

Willow Joystick

MAKER GUIDE

Overview

This document contains the necessary information to build the Willow Joystick, a low force magnetic joystick for users with low strength and range of motion



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Maker Checklist

This list provides an overview of the steps required to build and deliver the Willow Joystick.

Maker To Do List

- Read through the Maker Guide to become familiar with required components, tools, supplies, safety gear, and overall assembly steps.
- Talk to the User about customization options
 - Refer to the Customization Guide section of the Maker Guide
 - Colour of hub, colour of joystick
 - Joystick shell and base can be separate colours for a two-tone effect.
 - What toppers do they want
 - Review the topper selection guide for what toppers are available
 - What mounting supplies do they need
 - Camera mount adaptors, non-slip feet, hub stand, mounting arms, etc.
 - Do they want a wrist ramp
 - Flat ramp, right side flat, left side flat, no sides flat
 - Do they want the standard size, or a customized one.
 - How they would like to receive the “User Guide” (PDF or physical copy)
- Order custom PCB
- Order hardware components
- Gather tools, supplies, and safety equipment.
- Assemble the Willow Hub
- Assemble the Willow Joystick
- Flash firmware to the Willow Hub
- Test the Willow Joystick
- Print “Quickstart Guide” (if the User would like a physical copy)

Items to Give to User

- Willow Joystick
- Joystick Toppers
- Willow Hub
- USB C cable
- RJ11 Cable
- Hub Stand (If asked for)
- Non-Slip Foot (If asked for)
- Camera Mount Adaptor (If asked for)
- “User Guide”
- “Quick Start Guide”



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Tool List

Tools / Equipment

Tool ID	Description	Required / Recommended	Notes
T01	Soldering Iron	Required	For soldering electronic components.
T02	Wire Strippers	Recommended	For stripping the insulation off the stemma-Dupont cable if the headers fall off
T03	Phillips Screwdriver	Required	A jeweller's screwdriver or similar for securing M2.5 machine screws
T04	Flush Cutters	Required	For trimming soldered leads
T05	Crescent wrench / wrench / hex key	Recommended	For installing T-nuts into Hub and Joystick enclosures.
T06	Sandpaper/Files	Recommended	Cleaning up 3d prints; fixing bearing fits
T07	Needle Nose Pliers	Recommended	Installing bearings; routing cables
T08	Computer with Arduino IDE	Required	For flashing firmware to microcontroller

Supplies

Supplies ID	Description	Quantity	Notes
S01	Solder	<6 inches	Soldering

Personal Protective Equipment (PPE)

PPE ID	Description	Notes
P01	Safety Glasses	Preventing things from flying into the maker's eye when trimming wires or other parts.



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Customization Guide

Colours

- The joystick and hub can be printed in the user's desired colour.
- The text on the joystick and hub can be printed in a different colour using a printer with a multi material system, or a colour swap can be done on the hub after the first two layers to increase the contrast on the hub. A second layer swap can also be used to make the hub colours more consistent.

Toppers

- There are a variety of toppers available, as well as the base file to design your own custom topper. Refer to the included topper selection guide for more information. Make sure to consult with the user on this so that they can pick the best topper for them.
- If the user does not like any of the toppers available, there is a Fusion 360 file available to create a custom topper, as well as a topper intended for use with heat moldable plastic pellets

Mounting

- There is an optional arm rest available, with the design file included if the user needs a different height, length, etc.
- There is an optional non-slip base available for the Joystick, as well as mounting adaptors for ¼-20 thread and RAM B mount.
- There is an optional but recommended hub stand to keep the hub at a visible angle for the user.



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Custom Printed Circuit Board (PCB) Guide

The Willow Joystick Hub uses one custom circuit board. This circuit board is the same one used in the LipSync Hub.

The Custom PCB can be ordered from one of a variety of PCB Manufacturers. Typically, the minimum quantity for a custom PCB is five. Shipping options vary significantly in cost and shipping time. Plan on at least a week from the time of order to the PCBs arrival.

Ordering the Custom PCB

1. Select a PCB Fabrication Company
 - a. [JLPCB](#)
 - b. [PCBWay](#)
 - c. [OSH Park](#)
 - d. [Seeed Fusion PCB](#)
2. Create an account or use a guest login.
3. Upload the Gerber Files (e.g., LipSync_Hub_PCB_2024-02-09.zip).
4. Select the fabrication options:
 - a. PCB Layers: 2 Layers
 - b. PCB Quantity: 1 (Some companies have a minimum PCB order more than this, usually 5)
 - c. PCB Thickness: 1.5 mm
 - d. Surface Finish: HASL
 - e. PCB Color: Choose what you like. Note that certain colours may impact build time and cost.
 - f. The default settings for the other settings should work.
5. Select shipping option.
 - a. Shipping options and costs vary significantly. Select the best option based on your budget and timing.
6. Submit the order.



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3D Printing Guide

The device was originally printed on a Bambu P1S using Bambu Studio

The default speeds were used on all parts except for the two sled pieces. For these prints all speeds and accelerations were turned to 50% of the default value.

Testing has shown that a printer with automatic bed leveling is needed to properly print the components in the gimbal.

3D Printing Summary

Metrics	Total	Hub	Joystick	Optional
Total Print Time (hour min)	8:11	1:54	2:19	3:58
Total Number of Components	27	5	10	12
Typical Total Mass (g)	243	49	56	138
Typical Number of Print Setups	4	1	2	1

3D Printing Settings

Note that the 3D printing material should be assumed to be PLA unless otherwise noted in the table below.

Print File Name	Qty	Total Print Time (hr:min)	Mass (g)	Infill (%)	Support (Y/N)	Layer Height/Nozzle Diameter (mm)	Notes
Hub Files							
Willow_Hub_Bottom.stl	1	1:00	27	20	N	0.2/0.4	
Willow_Hub_LED_Spacer.stl	1	0:07	2	20	N	0.2/0.4	
Willow_Hub_Next_Button.stl	1	0:05	1	20	N	0.2/0.4	
Willow_Hub_Select_Button.stl	1	0:05	1	20	N	0.2/0.4	
Willow_Hub_Top.stl	1	0:37	18	20	N	0.2/0.4	
Joystick Files							
Willow_Joystick_Base.stl	1	0:52	22	20	N	0.2/0.4	
Willow_Joystick_Shell.stl	1	0:31	17	20	N	0.2/0.4	
Willow_Joystick_Inner_Gimbal_1.stl	1	0:07	2	20	N	0.2/0.4	
Willow_Joystick_Inner_Gimbal_2.stl	1	0:07	2	20	N	0.2/0.4	
Willow_Joystick_Outer_Gimbal.stl	2	0:08	3	20	N	0.2/0.4	



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Willow_Joystick_Sled_1.stl	1	0:11	3	20	N	0.2/0.4	Print at half speed
Willow_Joystick_Sled_2.stl	1	0:11	3	20	N	0.2/0.4	Print at half speed
Willow_Joystick_Gimbal_Shield.stl	1	0:03	1	20	N	0.2/0.4	
Willow_Joystick_Pin.stl	1	0:01	1	20	N	0.2/0.4	
Joystick Topper Files							
Willow_Topper_Concave.stl	1	0:06	1	20	N	0.2/0.4	Optional
Willow_Topper_Convex.stl	1	0:07	1	20	N	0.2/0.4	
Willow_Topper_Goalpost.stl	1	0:09	2	20	N	0.2/0.4	Optional
Willow_Topper_Stick.stl	1	0:09	1	20	N	0.2/0.4	Optional
Willow_Topper_Mouldable.stl	1	0:07	1	20	N	0.2/0.4	Optional
Optional Files							
Willow_Joystick_NonSlip_Base.stl	1	0:17	13	20	N	0.2/0.4	Optional
Joystick_Camera_Mount_Adaptor.stl	1	0:12	7	20	N	0.2/0.4	Optional
Joystick_RAM_B_Mount_Adapter.stl	1	0:17	9	20	N	0.2/0.4	Optional
Willow_Joystick_Wrist_Ramp.stl	1	2:00	85	20	N	0.2/0.4	Optional
Willow_Hub_Stand_Front.stl	1	0:20	10	20	N	0.2/0.4	Optional
Willow_Hub_Stand_Leg.stl	2	0:07	4	20	N	0.2/0.4	Optional

Post-Processing

Inspect the 3D printed parts for any printing defects, sharp edges, or burrs. Sharp edges and burrs can be removed with sanding or deburring tools.

Some parts, such as the concave topper or the wrist ramp, may need a slight sanding to smooth the surface and make them comfortable for the user.



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Examples of Quality Prints

Compare your 3D prints to the images here. If there are significant differences, you may need to reprint the part.

