Keyholder

Shaper Design Challenge

By Yuki Oyama

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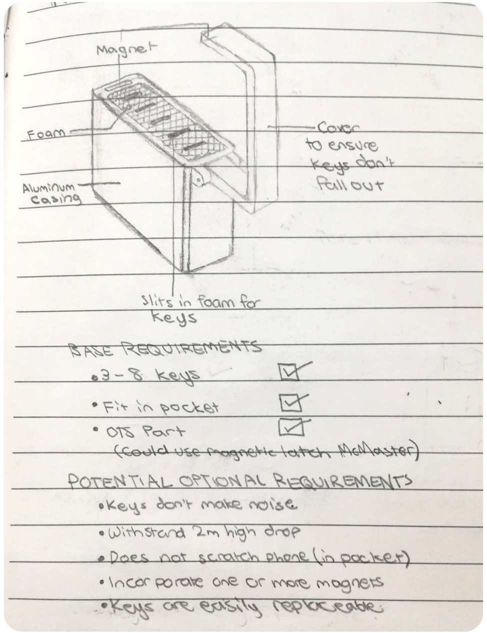
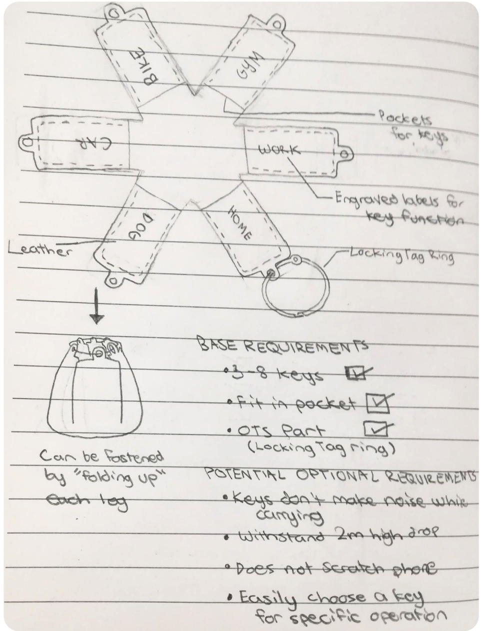
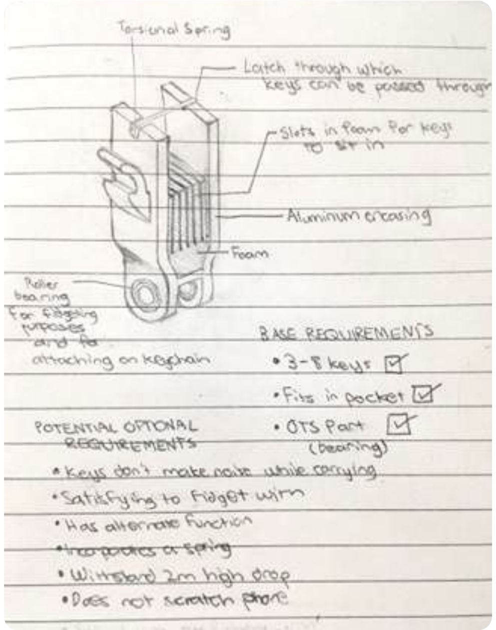
Preliminary Sketches & Ideas







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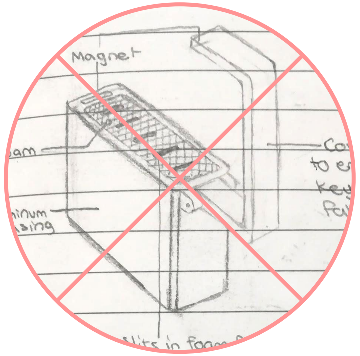
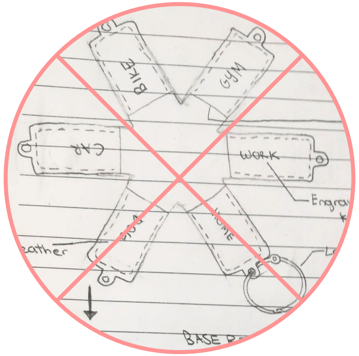
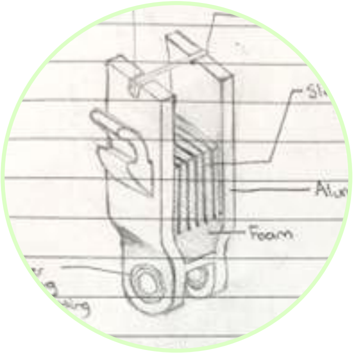
Pro-Con Analysis of Preliminary Designs



