University of Colorado Boulder

Mechanical Engineering

Reverse Engineering Project Report

MCEN 5045 - Design for Manufacturability

Reverse Engineering of Oster Fast Feed Adjustable Pivot Motor Clipper

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1. Executive Summary

Hair Clippers are an extremely common household appliance that most people are familiar with. They are relatively inexpensive and easy to understand, but they contain some complex components that are worth examining and studying. After initial disassembly, we gained a better understanding of the system's underlying design concepts, inputs, outputs and functionality.

The initial DFA demonstrated that while the product was designed well, there were some definite areas that could be bolstered, such as fastener standardization, part reduction, part count efficiency, and ease of assembly. After analyzing the material composition of the parts, it was determined that potentially varying material selection choices could be made to decrease the product's overall cost. In addition, an economic analysis of each component was conducted and parts that were overly expensive comparatively were noted.

Three design changes were implemented to increase the overall DFMA for the assembly as well as to cut down the overall cost of the assembly. The first design modification involved enhancing the drive lever assembly by removing the COTS springs and integrating them into the Drive lever mold, thus reducing part count, assembly time and cost. The second design change focused purely on decreasing cost by removing unnecessary parts, which included P/N 001 - Fast Feed Plate and P/N 006 - Holder Clip. Both of these parts are extraneous components, and, when removed, decrease assembly time and cost. The third change revolved around removing hardware components from the assembly and using snap-fit joints to join the two housing pieces (P/N 004 and P/N 008).

DFA and cost redesign analysis demonstrate clearly that the design changes are impactful from a time and monetary standpoint. The overall part count was reduced by 33% with many other metrics either achieving or approaching our goals. In addition, the overall cost of the part decreased by $3.36, which equated to an annual increase of $672,348.63 in profit. While unable to meet all design goals from a DFA/DFM perspective with this redesign, the changes made by these three design modifications are impactful and demonstrative.

Overall, the product after the redesign can now be assembled in less time with fewer intermediate steps, thus decreasing the assembly technician's burden, while increasing overall production flow. The product has become less expensive to manufacture which too greatly benefits the company as a whole, indicating this redesign effort to be profitable and worthwhile.

2. Design Problem and Objectives

Reverse Engineering provides the means by which an object can be broken down into its component parts and its overall design efficiency analyzed. By taking a common household item and examining its components, one can determine steps that can be taken to improve the overall assembly process of the item, cut cost and design using more sustainable materials, and improve methods for manufacturing the components. The fact that the appliance is something that most people are familiar with also helps in recognizing and understanding the functionality of the system thereby making it easier to assess for potential design improvements and changes.

Sections 3 through 7 below will go into more detail regarding the product itself and explain how our team elected to approach this reverse engineering project as a whole.

3. Product Description

The product that we selected to reverse engineer was an Oster Fast Feed Adjustable Pivot Motor Clipper as seen in Figure 1 below. This is a standard, commercially available product that is suitable for most applications of cutting hair. It can be purchased for a price of ~$50. The product comes with a number of blade guards that allow for the cutting of varying lengths of hair. The product is electric powered with a wired AC cord that connects to a standard outlet. It has a motor assembly that drives the blades and allows for the actual cutting of hair. The motor assembly consists of a coiled motor, a mounting frame, and magnets to induce the required magnetic field. The clippers have an integrated holding clip which allows the user to hang the clippers up when they are not in use. The main body of the clippers is shaped in an ergonomic fashion such that it fits in and conforms to the shape of one's hand very well. This product includes a blade lever, which allows the user to vary the length of the cut by a couple of millimeters via the alignment of two blade components. There is a relatively easily accessible power switch located on the side of the upper housing which will power the system on and off. For more information on the specifics of the components in this product, please refer to the Bill of Materials contained in Appendix A.

Figure 1 - Oster Fast Feed Adjustable Pivot Motor Clipper

Our inspiration for selecting this product for the Reverse Engineering Project stemmed from the fact that hair clippers are a common household appliance and something that our group members interact with somewhat regularly. Hair clippers are an appliance which most people would consider a basic necessity and have meaningful complexity that is often overlooked. As an electromechanical assembly, many hair clippers pose interesting concepts to analyze from a reverse engineering perspective, such as linear to rotary motion mechanisms, the usage of multiple material types across the assembly, and tight tolerances that are required for clipping functionality.

4. Gantt Chart

Project management is key to any project's success, and that certainly held true for this reverse engineering project. In order to better track timelines and deadlines, the team generated a Gantt chart as seen in Figure 2 above. A number of assignments for this course were directly related to the project, so the deadlines for the assignments became the overall deadline for the completion of those items. The work for this project began in late January with a fast deadline of March 7th when reports and presentations are due.

Because a number of the assignments for the Reverse Engineering project are related, the critical path was dependent on the completion of the engineering drawings, Design for Assembly Analysis, Material Selection, Economic analysis, Process selection, report completion and presentation completion. Many of the tasks were completed as a team, but a number of them were divided up between group members for increased efficiency.

The ultimate goal was to utilize the deadlines associated with each assignment to ensure that our project was moving forward in an efficient manner, while preventing us from postponing assignments until the last minute. By utilizing and following the below Gantt Chart, our team was able to efficiently distribute assignments, hold one another accountable, and complete assignments in a timely manner. Refer to figure 2 below for more detailed information.