Hub Enclosure Assembly		
Willow_Hub_Bottom.stl	Willow_Hub_LED_Spacer.stl	Willow_Hub_Next_Button.stl
		
Willow_Hub_Select_Button.stl	Willow_Hub_Top.stl	
		



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Joystick Enclosure Assembly

Willow_Joystick_Base.stl	Willow_Joystick_Gimbal_Shield.stl	Willow_Joystick_Inner_Gimbal_1.stl
		
Willow_Joystick_Inner_Gimbal_2.stl	Willow_Joystick_Outer_Gimbal.stl	Willow_Joystick_Pin.stl
		
Willow_Joystick_Shell.stl	Willow_Joystick_Sled_1.stl	Willow_Joystick_Sled_2.stl
		

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Toppers		
Willow_Topper_Concave.stl	Willow_Topper_Convex.stl	Willow_Topper_Goalpost.stl
A 3D printed model of a circular top cap with concentric grooves, designed to sit on top of a cylindrical stick.	A 3D printed model of a rounded, convex top cap with concentric grooves, designed to sit on top of a cylindrical stick.	A 3D printed model of a curved, hook-like top cap, designed to sit on top of a cylindrical stick.
Willow_Topper_Mouldable.stl	Willow_Topper_Stick.stl	
A 3D printed model of a complex, multi-pronged top cap, designed to be moulded around a stick.	A 3D printed model of a simple, tapered top cap, designed to sit directly on a stick.	

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Optional Parts		
Willow_Hub_Stand_Front.stl	Willow_Hub_Stand_Leg.stl	Joystick_Camera_Mount_Adapter.stl
Joystick_RAM_B_Mount_Adapter.stl	Willow_Joystick_NonSlip_Base.stl	Willow_Joystick_Wrist_Ramp.stl



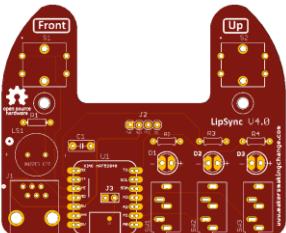
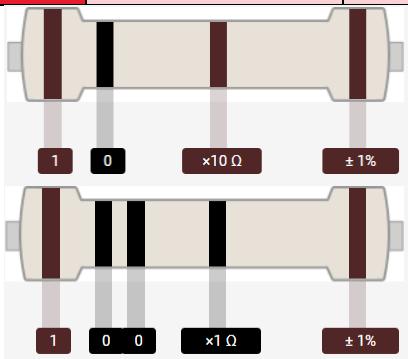
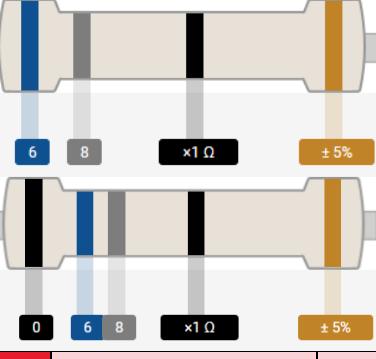
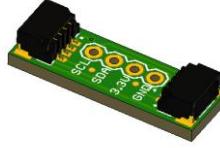
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Maker Component List

Part A: Hub PCB Assembly								
A1	LipSync 4 Hub PCB	QTY 1	A2	Capacitor, 10uF	QTY 1	A3	Resistor R1, 100 Ω, ¼ W, Through hole	QTY 1
								
A4	Resistor R2/R3/R4 68 Ω, ¼ W, Through hole	QTY 3	A5	Tactile Buttons S1/S2	QTY 2	A6	Piezo Buzzer PS1240	QTY 1
								
A7	Male Header, 4 position	QTY 1	A8	Sparkfun QWIIC Adapter	QTY 1	A9	Mono Switch Jacks	QTY 3
								

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A10	RJ11 Modular Connector Jack	QTY 1	A11	SeeedStudio Xiao hrF52840	QTY 1	A12	Male Header, 7 position	QTY 2
A13	Headers, Female, 7 Position	QTY 2	A14	LEDs, 5mm though hole	QTY 3	A15	Willow Hub LED Spacer	QTY 1

Part B: Hub Enclosure Assembly								
B1	Populated Willow Hub PCB	QTY 1	B2	STEMMA QT Cable – 100 mm	QTY 1	B3	OLED Display	QTY 1

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B4	Willow Hub Enclosure Top	QTY 1	B5	Willow Next Button Pusher	QTY 1	B6	Willow Select Button Pusher	QTY 1
	A grey plastic enclosure with two circular holes labeled "NEXT" and "SEL". The word "Willow Hub" is printed at the bottom.			A gold-colored metal button pusher with a ribbed top and a flat base.			A gold-colored metal button pusher with a ribbed top and a flat base.	
B7	Willow Hub Enclosure Bottom	QTY 1	B8	Screw, #4, 3/8" Length	QTY 5	B9	M2.5 Machine Screw, 8 mm	QTY 4
	A grey plastic enclosure with various ports and labels: "USB", "JOY", "S1", "S2", and "S3".			A silver Phillips head screw.			A blue M2.5 machine screw.	
B10	M2.5 Nut	QTY 4	B12	T-Nut	QTY 1	B13	Light Pipe	QTY 1
	A blue hexagonal nut.			A metal T-nut.			A white cylindrical light pipe.	

Part C: Joystick Prep								
C1	RJ11 Breakout Board	QTY: 1	C2	RJ11 Connector	QTY: 1	C3	Cable, STEMMA – DuPont, 150 mm	QTY: 1
	A red Sparkfun RJ11 breakout board.			A black plastic RJ11 connector.			A cable with four colored wires (red, blue, green, yellow) terminated with STEMMA-DuPont connectors.	

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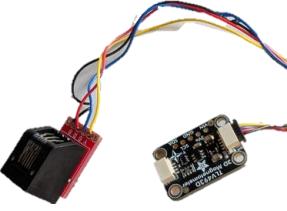
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C4	TLV493D STEMMA QT Board	QTY: 1					
							

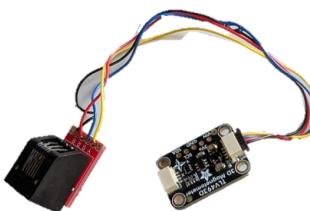
Part D: Flashing Firmware

D1	Magnetic Sensor Assembly	QTY: 1	D2	Willow Hub	QTY: 1	D3	RJ11 Cable	QTY: 1
								
D4	USB-C-USB-A Cable	QTY: 1						
								

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Part E: Joystick Assembly		
E1	Inner Gimbal 1	QTY: 1
	E2	Magnet QTY: 4
	E3	Inner Gimbal 2 QTY: 1
	E4	Bearings QTY: 4
	E5	Gimbal Shield QTY: 1
	E6	Outer Gimbal QTY: 2
	E7	Part C Assembly QTY: 1
	E8	Sled 1 QTY: 1
	E9	M2.5 Machine Screw, 8 mm QTY: 4
	E10	M2.5 Nut QTY: 4
	E11	Sled 2 QTY: 1
	E12	Base QTY: 1
		

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E13	M3 Nut	QTY: 2	E14	Pin	QTY: 1	E15	Shell	QTY: 1
E16	Screw, #4, 3/8" Length	QTY: 3	E17	Any Willow Topper	QTY: 1			

Part F: Optional Components Assembly								
F1	Nonslip Base	QTY: 1	F2	Nonslip Foot	QTY: 8	F3	Wrist Rest	QTY: 1
F4	Hub Stand Front	QTY: 1	F5	Hub Stand Leg	QTY: 2	F6	¼-20 Bolt	QTY: 1

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Assembly Guide



Assembly Section	
Part A: Hub PCB Assembly	
Part B: Hub Enclosure Assembly	
Part C: Joystick Prep	
Part D: Flashing Firmware	
Part E: Joystick Assembly	
Part F: Optional Components	

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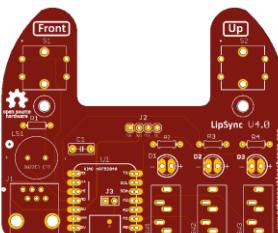
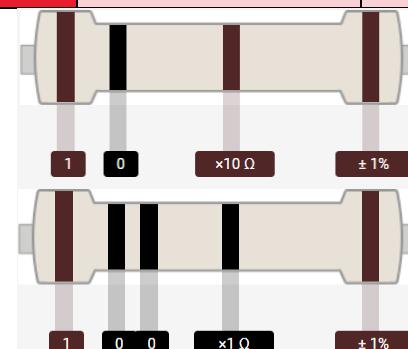
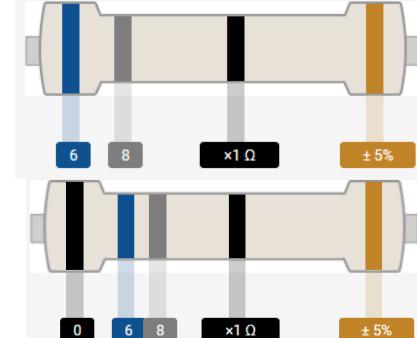
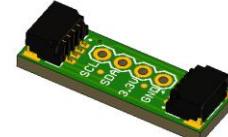
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Part A: Hub PCB Assembly

Part A: Components

A1	LipSync 4 Hub PCB	QTY 1	A2	Capacitor, 10uF	QTY 1	A3	Resistor R1, 100 Ω, ½ W, Through hole	QTY 1
								
