Makers Making Change
A Neil Squire Program

Iteration v0.2

Introduction

For people who have difficulty using typical input devices like computer mice or the thumbsticks on video game controllers, joysticks can provide a more accessible option. Commercial options can be expensive, difficult to source, or require too much force or range of motion. The goal of this project is to develop a cost-effective, open source, customizable lineup of joysticks, using easy to source components. These joysticks will be designed for Maker assembly with all the digital files necessary to customize key components easily.

The Adafruit Mini Analog Joystick (https://www.adafruit.com/product/3102) is a generic arcade style, analog joystick. The goal of this joystick is to have a slightly higher force, higher movement joystick with multiple topper options. Another goal with this design is to have modularly added buttons, as this joystick mechanism has a tall profile, making it difficult to reach buttons placed nearby.

Note: A CAD model of this joystick can be found at the following link:
https://www.digikey.ca/en/products/detail/adafruit-industries-llc/3102/6152821

Who

Who will be using the device?

- The device is intended for use by a single user at a time. However, through modular toppers, should be able to be used by different users.
- People unable to use a conventional game controller.
- OTs and other professionals to become familiar with the joystick.

Who will be affected by the device?

- The user.

What

What must the device do?

- The device is intended to be USB compatible with PCs.
- The device is intended to be USB or Analog compatible with the XAC.
- The device is NOT intended to be used to control a mobility device.

What needs must the device serve?

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Files available at https://github.com/makersmakingchange/Oak-Compact-Joystick/tree/v0.9

- Users with low thumb/finger dexterity
- Users with the following possible points of access:
    - Hand
    - Forearm
    - Elbow
    - Chin
    - Foot

Why

Why will the device be used?

- To enable or improve a user's ability to play video games

Where

Where will the device be used?

- In a home.
    - At a desk
    - At a wheelchair
    - On a bed
    - On a couch
- In a physical rehab setting.

When

When will the device be used?

- When using a computer or other compatible gaming unit (Xbox).
- When testing out different gaming set-ups.

Functional Properties

1. Goals

G01	Achieve a material cost of less than $80 CAD.
G02	Maker manufacturable in quantities of one.
G03	The use of support material in 3d printed components should be minimized.
G04	The number of different filament types should be minimized.

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Oak Compact Joystick
DESIGN RATIONALE

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Functional Requirements

F1.	The joystick design shall consist of a variant with USB output and a variant with XAC-compatible analog output.
F2.	The joystick shall be usable from a minimum distance of 1.5m away.
F3.	The joysticks shall be compatible with the Xbox Adaptive Controller.
F4.	Joysticks shall be PC compatible.
F5.	The joystick shall denote use orientation.
F6.	The joystick shall have a range of easily interchangeable toppers.
F7.	Toppers shall not interfere with the regular physical motion of the joystick.
F8.	Toppers shall have a secure connection to the joystick.
F9.	The joystick shall be designed to be used by either hand.
F10.	Joystick shall remain stable when in use.
F11.	The housing shall protect internal components from outside sources.
F12.	Joystick designs shall support camera mounting styles.
F13.	Joystick designs shall support hook and loop fastener mounting styles.
F14.	Joystick designs shall support tabletop mounting styles with no fasteners.

Non-functional Requirement

NF01	Documentation should be maintainable with the use of commonly available software.
NF02	Documentation must be available in a digital format.
NF03	Documentation must be printable.
NF04	Documentation, code, and hardware must have appropriate open-source licenses.

Constraints

C01	Joystick must be maker manufacturable.
C02	Joystick mechanisms must be analog by default.
C03	Not for use with mobility devices.
C04	The joystick shall be based on the commercially available Adafruit Mini Analog Joystick.
C05	The Adafruit Mini Analog Joystick has an approximate activation force of 525 grams.
C06	The Adafruit Mini Analog Joystick has an X and Y axis range of ±25°
C07	The Adafruit Mini Analog Joystick has a linearity of ±1%
C08	The Adafruit Mini Analog Joystick has a mechanical lifecycle of 500,000 cycles.
C09	The Adafruit Mini Analog Joystick has an operating temperature range of -10 - 80°C
C10	The Adafruit Mini Analog Joystick has an envelope of 67.4 high x 52.7 mm wide x 52.7 mm deep
C11	3D printed components shall be printable within a 180x180x180mm print volume.

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Research

Comparable designs:

Ultrastik by Ultimarc – SCCR has a 3D printed case available on Printables

- Quadstick also sell this in an enclosure. – 149 USD

Warfighters Engaged - Joystix-L (*Non-USB) – 65 USD

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Oak Compact Joystick
DESIGN RATIONALE

n-ABLER Joystick by Pretorian – 450 CAD

Slimline Joystick – 444 CAD

BJOY Chin – 650 CAD

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Oak Compact Joystick
DESIGN RATIONALE

Ideation

Electrical

- Protoboard and wires
- Direct to MCU
    - Wires
    - DuPont cables and headers
- Custom PCB

Considerations: Size, difficulty of assembly, MCU does not have mounting holes, will require wired connections regardless due to Joystick configuration, joystick must be screwed in from the top

CAD Model: https://www.digikey.ca/en/products/detail/adafruit-industries-llc/3102/6152821

Enclosure

- Simple box with room for wire routing
- Build out sides, not under the joystick component
- Top snap fit on or uses fasteners
    - Joystick component requires fasteners to mount
        - #4 3/8” work (same as MMC60)

MCU Mounting

- Solder to protoboard and then screw down the protoboard
- Built in slot for MCU within enclosure
- 3D printed clamp/cover to hold MCU in place

Topper Connection

- Clamping connection
- Set screw connection
- Threaded connection
- Press-fit connection

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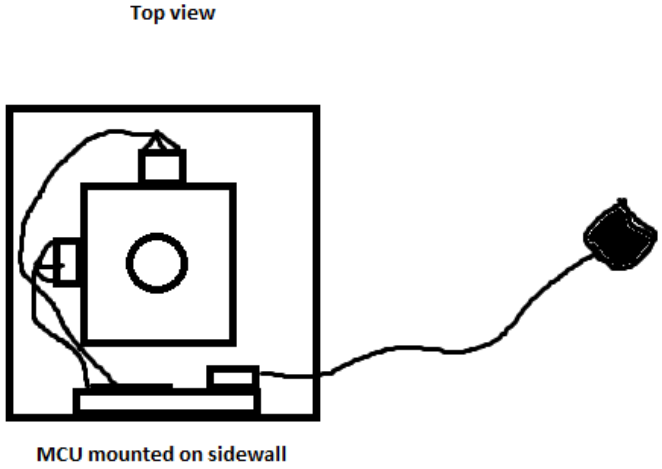
Conceptual Design

The main factors to consider with this design are size and cost as the joystick component is already quite large, so increasing the size significantly is undesirable, and the cost of the joystick component is ~$30. Therefore, using the space efficiently and minimizing fasteners (mainly number of different fasteners) is important.

Enclosure Design

Concept 1: Simple Square Box



Pros: Simple to design, low profile

Cons: Poor use of space – need space for the potentiometers and MCU, which keeps the joystick corners away from edges of the enclosure, small amount of space to wire the MCU.

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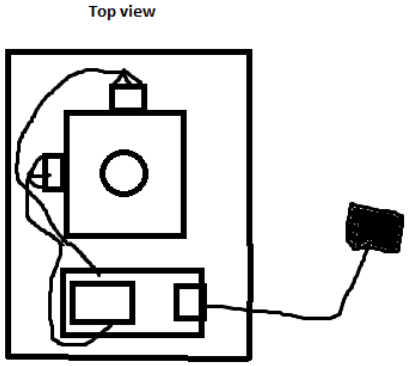
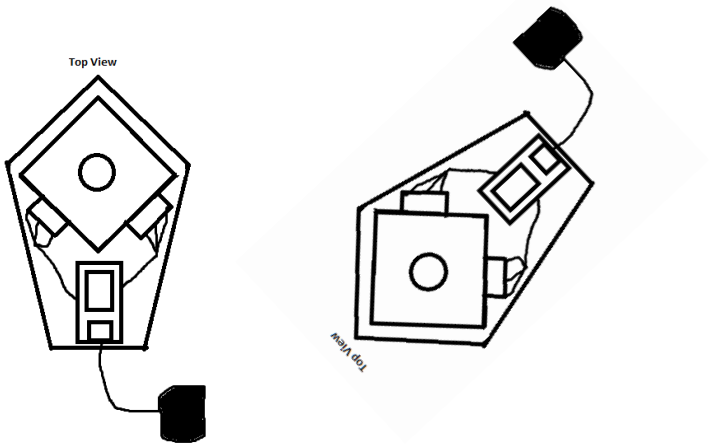
Concept 2: Rectangular



Pros: Simple to design, more room for wiring/mounting the MCU,

Cons: poor use of space, awkward spot for the USB port

Concept 3: MCU in top Corner



Pros: Efficient use of space, leaves room for MCU wiring, keeps most corners of joystick near an edge for mounting