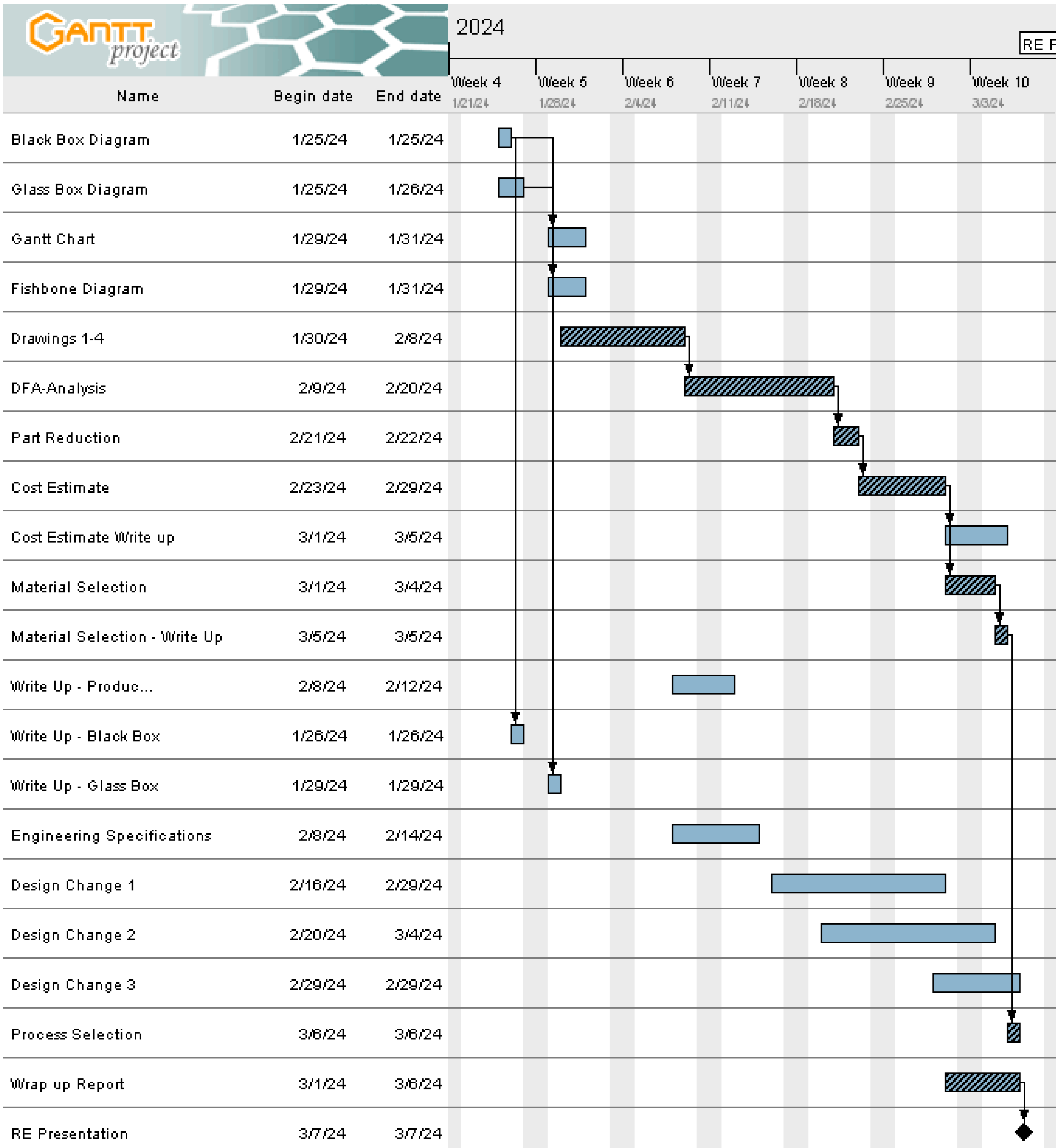


Figure 2 - Gantt Chart

5. Black Box Diagram

The Black box diagram is a simplistic model which shows the inputs and outputs associated with the system. For the Oster Fast Feed Hair clippers, when the blade lever is engaged by the user, it causes the blade alignment to change. In addition, when electricity is allowed to flow after the switch is engaged, this results in the outputs of blade vibration and noise. Reference Figure 3 below.

Figure 3 - Black Box Diagram

6. Glass Box Diagram

An expansion on the above Black Box Diagram is the Glass Box Diagram which takes the same inputs and outputs and conveys the components that are associated with each as seen in Figure 4 below.

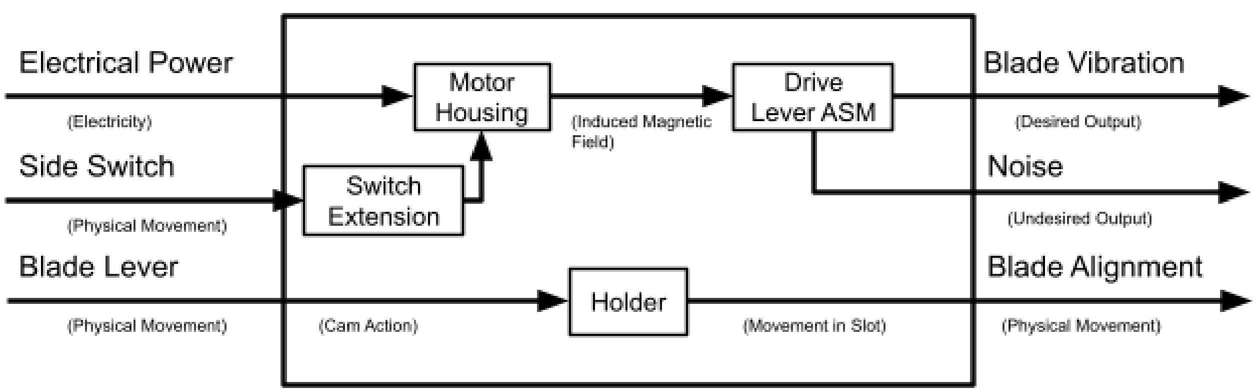


Figure 4 - Glass Box Diagram

7. Fishbone Diagram

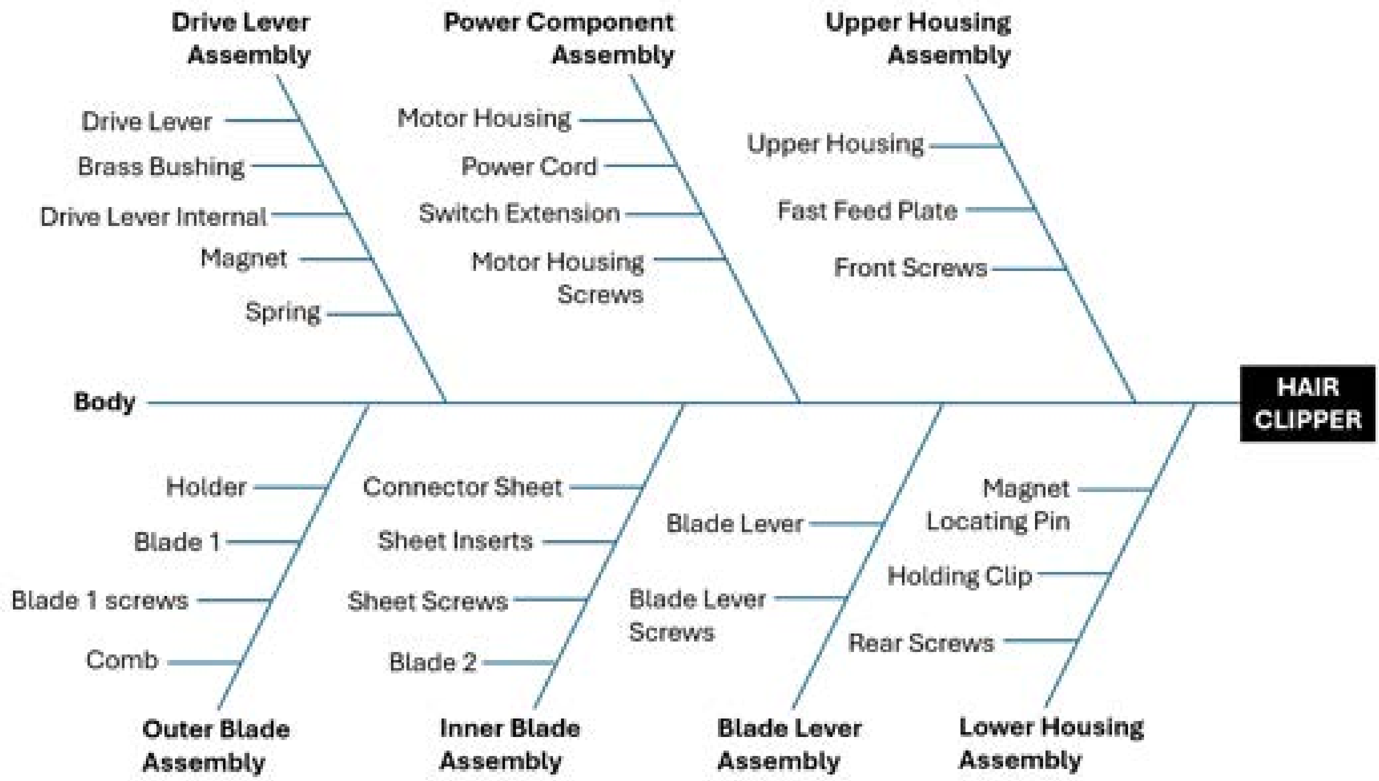


Figure 5 - Fishbone Diagram

After disassembling the hair clipper, each part was numbered as given in Appendix A. The components of the hair clipper can be divided into different subassemblies. A fishbone diagram, shown in Figure 5, helps to understand the relationship between these individual components and subassemblies. The head of the fishbone diagram represents the product we are reverse engineering, in our case the hair clipper. The central spine represents the body, the ribs attached to the spine represent the subassemblies, and the horizontal lines branching out from the ribs represent each individual component part of the hair clipper.

8. Detailed Design Documentation

The Detailed Design section of the report will comprise the majority of the report and discuss factors such as Design for Assembly, Design for Manufacturability, Material Selection, Economic Analysis, and Process Selection. Ref Table of Contents sections 9-21 for additional information.

9. DFA Analysis - Original design

After disassembling the individual components of the hair clipper, and understanding and documenting each part (see Appendix A), our initial evaluation of the product was that it seemed well optimized with complex parts mating efficiently. All the components used in the hair clipper had a logical reason for its presence. However, in order to understand the ease of assembly and efficiency of part use, we tried to reassemble the parts. We noticed that there were a number of opportunities to ease the assembly process and a good scope for part reduction, all of which is documented below. A DFA analysis spreadsheet, shown in Table 1, was a useful tool to quantify the interaction between parts and assemblies, gauge the scope for improvement and understand how far away we are from an optimized product.

DFA Analysis Worksheet

Assembly Name: Hair Clipper **Team:** Group 6 **Date:** 3/6/2024

If the answer is Yes to any of the metrics or questions enter a 1. If the answer is No then enter 0. Each cell must have a number.

