Trem-Lock

Final Report
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Executive Summary

Tremolo systems are a part of an electric guitar that allow the guitarist to vary the pitch of their sound while playing. These devices consist of a bar that can be pushed and a tremolo block that rotates. A proposal for a device that locks the tremolo system in place has been suggested and was developed by Generate. The main reasons one would wish to lock their tremolo would be to prevent accidental pitch changes and to simplify the complicated tuning process that comes along with tremolo systems. To begin, the team researched the inner workings of tremolo systems, surveyed guitarists about their preferences and habits, tested existing products, and devised three solutions that could solve our problem statement. The three designs are an Upgraded Tremol-no device, a Cover with Sliding Lock, and a Cover with Rotating Lock. The Upgraded Tremol-no was heavily inspired by the form factor of the Tremol-no, but focused on improving problem areas such as the finicky locking mechanism and complicated installation process. The latter two designs utilized an entirely new form factor by creating the entire device inside the cover of the tremolo cavity. The main difference between the two is the motion that the locking feature travels in order to engage with the tremolo block. The three designs underwent prototyping and have been reimagined for aesthetic and manufacturing purposes. The three designs were rated against each other in order to identify the most promising option. In short, the team proposes that the Cover with Sliding Lock is the best option if locking in two directions is a requirement. Otherwise, the Cover with Rotating Lock is the best option as it is simpler and therefore cheaper to manufacture and use.

Background Research

How the Tremolo Works

To begin the project, the inner workings of guitar needed to be studied to determine how the new device should work.

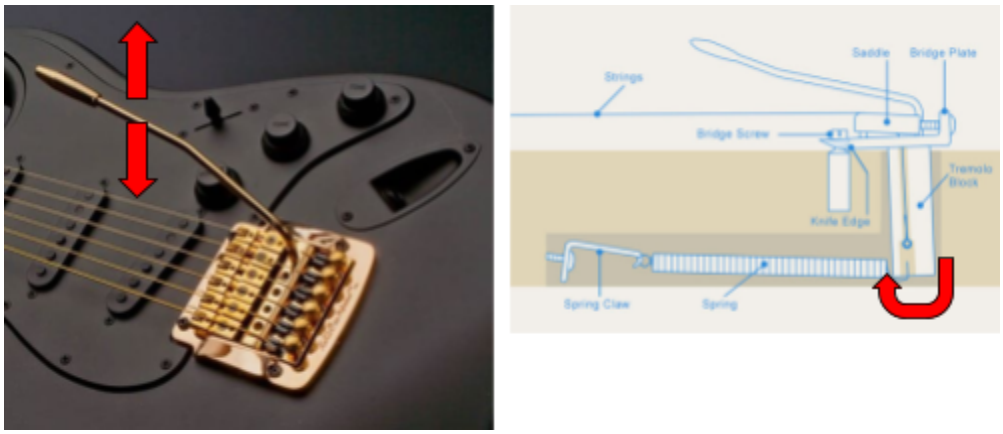
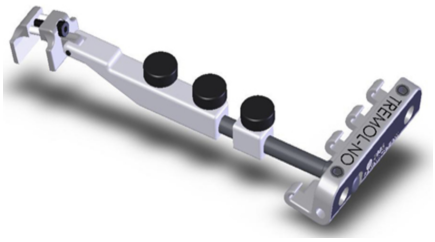


Figure 1: Tremolo Cavity

Figure 1 shows the front side of the guitar on the left side and a diagram of the tremolo cavity on the right side. When the tremolo is pushed down the tremolo block moves side to side to raise and lower the pitch of the guitar. When the tremolo is released, the tremolo block returns to its original place. The tremolo is also connected to the strings of the guitar, which means the pressing on the tremolo can cause the guitar to go out of tune.

Existing Solutions

There were a few existing solutions that locked the tremolo in place. The first one was the Tremol-no, which locks onto the tremolo block in a clamp fashion and replaces the existing guitar claw with its own.



The main drawbacks of this solution is the cost, the difficulty of installation, and the finickiness of the design. Since the design uses small pins to adjust the size, it is easy to lose the small pieces and hard to handle. Other existing solutions included a wooden block placed between the tremolo and the side of the guitar to stop movement all together. Drawbacks of this design include the chance that the block could fall out while playing and is subject to change due to climate.

User Survey/Interviewing

To determine why a tremolo locking system was needed and what most guitarists use their tremolo for, a survey was sent out to the Northeastern community. From the survey it was found that musicians have a variety of habits relating to their tremolo. Some would want the tremolo to lock and unlock while playing and

others are content with having their system locked permanently. People were also indifferent on how much the device should stick out. However, there were some commonalities in the preferences of how the system would work. Most people did not want their locking system to cause permanent changes or damage to the guitar, be too expensive, or stick out too much from the exterior of the guitar. Select results from our user testing are shown in Appendix B. An interview was also conducted with the head of the Rock Ensemble at Northeastern University, Junauro Landgrebe. Landgrebe has experience working with the Tremol-no. He hired someone to install it into his guitar because it is a complex process. He was able to give us insight on the purpose of a tremolo. It can be used to add “dramatic effects" to different songs and also gives a guitar a unique sound, even when it is not in use. Some people even buy guitars with tremolo systems just for this effect, or because their favorite artist plays the same guitar. He agreed with the survey results that the device should not make permanent modifications to the guitar, and also added that the device shouldn’t weigh too much in order to avoid adding extra resonance. The results of our interviews and google form can be seen in the appendix.

Product Requirement Document

After reviewing existing solutions and doing our own research, we filled out our Product Requirement Document to be sure our device fit all necessary requirements. We also assumed that our design would be for common brand guitars, such as Fender and Gibson, and that the device would be purely mechanical. The table below displays our requirements and reasoning behind it.

#	Title	User Story	Importance	Notes
1	Dimensions	*Device does not make user uncomfortable as they are playing*	*Contributes to initial reaction & satisfaction*	*Device should be easy to handle*
2	Device fits into multiple different guitar models	*User can take product and place it into any guitar they own*	*Model of guitar won’t have to be considered if user wants to lock tremolo system*	*Device should be adjustable*
3	Device costs less than $30 to manufacture	*User can buy a cost efficient product*	*Better for long term manufacturing of product and allows product to be cheaper for user*	*Should not feel cheap or brittle*
4	Weight does not affect the feel of the guitar.	*User doesn’t have to worry about the “feel”/ balance of the guitar being altered*	*Product won’t affect quality or familiarity of guitar*	*Should still feel substantial or trustworthy*
5	Ease of installation	*User can easily place product in guitar*	*Does not frustrate the user*	*Clasps must be easy to use*
6	Device takes less than 15 minutes to install	*User can quickly place product in guitar*	*Improves user experience*	*Clasps must be easy to use*

7	Device needs only one screwdriver to install	*User will not have to use multiple tools to install*	*Installation will be simple*	*Screwdriver must be easily accessible (household item) if lost*
8	Device is aesthetically appealing	*User is more likely to buy product if it aesthetically pleasing*	*Will be less noticeable in a performance setting*	*Ideally, will be hidden from view*
9	Device has less than 5 parts	*User will have an easy time using and installing product*	*Ease of use*	*Mechanically simple*
10	Device can be installed and removed repeatedly	*User doesn't have to worry about product decreasing in quality if used multiple times*	*Improves user experience and desire for product*	*Clasps should not leave any damage*

Some things we determined were out of scope were integration electronics and packaging design. There was no need for electronic integration, and we did not want to overcomplicate our design that could add an extra cost. Packaging design was too early in the design process to discuss.