A4	Resistor R2/R3/R4 68 Ω, ¼ W, Through hole	QTY 3	A5	Tactile Buttons S1/S2	QTY 2	A6	Piezo Buzzer PS1240	QTY 1
								
A7	Male Header, 4 position	QTY 1	A8	Sparkfun QWIIC Adapter	QTY 1	A9	Mono Switch Jacks	QTY 3
								

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A10	RJ11 Modular Connector Jack	QTY 1	A11	SeeedStudio Xiao nrF52840	QTY 1	A12	Male Header, 7 position	QTY 2
A13	Headers, Female, 7 Position	QTY 2	A14	LEDs, 5mm through hole	QTY 3	A15	Willow Hub LED Spacer	QTY 1

Part A: Tools

- Soldering iron
- Flush cutters
- Phillips Head Screwdriver
- OPTIONAL: Solderless Breadboard (For soldering male headers to microcontroller)

Part A: Personal Protective Equipment (PPE)

- Safety glasses



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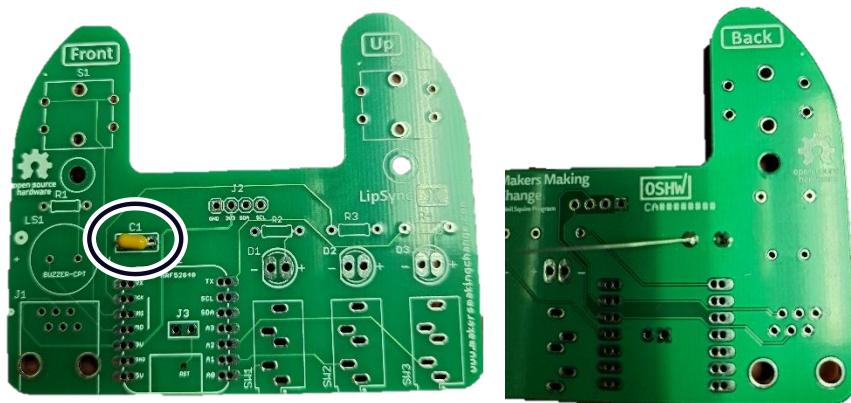
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Part A: Hub PCB Assembly Steps

Note that all parts will be inserted onto the side of the PCB labeled "Front", and all soldering will be done on the side labeled "Back".

Step A-01: Solder in 10 micro Farad capacitor, C1.

Insert the 10 micro-Farad capacitor (A2) into the position labeled C1 on the PCB (A1). Bend the leads of the capacitor to the side to hold it in place. Solder the capacitor onto the PCB. Once soldered, trim the extra from the leads.



Step A-02: Solder in 100 Ohm resistor, R1.

Insert the 100 Ohm resistor (A3) into the position labeled R1 on the PCB. Bend the leads of the resistor to the side to hold it in place. Solder the resistor onto the PCB. Once soldered, trim the extra from the leads.



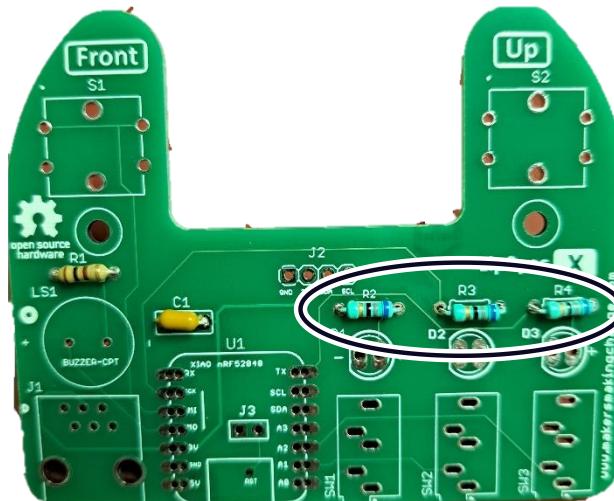
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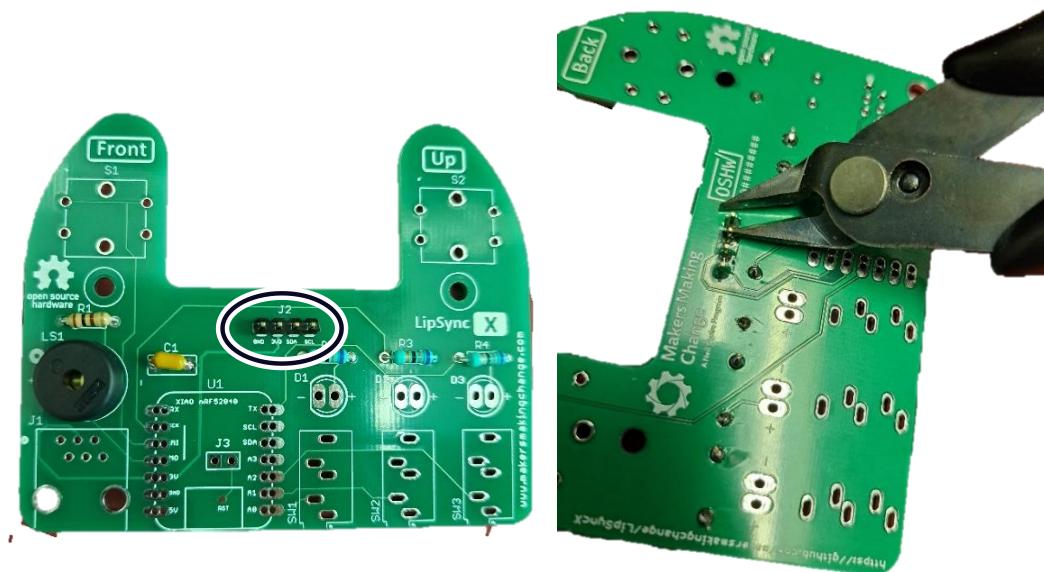
Step A-03: Solder in 68 Ohm resistors, R2, R3, and R4.

Insert the 68 Ohm resistors (A4) into the positions labeled R2, R3, and R4 on the PCB. Bend the leads of the resistors to the side to hold them in place. Solder the resistors onto the PCB. Once soldered, trim the extra from the leads.



Step A-04: Insert, solder, and trim the 4-pin Male header.

Insert the longer pins of the 4-pin male header (A7) into the position labeled J2. Solder it into place and trim the excess from the bottom.



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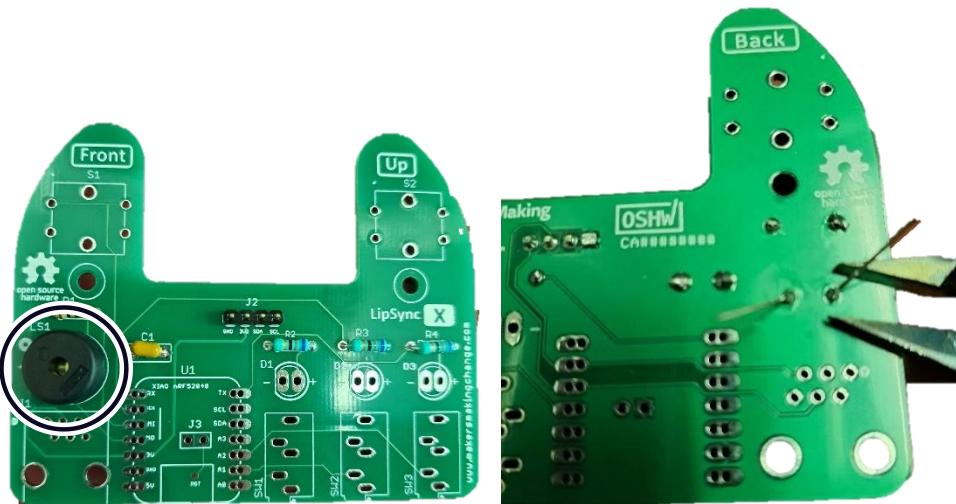
Files available at <https://github.com/makersmakingchange/Willow-Joystick> Page 24 of 58

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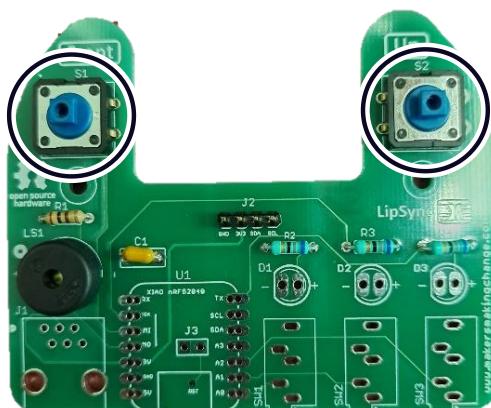
Step A-05: Insert, solder, and trim buzzer.

Insert the buzzer (A6) into the position labeled LS1. If using a buzzer with polarity, make sure the positive lead is in the hole marked with a “+” on the PCB. Note that the Piezo Buzzer PS1240 does not have polarity. Bend the leads to the side to hold the buzzer in place. Solder in place and trim excess from the leads.