Pros	Cons
Keys can be easily replaced and taken out without having to take out the rest Simple, manufacturable design	Cover may come off on a drop, keys may fall out Cover may detach inside pocket



Pros	Cons
Leather product, potentially appealing to customers from an aesthetic standpoint Makes it easy to determine the function of each key Keys will not fall out in a drop	Must remove all keys along with ring in order to remove one Ring is detachable from the main leather piece, and could get lost



Pros	Cons
Satisfies the most optional requirements out of three designs Keys do not have to be removed from the keyholder to be used (i.e. a key can be rotated out of the foam for use while it is still fastened by the torsional spring piece) Keys unlikely to fall out in a drop	In order to remove a key from the keyholder, must remove all keys to the right (in the view above) of said key

Opted for this solution since it had the most unique pros and fewest unique cons

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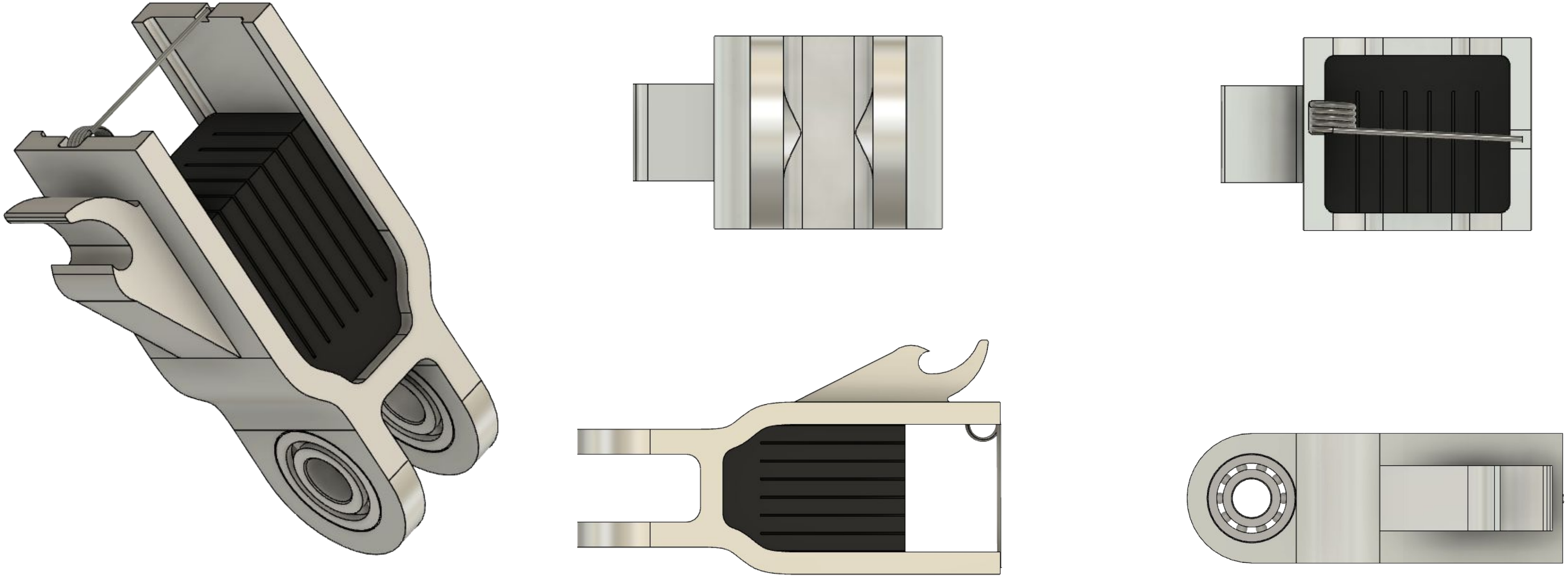
Version 1

Based off of hand-drawing



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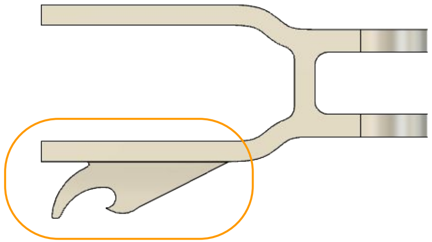
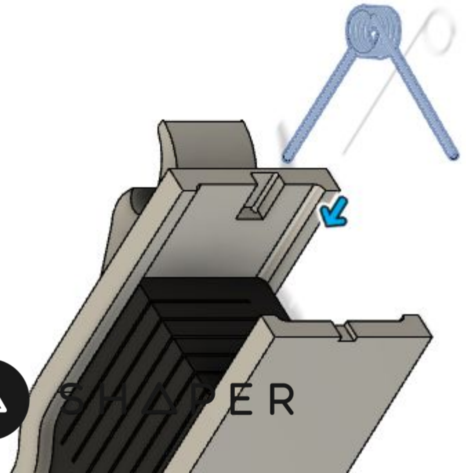
Problems with Design



Poorly Designed Frame

Initially design of “H” shape was for aesthetic reasons, but there are several functional demerits of this design.