Cons: unintuitive directions cable exits at an angle

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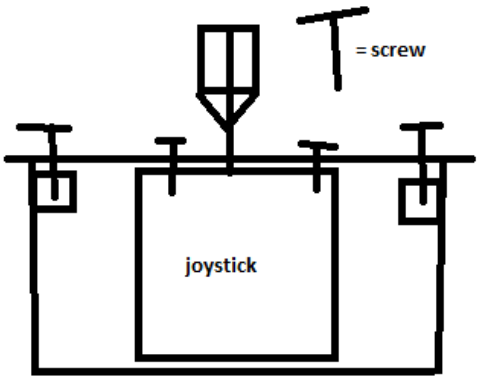
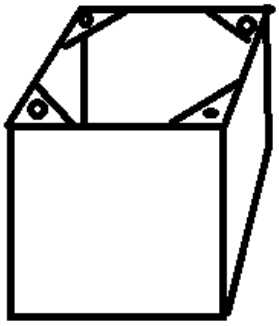
Joystick Mounting



Screw joystick into top piece and then the top into the base

This method would be simpler to do, but would require a larger overall base to leave room for the fasteners to hold the top piece on. It also requires more fasteners. Could be difficult to model due to the top ring of the joystick – would require either replacing the top ring with print, or having a very thin section. Likely more flexible (more connection points spaced out)

Thin bridge with holes over corners



This method allows for a lower profile base and fewer fasteners but would require some type of snap fit or otherwise to hold the top piece on. It also has the potential to be difficult to print depending on the length of bridge required. The section must be thin to fit in between the rubber boot and the joystick

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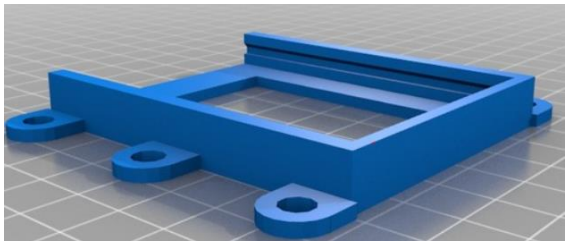
box. It may also be difficult to screw into all four holes depending on orientation. Likely more rigid (fewer connection points near the edge)

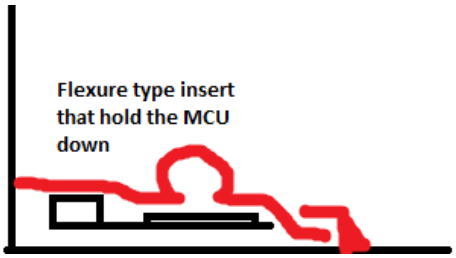
MCU Mounting

Slide-in Slot



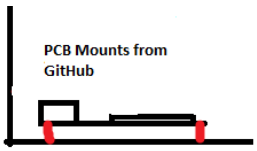
Slot to slide the MCU into and lock in place. Requires some type of retainment method.

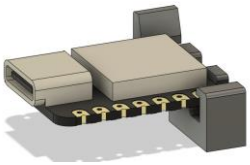
Flexure-based Clamp



Would require extra space to implement and only relies on pushing the MCU down into the base to hold it in place securely. Likely could wiggle back and forth a bit.

PCB Mounting Clips





Need to be glued/fastened down in some way. Need to test if it would block the voltage pin.

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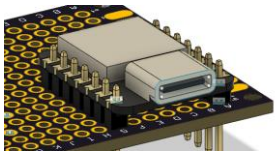
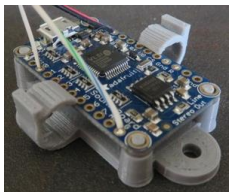
Solder to Protoboard



Could solder to protoboard and screw down. Would require more space but likely the most secure choice.

Print in Place Clip



Likely too brittle when printed in PLA (PETG or ABS suggested by designer)
https://www.thingiverse.com/thing:5230779

Prototype v0.1 Design

Microcontroller – SEEDStudio Xiao RP2040

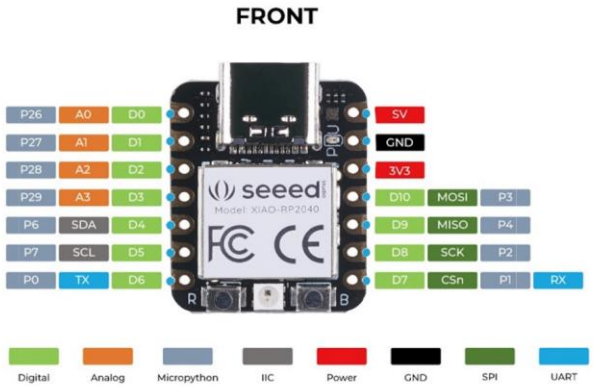


Figure 1 MCU Pinout. https://wiki.seeedstudio.com/XIAO-RP2040/

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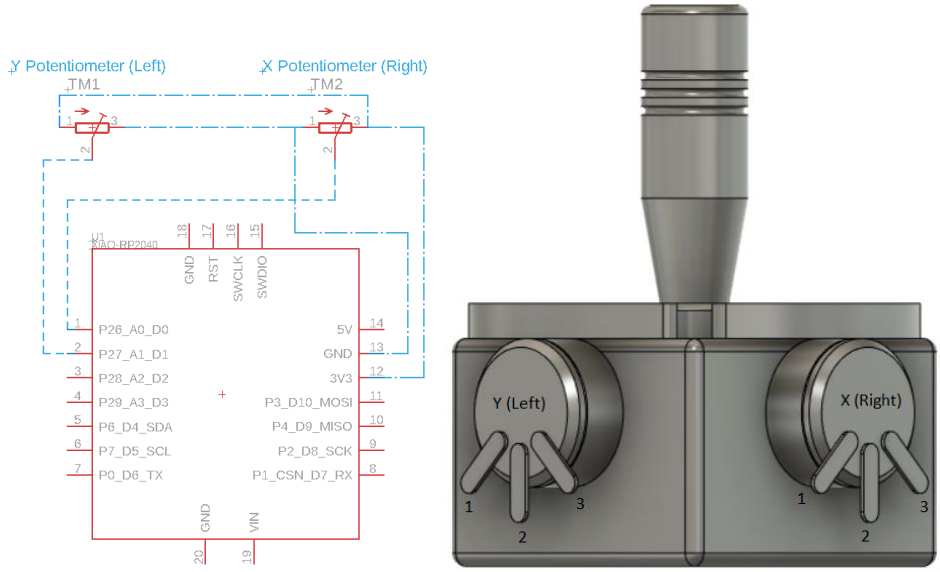
Oak Compact Joystick
DESIGN RATIONALE



Electrical diagram for wiring the potentiometers to the MCU.

Commented [SM1]: Has to go to 3v3, not 5v

Commented [JV2R1]: V and GND flipped

X goes to A0, Y goes to A1

XAC Analog wiring for TRRS:

Standard TRRS	Joystick
Tip (T)	X
Ring 1 (R1)	Y
Ring 2 (R2)	G
Sleeve (S)	V

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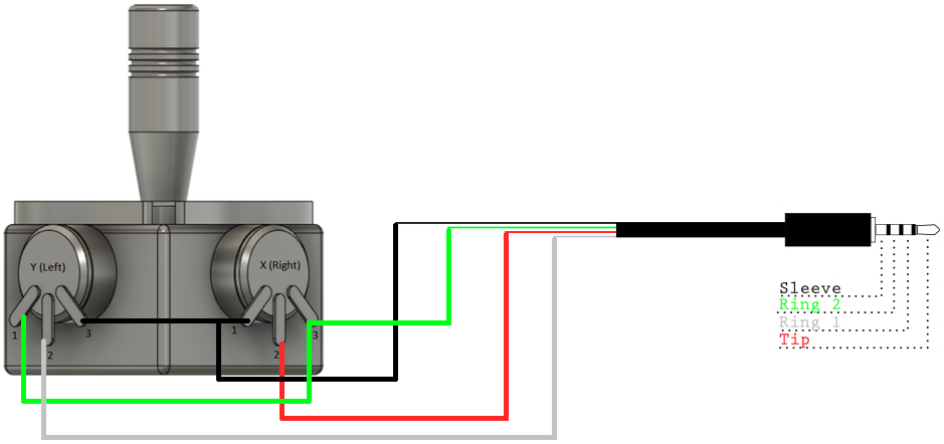

USB-c Cable Measurements

These measurements are used to define the dimensions of the USB-c cable port through the enclosure.

PS:The above dimensions are manually measured and may have minor errors.