Problem Statement

There exists a need for a device that can be attached to any electric guitar tremolo system that can quickly and easily lock and unlock the trem block to prevent pitch distortion and ease the process of guitar tuning.

Mechanical Design

Overview

To approach the problem statement, the team brainstormed multiple solutions that would lock the tremolo in efficient and universal ways. The first design was directly inspired by the Tremol-no, focusing specifically on the Tremol-no's faults and improving those. The other two designs were born out of a new idea for a tremolo locking device form factor. These two designs built the locking mechanism into the cover of the cavity itself. The main difference between the two is the motion required by the device to lock, where one rotates and one slides.

Design 1: Improved Tremol-no

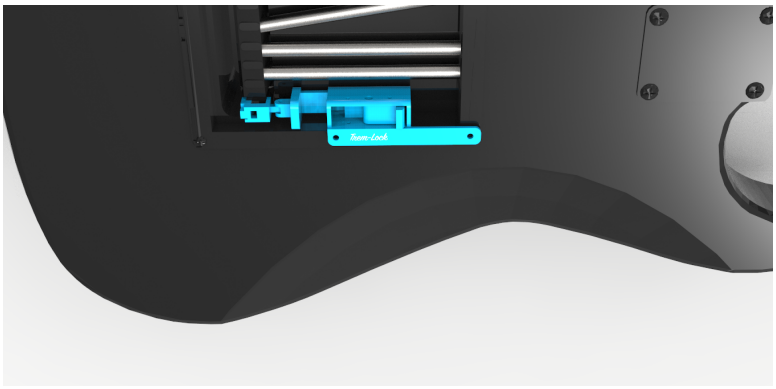


Figure 2: Labeled CAD images of design

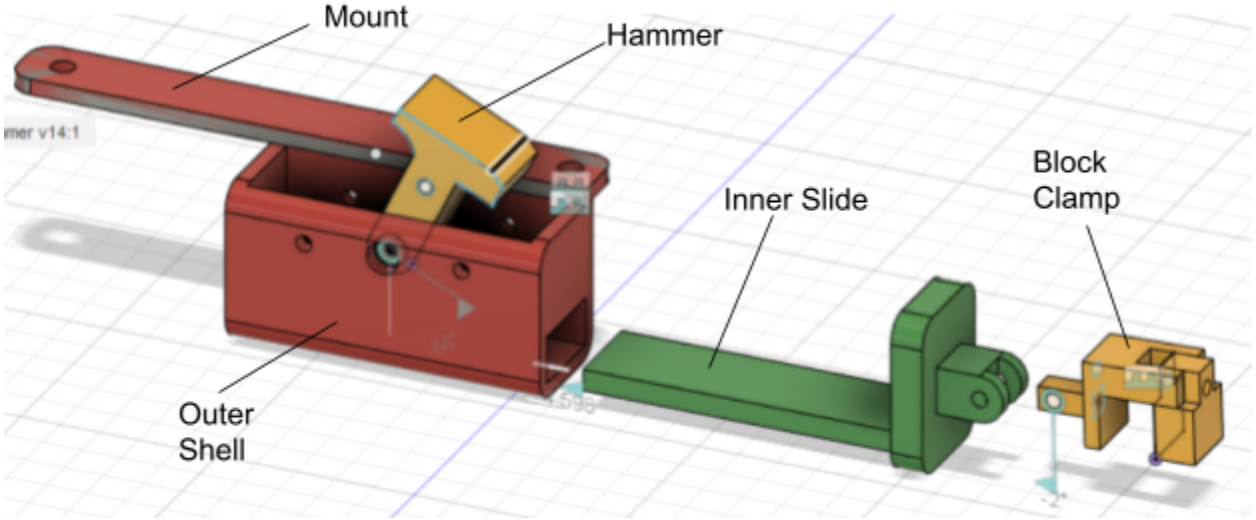


Figure 3. Exploded View and Labeled Parts

Tremol-no Background Research

The Tremol-no, shown under "Existing Solutions" above, is a product on the market that is intended to block any movement of the tremolo block in either direction. The process of installing the device included removing the original tremolo cavity claw hook and installing the claw hook attached to the tremol-no, adjusting the section of the tremol-no that's parallel to the springs to the correct length, and securing the clamp snugly around the tremolo block. Screws along the middle of the tremol-no are what control whether the device is locked or unlocked. Upon purchasing the device for analysis, it was immediately apparent that the installation was tedious and required possibly multiple hours, and the screws and pin used to adjust the clamp and Tremol-no body were difficult to use due to their diminutive size and would easily break.

Attachment to Guitar

The initial mounting mechanism connected the body of the product to the existing screws used to hold the claw hook in place in the cavity. Due to the variability of tremolo cavities, the angle for the mount would differ and be difficult to get an exact fit. The final mount design as shown in Figures 2 and 3 is a "shoulder" attached to the outer shell of the device that utilizes an out screw hole used to hold the cavity cover in place. This method of securing the device is more reliable and secure, and permanent modifications aren't needed since the screw holes were originally created to secure the cavity cover.

Locking Mechanism

The locking mechanism shown in Figure 4 consists of a hammer that rotates within the outer shell with the larger hole as the hinge. The two smaller holes line up with the hole in the hammer so that a pin can slide through both and hold the hammer in place. The hammer can either be held in the "locked" or "unlocked" position. In the locked position, the hammer will exert force onto the inner sliding piece to create friction that disables any sliding movement. There is a ⅛" layer of rubber placed on the top surface of the inner sliding piece to ensure sufficient friction to prevent sliding. In the unlocked position, friction should not be applied to the inner sliding piece so the hammer is held in place by the pin for the sole purpose of keeping the hammer still for the convenience of the client.

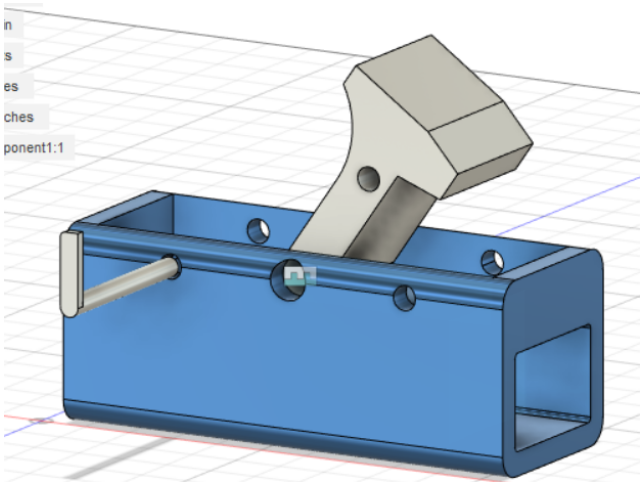


Figure 4. Outer Shell and Hammer Mechanism

Adjustability Features

The goal of this design was to improve upon the Tremol-no and remove any unnecessary features that were not required by the client. The set screws on the tremol-no proved to be ineffective and were replaced with the hammer mechanism in the updated design. The installation of the tremol-no was very difficult because the whole claw hook needed to be replaced. The new design rids of that necessity by using the shoulder mount. The tremolo block clamp is similar to the tremol-no design and allows for any block size to be held in place. The block clamp also swivels to allow for the block to move when in the unlocked position. This is a key feature that allows the device to stay in the guitar at all times without interference.

