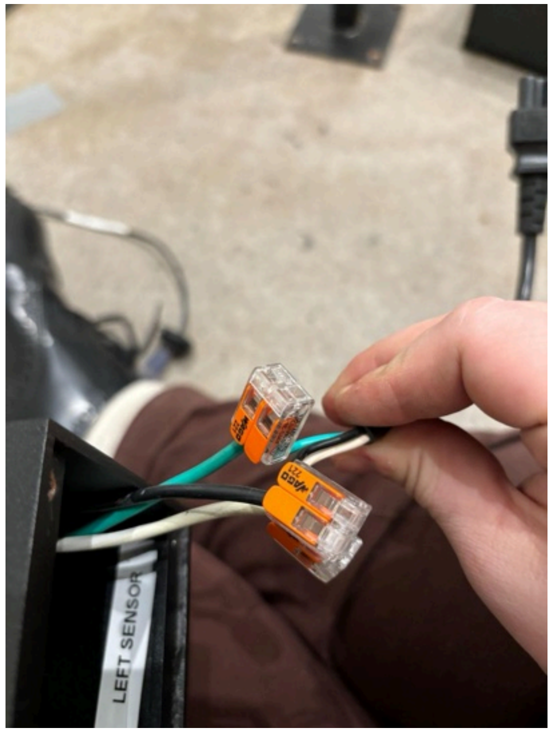
The power cords used for the finger and hand sensors are running from the sensors' bases to the projector base. To help installation, the power cords provided might have been cut into 2 ends, then reconnected with Wago connectors. There would be 2 types of power cords: C5 (Mickey Mouse) and C13 (regular).

As seen in the images below the cables will be clearly labeled as to which sensor they belong to on both ends. The female ends of the cord will connect to the power supply bolted to the PCB inside the sensor stands while the male ends will go inside the projector stand.



The end of a C5 power cable

The end of a C13 power cable



Wago connector assembly

As you may notice on the picture above, the Wago connectors are used on each individual leads of a power cable. It is crucial to not mix and match the cable colours within a Wago connector, as this would create a short-circuit and damage the equipment and be a security hazard.

In short, power cables would have three leads (typically black, white, and gray coloured, but this may vary): three Wago connectors would be used per power cord. The first Wago would connect the 2 white leads together, the second would connect the 2 black leads together and the third would connect the 2 gray leads together.

Networking Switch

The networking switch interconnects all the sensors and the computer together allowing them to exchange data and communicate over the software. Any network switch used should have a Gigabit speed and have enough ports to allow each sensor and the computer to be connected: if you have 3 sensors and 1 computer, it would need to be at least 4 ports.

Water Tank

The water tank used for the work will contain the water used as a mirror to reflect the projector's light on the ceiling and surrounding walls.

The tank is typically built with Stainless Steel 304, 10 gauge, in order to have a good resistance to torsion and have a better protection against rust.

The tank is then powder coated in matte black Sandtex paint. That aesthetic is preferred to make the tank more subtle and prevent the creation of a second layer of reflection within the tank, which would make the light reflection blurry. This would be induced by the projector's light refracting on the water surface, reflecting at the bottom of the tank, and finally refracting again when getting out of the tank.

In order to add even more protection against rust, once the tank is painted, a bead of black silicone is added to the tank's corners.

Dimension wise, the tank needs to match the aspect ratio of the projector, usually 16:9, matching fullHD and 4K projectors, which are a standard at the time of writing this manual. There's no specific tank dimensions, however the height should be about 10 centimetres high, while for the width and length discussions have to happen between the studio and curators and collectors to decide what size would be best to make the tank of a good size for the exhibition's space. So far, we produced tanks 2.5 x 1.4 metres big and 2.3 x 1.3 metres big.

The desired **water level** will vary depending on the tank's dimensions, and sensors in use. A water level gauge might be provided to allow you to ensure the level is optimal. Ultimately, we want the acrylic ball(s) and the acrylic bar(s) to not touch the water while the work is at rest, but when in motion they should dip deep enough in water to create good waves in the tank.