Step A-06: Insert, solder, and trim switches.

Insert the two tactile switches (A5) into the positions labeled S1 and S2. Once soldered in place, trim any excess from leads of the switches.



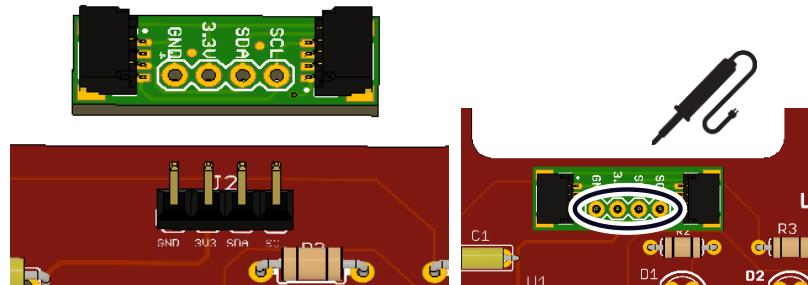
Willow Joystick

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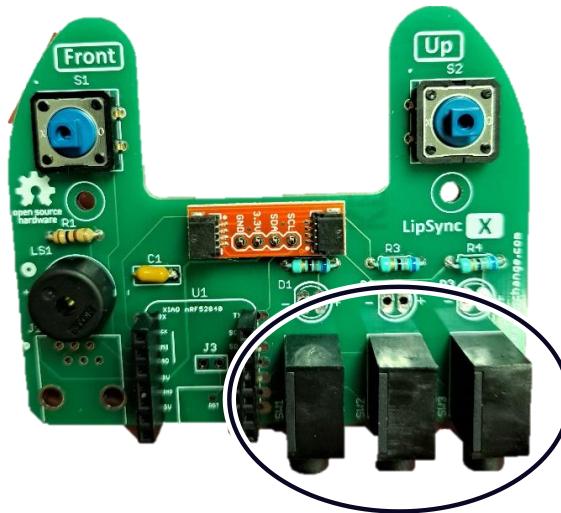
Step A-07: Insert and solder SparkFun QWIIC Adapter.

Place the SparkFun QWIIC Adapter (A8) on the 4-pin male header (A7) that was attached to J2 in step A-04. Ensure the pin labels on the adapter matches the pin labels on the Hub PCB. Solder the four pins on the adapter.



Step A-08: Insert and solder switch jacks.

Insert the switch jacks (A9) into the positions labeled SW1, SW2, and SW3. Solder one pin on each switch jack, then check the alignment. If the alignment needs to be changed, reheat the solder joint until the solder melts, then reposition the jack. Once the jacks are positioned properly, solder the remaining pins.



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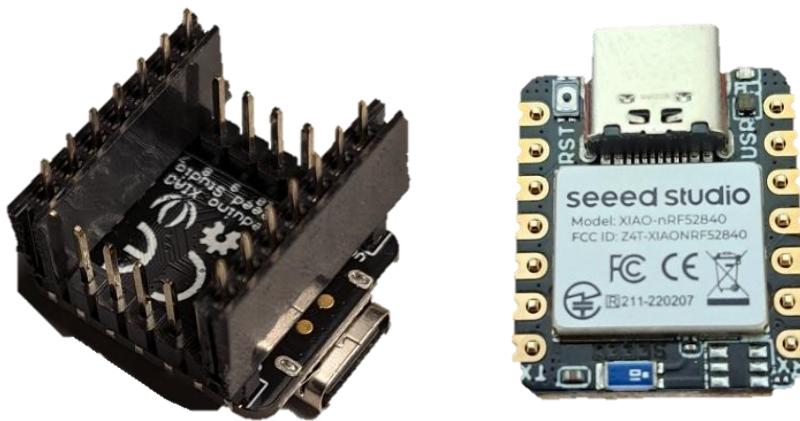


Step A-09: Solder male headers onto microcontroller.

Insert the short side of the male headers (A12) into the SeeedStudio Xiao nrf52840 microcontroller (A11) from the bottom of the board. To align the male headers and keep them straight when soldering, take the 7-position female headers (A13), and insert the male headers into the female headers across the microcontroller (as shown in the picture on the left).

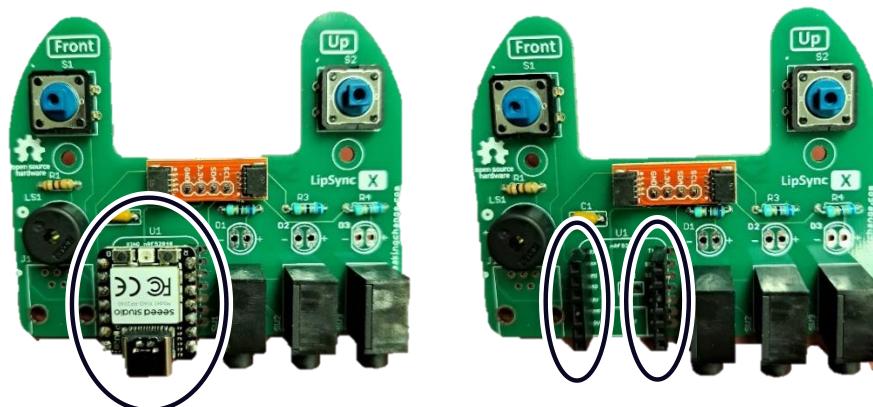
Alternatively, a solderless breadboard can be used, plug the unsoldered microcontroller and headers into the protoboard and the protoboard will hold the headers in the proper alignment.

Solder the male headers onto the microcontroller, making sure not to connect adjacent pads together with solder. Once soldered, remove the 7-pin female headers from the male headers.



Step A-10: Solder female microcontroller header into PCB.

Insert microcontroller with male headers into the female headers (A13). Insert the female headers into PCB. Solder 1 pin on each header. Check alignment and adjust if necessary. If you need to adjust the alignment, heat the single soldered pin until the solder melts again and adjust the position of the row of headers. Once aligned, solder remaining headers.



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Step A-11: Insert and solder the RJ11 jack.

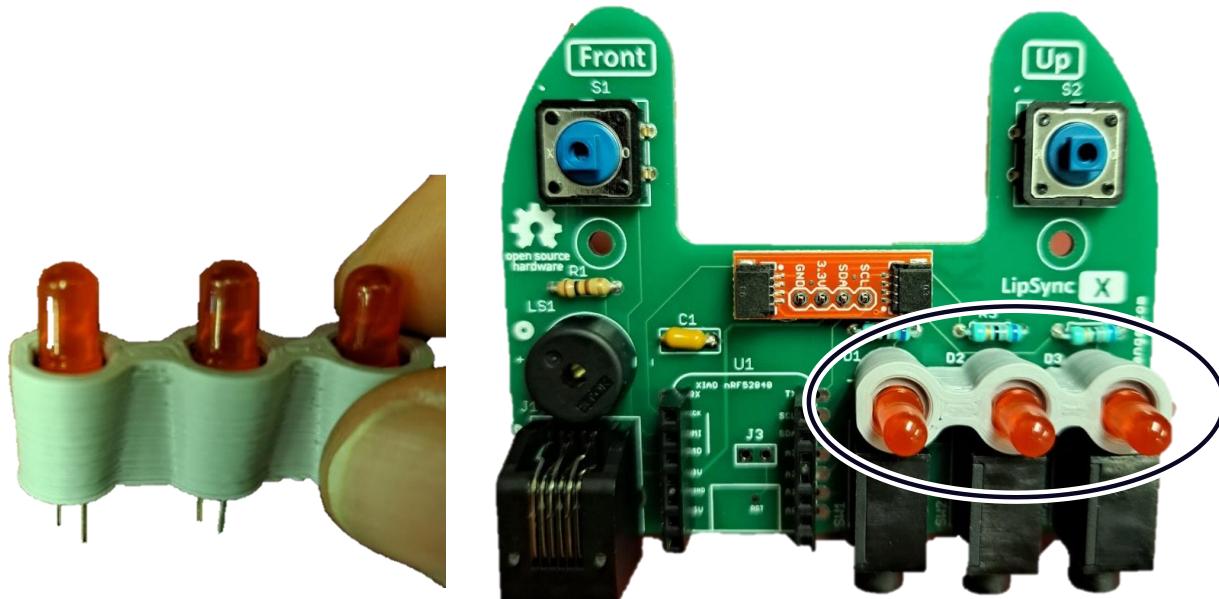
Insert the RJ11 jack (A10) into the position labeled J1 on the PCB. Solder the six pins into place.



Step A-12: Insert, solder, and trim LEDs.

Insert the three LEDs (A14) into the 3D printed LED Spacer(A15). Ensure the shorter lead of the LED (the negative lead) is on the same side as the flat edge of the LED Spacer. The LED will also have a flat edge matching the flat edge on the spacer.