Design 2: Cover with Sliding Lock

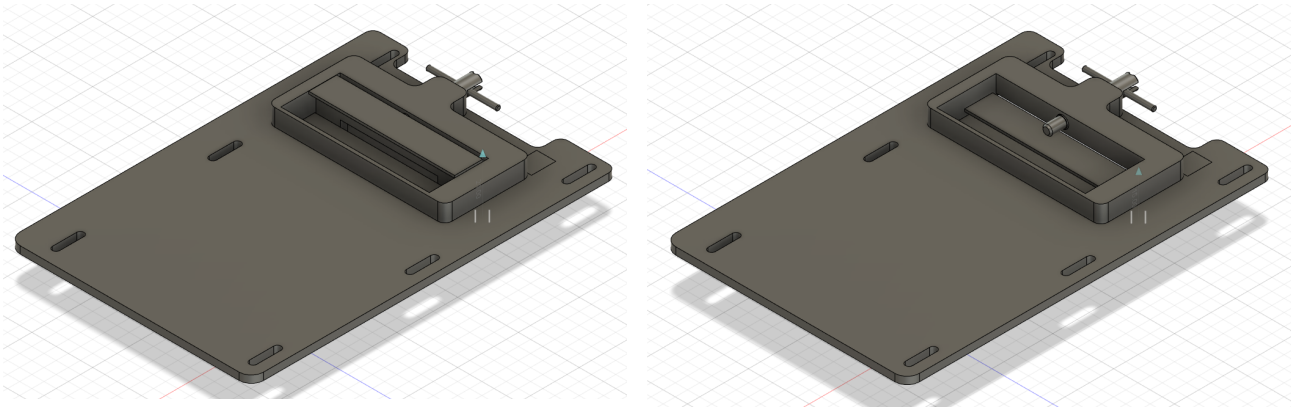


Figure 5: CAD images of design. Left shows unlocked position, right shows locked

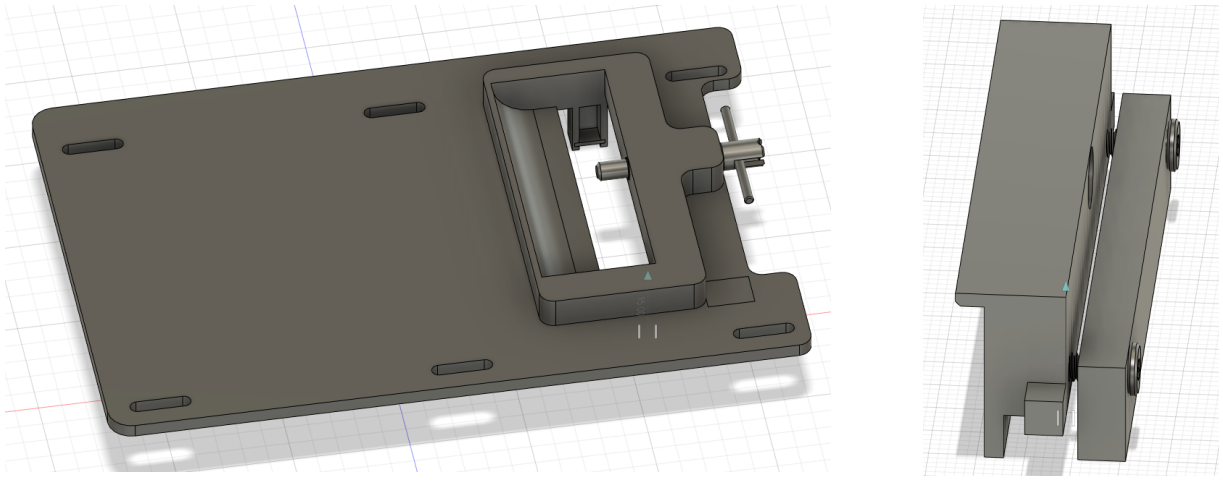


Figure 6: CAD images of design. Left shows cover and retractable pin, right shows sliding lock with two adjustable screws

Attachment to Guitar:
This device replaces the cover that exists on the back of the guitar, using the six existing screw holes as mounting points for the device. The cover utilizes slots rather than clearance holes in order to allow the user to shift the cover and attached Trem-Lock depending on the location of their tremolo block. This makes the installation of the Trem-Lock fairly simple, requiring the user to only adjust the width of the Trem-Lock to fit their tremolo block and then screw the cover and attached Trem-Lock onto the back of their guitar.

Locking Mechanism:
This iteration of the Trem-Lock utilizes a helmet-like cover which slides up and down over the tremolo block, locking the tremolo block on both sides. The locking mechanism fits inside two tracks built into the cover, restricting movement in all directions except vertically. When set to the locked position, the Trem-Lock sits atop the tremolo block, locking the tremolo block in place, and it is restricted from coming loose by a retractable pin overtop the Trem-Lock. When unlocked, the Trem-Lock is flush with the exterior cover, with the retractable pin inserted in the Trem-Lock to prevent movement. In order to lock and unlock the Trem-Lock, the pin is retracted, the lock is slid up to unlock the tremolo block or down to lock the tremolo block, then the pin is released.

Adjustability Features
This iteration of the Trem-Lock features a few adjustable components to allow the Trem-Lock to fit in the majority of electric guitars. As mentioned previously, the cover is fitted with slots rather than clearance holes. Because the tracks of the Trem-Lock need to align with the tremolo block in order to ensure a proper lock, the slots in the cover allow the tracks to be shifted to their ideal position to set up the Trem-Lock in tremolo cavities that may differ in size. Additionally, because tremolo blocks can differ in size and shape, the locking mechanism consists of two separate parts which can expand or compress around the tremolo block's width by tightening or loosening two screws in the locking mechanism. This allows for the utilization of this design in various tremolo systems with differing shapes and sizes, similarly to how the competitor, Tremol-No, has different products for different tremolo blocks.

Future Work/Areas for Improvement:
A prototype to test the sliding locking mechanism was created and tested on the team's guitar. During testing, it was noted that tuning the guitar by tightening and loosening the strings caused the tremolo block to tilt at varying angles. In attempting to lock the tremolo block from both sides, the Trem-Lock must be able to adjust such that the path it follows is always aligned co-linearly with the tremolo block's angle, in order to allow the Trem-Lock to smoothly cover and uncover the tremolo block. Without such a feature implemented, as in the current iteration of the design, the guitar must be tuned to ensure the tremolo block is completely vertical, otherwise, the Trem-Lock is harder to install and utilize. Future iterations of this design will also change the material used in order to ensure strength and prevent the lock from breaking under high force. Additionally, the aesthetics of the design are a work in progress, and will be discussed more thoroughly later in this report.