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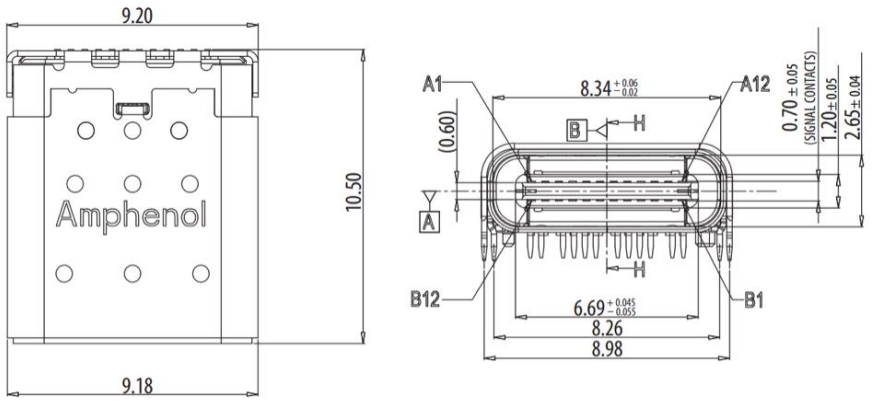

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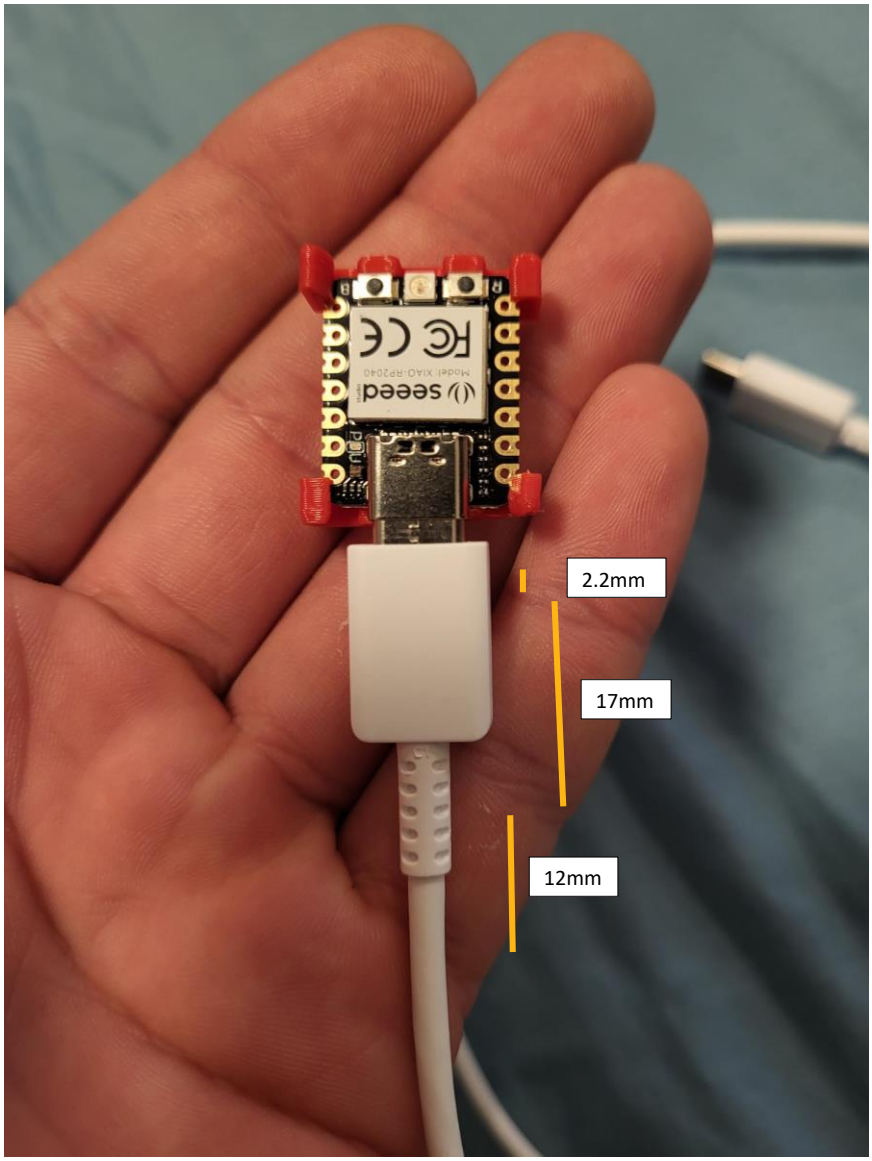

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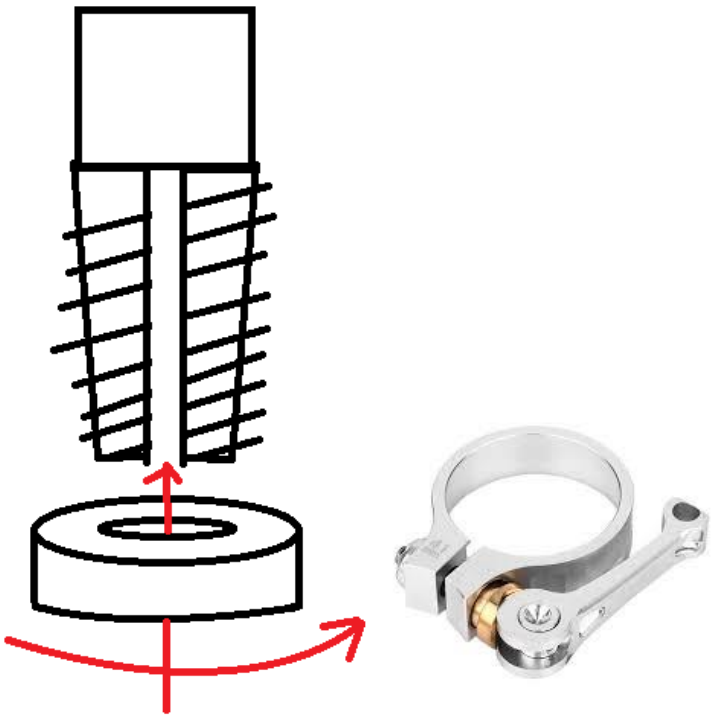
Toppers

Topper Connection ideas

1. Two halves clamped together
    a. Threads with a split through the cylinder that get snugged up with a nut (all 3D printed)
    b. Quick release style clamp
    c. Hose clamp
2. Friction fit
    a. Tight tolerance
    b. Crush ribs
3. Set screw
4. Threaded (tap and die to joystick handle and topper)



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Prototyping

~~Concept 1: uses the MCU in the top corner arrangement with the bridged corners for joystick mounting and snap fits for the MC- U mount.~~

Concept 2: Uses a rectangular shaped box with the joystick screwed into the lid for joystick mounting, and glue-in snap fits for the MCU mount.

OFIs

Enclosure

- ~~Add a ridge around the connection point between the top and bottom of the enclosure~~
- ~~Move screws for connecting the enclosure together to the bottom~~
- ~~Chamfer all top edges~~
- ~~Increase arrow visibility~~

~~Prototype 1~~

Flat plate top that screws down into the base.

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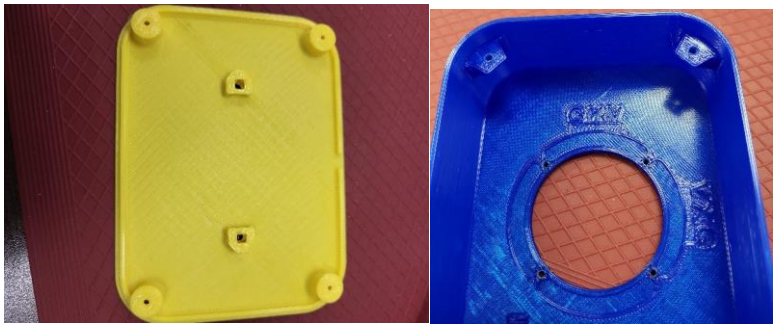
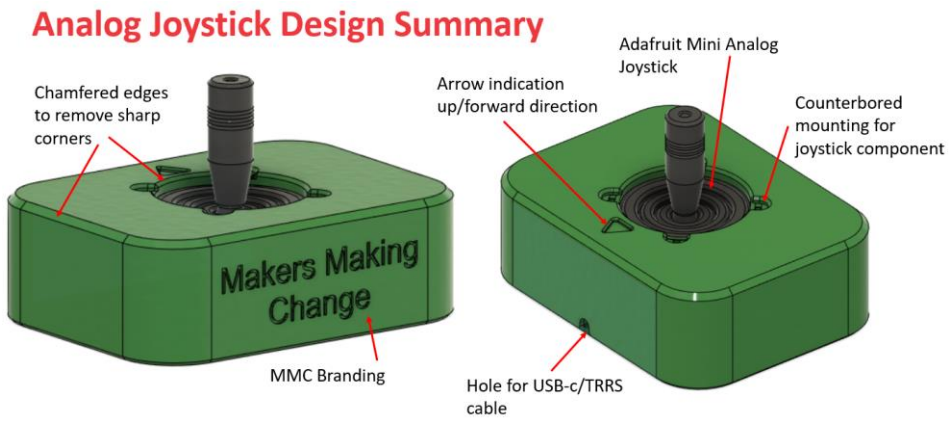
Prototype 2

Connect the walls to the top so the flat plate base now screw up into the top enclosure print. USB port widened for removability – change dependent on user testing feedback/preferences



The design started with the walls being attached to the bottom and the top piece just being a plate, which was flipped (as seen in the above photos where the walls are attached to the top piece of the enclosure) so that the screws fastening the two pieces together were on the bottom and not the top. On the top, a screw sticking out could pose a risk to scratch the user and does not look as nice as a smooth, flat surface.