Part		DFA Complexity		Functional Analysis / Redesign Opportunity				Error Proofing		Handling			Insertion				Secondary Operations				
Part Number	Part Name	Number of Parts (Np)	Number of Interfaces (Ni)	Theoretical Minimum Part	Part Can Be Standardized (if not already standard)	Cost (Low/Medium/High)	Practical Minimum Part	Assemble Wrong Part/ Omit Part	Assemble Part Wrong Way Around	Tangle, Nest, or Stick Together	Flexible, Fragile, Sharp or Slippery	Pliers, Tweezers, or Magnifying Glass Needed	Difficult to Align/ Locate	Holding Down Required	Resistance to Insertion	Obstructed Access/ Visibility	Re-orient Workpiece	Screw, Drill, Twist, Rivet, Bend, or Crimp	Weld, Solder, or Glue	Paint, Lube, Heat, Apply Liquid or Gas	Test, Measure or Adjust
	Lower Housing Subassembly																				
008	Lower Housing	1	18	1	0	M	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0
005	Magnet Locating Pin	1	3	1	1	L	0	0	1	0	0	1	0	0	1	0	0	0	0	0	1
006	Holding Clip	2	1	0	1	L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Drive Lever Subassembly																				
015	Drive Lever	1	8	1	0	M	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1
017	Brass Bushing	1	2	0	1	L	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
013	Drive Lever Internal Part	2	4	0	1	L	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0
016	Magnet	1	3	1	0	L	1	0	1	1	0	0	1	1	1	0	0	0	0	0	1
018	Spring	2	4	0	0	L	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0
	Power Component Subassembly																				
007	Motor housing	1	6	1	0	M	1	0	1	0	1	0	0	1	0	0	0	1	1	0	1
106	Motor housing Screws	4	8	0	1	L	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0
019	Power cord	1	2	1	1	L	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0
003	Switch Extension	3	2	0	0	L	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
	Upper Housing Subassembly																				
004	Upper Housing	1	7	1	0	L	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
001	Fast Feed Plate	1	3	0	0	L	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
101	Rear Screws	2	6	0	1	L	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0
102	Front Scews Through Plate	2	6	0	1	L	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0
	Inner Blade Subassembly																				
014	Connector Sheet	1	4	0	1	L	1	0	1	0	1	0	0	1	0	0	1	0	0	0	0
020	Inserts for Connector Sheet	2	4	0	1	L	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
103	Connector Sheet Screws	2	4	0	0	L	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
010	Blade 2	1	3	1	0	H	1	0	1	0	1	0	1	1	0	0	0	1	0	0	0
	Outer Blade Subassembly																				
011	Holder	1	5	0	0	M	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0
009	Blade 1	1	4	1	0	H	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0
104	Blade 1 Screws	2	2	0	0	L	0	1	0	0	1	0	1	1	0	0	0	1	0	0	0
002	Blade lever	1	2	1	0	L	1	0	0	0	0	0	1	1	0	0	1	1	0	0	0
105	Blade lever Screws	1	2	0	1	L	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0
012	Comb	1	1	1	0	L	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Totals	39	114	11	11	0	16	6	7	5	6	1	5	10	5	0	5	13	2	0	4
	Design for Assembly Metrics	66.68		28.2%	←Theor. Effy. Pract. Effy.→		41.0%	1.18		1.09			1.82				2.18				
	Targets	40		60.0%			60.0%	1.00		1.00			1.25				1.50				

Table 1 - Design for Assembly Analysis Worksheet

9.1 DFA complexity factor

Oster Fast Feed Adjustable Pivot Motor Clipper has a total of 39 (N_p) components including 20 unique components and 13 fasteners. The components are arranged in the order of assembly in the DFA spreadsheet. There are a total of 114 interfaces (N_i) among all the parts, using equation (1), with a complexity factor of 66.68. As we can see from the DFA Analysis Sheet above, the lower housing has the highest number of interfaces with 18 interfaces. Our team decided to set a target Complexity factor of 40 that we hope to achieve after redesigning.

$$complexity\ factor = \sqrt{(Np \times Ni)} \tag{1}$$

9.2 Functional Analysis

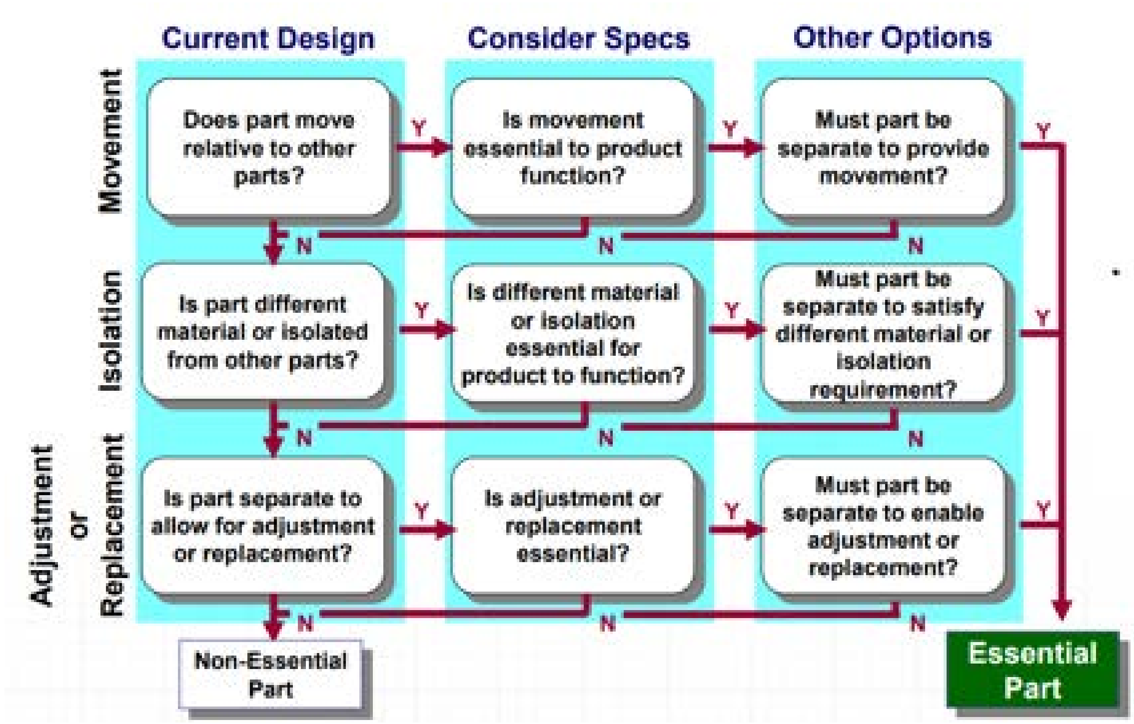


Figure 6 - Functional Analysis Diagram

The goal of functional analysis is to analyze which components can be standardized theoretically and practically. Theoretically, the part can be considered as an essential or non-essential component based on the flowchart shown above, and based on the actual functionality of the component we can practically define the component's essentiality. After finding the theoretical and practical minimum parts, we can find the Theoretical and Practical efficiencies based on the equation shown below. We found the theoretical efficiency as 28.2% with a total theoretical minimum part count of 11 components and the practical minimum part efficiency as 41% with a part count of 16. The team decided to achieve a target minimum part efficiency of 60% after redesigning.

$$Theoretical\ part\ count\ efficiency = \frac{Theoretical\ minimum\ part\ count}{Total\ number\ of\ parts} \quad (2)$$

$$Practical\ part\ count\ efficiency = \frac{Practical\ minimum\ part\ count}{Total\ number\ of\ parts} \quad (3)$$

9.3 Error Proofing

Error proofing is essentially anticipating potential errors that may arise during the assembly process. The possible errors that can occur during assembly are assembling incorrect components, putting the component in the wrong direction or completely missing the component. A solution to this problem is to error-proof the assembly process or component. In our device, there are a total of 6 components that could be assembled with a wrong component or can be completely omitted. 7 components in our device could be assembled in the wrong direction. We could find the error factor using the equation shown below. From the analysis, we got an error factor of 1.18 and we aim to achieve an error factor of 1.0.

$$Error\ Factor = \frac{Assembled\ wrong\ part/omitted\ part + Assembled\ part\ wrong\ way\ around}{Theoretical\ Minimum\ part\ count} \quad (4)$$

9.4 Handling

Handling is essentially a metric of how easy are the components to handle while assembling. It is important to know the possible challenges that may arise during the assembly of the product. This may include how many hands are required to assemble, and whether there is a need for grasping assistance if the components are small in size, slippery, sharp or flexible which will affect the component's handling. Overall, we got a handling factor of 1.09 by analyzing all the components in our device. Furthermore, we aim to achieve a handling factor of 1.0 post-design improvements.