Design 3: Cover with Rotating Lock

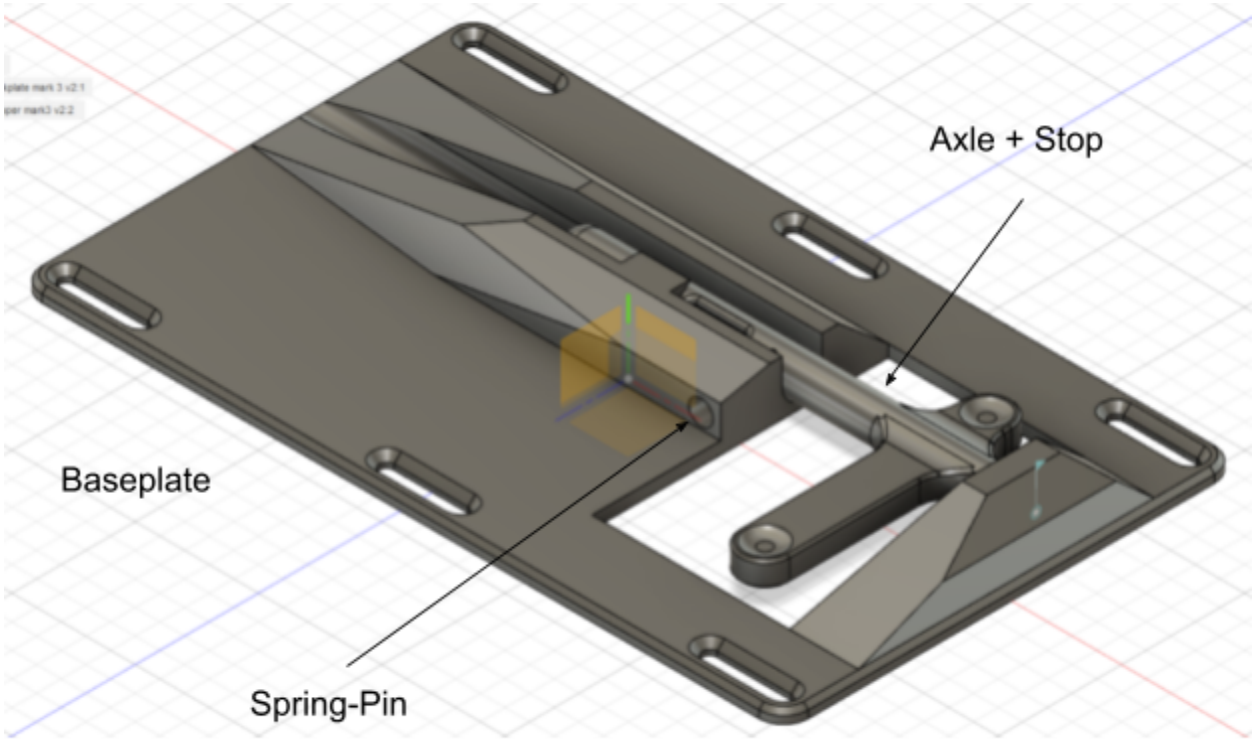


Figure X: Design 3

Design 3 is comprised of two parts: A baseplate and an axle with a stop attached

The device is attached to the guitar using the same six screws that the cover would be held on with. The holes on the baseplate were turned into slots, so that the user could slide the device to the right position for the lock to be able to engage.

The axle falls into a slot in the baseplate. There is a keyhole in the axle that matches up with a key in the baseplate. The axle then slides over until the end of the axle hits the hole designed for it. It is kept in place by a spring pin, and the key blocks the axle from coming out.

The mechanism is activated and deactivated by the user pushing on one of two touchpoints. Pushing on the touchpoint on the long side pushes the beam into the tremolo cavity and blocks the tremolo block from moving. Pushing on the other touchpoint reverts the device into its original form.

This design focuses on simplicity in the design. Only one moving part, one spring-pin, and using existing hardware. The device only moves in one axis, which makes controlling the product rather simple. This makes installation and usage easier than the tremel-no. However, this device only locks the tremolo block in one direction and does jut out from the guitar slightly. In the end, we believe that this design is an overall improvement and would satisfy the problem statement.

Aesthetic Design

Overview

The exterior designs of the devices were considered as an element that would better their functionality instead of being a last minute afterthought. Emphasis on user touchpoints, intuitive shapes, and simplicity are themes found in the team's three designs. Designs 2 and 3 were created with low poly, geometric inspiration.

Design 1: Improved Tremol-no

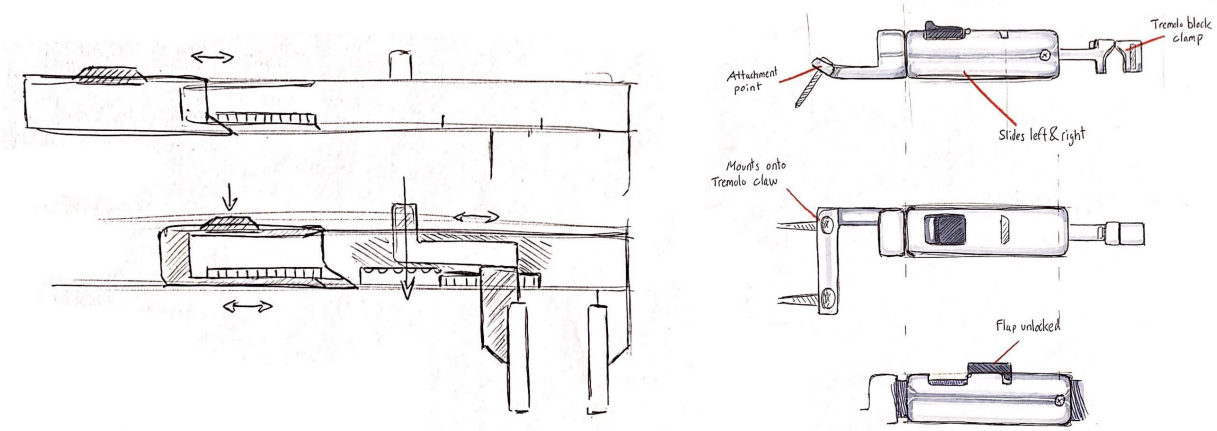


Figure X: From left to right, a major early jump in the device design

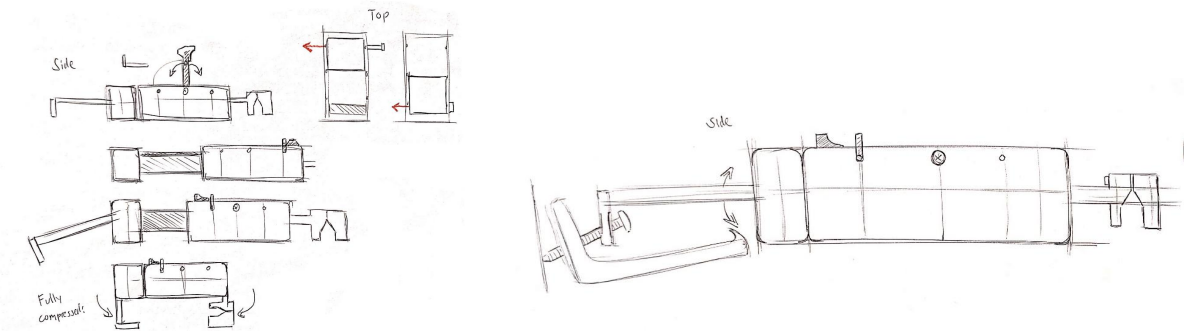


Figure X: Departing from the "flap" locking design to a rotating hammer lock

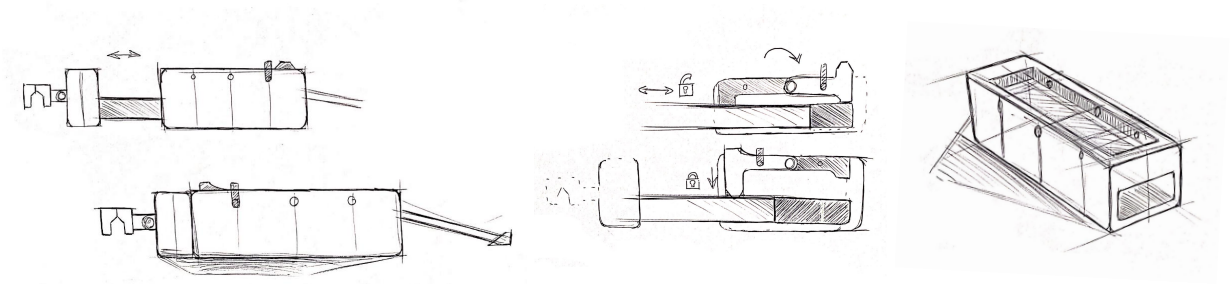


Figure X: Final sketches, with the clamp piece relocated from the outer shell to the inner slide