With the LEDs inserted into the spacer, insert the LEDs into the matching holes in the PCB. The flat side of the LED spacer should be on the left with the rounded side on the right, when looking at the PCB from the front. Solder the LEDs in place and trim the excess from the leads.



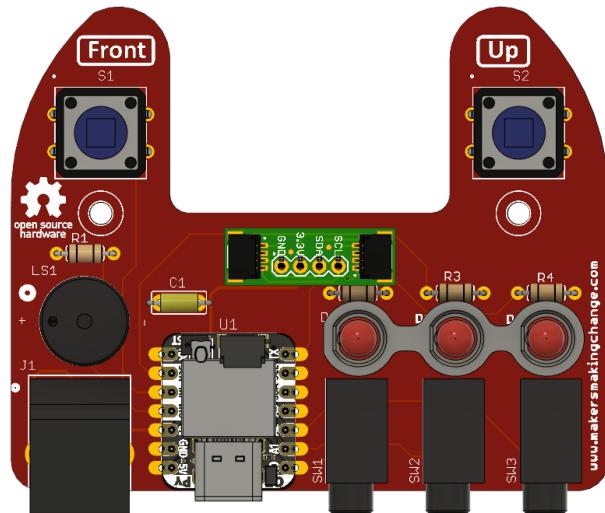
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Part A Complete



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Part B: Hub Enclosure Assembly



Part B: Components

B1	Populated Willow Hub PCB	QTY 1	B2	STEMMA QT Cable – 100 mm	QTY 1	B3	OLED Display	QTY 1
B4	Willow Hub Enclosure Top	QTY 1	B5	Willow Next Button Pusher	QTY 1	B6	Willow Select Button Pusher	QTY 1
B7	Willow Hub Enclosure Bottom	QTY 1	B8	Screw, #4, 3/8" Length	QTY 5	B9	M2.5 Machine Screw, 8 mm	QTY 4

Willow Joystick

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B10	M2.5 Nut	QTY 4	B12	T-Nut	QTY 1	B13	Light Pipe	QTY 1

Part B: Tools

- Phillips Head Screwdriver

Part B: Personal Protective Equipment (PPE)

- Safety glasses



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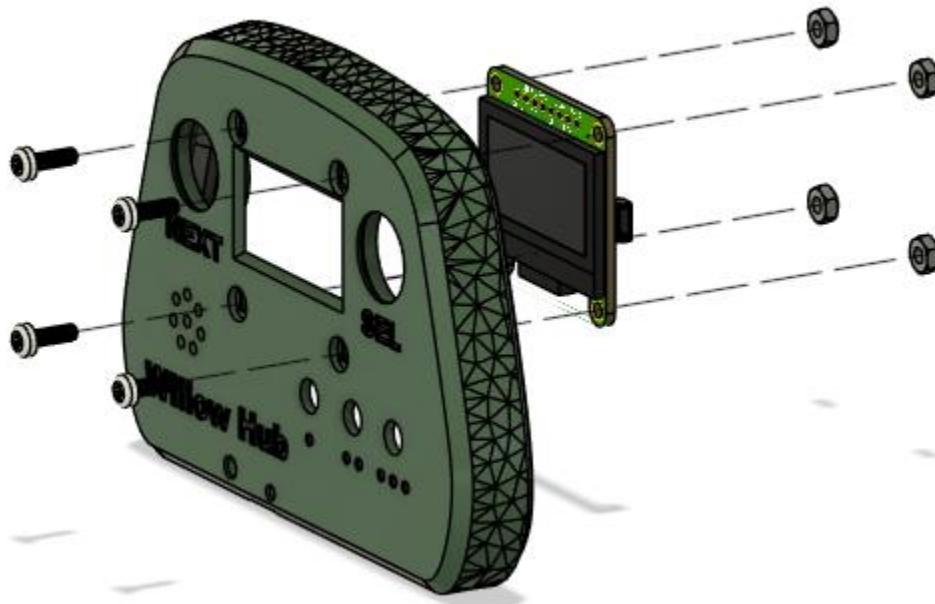
Willow Joystick

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Part B: Assembling Hub Enclosure Steps

Step B-01: Connect Display to Willow Hub Enclosure Top

Peel off the protective film on the Display (B3) and connect it to the Hub Enclosure Top (B4) using four nylon M2.5 machine screws (B9) and four nylon M2.5 hex nuts (B10). Do not overtighten.



Step B-02: Insert the Light Pipe

From the front side, insert the **light pipe** (B13) into the Hub Enclosure Top.

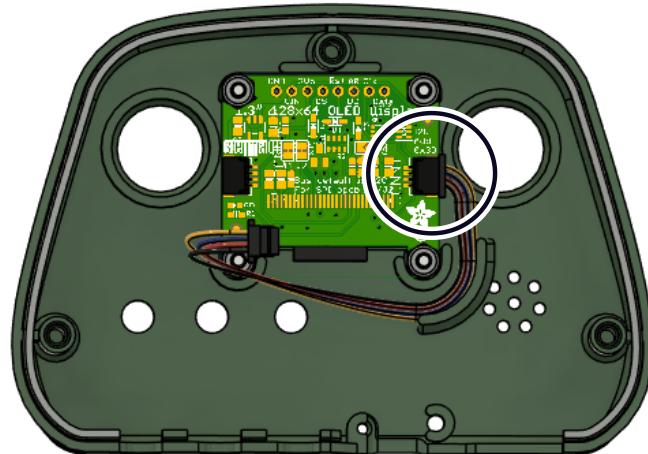
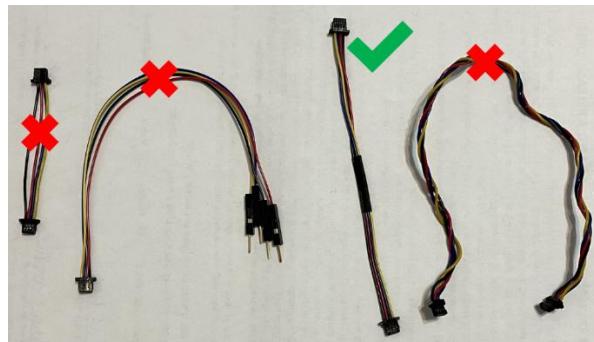


Willow Joystick

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Step B-03: Connect STEMMA / QWIIC Cable to Display

Flip the Hub Top over so the Display is facing down. Connect the 100 mm STEMMA/QWIIC cable (B2) to the port on the right-hand side of the Display as shown. Ensure the holes for the pins in the cable line up with the pins in the port on the PCB. Do not connect the second end of the STEMMA/QWIIC cable to the second port on the screen.



Step B-04: Insert the Tee Nut into the Hub Bottom

Insert the tee nut (B12) into the slots inside the Hub Bottom. A $\frac{1}{4}$ " machine screw or hex bolt can be used to tighten the Tee Nut into place. The nut should sit flush with the enclosure.



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Step B-05: Secure Willow Hub PCB into Hub Bottom

Use two #4 sheet metal screws (B8) to secure the PCB (A1) into the Hub Bottom.



Step B-06: Connect the STEMMA / QWIIC Cable to the QWIIC Adapter on the PCB

Connect the 100 mm STEMMA/QWIIC cable from the display to the QWIIC adapter on the PCB. Again, ensure the holes for the pins in the cable line up with the pins in the port on the PCB.



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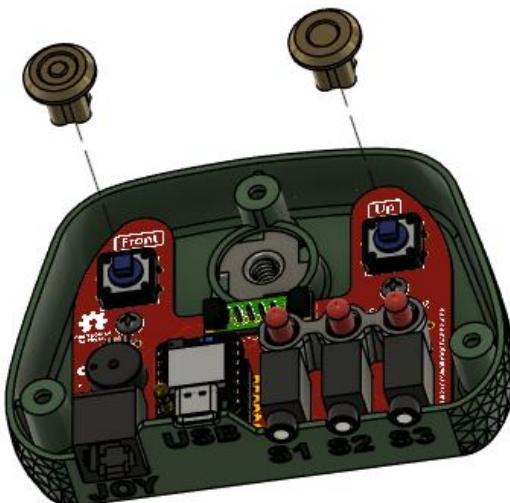
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Step B-07: Place the Button Pushers on top of the Buttons

Position the Select Button (B6) and the Next Button (B5) on top of the Buttons on the PCB. The Next Button goes on the left button and has a target shape on the front. The Select Button goes on the right button and has a ring printed on the front.



Step B-08: Position the Hub Top on to the Hub Bottom

Position the Hub Top onto the Hub Bottom, making sure to align the Button Pushers and their LEDs with the corresponding hole.