9.5 Insertion

In this metric, we analyze how easy or difficult it is to assemble a specific component. The insertion factor is based on whether the component is difficult to align if it requires a hold down to maintain its location, adequate accessibility and visibility. We can find the insertion factor using the equation shown below. In our device, a total of 5 components are difficult to align or relocate, 9 components require holding assistance, 4 components give resistance to insertion and no components have obstructed accessibility and visibility. We got an Insertion factor of 1.82 and we aim to reduce this factor to 1.25 after the redesigning.

$$insertion\ factor = \frac{difficult\ to\ align\ parts + holding\ required + resistance\ to\ insertion + obstructed\ access}{Theoretical\ Minimum\ \#\ parts} \quad (5)$$

9.6 Secondary Operations

These are the additional operations such as screwing, drilling, twisting, riveting, bending, or crimping that are required to assemble the components. These operations may also include but are not limited to welding, soldering or gluing. In our device, 13 components require screwing during assembling, 5 components may require workspace to be reoriented and 4 components required adjustment. We calculated the secondary operations factor and got 2.18 as the secondary operations factor, and we aim to reduce it to 1.5.

10. Engineering Specifications of Product and DFMA principles

Model	23-310A
Electric Specs.	120 V, 9 W, 60 Hz
Power Rating	9 Watts
Motor Type	Electromagnet
Blade Material	High Carbon Steel
Adjustable Blade Settings	Yes
Cutting Length	Adjustable
Cutting System Technology	Pivot Motor
Dimensions	1.6" H x 2.1" W x 6" L
Weight	1.16 lbs
Power Cord Length	8 ft
Warranty	1 Year
Cleaning Instructions	Remove hair, clean with Spray Disinfectant, and lubricate blades with blade lube between each use.

Table 2: Engineering Specifications of Product

The product specification as described by the manufacturer markets the product as a ‘Sleek, adjustable-blade clipper that works through cut after cut quickly and effortlessly with a powerful Whisper Quiet™ pivot motor. The Fast Feed® clipper keeps noise level down and productivity up. Designed with a convenient, adjustable blade lever to change settings easily. It is ultra-durable and built for long-lasting performance to provide years of use. Adjustable blade size 000-1. Also includes three comb guide attachments, blade guard and cleaning accessories.’ Refer Table 2 for details.

The Oster Fast Feed Hair Clipper incorporates several Design for Manufacturability and Assembly (DFMA) principles. One notable feature is the self-aligning upper housing to lower housing feature. This helps to ensure accurate alignment during manufacturing. This design choice simplifies assembly steps and reduces the risk of misalignment errors. Furthermore, the drive lever has a circular feature for spring alignment that eases the assembly process. This design helps in the positioning of the spring and ensures consistent and precise alignment, contributing to both manufacturing efficiency. The clipper assembly includes modular components, allowing for easy replacement. The clipper also has a comb set which can be used interchangeably for different cut lengths. The snap functionality of the comb to the blades assists easy and quick comb changing and replacement during operation. The product is well balanced and has a symmetric design which makes it easy to handle. The housing has molded serrations for enhanced grip.

These DFMA principles showcase a thoughtful design keeping in mind the end-user experience and prioritizes some manufacturing processes. However, there was scope for improvement in many areas. This will be discussed in the Design Changes section.

11. Material Selection Case Study

An integral component of our DFMA analysis is to look at the materials of each component and determine, based primarily on design parameters, such as the Material Performance Index, if another material that could provide the same functionality could be used instead. Table 3 below shows a case study of five components that were analyzed with potential improvements with material choice.

Part Number	Description	Material	Material Performance Index	Suggested Material
003	Switch Extension	ABS	Bar in Tension and/or beam in bending	PLA
018	Spring	Stainless Steel	Beam in Bending	ABS
006	Holding Clip	6063 Aluminum	Bar in Tension	304 Stainless Steel
009	Blade 1	High Carbon Steel	Beam(Blade Teeth)in bending	Stainless Steel
002	Blade Lever	ABS	Beam in Bending	PET

Table 3 - Material Selection Table

For the purpose of brevity within the report, only one of these five cases will be discussed in depth here. Refer to Appendix B for a discussion on the other 4 parts mentioned above.

The Spring, Part Number 18, is made of stainless steel and is a commercial part purchased through a third-party vendor. Its primary role is to dampen vibrations of the drive lever assembly when the clippers are in operation. Due to this, a spring can be considered a long beam in bending. When a compression spring is compressed, it undergoes bending deformation as the coils are pressed together. The material on the outer side of the coil experiences tension stresses, while the material on the inner side experiences compression stresses. The spring made of stainless steel wire requires high bending stiffness to ensure the appropriate spring constant is achieved. This part has to withstand repeated bending conditions at high speed due to its oscillating motion which causes the blade to move back and forth for cutting.

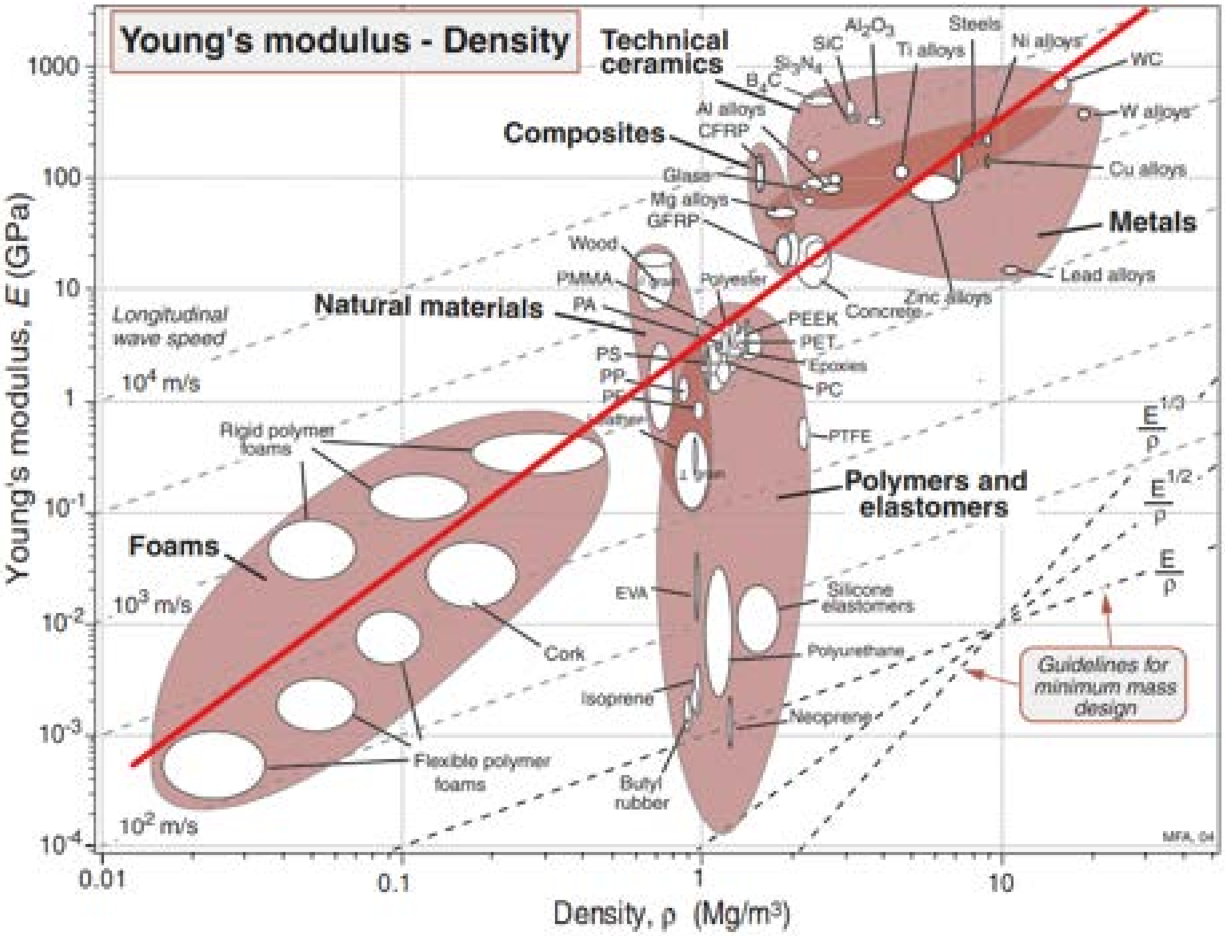


Figure 7 Ashby Chart depicting Stiffness vs Density

By analyzing the Ashby chart in the Figure above, which compares Young's modulus to density, we can find a comparable material in natural materials, almost all of composites and ceramics, and notably the higher modulus range of polymers and elastomers. Hence using an integrated ABS plastic spring can meet the material requirement. This idea that ABS would be a good material choice for the spring will be explored further in section 15 under Design Change number 1.