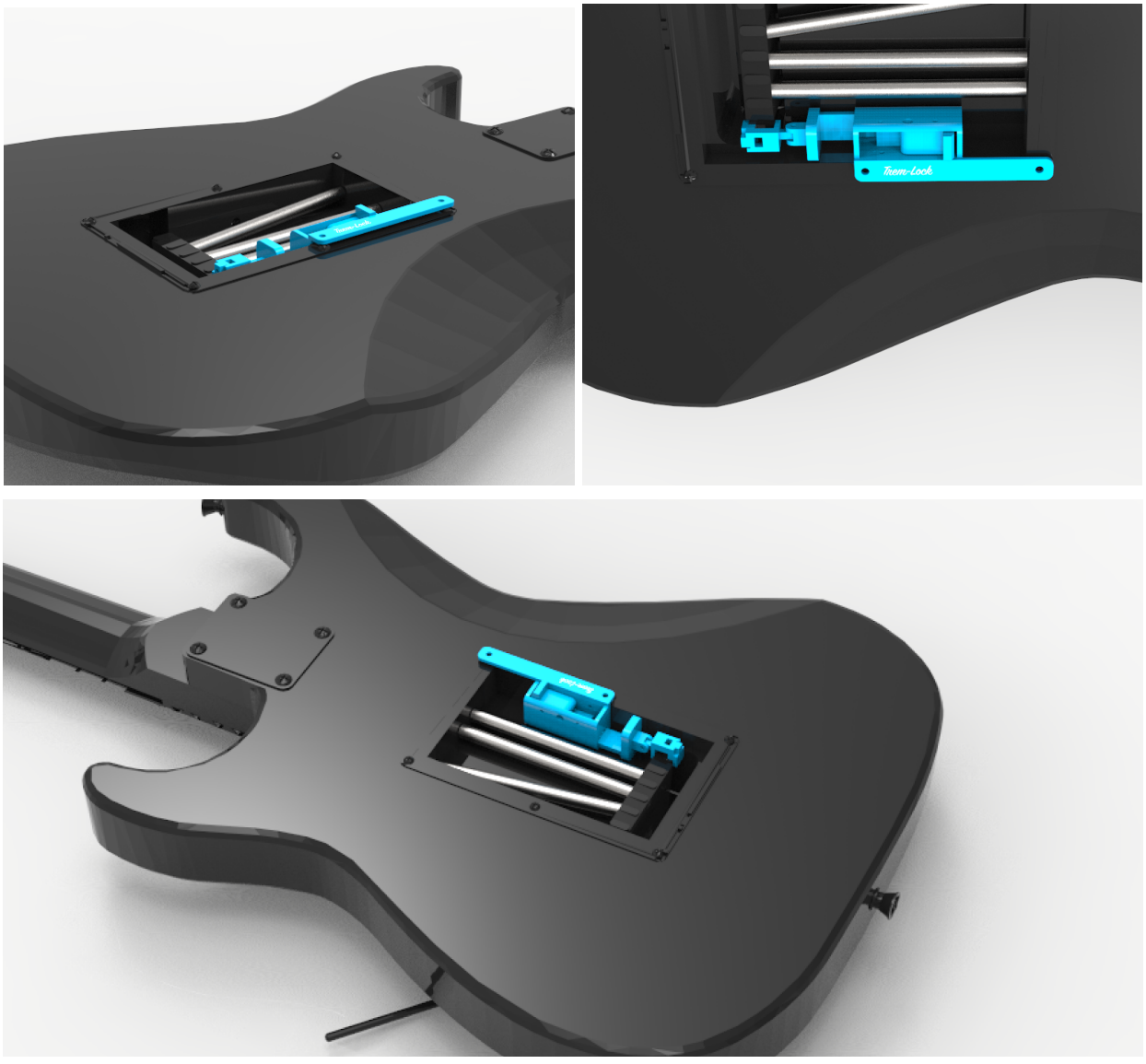


Figure X: Final renderings with the “shoulder” mounting design

Design 1's exterior shape, much like its functional features, was driven by the idea of improving upon Tremol-no. Its rectangular forms are easy to interact with and its locking mechanism makes for a satisfying, confident operation. This was an important feeling to create, as Tremol-no's locking design can be inconsistent for some users.