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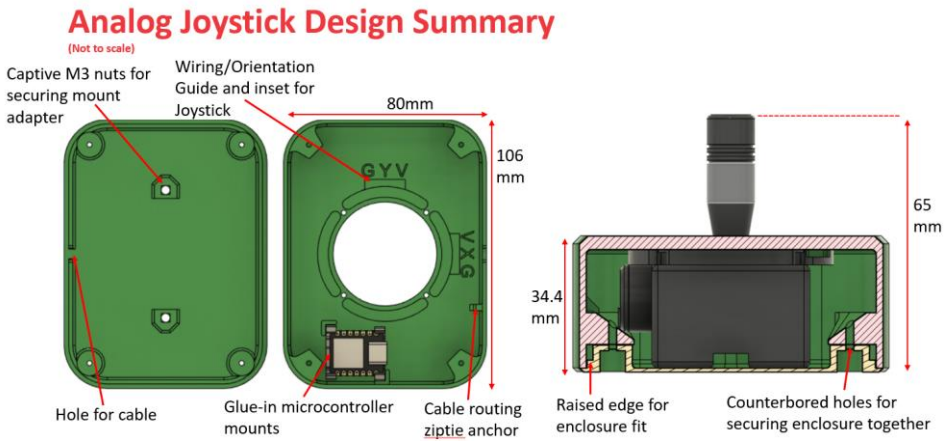
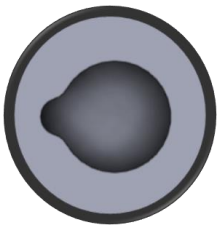


Toppers

Topper attachment: press fit – easiest to design and least material required. Also requires no extra hardware or tools for the maker or user.

Joystick shaft has a 12.232mm diameter in CAD model and 11.9mm from caliper measurement. Press fit diameter modelled to 12mm. Added an air-hole so not pocket of air is created. Added chamfers to edge of hole for easier alignment.



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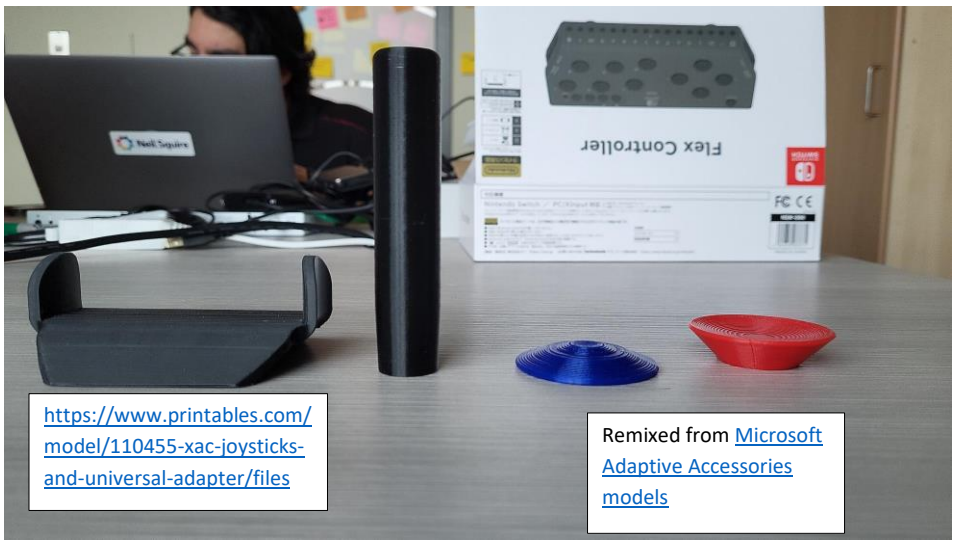
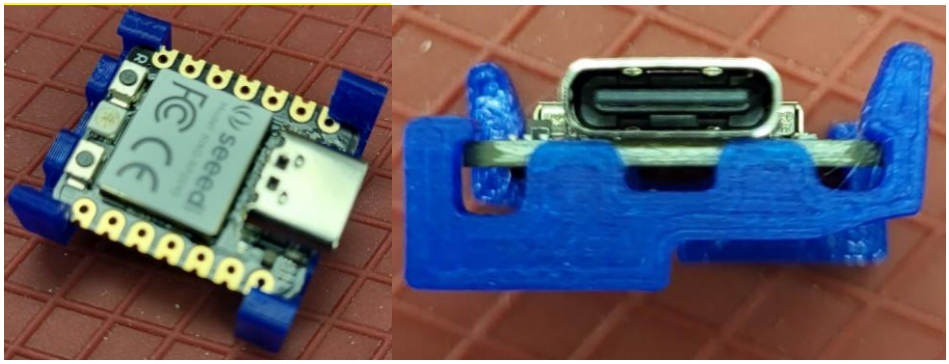


Goalpost Topper Cylindrical Topper Convex Topper Concave Topper

Testing

PCB Mounting:

Glue-in snap fits: Current



Built in slot: Needs a better retainment method (no extra prints)

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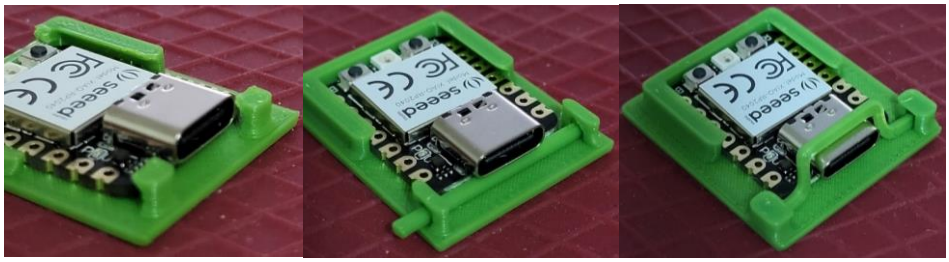

Screws (capturing with 3D print or just screws on the edges): Uses extra prints or fasteners

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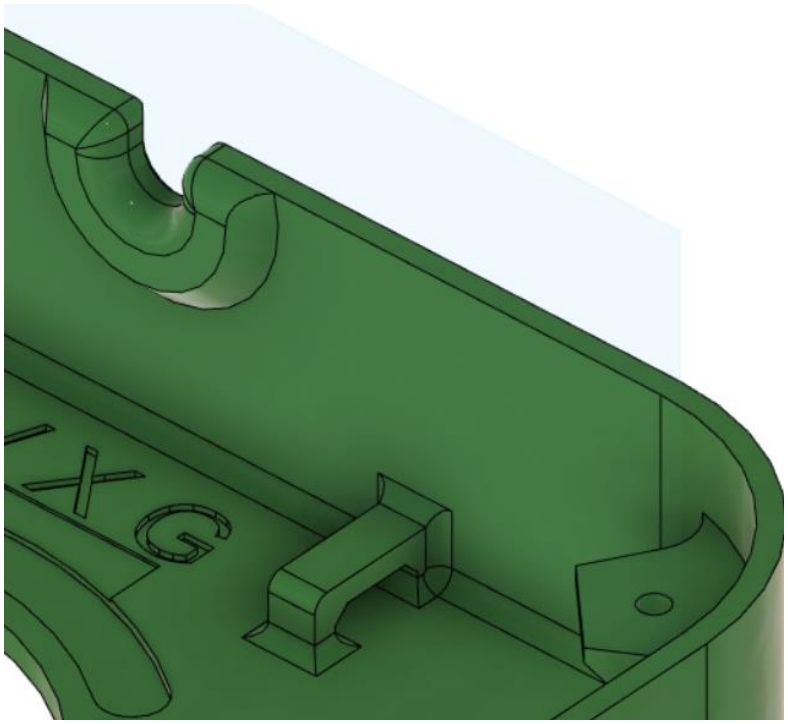
Prototype v0.2 Design

Cable Routing: Added cable strain relief via rounded edges and a zip tie anchor for the cable.