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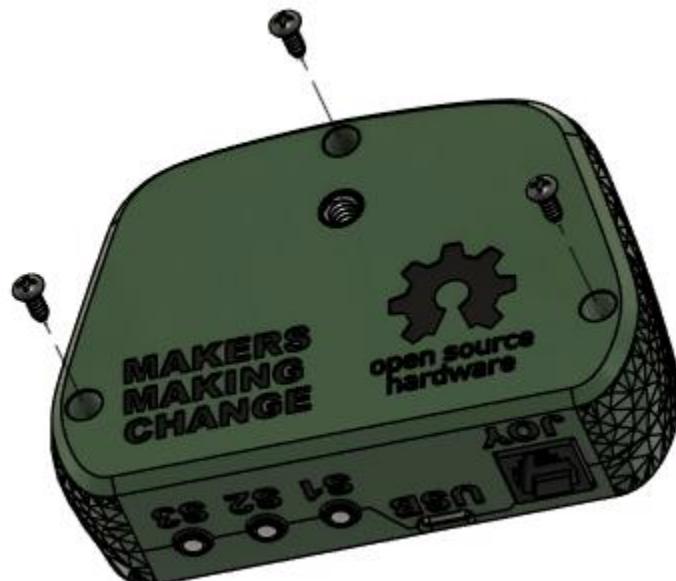
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Step B-09: Secure the Hub Top and Hub Bottom

Carefully turn the Hub over. Use a #4 sheet metal screw(B8) in each of the three holes to secure the two parts together.



Part B Complete



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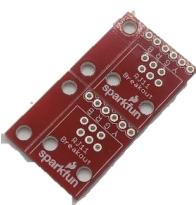
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Part C: Joystick Prep

Part C: Required Components

Joystick Prep								
C1	RJ11 Breakout Board	QTY: 1	C2	RJ11 Connector	QTY: 1	C3	Cable, STEMMA – DuPont, 150 mm	QTY: 1
								
C4	TLV493D STEMMA QT Board	QTY: 1						
								

Part C: Required Tools and Supplies

- Soldering Iron

Part C: Required Personal Protective Equipment (PPE) Safety glasses

Part C: Joystick Assembly Steps

Step C-01: Snap the breakout boards

Separate the two RJ11 breakout boards (C1) by snapping them apart by hand. Snap off the thin portion with the two mounting holes.



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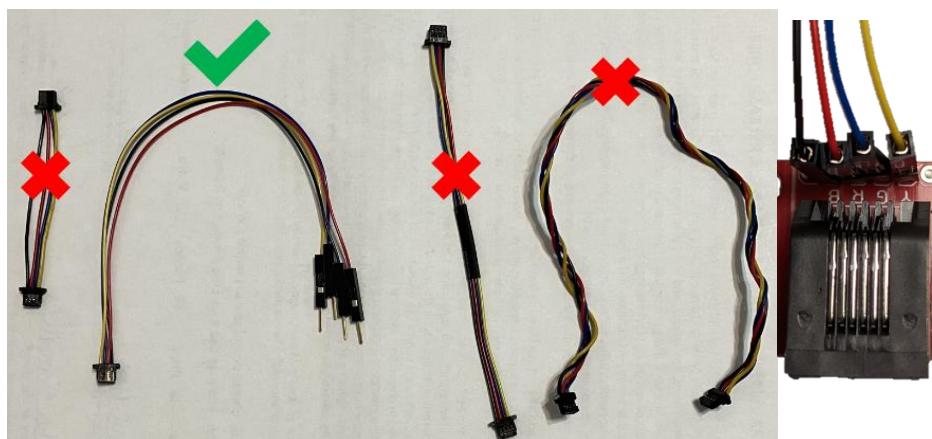
Step C-02: Solder the RJ11 jack to the RJ11 Breakout Board

Press the RJ11 Jack (C2) into the breakout board so the pins stick out of the numbered side. Solder the six RJ11 pins poking through the board, **NOT THE NUMBERED HOLES**.



Step C-03: Solder the STEMMA QT Cable to the RJ11 Breakout Board

Insert the DuPont headers on the Stemma-Dupont connector (C3) into the through holes on the RJ11 Breakout Board from the same side as the RJ11 Connector, following the order in the table. Solder in place, and trim the DuPont ends sticking out the back side.



RJ 11 Breakout	STEMMA QT Cable
2 (B)	Black (Gnd)
3 (R)	Red (Vcc)
4 (G)	Blue (SDA)
5 (Y)	Yellow (SCL)

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Step C-04: Plug Stemma Cable into Magnetic Sensor

Take the stemma cable that is soldered to the RJ11 jack and plug it into the left side of the magnetic sensor board (C10) when looking at it with the text at the top, right side up.



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Part D: Flashing Firmware to Willow

Part D: Required Components

Flashing Firmware								
D1	Magnetic Sensor Assembly	QTY: 1	D2	Willow Hub	QTY: 1	D3	RJ11 Cable	QTY: 1
D4	USB-C-USB-A Cable	QTY: 1						

Part D: Required Tools and Supplies

- Computer with Arduino IDE to flash firmware

Step D-01: Connect the Willow Joystick to The Hub

Plug in the Joystick (D1) to the Hub (D2) using the RJ 11 Cable (D3).

Step D-02: Connect the Willow Hub to the Computer

Plug in the Hub (D2) to a computer via USB Cable (D4).

Step D-03: Setup Arduino IDE on Computer

1. Download Arduino IDE for your operating system at <https://www.arduino.cc/en/software>
2. Install the Arduino IDE.

Step D-04: Setup Arduino IDE for Seed Studio Xiao nRF52840 Development Board

1. Open Arduino IDE.
2. Click on **File -> Preferences**.
3. Locate the text field that says **Additional Boards Manager URLs** beside it.
4. Copy and paste the following link into the field as a new line:
https://files.seeedstudio.com/arduino/package_seeeduino_boards_index.json
3. Click on **OK**.
5. Restart the Arduino IDE.
6. Open the **Boards Manager** option from the **Tools-> Board-> Boards Manager...**,



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7. Search for “Seeed nrf52” and select “Seeed nRF52 Boards” by Seeed Studio.
8. Click **Install** to install the board.

Step D-05: Install Libraries

1. In the Arduino IDE, go to **Tools -> Manage Libraries...**
2. For each of the libraries in the table below, search for the name, and click **Install**. If prompted to install any dependent libraries, click **OK**.

Name	Author
Adafruit_SSD1306	Adafruit
ArduinoJson	Benoit Blanchon
TLV493D-A1B6	Infineon Technologies
Adafruit_TinyUSB	Adafruit

3. Directly download the compressed zip file for the TLV493D-A1B6 Library:
 - a. <https://github.com/Infineon/TLV493D-A1B6-3DMagnetic-Sensor/archive/refs/heads/master.zip>
4. In the Arduino IDE, go to **Sketch -> Include Library -> Add .ZIP Library...** When the dialog box opens, navigate to where the library ZIP file was downloaded in the previous step, select it, and press and select the library downloaded in the previous step.

Step D-06: Setup Local Code Directory

1. Download the Firmware_Files from the GitHub Repository:
https://github.com/makersmakingchange/Willow-Joystick/blob/main/Build_Files/Firmware_Files/Willow_Firmware.zip
2. Extract / unzip the folder to a known location.
3. Confirm that you have the following folder structure:
 - Willow_Firmware (folder)
 - o Willow_Firmware.ino
 - o LSAPI.ino
 - o LSTest.ino
 - o LSBLE.h
 - o LSBuzzzer.h
 - o LSCircularBuffer.h
 - o LSConfig.h
 - o LSInput.h
 - o LSJoystick.h
 - o LSMemory.h
 - o LSOoutput.h
 - o LSScreen.h
 - o LSTimer.h



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- LSUSB.h
- LSUtils.h

Step D-07: Upload the Code to the microcontroller.

1. Open Willow_Firmware.ino with Arduino IDE.
2. Select **Seeed Xiao NRF52840** from Tools -> Board -> Seeed NRF52 Boards
3. Connect the Willow using the USB cable to the computer.
4. Select the correct port from Tools -> Port menu.
5. Verify and upload the code.

Part E: Joystick Assembly

Part E: Required Components

Joystick Assembly		
E1	Inner Gimbal 1	QTY: 1
E2	Magnet	QTY: 4
E3	Inner Gimbal 2	QTY: 1
E4	Bearings	QTY: 4
E5	Gimbal Shield	QTY: 1
E6	Outer Gimbal	QTY: 2
E7	Part C Assembly	QTY: 1
E8	Sled 1	QTY: 1
E9	M2.5 Machine Screw, 8 mm	QTY: 4



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E10	M2.5 Nut	QTY: 4	E11	Sled 2	QTY: 1	E12	Base	QTY: 1
E13	M3 Nut	QTY: 2	E14	Pin	QTY: 1	E15	Shell	QTY: 1
E16	Screw, #4, 3/8" Length	QTY: 3	E17	Any Willow Topper	QTY: 1			

Part E: Required Tools and Supplies

- Phillips head screwdriver
- Optional: Sandpaper
- Optional: Wire Strippers
- Optional: Needle Nose Pliers

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Part E: Joystick Assembly Steps



Step E-01: Insert the Magnet

Press the magnets (E2) into one of the inner gimbal prints (E1), it is not important which one. It is important that they are both in the same orientation, attracting each other instead of repelling.