Design 2: Cover with Sliding Lock

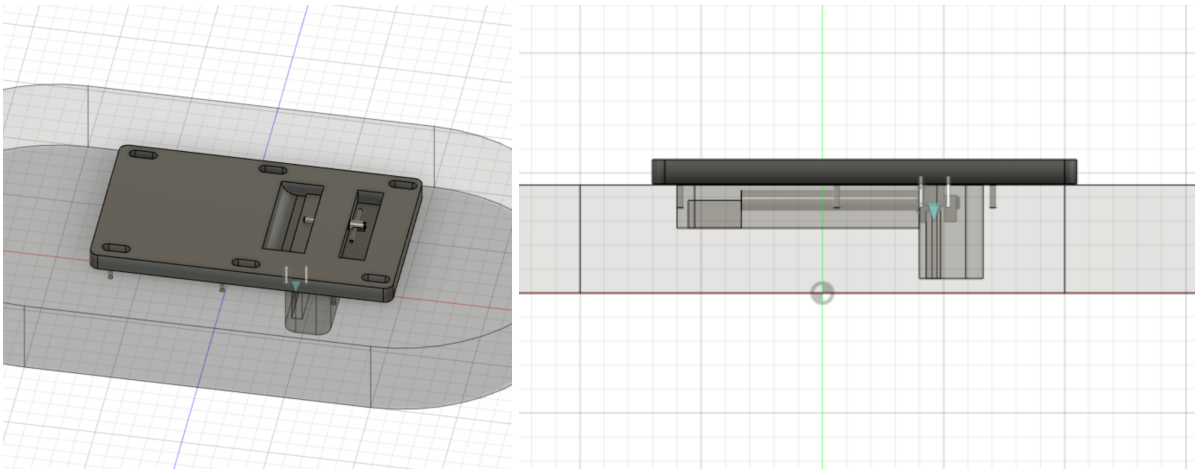


Figure X: Original CAD models

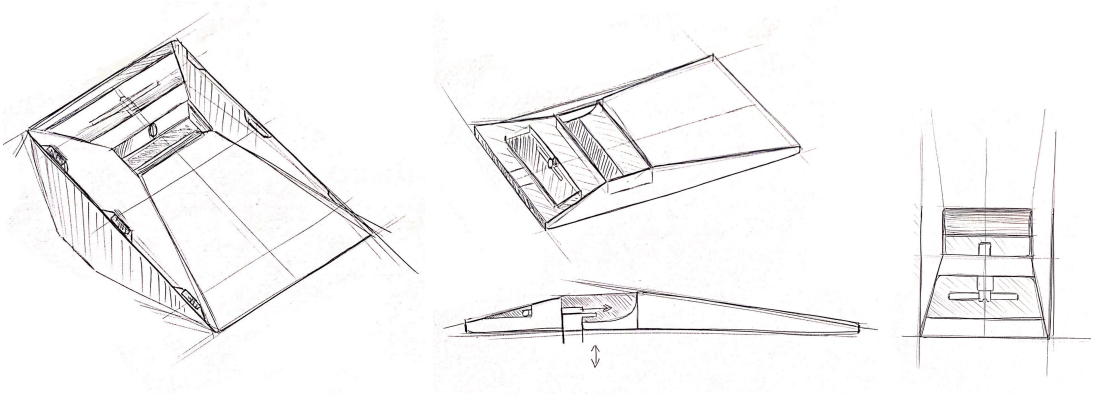
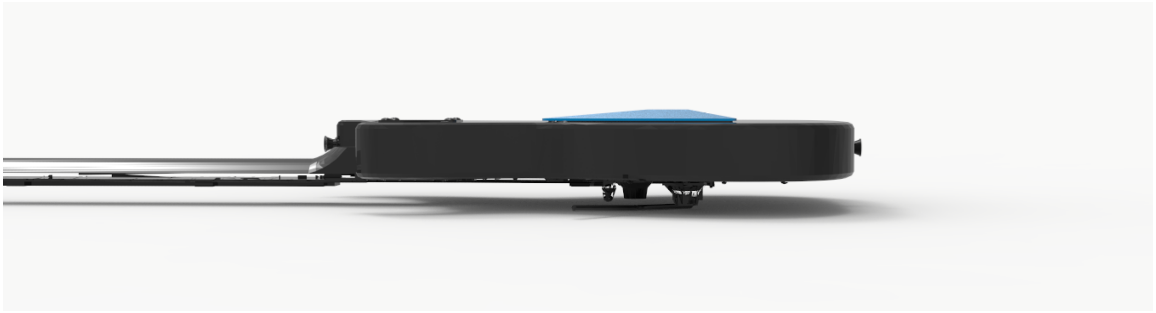


Figure X: Final design sketches



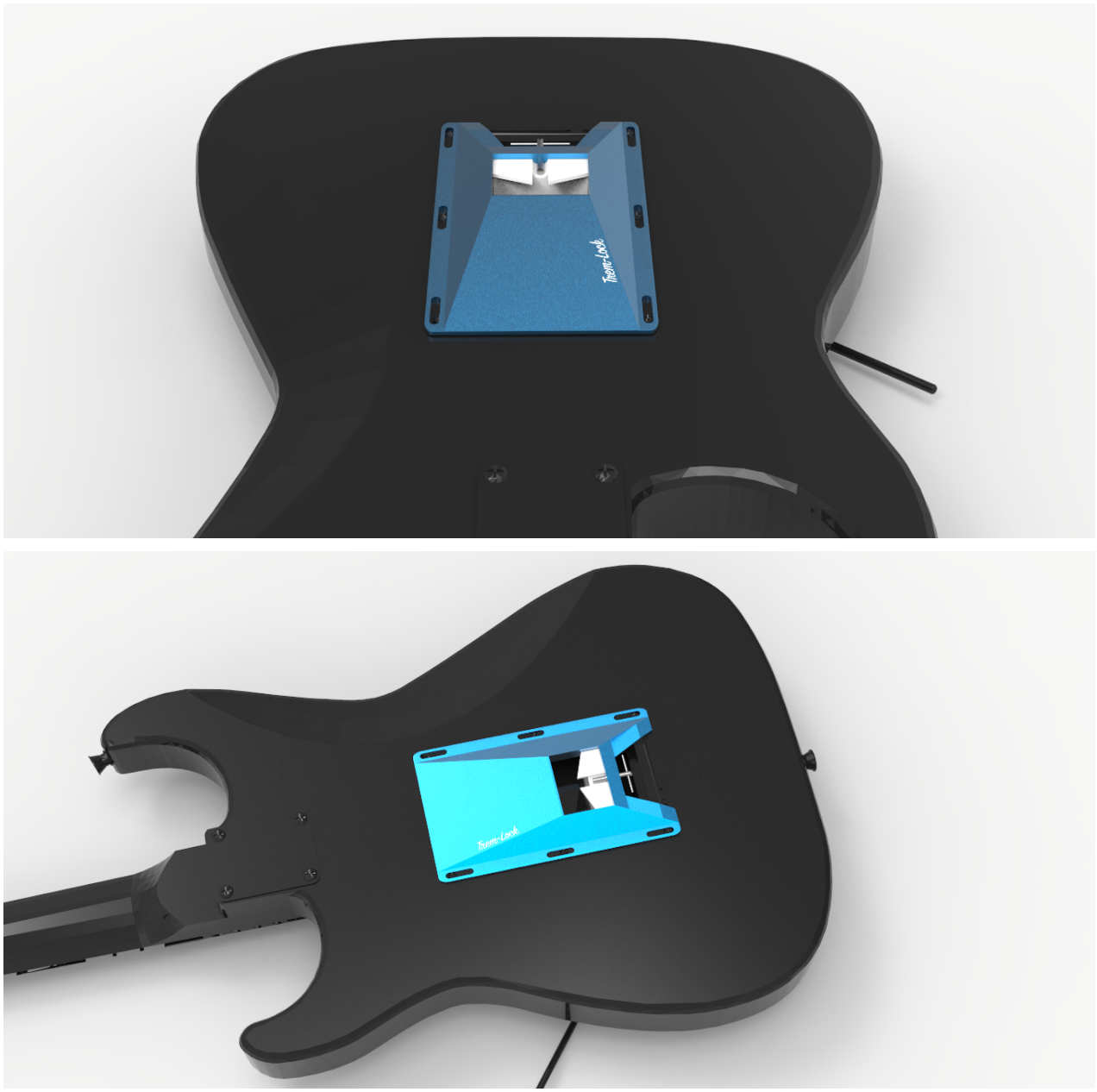


Figure X: Final renderings of the geometric design

Design 2's sleek exterior shape is meant to conform to the guitar's rear surface as much as possible, minimizing any protrusion that its mechanism causes. This idea behind implementing as many flat features as possible shields the guitarist from any accidental interactions with potentially pointy, obtrusive elements.