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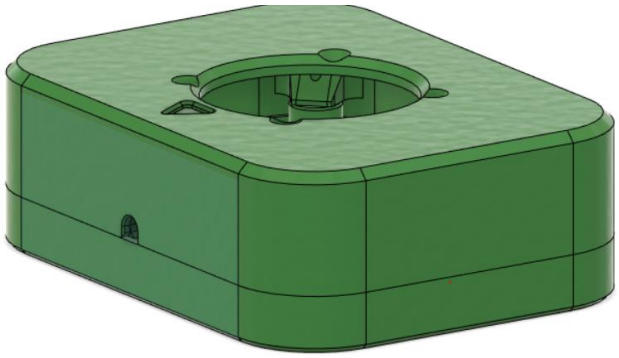
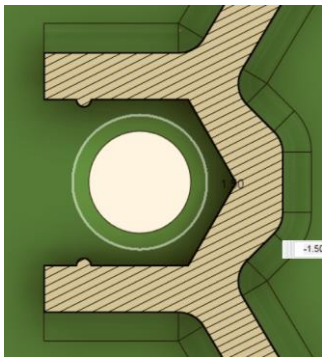
Files available at https://github.com/makersmakingchange/Oak-Compact-Joystick/tree/v0.9

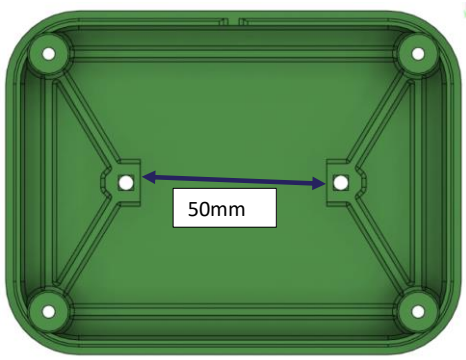
Top Surface: Chamfered all edges. Removed floating holes and replaced with chamfered holes as the screws are chamfered.

Split Line: Raised the split line so the bottom half of the enclosure has some more rigidity and meets the top enclosure piece better.



Bottom Enclosure: Added supports for rigidity connecting the holes in the bottom of the enclosure. Also added nut retainment to the slots for the optional camera mount adapter.





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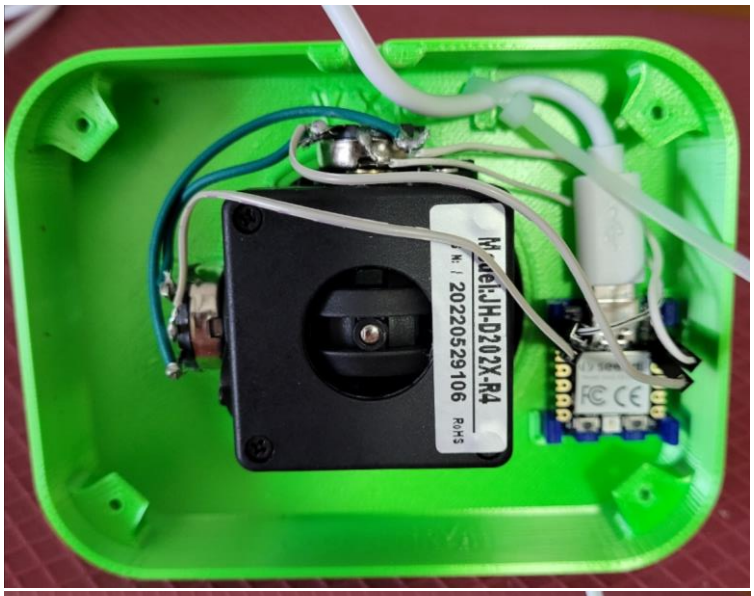
Built Final Prototype



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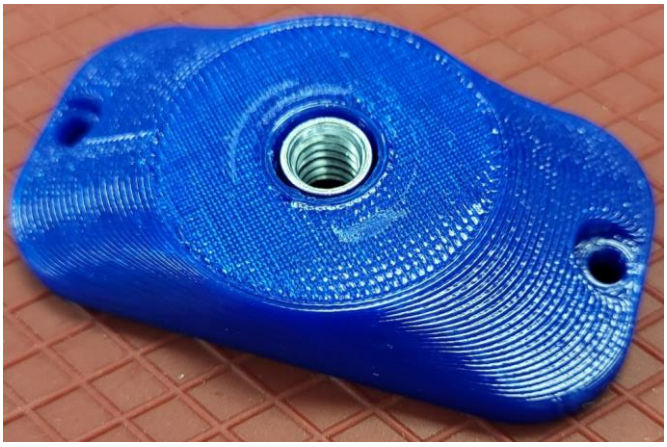

Opportunities for Improvement

- Reduce to only requiring top and bottom enclosure print (no small extra prints for PCB mounting) – Would standardise the print between USB and TRRS versions.
- Customising the output/centering with potentiometer adjustment
- Versions with limited joystick throw (necessary with Ultrastik??)

Iteration V0.9

Introduction

The focus on this next iteration of the Oak Compact Joystick is to pair the Analog build with the Enabled Controller Mini to test a separate switch interface and make the decision whether to pursue standalone joysticks, or joysticks with an additional interface. There will also be a focus on the development of a joystick-based mouse code. (see Cedar Mini Joystick for code development)

The key design focus in this iteration is to:

1. Design a more robust, easily swappable topper connection solution.
2. Create parametric topper designs.
3. Optimize the enclosure design to minimize print time.

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Existing Devices and Designs

Commercial Options

Ultrastik
https://www.ultimarc.com/arcade-controls/joysticks/ultrastik-360-oval-top-clone/
Ultimarc
Commercial Device
59 USD
Requires an enclosure, but has gamepad and mouse function built in.

DIY Designs

Oak Compact Joystick v0.2
https://github.com/makersmakingchange/Oak-Compact-Joystick
Neil Squire / Makers Making Change
CERN-W
~54 CAD
The previous iteration of this project and the current baseline for this design.

Requirements

These requirements are for the physical design of this project, not the code.

Goals

G01	Able to install and remove toppers without tools.
G02	
G03	

Functional Requirements

F01	Toppers shall be removeable and interchangeable.
F02	Topper interface shall be non-destructive.
F03	Toppers shall attach securely, not spinning or able to be pulled off the joystick.

Non-functional Requirement

NF01	Print time shall be as reasonably short as possible.

Constraints

C01	

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C02	
C03	

Toppers

Topper Sizing

For ease of selection, three sizes of each topper were generated into STLs. As these toppers will be used with a large range of ages, a range of average hands sizes from child to adult were used to choose the sizes.

Using hand length and width averages from https://www.healthline.com/health/average-hand-size#children as a first estimation, we can derive a range of topper sizes to provide. We are aware this is not representative of the intended users, but are using it as a first step to gain feedback. The given averages are for 6, 11, and 40 year old males and females. (Studies done in 1973 [6 and 11 year olds by US Department of Health, Education, and Welfare] and 2000 [40 year olds by NASA])

	6 year olds		11 year olds		40 year olds	
	Male	Female	Male	Female	Male	Female
Avg Hand Breadth [in]	2.1-2.6	2.0-2.7	2.0-3.1	2.0-3.1	3.5	3.1
Avg Hand Length [in]	4.6-5.7	4.4-5.7	5.5-6.8	5.6-7.0	7.6	6.8

Note: These measurements are just for ballpark numbers and are not perfect representations of the required sizes. A maximum breadth of 3.5” has been determined to be smaller than we want for a large sized topper, based on user testing.

Using the assumption that 19.7% of the hand length is the ideal grip size (2005 Study from previous link) will dictate the diameter of the stick topper, approximately half the length will dictate the depth of the toppers, while the hand breadth will dictate the width of the toppers and height of the stick topper. Note: All conversions are approximated to the nearest multiple of 5mm.

Small: Width = 2” ≈ 50mm, Depth = 2.5” ≈ 65mm, Diameter = 0.197*5” = 0.985” ≈ 25mm

Medium: Width = 3” ≈ 75mm, Depth = 3” ≈ 75mm, Diameter = 0.197*6” = 1.221” ≈ 30mm

Large: Width = 4” ≈ 100mm, Depth = 3.5” ≈ 90mm, Diameter = 0.197*7” = 1.497” ≈ 35mm

These dimensions will be used for the MVP user testing and next iterations on sizing will be dictated by the testing feedback. Note as well that the “bump” heights of the goalpost and convex topper aren’t being changed, nor is the dent in the concave or the height of the goalpost walls, nor the width of the stick topper base. These will also be modified in further iterations based on user feedback.

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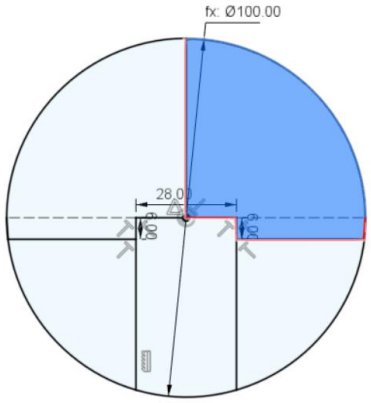
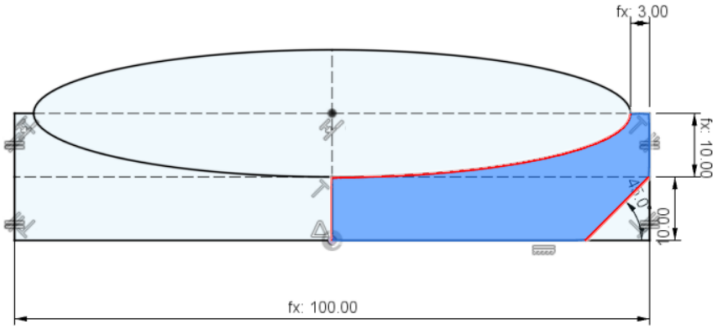
Parametric Topper Detailed Designs

Ball Topper



The ball topper is a revolved extrude of the above highlighted section of the sketch. The Diameter of the circle is an adjustable parameter with a minimum possible value of 35mm. This design could be improved to increase the portion of the resulting sphere below the centreline of the shape. As it currently exists, it is more aptly a hemisphere. The Diameter in the above sketch is currently fx: 100.00.