Step E-02: Attach second half of inner gimbal

Press the second half of the inner gimbal (E3) onto the first and squeeze it tight.



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Step E-03: Attach inner gimbal bearings

Push bearings (E4) onto the posts on the inner gimbal assembly.



Step E-04: Attach the Gimbal Shield

Screw the gimbal shield (E5) onto the threads on the inner gimbal.



Step E-05: Add Outer Gimbal

Take both halves of the outer gimbal (E6) and press them around the inner gimbal. Add the bearings (E5) on the bearing posts to secure them in place.



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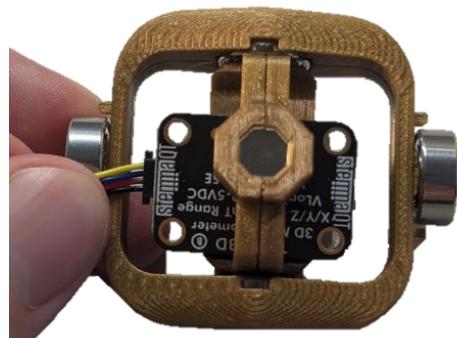
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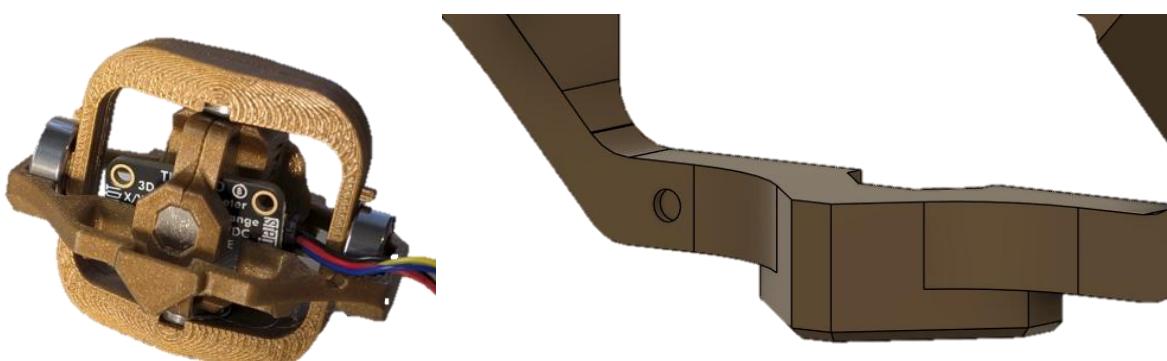
Step E-06: Add the Magnetic Sensor assembly

Pass the magnetic sensor assembly (E7) through the loop at the bottom of the gimbal assembly.



Step E-7: Press Gimbal into Sled

Press the gimbal into the sled 1 piece (E8), marked by a single dot by the bottom magnet piece. The magnet in the gimbal should be facing the magnet slot in the bottom of sled 1.



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Step E-08: Bolt the magnetic sensor into place

Take 2 of the M2.5 bolts (E9) and pass them through the magnetic sensor and sled from the top. Take two of the M2.5 nuts (E10) and secure the bolts in place. Passing the bolts through from the bottom also works, and some makers have found it easier to assemble this way.



Step E-09: Insert the Sled Magnet

Press a magnet into the slot on the base of the sled 2 prints(E11), the one that the magnetic sensor is not bolted to. Make sure it matches the orientation of the other magnets, so that the gimbal is attracted to the base instead of repelled.



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Step E-10: Attach Second Half of Gimbal

Press the other half of the gimbal into place so that the magnet is fully captured. Use two of the M2.5 bolts (E9) and nuts (E10) through the magnetic sensor to secure the second half of the gimbal in place. Zip ties can be used to temporarily hold together the sled magnet section while inserting the bolts, but make sure to remove it after this step.



Step E-11: Insert the M3 Nuts

Take the two M3 nuts (E13) and insert them into the slots on the base (E12) of the joystick.



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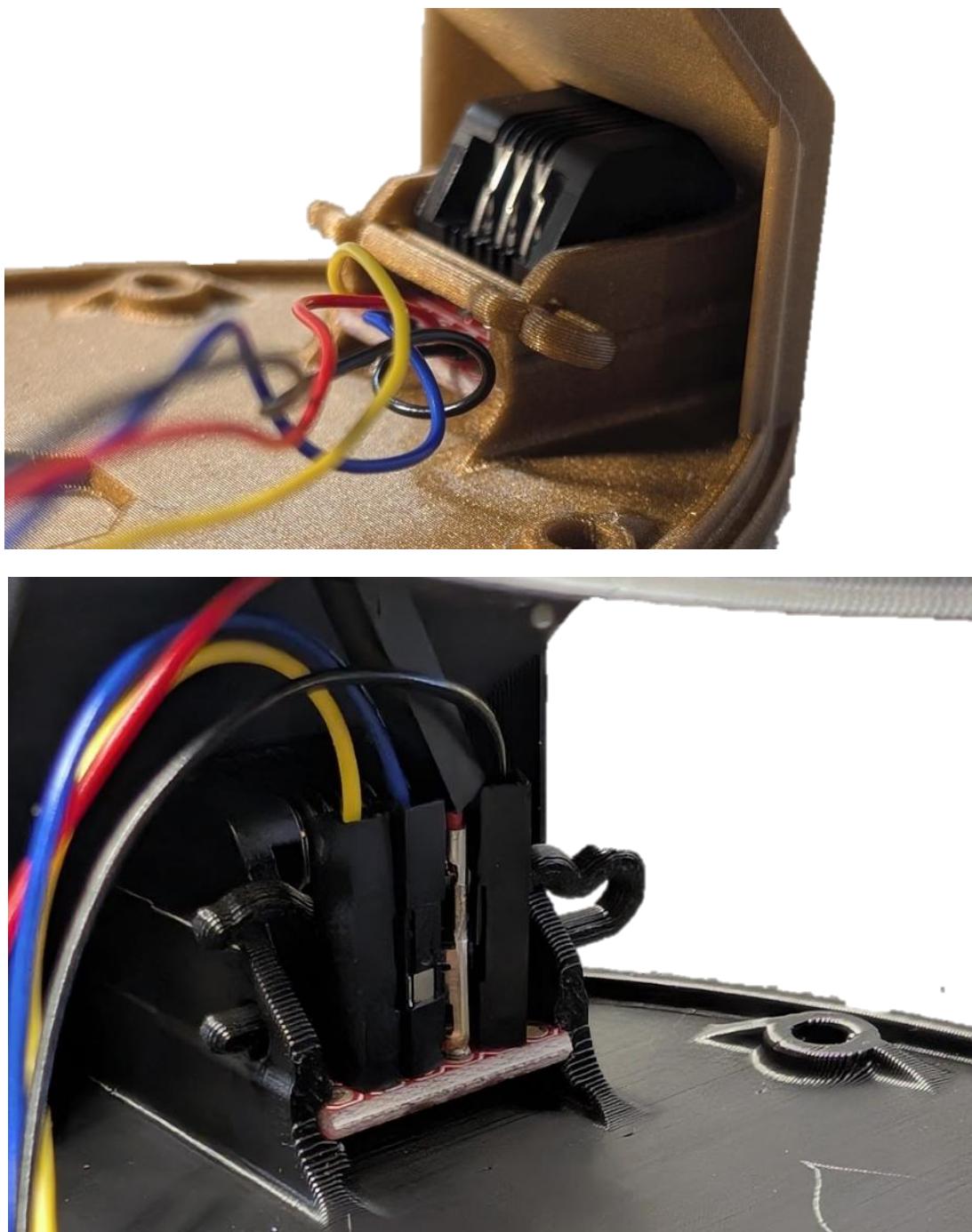
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Step E-12: Attaching the RJ11 Jack

Slide the RJ11 jack into the slots on the inside of the base and secure it with the pin (E14). The picture below has the wires with the DuPont headers removed, but it can be assembled with or without the headers.