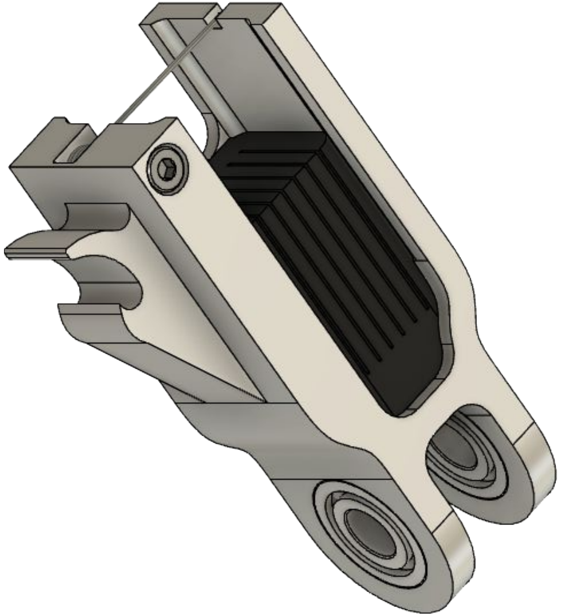
1. The frame may bend when used as a bottle opener since the “leg” (orange) is so long and thin.
2. During the machining process, since the legs are so long, the frame is subject to vibrating which would lead to greater errors during the machining process.

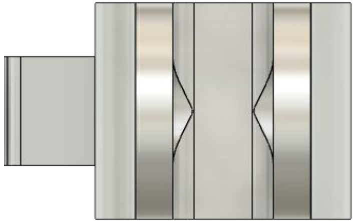


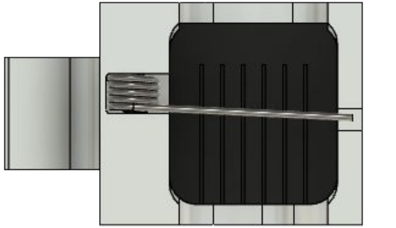
Badly constrained torsional spring

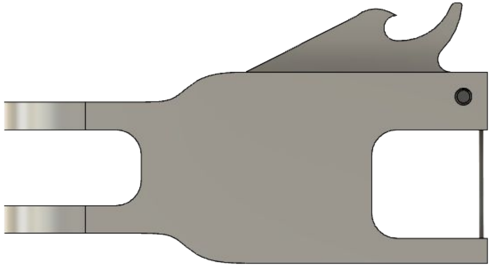
While the torsional spring is constrained fully, it is only held in place vertically (in the direction of the hole) by adhesives. Adhesives are stronger in shear (which is appropriate for this application), but the design could be improved by passing an axle through the inner diameter of the torsional spring, mechanically constraining it.