12. Material and Manufacturing Analysis

The next step in design analysis is to identify the various materials of construction and the manufacturing methods used and understand why they were used. It is also important to understand why parts were designed unique to the hair clipper and where COTS parts were used. By doing the study of materials and manufacturing we hope to find opportunities for redesign and highlight and solve efficiency issues. The following Table 4 outlines the materials and manufacturing processes used for each of these.

Part Number	Part Name	Material	Manufacturing Process	Weight of part [lb]
001	Fast Feed Plate	24 GA Aluminium	Metal Stamping	0.001
002	Blade Lever	ABS	Injection Molding	0.002
003	Switch Extension	ABS	Injection Molding	0.100
004	Upper Body Housing	ABS	Injection Molding	0.200
005	Magnet Locating Pin	Aluminum	Lathe	0.001
006	Holding Clip	Stainless Steel	Wire Bending	0.003
007	Motor Housing/Assembly	Aluminium	Stamping, sheet bending	0.500
008	Lower Body Housing	ABS	Injection Molding	0.350
009	Blade 1	High Carbon Steel	Milling	0.022
010	Blade 2	High Carbon Steel	Milling	0.018
011	Holder	Stainless Steel	Stamping, sheet bending	0.062
012	Comb	ABS	Injection molding	0.100
013	Drive Lever Internal	Cast Iron	Cast	0.017
014	Connector Sheet	Stainless Steel	Stamping, sheet bending	0.003
015	Drive Lever	ABS	Injection Molding	0.089
016	Magnet	Ferromagnet	Powder metallurgy	0.200

Table 4 - Material and MFG Process

The materials used in the manufacturing of unique parts include metals like Aluminium, Stainless Steel, High Carbon Steel, and Cast Iron, and ABS plastic. A case study of the materials selection and replacement for five parts is discussed in Section 11 and Appendix B. The various manufacturing processes used for the selected materials and why these materials were selected are explored in this section.

Injection Molding:

All the ABS plastic components used in the hair clipper are made using injection molding. Injection molding forces plastic into a mold under high pressure. The plastic components weigh from 0.01 lb to 0.35 lb and based on the estimate of manufacturing and selling 200,000 units, we can see from Figures __ and __ that the only manufacturing processes that are the best fit are injection molding and blow molding. Injection molding is used for complex solid components whereas blow molding is used for thin-walled hollow parts. In our case, every plastic part of the hair clipper can be considered complex. Hence, considering the high-volume molding operations capability, lower cost per unit for high-volume parts and complexity of parts, injection molding is the right choice for all the ABS parts listed in the table.

Also answering the question as to why ABS is the chosen material for injection molding, it is widely used in injection molding because of its desirable properties. These include high strength, low melting temperature, recyclability, and good resistance to chemicals and heat. It is also relatively easy to process and can be molded into a variety of shapes and sizes. ABS can maintain its characteristics and performance in extreme temperatures but also has a low melting temperature making it easy to use when injection molding.