Design 3: Cover with Rotating Lock

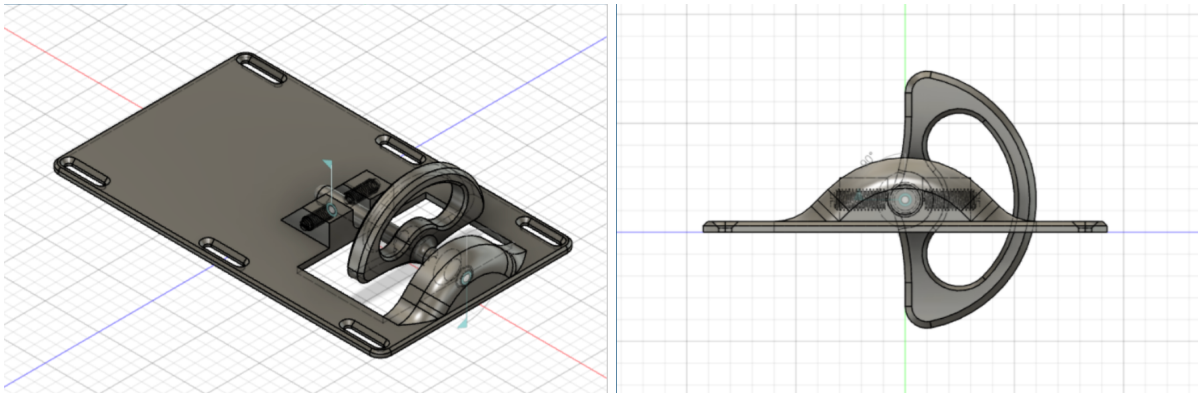


Figure X: Original CAD model with a semi-circular locking beam

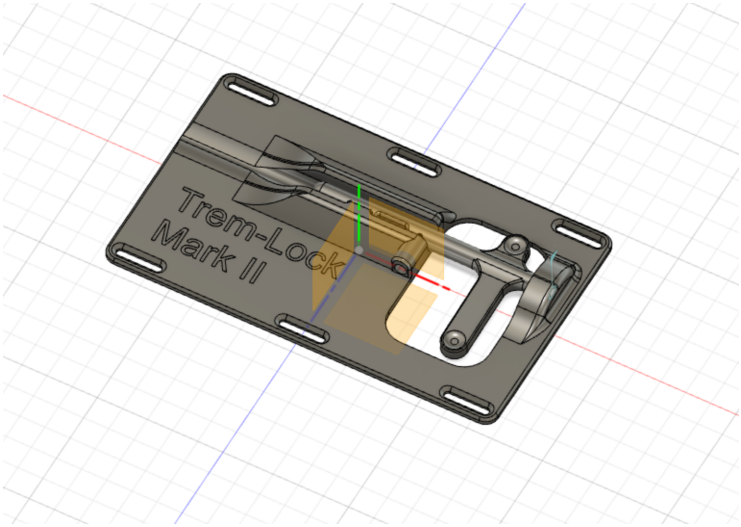


Figure X: "Mark II" CAD model with a space-saving locking beam and mechanism

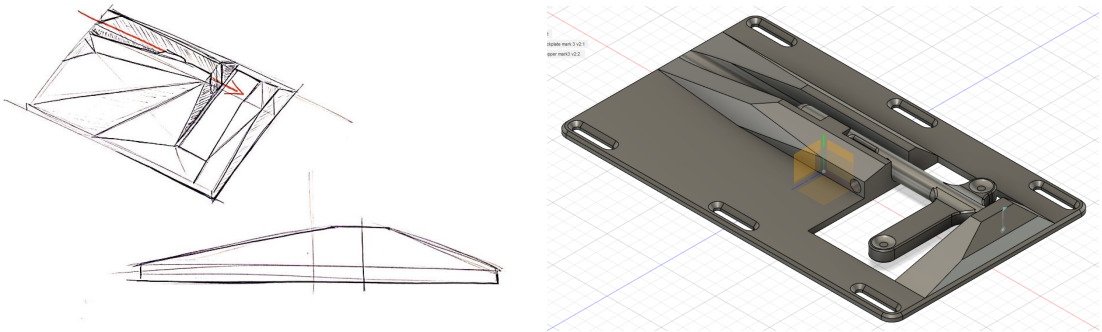


Figure X: Geometric design concept sketch and the final model

Figure X: Final renderings with the tremolo block visible below

The jump from the original CAD model to the “Mark II" version of Design 3 opened up new possibilities for its aesthetic design and for its perception as an undoubtedly simple, minimally obtrusive design. The steps taken between Mark II and the final iteration show a device whose aesthetic forms were designed with intention. Design 3 looks like a unique, stylish device that follows the theme of simplicity through its shape and its function.

Next Steps

Proposed Solution

Although all three solutions show promise in satisfying the problem statement, each device has its pros and cons. The first design is similar to the Tremol-no and improves the already proven technology, but it does not lower the cost or complexity of manufacturing. The second design that uses a sliding lock is simpler than the first design, but still has more parts and complexity than the third. The last design with the rotating lock is the simplest solution to lock the tremolo and would be the cheapest and simplest to manufacture. However, the device can only lock the tremolo system in one direction. A decision matrix has been made to grade each design on various criteria.

	Upgraded Tremol-no	Cover with Sliding Lock	Cover with Rotating Lock
Meets deliverables	5	5	3
Percentage of development complete	3	4	4
Simplicity of final product	2	3	5
Innovativeness (compared to existing products)	3	5	5
Intuitiveness	4	4	5
Ease of installation	3	5	5
Total	20	26	27

The team proposes that the client move forward with one of the two latter designs. If the ability to lock the tremolo in both directions is a higher priority than keeping cost and simplicity down, then the Cover with Sliding Lock is the best option. If low cost and simplicity are the highest priority, the Cover with Rotating Lock design should be chosen.

User Testing

In order to test the three designs, a user testing procedure was created. While we were unable to test the design before the end of the semester, this is the protocol that can be used for future testing. There are two parts to testing: testing installation time and using while playing.

Installation

1. Start Timer
2. Install device into guitar
3. Stop timer
4. Start timer
5. Retune guitar

6. Stop timer
7. Repeat process with 2 other team members

Using while playing

1. Play simple guitar song
2. Unlock tremolo while playing
3. Record ease of locking and unlocking
4. Jump with guitar and record any observations about the tremolo blocking device

For these procedures, the following table could be used:

	Installation Time (sec)	Tuning Time (sec)	Ease of Locking/Unlocking (1-5 scale)	Jump Test (Fell Out/Moved inside cavity/Stayed In)
Design 1	--	--	--	--
Design 2	--	--	--	--
Design 3	--	--	--	--

Design for Manufacturing

In order to bring these concepts to life, each one needs to be evaluated in terms of design for manufacturing. This involves identifying parts that can be replaced by pre-existing off-the-shelf components that will be cheaper than custom ones, identifying parts that will be injection molded and how well the current design lends itself to that manufacturing process, and identifying parts that will be machined and how well the current design lends itself to that manufacturing process. Injection molding is used when custom plastic parts are necessary. However, it has a very high up-front cost and very low production cost, so it is only well suited for products that are created on a larger scale.

The Upgraded Tremol-no currently uses many custom parts. For most of the parts, such as the clamp pieces, the outer shell, and the hammer, injection molding can be utilized to make cheap plastic parts in bulk. One strategy we would suggest exploring for this design is identifying flat parts of the design, such as the flat part of the outer shell that mounts to the guitar, and splitting it from the outer shell. By isolating the flat piece, it can be cut from stock and manufactured very cheaply. Then, the parts can be assembled with screws. This design will most likely be the most expensive to manufacture as it has many custom parts will unique geometries.