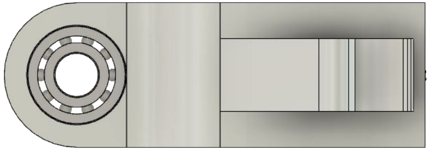
Version 2



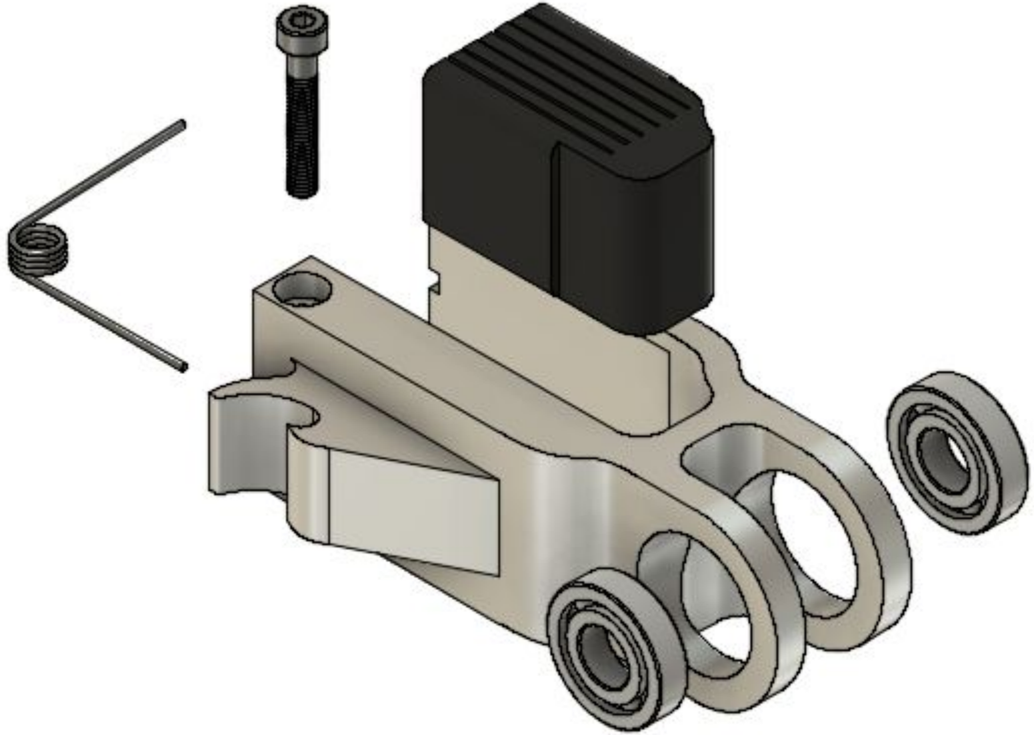








Version 2 Exploded View



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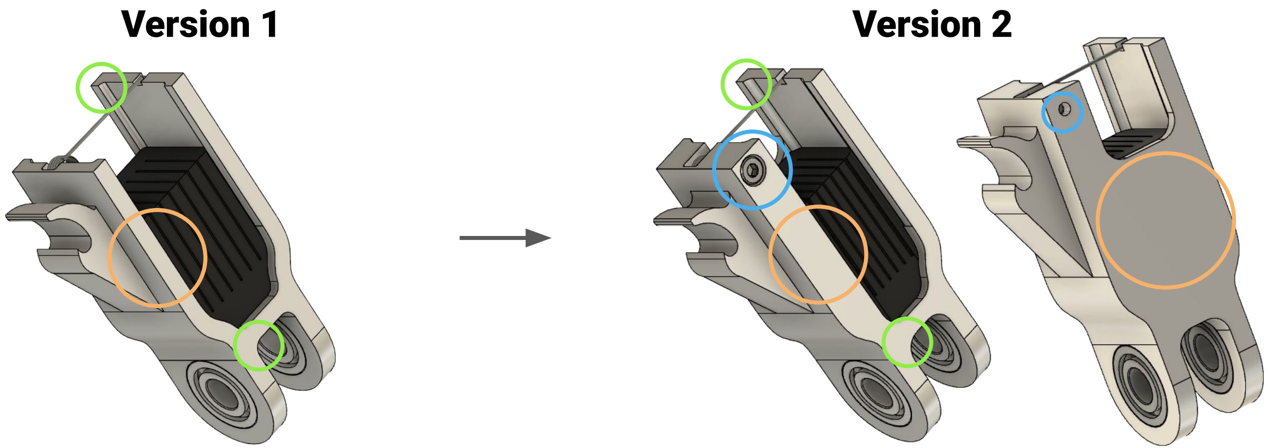
Version 2 Improvements



1. **Larger inner-edge fillets** to reduce machining costs & error and stress concentrations (green)
2. **Constrained torsional spring** using a screw and tapped hole & counterbore (blue)
3. **Increased structural integrity** due to thicker side section & added back support plate to resist bending when using bottle opener (orange)

Base Requirements Satisfied

1. Fits in pocket

   Yes, assembly is roughly 10cm x 5.5cm x 3.2cm

2. Holds 3-8 keys

   Yes, holds 6 keys (in the 6 slots)

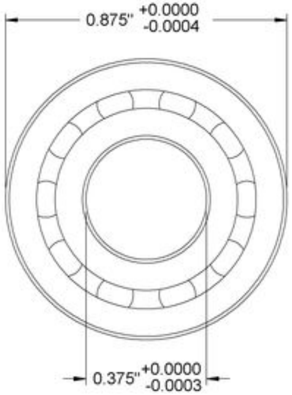
3. Must use an OTS part

   Yes, uses a McMaster torsional spring, bearing, and screw

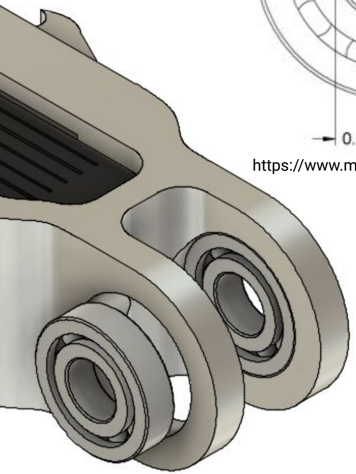
Optional Requirements Satisfied

1. Keys don’t make noise while carrying
2. Has an alternate function: bottle opener
   a. (Another cool function would be using the bottom fidget spinning bearings as guides for a pencil sharpener sandwiched between the two bearings)
3. Incorporates a spring
4. Withstand a 2m high drop
5. Does not scratch your phone (in your pocket)
6. Satisfying to fidget with