Considering the texture of the tank's paint, it is important that the water used in the tank is of good quality. By this, we mean the water should be as exempt as possible of particles in suspension to prevent debris from agglomerating to the tank over time. **If your site is known for bad water quality, the studio recommends the use of a pre-filtering system**, making the water cleaner prior to being filled in the tank. The more debris or particles in suspension you will have in water, the more deposit there will be in the tank in the long term and more maintenance / cleanup will be required, at shorter intervals.

Filter

The artwork requires a filter (or few) to be run at night to remove the surface debris that accumulates over a day. The filter is not part of the work and should only be used for maintenance.

A model that has been used with the work so far is the Aqueon QuietFlow LED Pro Size 10-100 GPH. That being said, the model could be changed for another filter with similar specs.

The filters should be removed from the tank at least 30 minutes prior to an exhibition open hours to let the water turbulence dissipate on time to give you time to figure out if water needs to be added.

Specification	Details
Gallons per hour	100 GPH ***Note: we recommend** a minimum of 100GPH per every 300 litres contained in the used tank.* *Eg: a tank containing 250 litres should use filter(s) of at least 100GPH flow, a tank containing 900 litres should use filter(s) of at least 300GPH flow.*
Voltage	120-240 VAC
Filter per square meters	We recommend to use a minimum of one filter (independent of its GPH spec) per 3 square meters of water surface in tank. More filter will make the water surface cleaner faster, but would accelerate the water evaporation. *Eg: a tank containing 250 litres should use at least one filter, a 900 litres tank would require at least 3 units.*

If the quality of the water available in the exhibition space is known for being not so good (hard water, water known for having particles in suspension, etc.), the studio recommends the use of a pre-filtering system, making the water cleaner prior to being dropped in the tank. The more debris or particles in suspension you will have in water, the more deposit there will be in the tank in the long term and more maintenance / cleanup will be required, at shorter intervals. For this piece, the water could be distilled, this wouldn't impact the reaction of the work.

APPENDIX III - INSTALLING THE ARTWORK IN THE EXHIBITION SPACE

When installing the artwork begin by placing the rubber mats that will support the tank on the floor. Make sure they are providing support to each corner as well as the center of the tank.

After placing the mats, prepare the wires that will run under the tank from the sensors, tape them firmly in place with water resistant tape such as gaffers tape.

Now you may place the tank body on the mats and begin arranging the sensors and projector. Make sure to simply place the sensors and projectors at this stage, avoiding drilling into the floor until their positioning is finalized in a later step.

Consult the wiring diagram for information on how to connect the wires from the sensor to the electronics inside of the projection stand - and, potentially, to the power bar under the tank.

Once everything is connected, fill the tank, consult the “tank” section of this manual for information on the ideal water level. Always ensure using filtered water (unless the building’s water quality is pristine).

After filling the tank begin properly positioning the sensors, tape them in place so that they will be easy to adjust as you find their ideal positioning. The heads of the acrylic ball should hover just slightly above the surface of the water and create strong ripples. The acrylic bar similarly should not touch the water but will create a clean line when deployed.

Once the exact positioning has been arranged: we suggest the following. First mark every sensor location, projector location and tank location on the floor. Then you will have to disassemble the sensors to reach their T base: disconnect the cabling coming from the sensor’s metal tubing, easing the access to the T base. Finally ensure to realign the bases in place and mark the mount and bases hole to the floor.

Then you can either empty the tank and move it out of the way or use a tensile material to tarp the whole tank. This will prevent dust from settling onto the tank or into the water. Then drill the sensor T bases and the projector’s mount floor anchor points.

Different anchoring screws / floor material can be encountered, best scenario should be figured out once exhibition’s space conditions are known. Note that screws holding T bases to the floor should be countersunk flat head so the rectangular boxes sit flush onto T bases.

If the tank was tarped, wait a few hours so the dust floating in the air can settle down and do a cleanup (ideally with a damp mop and an antistatic duster before next steps.

Untarp the tank if it was tarped. If the tank was emptied and moved out, bring it back in place and fill it again. Assemble all the sensors and test run the artwork.