Concave Topper



The concave topper is a revolved extrude of the above highlighted section of the sketch. The Diameter of the extrude is an adjustable parameter with a minimum possible value of 50mm. The Rim Width is another adjustable parameter that dictates the inner diameter of the concave portion and the Depth is the last parameter, dictating the depth of the internal concave portion. The Diameter in the above sketch is currently fx: 100.00, the Rim Width is fx: 3.00, and the Depth is fx: 10.00.

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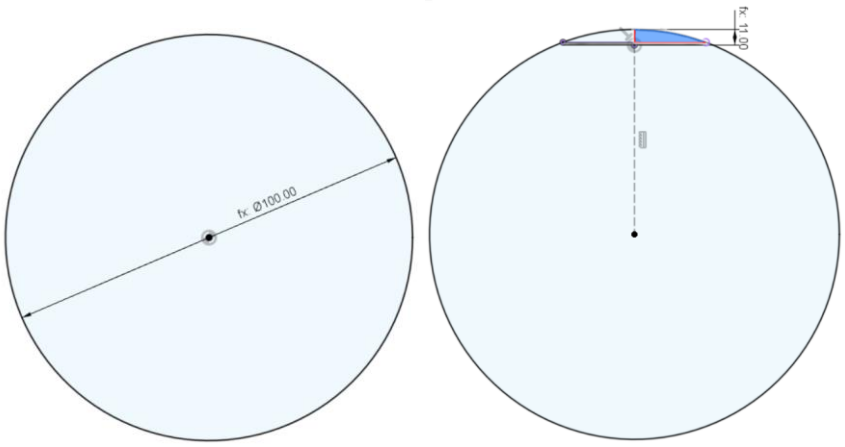
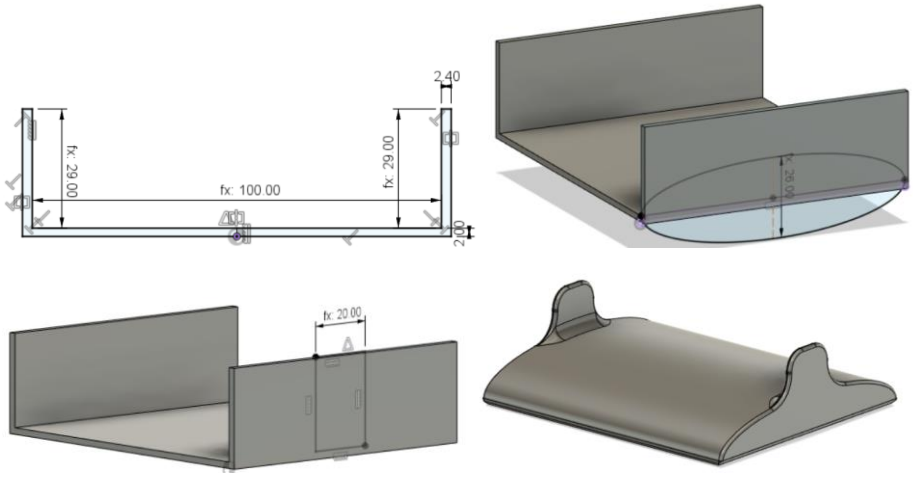
Convex Topper



The convex topper is a combination of a 2mm boss extrude of the Diameter and a revolved extrude of the highlighted portion in the sketch to the right. The combination is unnecessary, but is how I originally made it. The Height is created by dictating the distance of the edge of a circle from the top edges of the 2mm disc. The Diameter in the above sketches is fx: 100.00 and the Height is fx: 11.00.

Goalpost Topper



The Goalpost topper started as a boss extrude of the Width and Wall_Height, set in the top left screenshot about to fx: 100.00 and fx: 29.00, respectively. The length of the extrude was set to the

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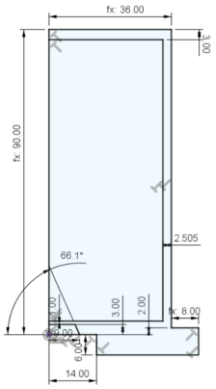
Depth Parameter. Next, to create the rounded surface for a hand to sit on, an ellipse was used and the height of it set to Bump_Height, which is set to fx: 26.00 in the top right screenshot above. The walls were also shaved down using the Wall_Depth parameter, set to fx: 20.00 in the bottom left screenshot above. Lastly, the sharp edges were filleted and chamferred.

Stick Topper



The stick topper is a revolved extrude that uses Height, Diameter, and Base_Brim for parameters. The Height is currently set to fx: 90.00, the Diameter to fx: 36.00, and the Base_Brim to fx: 8.00. Note: the diameter had to be modified so it was the inputted parameter divided by two as the actual dimension is of a radius.

Topper Connection

Ideation

The current v0.2 uses a press-fit to connect the toppers to the joystick. This is an ok solution; however, the press-fit will loosen over time and the toppers will become less secure to the joystick. This also does not keep them from spinning on the joystick. Therefore, a different type of interface between the joystick and the topper is desirable. Ideally, the angle the topper is mounted relative to the forward direction is adjustable.

The black topper that comes installed on the joystick proves very difficult to remove. So removing it is out of the question.

A direct connection topper to joystick would likely be lower profile overall, but adding an interface could make changing out toppers easier and require fewer components overall. (hardware just in interface piece)

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Methods to fasten to joystick	Pros	Cons
Inward facing setscrew	Easy concept	Requires a tool, requires trapped nut which adds bulk,
Hole and push/pull tab		Require flexible printed parts, permanently deforms joystick
Threads		Requires a die set, permanently deforms joystick, black plastic on joystick may not thread well
Glue	Secure, doesn't rely on friction	Permanent solution
Keyway	Doesn't rely on friction	Permanent solution, could be difficult to add a keyway slot, black plastic on joystick may not machine well,
Quick release clamp	Easy concept	
hose clamp (metal or 3D printed)	Easy to use	Requires a tool, very small diameter to go around
Collet	Fully 3D printable, doesn't require hardware or tools, easy concept	Print orientation will likely matter, relies on friction, requires something to tighten it in place
Methods to fasten to topper from a 3D printed interface		
Inward facing setscrew	Easy to use, can adjust angle easily	Requires a tool, have to remove the set screw or have it in the topper (increases hardware required), can mar the black joystick top
Outward facing setscrew	Easy to use, doesn't require removing a screw to change out,	Requires a tool and hardware, fewer options for angle adjustment
Threads with lock nut	Able to adjust angle and height, locks in place	Could be difficult to remove if overtightened, difficult to 3D print
Twist lock (pill bottle type)	Easy concept	Could come loose by accident when pushed down on, patents…?,
Push tabs	Easy concept	Requires two hands to remove, relies on flexible 3D print,

Both the Collet and Setscrew ideas will be pursued for initial prototyping.

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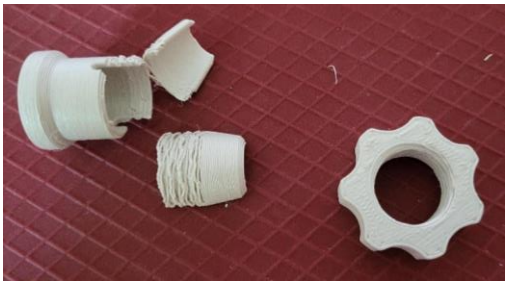
Prototyping

Concept 1: Collet



The first attempt failed immediately. Vertical print orientation proved a poor choice. This also is not a true collet; learned about this during the design process and tried a true collet in attempt 2.

The second attempt was a collet with only one side split. This fit over the joystick well, but only one side of it could clamp down on the joystick and this first try had lots of unnecessary bulk.