Detailed Design | Bearings



https://www.mcmaster.com/60355k504



****Satisfies "Satisfying to fidget with" requirement**

Bearing Choice

Chose to use a ball bearing

Rationale: load applied to bearing acts primarily in the radial direction when letting the keyholder hang from a keychain or rope (would have used a roller bearing if it was necessary to support axial load).

Ball bearing also provides lower friction than a roller bearing, useful for fidgeting purposes.

Pressure-fitting bearings

As a general rule of thumb, in order to pressure fit bearing into hole, the hole should be .0005in smaller than the outer diameter of the bearing.
Using the tolerances on McMaster-Carr, calculated the average expected outer diameter and subtracted 0.0005in from this diameter to calculate desired hole diameter for the bearing.

.875in + (0.0000-0.0004)in/2 - 0.0005in=0.8743in=**22.20722mm**

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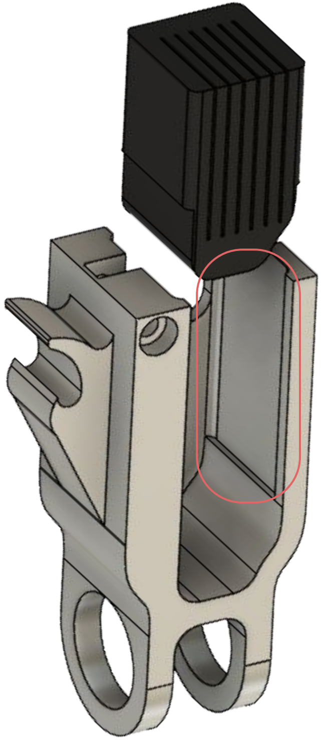
Detailed Design | Foam



****Satisfies "Keys don't scratch phone", "Keys don't make noise while carrying", "Does not scratch phone" requirements**

Foam Piece (black)

Used foam as bedding with slots for keys to sit in

Rationale: Foam will deform to different key sizes

Foam will be glued to aluminum frame

Rationale: Rotating keys out of the slots will shear against the foam which will shear against the metal. Adhesives strong in shear.

Indent

Designed an indent (red)

Rationale: Dangerous to have glue provide sole constraining force on foam. Indent helps mechanically constrain foam.

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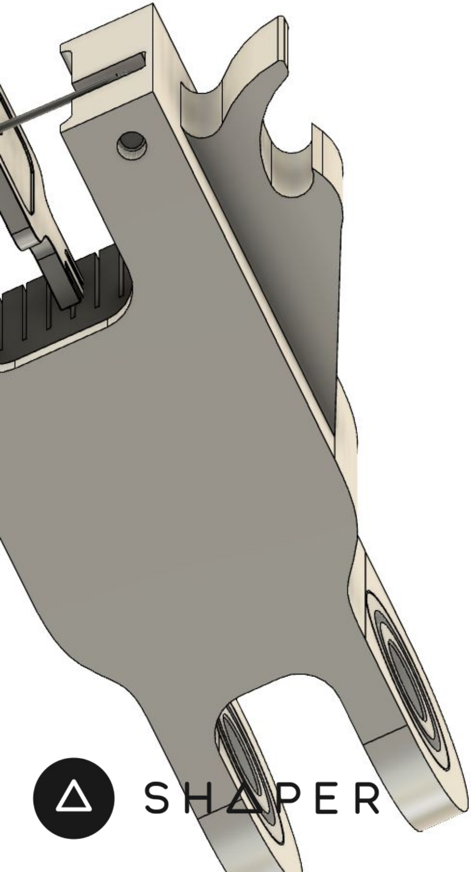
Detailed Design | Bottle Opener



****Satisfies "Has an alternative function" requirement**

Profile

Used design for an existing bottle opener found online, and simply converted entities in CAD to achieve shape shown.