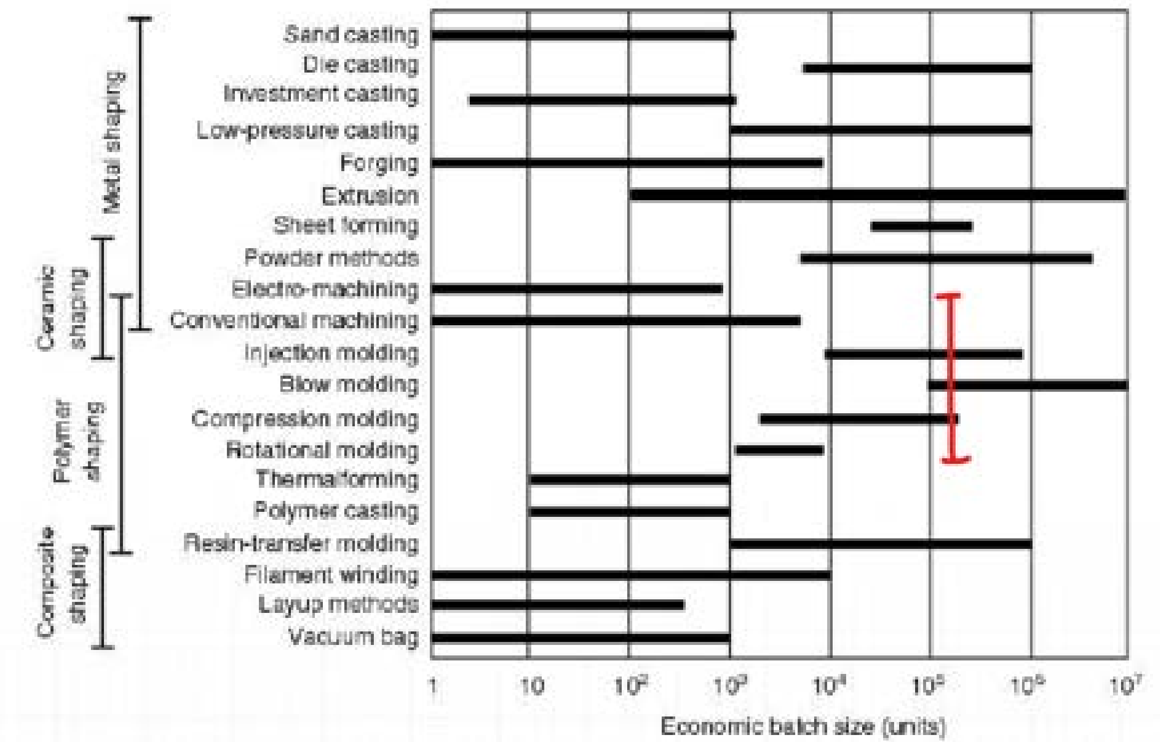


Figure 8 Batch Size vs Manufacturing Processes

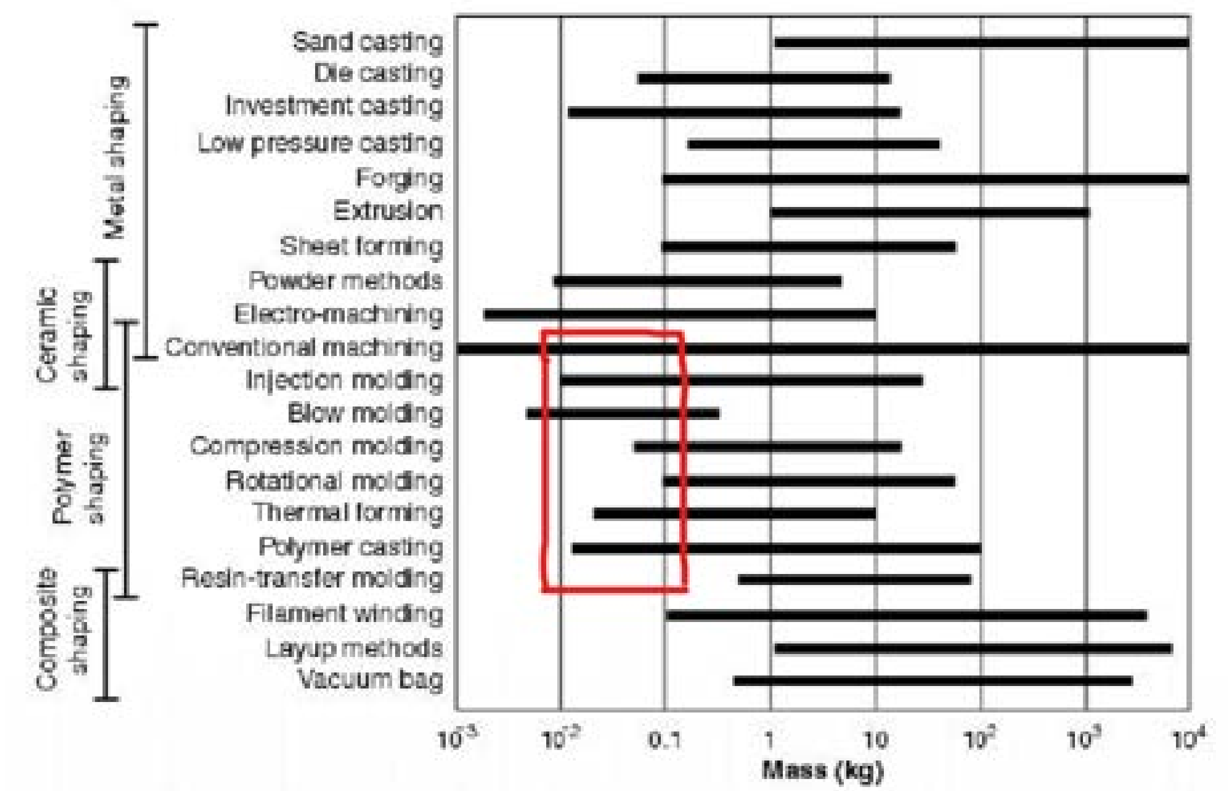


Figure 9 Mass vs Manufacturing Process

Metal Parts' Manufacturing Processes:

The metal parts' manufacturing processes include sheet metal stamping, bending, wire drawing, lathe and mill machining, and casting, as shown in Table __. These processes largely depend on the specific requirements of the final product, including factors such as the desired shape of the part, the complexity of its design, the level of precision needed, and considerations related to material properties. The choice of the manufacturing method is guided by a careful assessment of these factors to ensure cost effectiveness, efficiency, and the ability to meet the intended functionality and quality standards of the steel components. Stamping and bending is used for parts with consistent shapes, shaping flat sheets into three dimensional geometries, enclosures and efficiency in producing parts with uniform cross-section, in this case constant thickness (parts 001, 007, 011, and 014). Wire drawing and bending is used to produce wires with precise diameters and smooth surfaces (part 006). Lathe and milling operations are used for the parts requiring high precision manufacturing, like the cutting blades (parts 009 and 010) and the magnet locating pin (005). These parts are parts that move relative to other surfaces, thereby requiring high precision, which is best achieved by these operations. And lastly casting, for the drive internal part (part 013) which has a relatively complex shape but does not require precision manufacturing nor surface finish. Casting helps reduce the metal waste while achieving the desired shape.

Outsourced Parts or COTS:

The parts 016 - Magnet, 017 – Brass Bushing, 018 – Springs, 019 – Power Cord, 020 – Inserts and the 100 series parts which include all the fasteners are Off-the-shelf (COTS) parts used in the assembly. These COTS parts are made from various processes, such as powder metallurgy for the magnet, wound wire for the spring, extruded and turned brass for bushing, thread rolling and cold forming for screws, and various wire drawing and coating processes for the power cord.

13. Process Selection (Case Study):

Another aspect of this design that merited a more thorough investigation was the processes used to manufacture each component of the assembly. Manufacturing processes used are determined by the design engineers and company management and are usually motivated by factors such as cost, schedule and performance.

As mentioned above in Section 12, we found that the manufacturer utilized a few specific manufacturing processes for the majority of the components. About half of the components were plastic and fabricated via injection molding, while the metal parts were either machined or stamped/bent.

To better understand process selection, our team evaluated the possibility for selecting a new manufacturing process for P/N-008 Lower housing. The Lower Housing is made of ABS plastic and produced at a very high volume of 200,000 parts annually. Based on quantity of production alone, many processes were eliminated immediately, leaving methods such as casting, extrusion, injection molding, blow molding, compression molding, and resin transfer molding. Due to the unique shape factor of the lower housing assembly, all casting, extrusion, resin transfer molding, and even compression molding methods were eliminated. This only left injection and blow molding processes for evaluation in process selection.

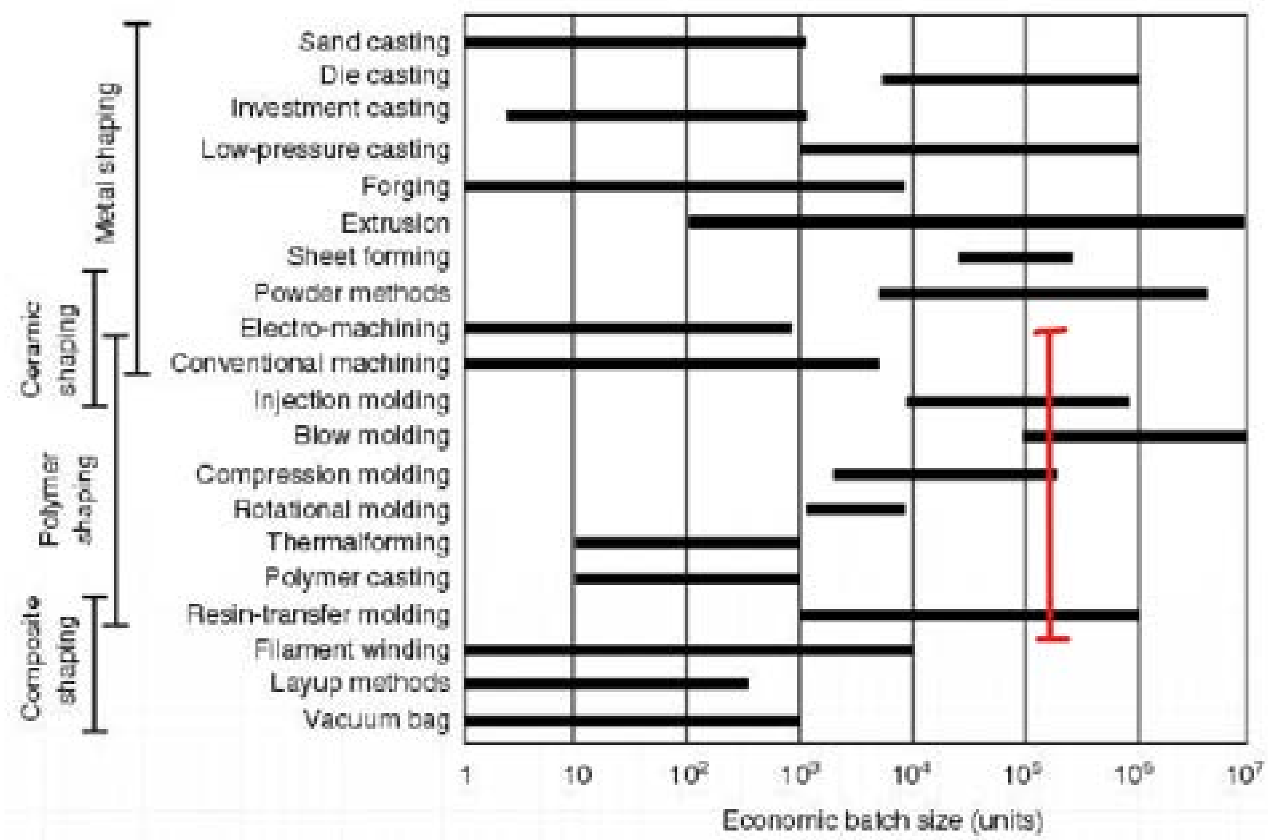


Figure 8 (Previously listed above)