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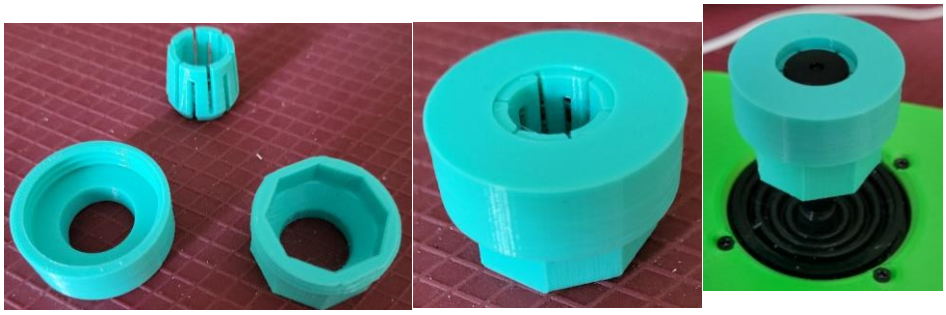
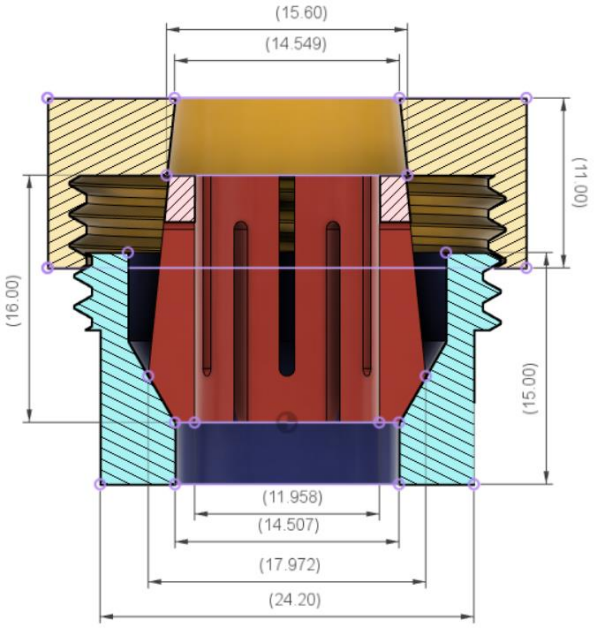


The third attempt used a 3 piece approach and a more standard collet design. The octagonal bottom piece prints on its side for increased strength while keeping the walls thinner. The round top piece and the collet print vertically. It took a few attempts to achieve a secure fit, namely letting the collet ends have a cone to compress into was important.



M28x2 threads

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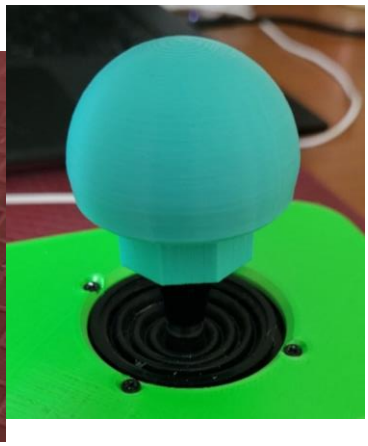

The third attempt integrates the top piece of the collet design into the topper itself. It works best to slide the lower fastener onto the joystick, fit the collet over the joystick, press the topper onto the collet, and then screw on the lower fastener into the topper.

Note: The collet does not seem to last very long. It doesn't seem to be a print quality issue as much as a design issue.

The collet seems to break just below where it interfaces with its surrounding fastener pieces. This is likely due to some stress concentration/difference of stress on the compressed and uncompressed parts. So we tried flipping the collet upside-down and modifying the inner walls of the fastening pieces to have more surface contact over the entire area.

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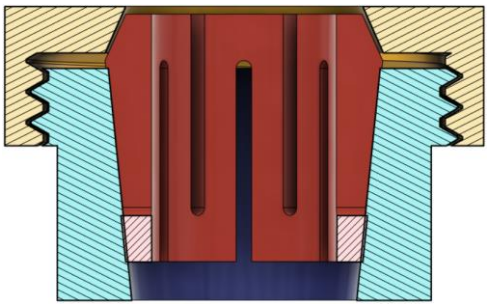
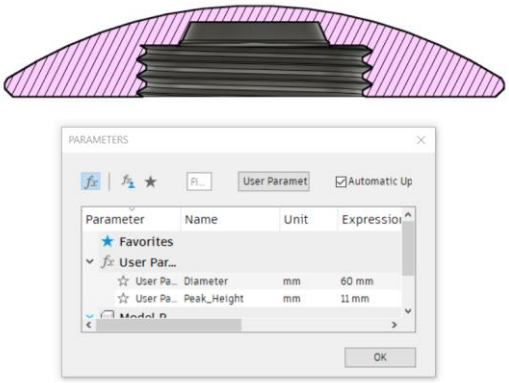


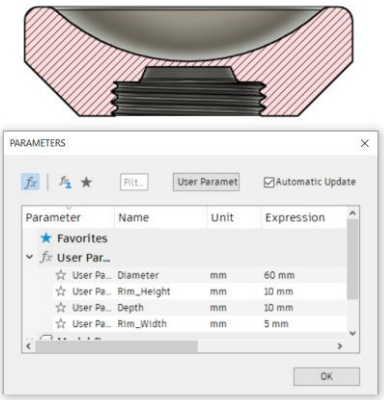
The inner wall of the blue piece was offset to add more space, as the collet must expand slightly to fit around the joystick. The collet and lower fastener tend to stay stuck on the joystick after removing the topper, but this is mitigated through pushing the entire assembly (with the topper removed) downward to the base of the joystick, and removing the collet, then fastener, respectively.

This could be due to the layer lines being in the same orientation and wedging together as the collet is compressed. The angles on the outer walls of the collet could also contribute, namely the longer side of the collet that has a steeper angle.

Integrating with Parametric Toppers

The initial designs of the parametric toppers. These will be broken out further under detailed design. They are listed here to show the integrated threads.





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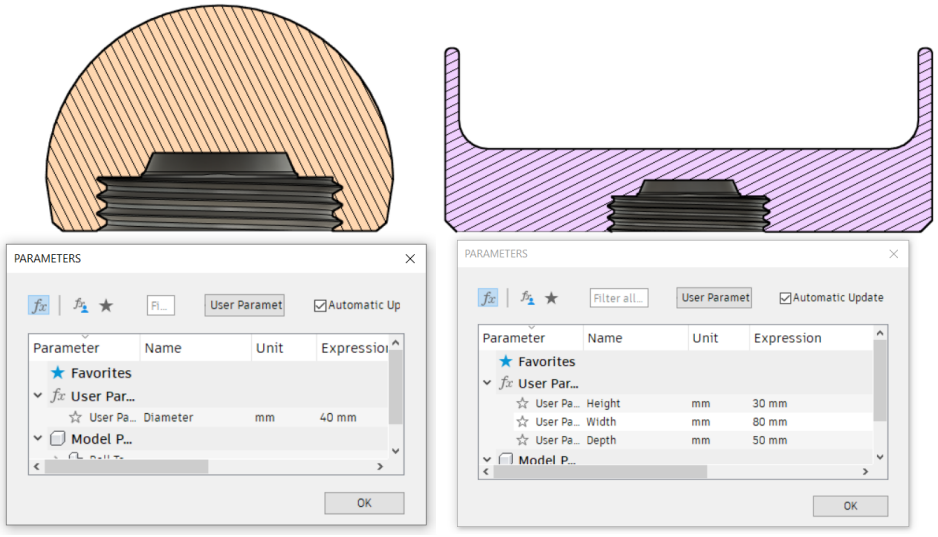
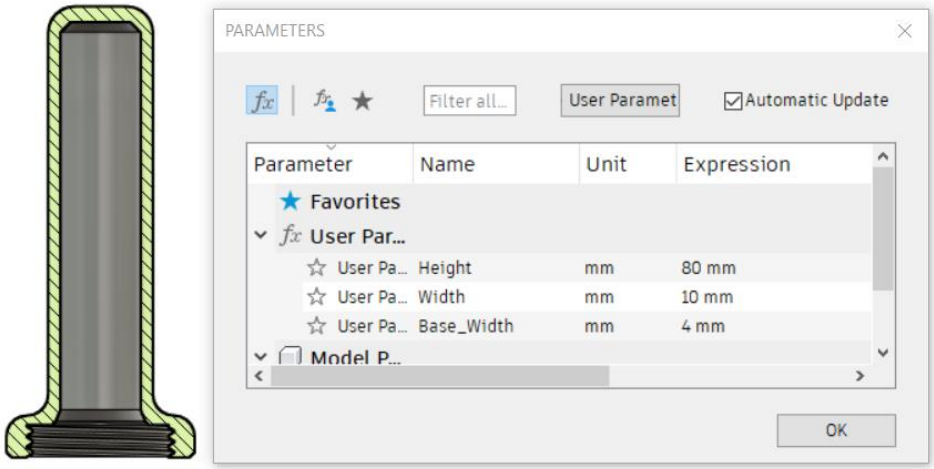
Oak Compact Joystick
DESIGN RATIONALE





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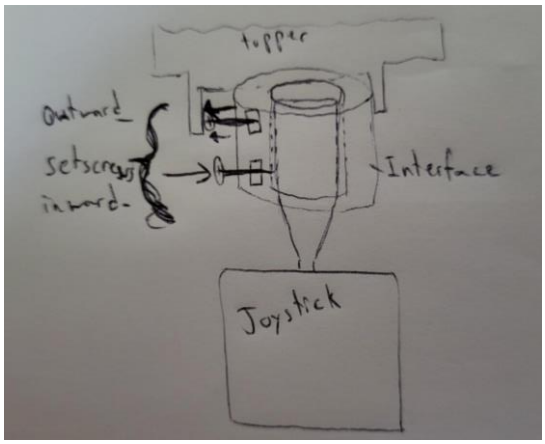
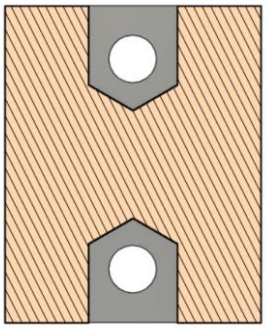
Concept 2: Setscrews





The first print was a bit large, inner diameter was 13.4mm. Updated to 12.2mm. Screw used was M3 x 10mm, based on measurement, 6mm should be ideal for both top and bottom. It was possible to move the joystick to full extents without interference from the enclosure.

https://www.digikey.ca/en/products/detail/apm-hexseal/RM3X6MM-2701/612968

Selection of Topper Interface

Due to the Setscrew method requiring tools, we will pursue the collet design to hopefully reduce the need for tools and extra hardware to install and remove toppers.