Placement

On same side as torsional spring mount

> *Rationale: In V2 of design, thickened the aluminum bar on the torsional spring side because it was necessary to thread a screw through that constrained the spring.*
>
> *Beam bending theory states that a thicker bar will deflect less. Thus, placing opener on the thicker side made sense, since in theory the opener would induce less deflection when used to open a bottle.*

Near top of frame

> *Rationale: Placing the opener near the end of the fixture gives the user a larger moment arm to operate with, providing more mechanical advantage.*

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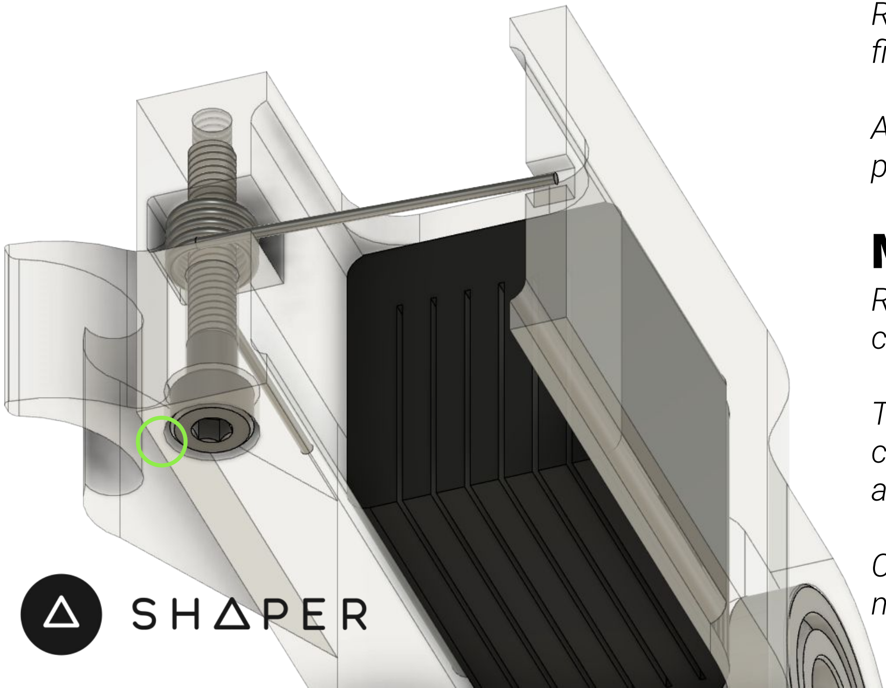
Detailed Design | Key locker



****Satisfies "Incorporates a spring" requirement**

Torsional Spring

Rationale: Torsional spring has a small diameter so it should be able to fit through holes on many variations/shapes of keys.

Also allows for easily taking keys in and out of the holder by simply pulling it upwards.

M4 Screw

Rationale: Chose to use an M4 screw because it has a thread diameter close to the inner radius of the torsional spring.

The head diameter of the M4 screw also is just small enough that the counterbore creates a wall thickness of 1mm (green). When machining aluminum, wall thicknesses >0.8mm are recommended.

Clearance hole on one side, tapped hole on other (only tapped where necessary to reduce cost)

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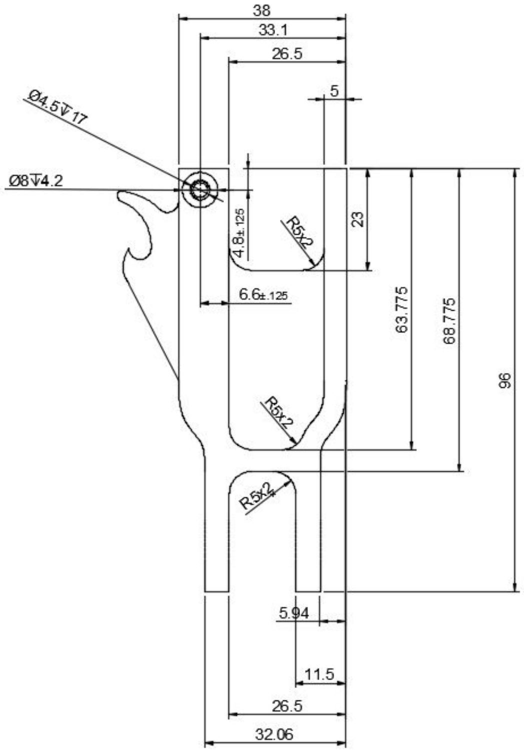
Detailed Design | Aluminum Frame



Design for 2-Axis CNC Milling

Rounded inner edges to reduce stress concentrations and allow for CNC milling

Designed **hole diameters as increments of 0.1mm** (for standard drill bits)

Necessary endmill diameters (for fillets): 1.1mm, 4mm, 10mm

Necessary drill diameters (for bores & holes): 1.1mm, 8mm, 4.5mm

Limit thread depth to 3x hole diameter for lower cost

No 3D surfaces (surfaces where x, y, and z are changing at the same time)