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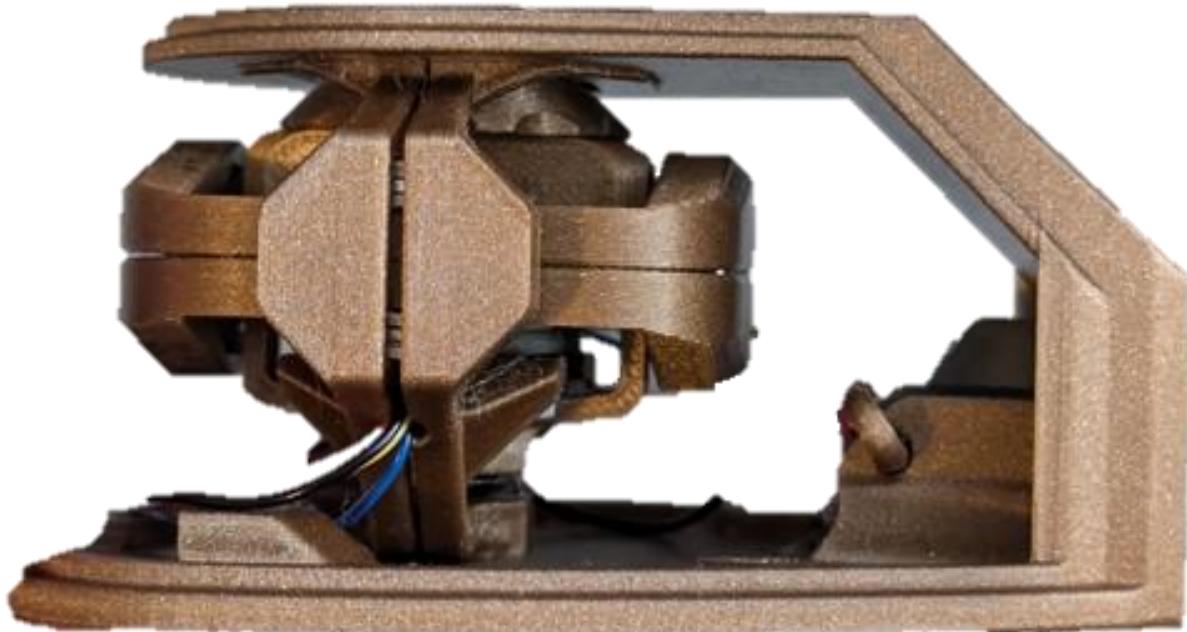
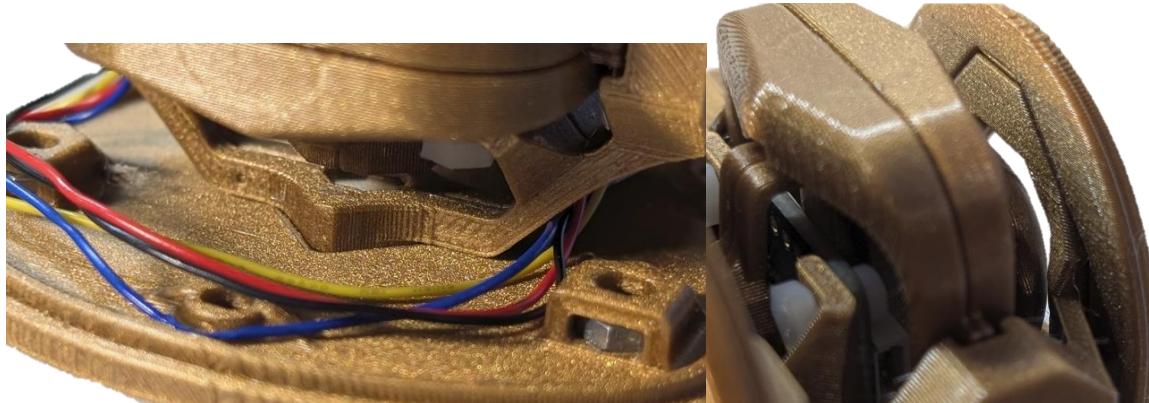
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Step E-13: Insert the Gimbal

Wind the cable once around the base of the gimbal. Slot the gimbal into the base, with the top and bottom of the gimbal fitting in the octagons on the top and bottom of the base. The tops and bottom of the octagons of both the gimbal and the base have a slot that fit into each other so that the gimbal can only be inserted in one direction.



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Step E-14: Attach the shell to the base

Attach the shell(E15) with 3 #4 sheet metal screws (E16). Be careful to not pinch the cables when attaching the shell.



Step E-15: Attach the topper

Take the chosen topper (E17) from the list of toppers and insert it into the slot on the top of the joystick gimbal. Twist the joystick clockwise to tighten it, or 'righty tighty'.



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Part F: Optional Components



Part F: Required Components

Optional Components Assembly					
F1	Nonslip Base	QTY: 1	F2	Nonslip Foot	QTY: 8
F4	Hub Stand Front	QTY: 1	F5	Hub Stand Leg	QTY: 2

Part F: Required Tools and Supplies

- Optional: Wrench or screwdriver to attach the bolt to the hub



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Step F-01-A: Build the Non-Slip Base

Take the nonslip base print (F1) and four of the adhesive feet (F2). Remove the adhesive backing from the feet and press them onto the four indents in the bottom of the 3D print.



Step F-01-B: Attach the Non-Slip Base to the Joystick

Place the joystick on the indent on the non-slip foot and use 2 M3 bolts (F3) to attach the foot to the mounting nuts in the joystick.



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Step F-02: Wrist Ramp

Take the wrist ramp 3D print (F4) and four of the adhesive feet (F2). Flip over the ramp and remove the adhesive backing from the feet. Press the feet into the indents in the bottom of the wrist ramp.



Step F-03-A: Clip Legs to Hub Stand

Take the hub stand front print (F5) and two of the hub stand leg prints (F6). Clip the leg prints into the slots on the back of the front print.



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Step F-03-B: Attach Hub Stand to Willow Hub

Rest the Willow hub on the front stand, with the screw holes on the hub resting on the pillars on the front of the hubs stand. Use a ¼-20 bolt (F6) to secure the stand to the hub.



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Testing

After building the Willow Hub and Joystick, you must verify both units are functioning properly.

Testing the Willow

1. Does Display turn on?
 - a. Ensure that the Willow joystick is plugged into the Hub using the RJ11 cable.
 - i. Ensure that the Willow Joystick light pipe lights up green.
 - b. If the Hub turns off and does not work, reset the device, and open the serial monitor in Arduino IDE right after resetting to see if one of the STEMMA boards is not being recognised.

Testing Mouse Mode

Refer to the Willow User Guide for instructions on how to connect the Willow to a Host Device and change the operating mode to USB Mouse Mode. When in USB Mouse Mode, ensure moving the joystick moves the mouse cursor. Additionally, test the external switches and buttons on the Hub. Ensure that each external switch and Hub button action are consistent with the following tables.

Testing External Switches

Plug an assistive switch into the external switch jacks and activate the assistive switch. S1 is the left switch, S2 is the center switch, and S3 is the right switch.

The behaviour for each switch and type of activation is outlined in the table below:

Input	Mouse	Gamepad	Menu/Settings Mode
S1 Short Press	Left Click	Button 1 press	Next
S1 Long Press	Start drag mode	Button 3 press	N/A
S1 Very Long Press	Enter settings mode	Enter settings Mode	Exit settings mode
S2 Short Press	Middle Click	Button 5 press	N/A
S2 Long Press	Middle click	Button 6 press	N/A
S2 Very Long Press	Perform Center Reset	Perform Center Reset	N/A
S3 Short Press	Right Click	Button 2 press	Select menu item
S3 Long Press	Start scroll mode	Button 4 press	N/A
S3 Very Long Press	Middle click	N/A	N/A

Testing Hub Buttons

Ensure the following behaviours are consistent when pressing the buttons on the Hub.

Willow Hub Button Inputs	Select Short Press	Select Long Press	Select Very Long Press	Next Short Press	Next Long Press	Next Very Long Press	Next and Select
Mouse Behaviour	Left Click	Start Drag Mode	Enter Hub Menu	Right Click	Start Scroll Mode	Middle Click	Next and Select



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Input Feedback

Each LED is designated to a set of inputs:

Left LED •: Next (Hub), S1

Middle LED ••: S2

Right LED •••: Sel (Hub), S3

The time durations Short, Long, and Very Long for the switch/button inputs are the following:

Short: Less than 1 seconds. Indicated by the respective LED blinking once button is released.

Long: Between 1 to 3 seconds. Indicated by the respective LED turning on and staying on.

Very Long: 3 seconds or longer. Indicated by the respective LED turning off.

Ensure the LEDs behave as outlined above.

Troubleshooting

1. Arduino IDE is stuck when uploading code to the board.

You can first try to reset the board by clicking the "Reset Button" once. If that does not work, rapidly click it twice to enter bootloader mode. If that also doesn't work, disconnect the board from the PC, and connect the board again.

2. The board is not showing up as a serial device on Arduino IDE.

You can first try to reset the board by clicking the "Reset Button" once. If that does not work, rapidly click it twice to enter bootloader mode.

3. The Willow plays an error tone and then lists an error in Safe Mode.

- Disconnect the Hub from power.
- Wait 15 seconds.
- Unplug the Willow Interface cable on both ends and plug both ends back in.
- Reconnect the Hub to power.

If this does not resolve the error, make note of the error code on the Safe Mode menu screen, and refer to the table below:



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Table 1. Willow Error Table - Makers



Error Code	Connection Error	Maker Action	
	Display	Joystick Sensor	
ERROR-001		●	1. Check that I2C cables are securely inserted into the magnetic sensor inside joystick. 2. Check that the LipSync interface cable is securely connected on both ends. 3. Confirm the LipSync Interface Cable is the right type. 4. Check that the RJ11 Connector board inside the joystick has all wires connected.
ERROR-002	●		Check that I2C cable is securely inserted into Display within Hub.
ERROR-003	●	●	Check that I2C cables are securely inserted into each sensor inside joystick.