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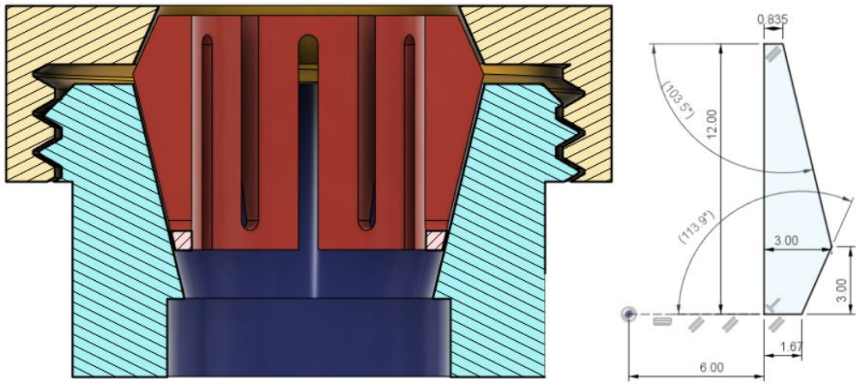
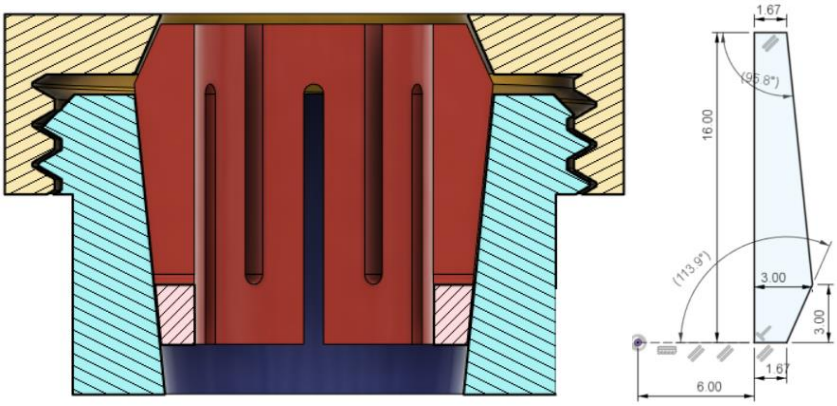
Topper Interface Testing

In testing the collet design, there were many times that the nut and collet wedged together and became stuck to the black joystick shaft. When this occurred, it was very difficult to remove the nut and collet from the joystick, or to position new toppers properly. One of the main contributing factors was the exterior angles on the collet, specifically the one on the longer side that was closer to 90 degrees. Another contributing factor is the print orientations being the same, meaning that the layer lines will want to wedge together and resist axial forces. It was found in testing that the threads printed much better vertically than horizontally, and the threads would bind more if printed in a different orientation than their mating threads on the topper portion. increasing the angle and decreasing the size of the collet proved effective enough to stop the collet from getting stuck without modifying the print orientation and still resulting in a secure fit.

Modified Collet



Original Collet



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Files available at https://github.com/makersmakingchange/Oak-Compact-Joystick/tree/v0.9

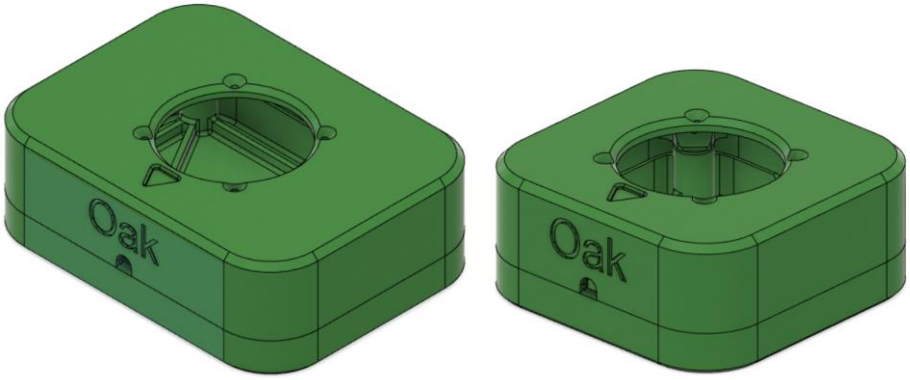
Enclosure

From v0.2, there have been some suggestions on improvements to the Oak enclosure.

1. Reduce print time
    a. Remove some of the strength supports on the bottom
2. Add build redundancy
    a. Add cutout for cable relief onto both sides of the bottom enclosure piece so it is correct regardless of which way the maker lines up the top and bottom rectangles.
3. Modify the cable anchor so that the cable runs alongside it and the zip tie can wrap around the anchor and cable easily.

Due to this iteration focusing on the Analog variant, the extra space on the sides is not required for the microcontroller. Therefore, we can reduce the joystick to a square outline, instead of rectangular. This should help to further reduce print time and decrease the chance of topper/enclosure interference. This will likely cause the joystick to be less stable, but this can be mitigated through mounted baseplates.

Prototyping



From a rectangular outline to a square outline.

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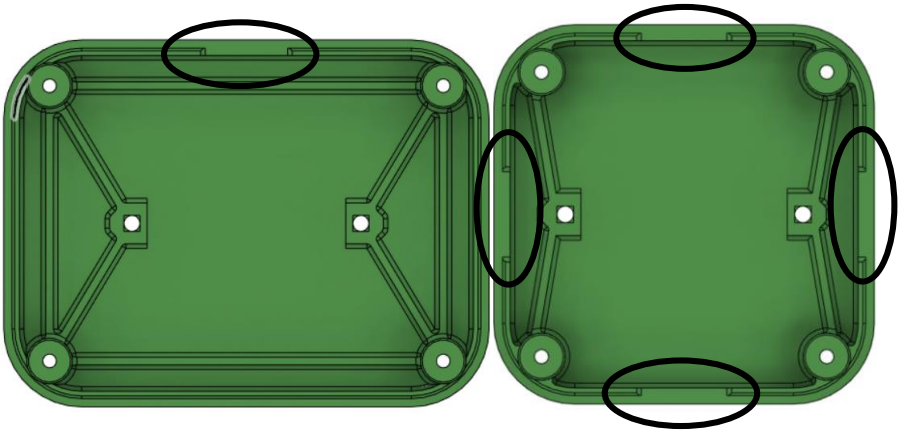

Removing some of the strength supports as the sidewalls should be sufficient strength across the span of the device. Also adding cutouts along each side of the bottom piece so that the top piece can mesh with the bottom in any (obvious) orientation.

Moved the cable anchor to in between the potentiometers so the cable requires fewer bends to exit. Also positioned the anchor so the cable can wrap around both the anchor and cable in the same direction. Lastly, the corners for the microcontroller mounts were removed. If a fully integrated structure is chosen for the final designs, there is still room in this enclosure for the microcontroller, but the mounting of it will have to be changed.

Note: The bores for the #4 3/8” screws the thread into were too large, and were reduced. Other holes for the screws to pass through were too small and were enlarged.

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- Top enclosure
    - Joystick mounting hole diameter = 2.4mm
    - Screw hole diameter to connect to bottom enclosure = 2mm
- Bottom enclosure
    - Optional mount hole diameter = 3.5mm
    - Screw hole diameter to connect to top enclosure = 3.2mm

Opportunities for Improvement

- Meaningful topper dimensions
    - The current topper dimensions were taken from old studies on average hand sizes for various ages. These materials are not representative of our goals, and therefore should be revisited to be modifiable to more custom scenarios. This next iteration on toppers should be guided by user input.
- Topper types (t-bar, custom with instamorph, integrated buttons, switch mounts etc.)
    - Similar to above, some of the topper types were created due to request for that shape of topper, but further user feedback would help to guide the development of toppers with switches/buttons as well as other shapes.
- Mounting options
    - The joystick is currently limited to tabletop, velcro, and ¼”-20 mounting solutions. Identifying and designing further mounting solutions for users would be beneficial. (RAM, modular tray, etc.)
- Design wrist support components
    - There has been feedback that the Oak Compact Joystick is a bit too tall to be comfortable for extended periods of use as the user has to support their arm. The next iteration should include some solution to allow the user to use their joystick for extended periods without risk of fatigue from holding their arm up to use the joystick.

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