All **wall thicknesses** are greater than 0.8mm (recommended for aluminum)

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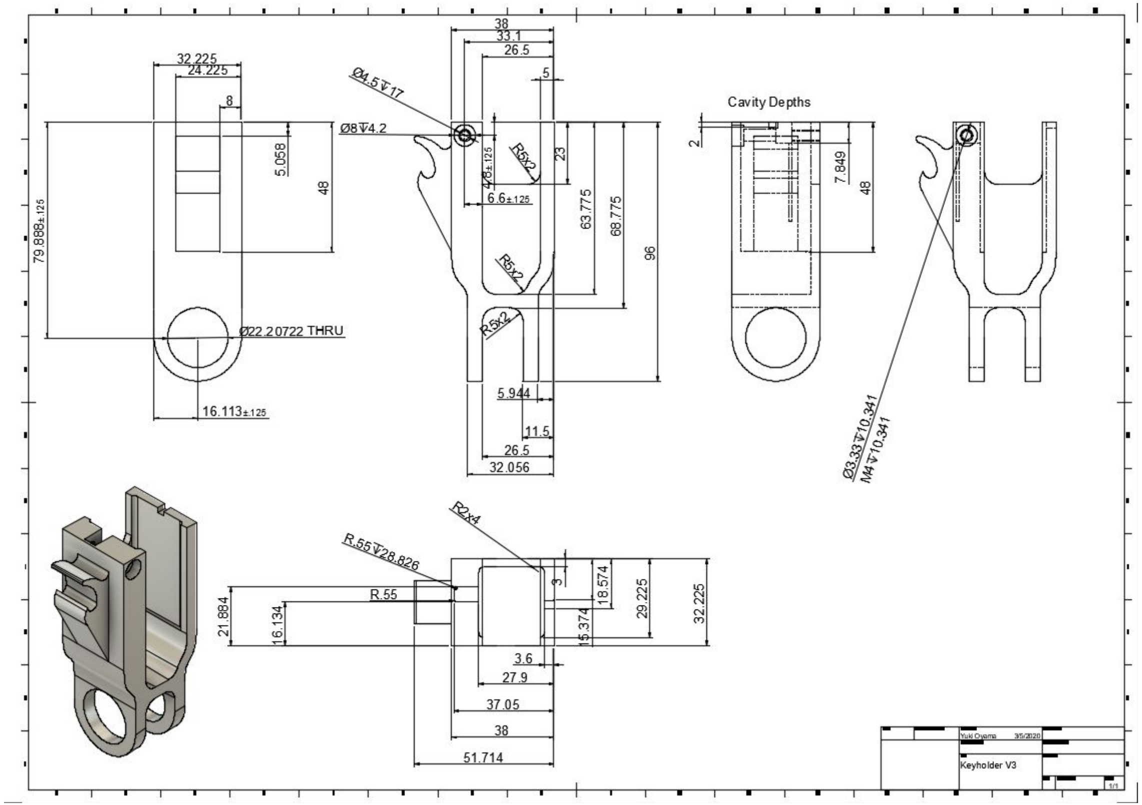
Frame Drawing



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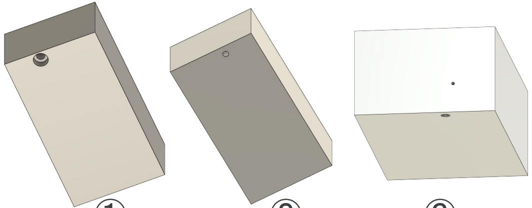
Manufacturing Plan



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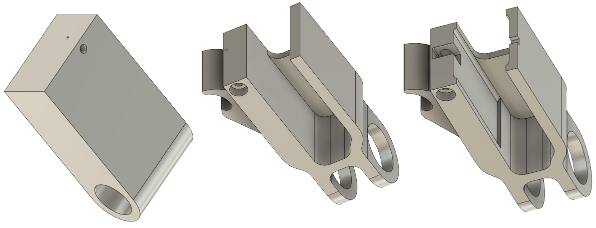

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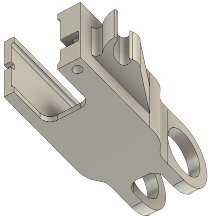

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Fabricate Pre-machine | Manual Mill | 3 setups

① Face off two sides of a block to create the zero corner. Then mill a clearance hole & counterbore on one side.
② Tap hole on the other for the torsional spring mounting screw.
③ Mill a 1.1mm hole for torsional spring.