The Cover with Sliding Lock design is currently at a point that lends itself well to manufacturing. The locking block pieces can both easily be manufactured by injection molding or machining if stronger parts are required. One issue with injection molding the entire cover piece would be accommodating the hole for the spring pin, as it creates an overhang that cannot be accomplished by a simple two-part mold. One way to alleviate this issue would be to use side action to create a hole and add a heat-set insert to the part. Another option would be to completely remove the feature with the hole from the flat part of the cover and injection mold the part with the hole, cut the cover from stock material, and mount the injection molded part with

screws. All options would need to be quoted before determining the best route. Lastly, the spring pin is an off-the-shelf component that is pricey, but should not be an issue compared to injection molded parts.

The Cover with Rotating Lock is currently the most adaptable for manufacturing. Similar to the previous design, almost all parts could be readily injection molded. As previously mentioned, one option for manufacturing this design would be to remove all features of the cover that are not flat, injection mold those parts, and mount them to a flat piece that is cut from stock material. Quotes for this method and a single injection molded part would need to be made before determining the best route. Lastly, the rotating lock would most likely need to be machined for this product to function correctly. Although it is likely possible to machine, the small indents for the spring pin may be difficult to create. There may be some way to redesign this part to make it more well suited for this manufacturing process, but it is out of the scope of this semester's work.

Appendices

Appendix A: Bill of Materials

Design 1: Updated Tremol-no

Item/Part Number	Description	Material	Source	QTY	Unit Price	Total Price
Top Level Assembly:						
Dowel Pin	For locking mechanism	Steel	McMaster	1		
Outer Shell	Mount+Outer Shell	Lightweight metal	manufacturing	1	TBD	TBD
Inner Slide	Inner Slide+block clamp	Lightweight metal+sheet of rubber	manufacturing	1	TBD	TBD
					Totals:	**$**

Design 2: Cover with Sliding Lock

Item/Part Number	Description	Material	Source	QTY	Unit Price	Total Price
Top Level Assembly:						
Clamping Block	Sliding Part of Locking Mechanism	Lightweight Metal	Manufacturing	1	TBD	TBD
Baseplate	Visible Back Cover of Guitar	Plastic	Manufacturing	1	TBD	TBD
Screws	Off the Shelf Part	Prefab	McMaster	2	$3.46	$6.92
Retractable Pin	Off the Shelf Part	Prefab	McMaster	1	$16.80	$16.80
					Totals:	**$23.72**

Design 3: Cover with Rotating Lock

Item/Part Number	Description	Material	Source	QTY	Unit Price	Total Price
Top Level Assembly:						
Baseplate	Base of Device	plastic	manufacturing	1	TBD	TBD
Axle	Moving part of device	Plastic / aluminium	manufacturing	1	TBD	TBD

Spring Pin	Off the shelf part			prefab		Mcmaster		1		2.29		2.29
										Totals:		**$**

Appendix B: User Testing Survey Results

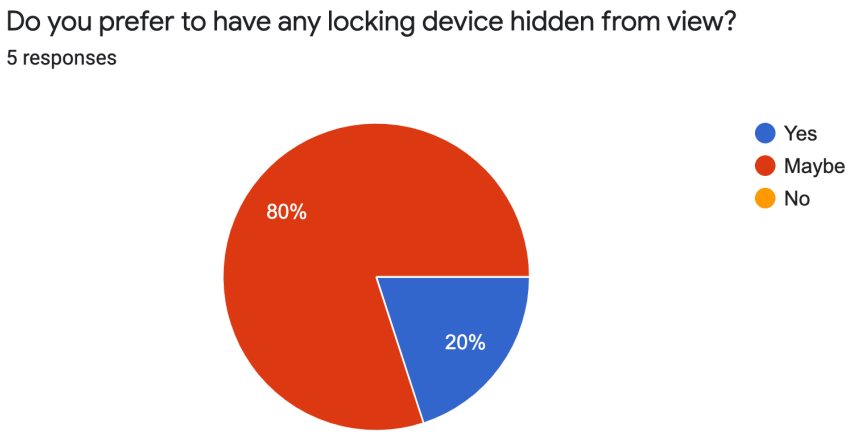


Figure 1: Preference of Locking Device Hidden from View

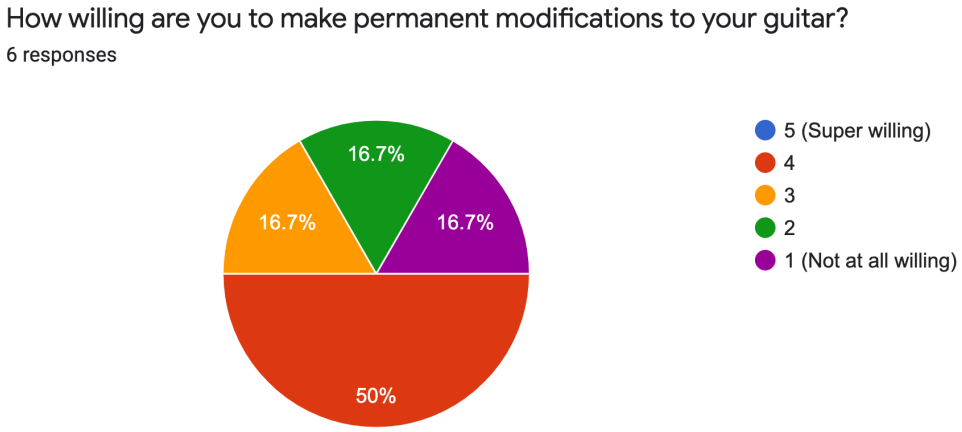


Figure 2: Permanent Modifications

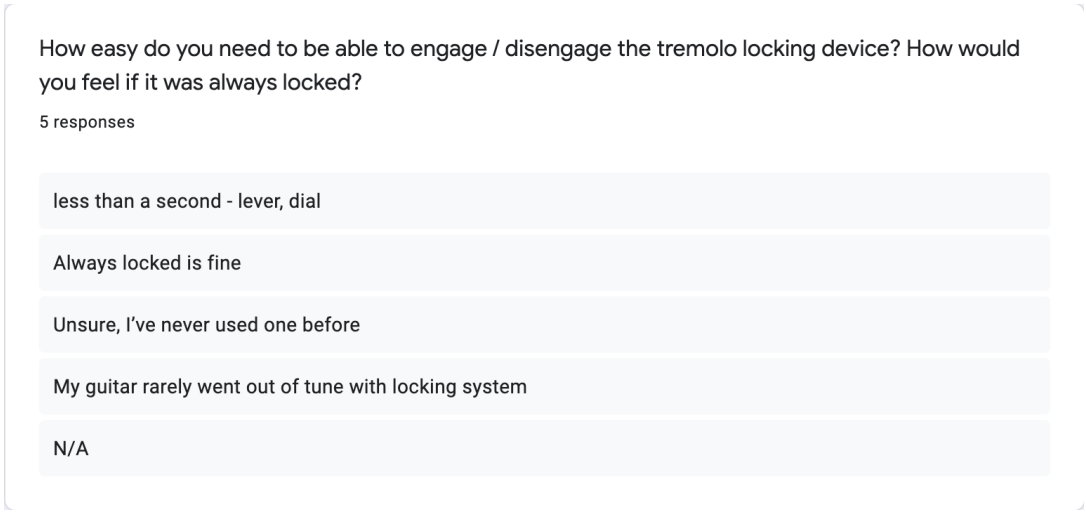


Figure 3: Engaging the Tremolo locking Device