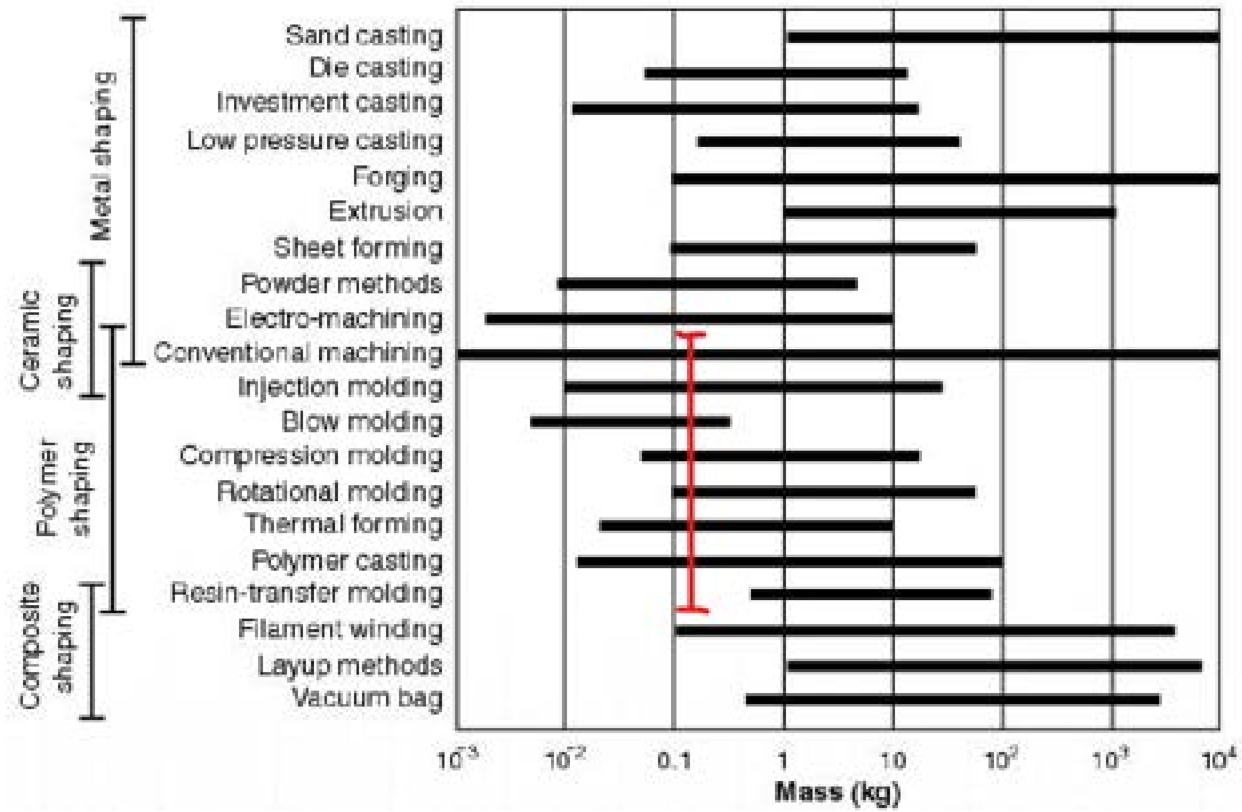


Figure 10 - Mass vs Mfg process at ~0.35 lbs

Out of the two remaining methods, it was determined that injection molding would produce the part at a lower cost of $5.01, while blow molding came in at $5.89 per unit. While the price difference doesn't seem significant on this scale, when compared to an overall annual production of 200,000 units, it is significant and evident why the manufacturer selected injection molding as the process of choice.

14. Economic analysis

A thorough Economic analysis was conducted to evaluate the cost of each component in the hair clippers. By analyzing the sum of each component's material cost, labor cost, tooling cost, equipment cost, and overhead costs, the unit cost for each component was determined. Tables 5-8 below clearly portray each of these values as seen below:

Part Number	001	002	003	004	005	006
Part Name	Fast Feed Plate	Blade Lever	Switch Extension	Upper Body Housing	Magnet Locating Pin	Holding Clip
Manufacturing Process	Metal Stamping	Injection Molding	Injection Molding	Injection Molding	Lathe	Wire Bending
Material	24 GA Aluminium	ABS	ABS	ABS	Aluminum	Stainless Steel
C_M Material cost [$/unit]	$0.03	$0.003	$0.137	$0.274	$0.036	$0.033
C_L Labor cost [$/unit]	$0.25	$0.50	$0.50	$1.25	$0.71	$0.42
C_T Tooling cost [$/unit]	$0.00	$0.05	$0.05	$0.05	$0.01	$0.00
C_E Equipment cost [$/unit]	$0.100	$0.100	$0.100	$0.167	$0.009	$0.007
C_OH Overhead costs [$/unit]	$0.60	$1.20	$1.20	$3.00	$1.71	$1.00
C_U Unit cost [$/unit]	$0.99	$1.85	$1.99	$4.74	$2.48	$1.46
OME Manufacturing cost [$/unit]	$0.10	$0.008	$0.411	$0.821	$0.107	$0.100
OME Price [$/unit]	$0.31	$0.025	$1.232	$2.463	$0.321	$0.300
xometery.com quote price [$/unit]	$1.33	$2.11	$2.03	$5.87	$2.74	$5.45
P Sales price to break even [$/unit]	$0.79	$1.05	$1.19	$2.07	$0.80	$0.49
Break Even Sales Price (Total)	$25.92					
Unit Build Price	$44.23					
Unit Sale Price	$53.07					
Profit per Unit	$8.85					
Annual Proft	$1,769,048.21					

Table 5 Cost Analysis Part 1

Part Number	007	008	009	010	011	012
Part Name	Motor Housing/ASM	Lower Body Housing	Blade 1	Blade 2	Holder	Comb
Manufacturing Process	Wire Bending	Injection Molding	Milling	Milling	Stamping, sheet bending	Injection molding
Material	Aluminium	ABS	High Carbon Steel	High Carbon Steel	Stainless Steel	ABS
C_M Material cost [$/unit]	$3.125	$0.455	$0.190	$0.081	$1.240	$0.130
C_L Labor cost [$/unit]	$0.83	$1.25	$0.71	$0.71	$0.50	$0.42
C_T Tooling cost [$/unit]	$0.00	$0.05	$0.15	$0.15	$0.01	$0.05
C_E Equipment cost [$/unit]	$0.014	$0.250	$0.381	$0.571	$0.100	$0.083
C_OH Overhead costs [$/unit]	$2.00	$3.00	$1.71	$1.71	$1.20	$1.00
C_U Unit cost [$/unit]	$5.97	$5.01	$3.15	$3.23	$3.05	$1.68
OME Manufacturing cost [$/unit]	$9.375	$1.365	$0.571	$0.243	$3.720	$0.390
OME Price [$/unit]	$28.125	$4.095	$1.713	$0.729	$11.160	$1.170
xometery.com quote price [$/unit]	$3.19	$5.52	$6.32	$6.06	$10.00	$2.08
P Sales price to break even [$/unit]	$4.00	$2.26	$3.05	$2.95	$2.25	$1.10

Table 6 Cost Analysis part 2

Part Number	013	014	015	016	017	018
Part Name	Drive Lever Internal	Connector Sheet	Drive Lever	Magnet	Brass Bushing	Spring
Manufacturing Process	Cast	Stamping, sheet bending	Injection Molding	Powder metallurgy	COTS	COTS
Material	Cast Iron	Stainless Steel	ABS	Ferromagnet	Brass	Stainless Steel
C_M Material cost [$/unit]	$0.011	$0.048	$0.116	$0.250	COTS	COTS
C_L Labor cost [$/unit]	$0.42	$0.21	$0.33	$0.50	COTS	COTS
C_T Tooling cost [$/unit]	$0.00	$0.01	$0.06	$0.01	COTS	COTS
C_E Equipment cost [$/unit]	$0.001	$0.003	$0.067	$0.010	COTS	COTS
C_OH Overhead costs [$/unit]	$1.00	$0.50	$0.80	$1.20	COTS	COTS
C_U Unit cost [$/unit]	$1.43	$0.76	$1.37	$1.97	$0.38	$0.28
OME Manufacturing cost [$/unit]	$0.034	$0.144	$0.347	$0.750	COTS	COTS
OME Price [$/unit]	$0.102	$0.432	$1.041	$2.250	COTS	COTS
xometery.com quote price [$/unit]	$1.00	$8.36	$1.89	$3.76	COTS	COTS
P Sales price to break even [$/unit]	$0.44	$0.28	$1.00	$0.81	COTS	COTS

Table 7 Cost Analysis part 3

Part Number	019
Part Name	Screws
Manufacturing Process	COTS
Material	stainless steel
C_M Material cost [$/unit]	COTS
C_L Labor cost [$/unit]	COTS
C_T Tooling cost [$/unit]	COTS
C_E Equipment cost [$/unit]	COTS
C_OH Overhead costs [$/unit]	COTS
C_U Unit cost [$/unit]	$0.06
OME Manufacturing cost [$/unit]	COTS
OME Price [$/unit]	COTS
xometery.com quote price [$/unit]	COTS
P Sales price to break even [$/unit]	COTS

Table 8 Cost Analysis Part 4

The four Tables above display the cost information for the major components of this system. From these parts, it is important to note that the Overhead costs make up a decent portion of the unit cost for each component. Because most of the parts are quite lightweight, the material cost does not play a very pronounced role in the overall cost of the product.