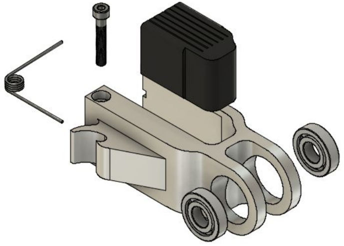
Fabricate the rest | CNC | 3 setups

① Cut bearing hole (we CNC this because tight tolerances necessary and hole is not a standard drill size) and fillet edges.
② Cut out general shape. Shave top side of bottle opener.
③ Cut out indent & torsional spring cavities.
④ Shave bottom side of bottle opener.

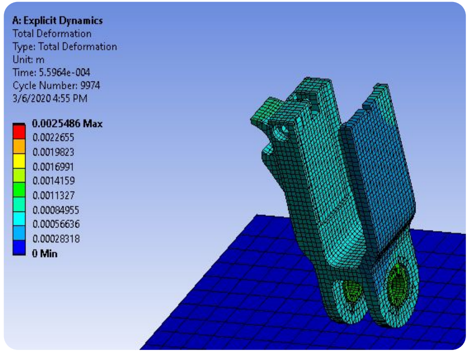
****Chamfer/file edges to satisfy "Does not scratch phone" requirement**

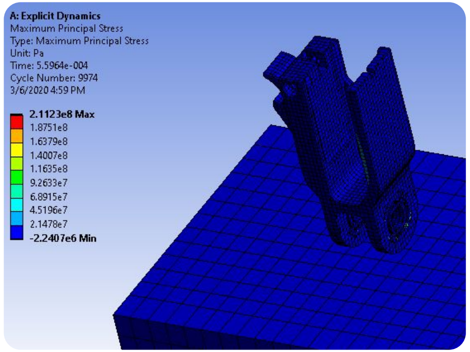
Assembly

Pressure fit bearings, glue in the torsional spring and constrain it with screw. Glue in foam (which will also be CNC'd).



Drop Test





**Satisfies "Withstand a 2m high drop" requirement

ANSYS Explicit Dynamics

Structural steel block to model ground, fixed support on four sides

Initial impact velocity of 6.246m/s

Kinematic Calculation:

$$\sqrt{2gh} = \sqrt{2 * 9.81m/s^2 * (2m)} = 6.246m/s$$

Results

Maximum Principal Stress: 211.23MPa

Less than the Aluminum 6061 yield strength of 240 MPa

Maximum total Deformation: 2.5486 mm

2.55mm is significant deflection, but it occurs in the bearing. According to McMaster, bearing can sustain up to 750 lbf which is well over the impact from a 2m drop. Bearing was also modeled in simulation as aluminum and not steel. Thus it is safe to assume there won't be significant deflection in the actual assembly.

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Renders

Note how key can be rotated out 180 degrees from slots to be used without removing from keyholder

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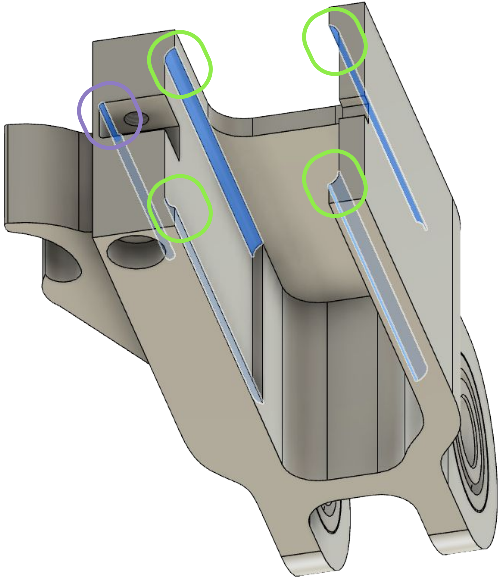
Areas of Improvement



Deep Hole, Small Diameter

While it is feasible to mill up to 40x the drill hole diameter, it is recommended only to drill up to 10x due to vibrations. For the torsional spring, my design requires a ~28mm deep 1.1mm hole to be drilled (purple). The diameter to depth ratio here is 25.5, which is close to the maximum feasible ratio of 40 and well over the recommended 10.

Deep Cavities, Small Diameters

Same issues as the holes, the indent I designed (green) to sit the foam in must be filleted with a 4 mm diameter endmill. The cavity depth is 48mm. Generally the corner radius should be at least ⅓ of the cavity depth. 4 mm endmill is a thin tool that will be subject to vibrations at 48mm depth.

Requires many setups

3 setups are required to fabricate the pre-machine block, and then 4 steps are required for 2-axis machining (see *Manufacturing Plan*). Could definitely be reduced.

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