As seen in Table 5, the unit cost comes out to a total of $44.23. With an anticipated markup of twenty percent for retail pricing and increased profit margins, the clippers would sell at a price of $53.07, resulting in an overall profit of $8.85 per system purchased. Based on the business model, it is assumed that the company will produce and sell 200,000 hair clippers annually, which would result in a net profit of 1.77 million dollars for the year. In addition, analysis was conducted to determine the price required per component to break even assuming 200,000 units are sold, and the unit cost was calculated to be $25.92, indicating that the system sold at cost or higher will be profitable annually.

15. Design Changes

Based on the extensive analysis on the product we decided to focus on the design changes which improve the assembly process and without changing the functionality of the original product. We focused on reducing the number of parts, eliminating unnecessary components, standardizing parts, and reducing assembly steps, thereby reducing the manufacturing assembly time and reducing material usage thereby saving costs. Reducing the cost of the product is the main goal. The changes in design we came up with are documented below.

15.1. Design Change 1 - Drive Lever Redesign

The first proposed design change was to redesign the drive lever. Before going into the redesign, let's look at the original drive lever design and its working. As seen in Figure 11, the drive lever houses a Brass Bushing (P#017), a Magnet (P#016) and two cast iron Drive Lever Internal parts (P#013). This subassembly is placed within the main body lower housing with the Springs (P#18) on either side as shown in Figure 12. The brass bushing slides within the shaft feature of the lower housing. This assembly forms the drive lever subassembly. The function of the drive lever subassembly is to provide the oscillating motion to the moving blade which ultimately is responsible for the cutting action. So, how is this oscillating motion achieved? The motor is housed right below the drive lever which alternates the current and thereby the magnetic field which causes the magnet of the drive lever to rock about the axis of the brass bushing. In order to contain the rocking motion to a specific displacement there are pre-compressed springs on either side. In essence, the motor causes the drive lever to rock which causes the cutting blade to oscillate.

Figure 11 Drive Lever Subassembly

Figure 12 Drive Lever Sub-assembly Housing

Now that we know how it works, let's try to understand the assembly process. Once the assembler has assembled the busing, magnets and the internal part adjacent to the magnet, the assembler has to place this within the lower housing while compressing the two springs at the same time. Unless there is a separate fixture to assist this assembly, which we believe is highly unlikely, the time taken to take two springs from the box, compress them, hold them in place and also align the drive lever within the magnet locating pin came to about 15 seconds on average. This doesn’t include the times when the spring slips and doesn’t align correctly, gets stuck to the magnet and between parts. And there’s two of them. This was something we needed to fix and empathize more with the assemblers.

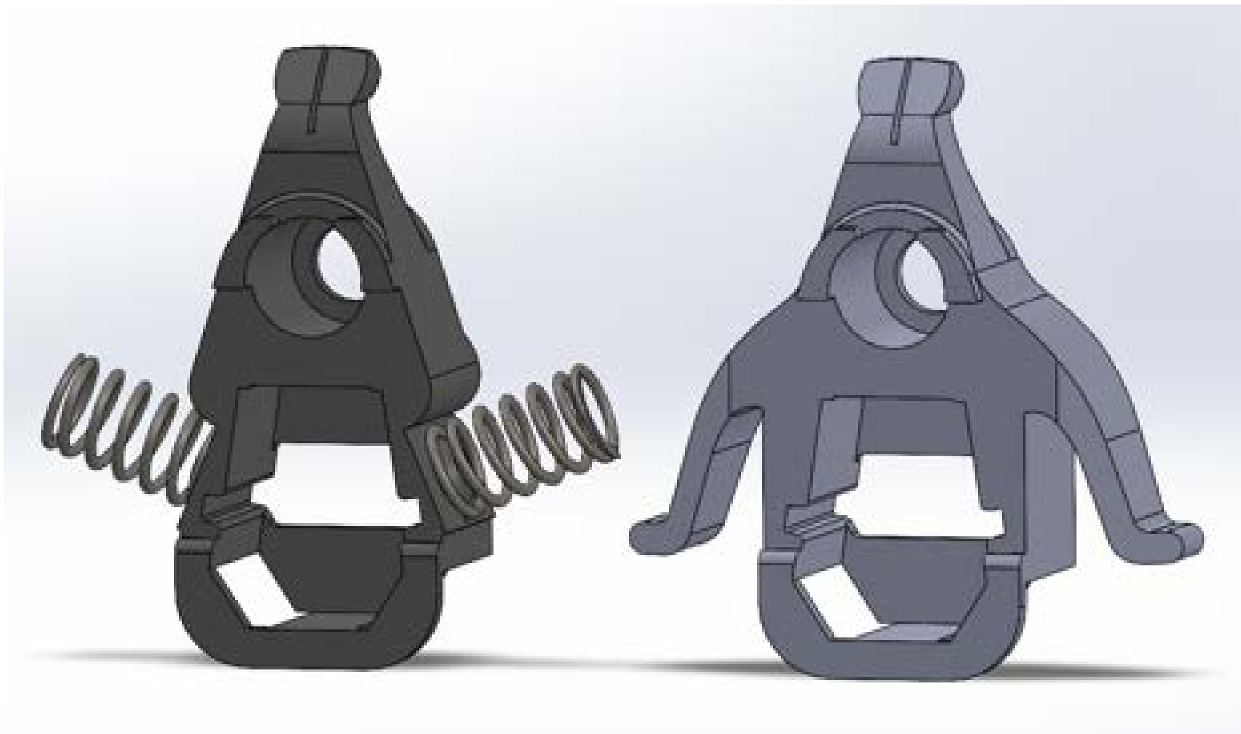


Figure 10 Original Drive Lever with Springs and Drive Lever Redesign with Integral Springs

The design we came up with incorporates an integral spring in the drive lever itself, eliminating the requirement for two separate springs, which translates to reduction in cost associated with springs. The detailed cost analysis is discussed in the economic analysis section of this report. The incorporation of an integral spring would bring down the assembly time to less than 5 seconds, as it doesn't require any handling of separate springs, and adjustments in the orientation for aligning it perfectly. During the assembly of the redesigned drive lever, the assembler has to just compress the integral spring and place it within the lower housing, not worrying about reaching out for additional parts, parts slipping off, or sticking to the magnet and getting stuck between the housing and the drive lever.

15.2. Design Change 2 - Removal of extraneous assembly components

The second proposed design change would be to eliminate all parts that play little to no function within the system. The targeted parts include 006 - Holding Clip and 001 - Fast Feed Plate. While the holding clip does play the role of supporting the weight of the hair clippers when suspended from it, there are few instances where this would be required. The body of the hair clippers is mostly flat and the item can be placed on its lower housing without any fear of the housing getting damaged. A user would have to have a wall mounted hook or similar in order to suspend the hair clippers by the Holding Clip, which just seems excessive and needless. Thus the holding clip is something that can easily be eliminated from the overall assembly without affecting the function of the part. The removal of this part would decrease the overall cost of the assembly, if only minimally. It would also save valuable production technician time. This also allows the design team to remove the cut out features from the lower housing, which should decrease the overall price of the mold as well as each component that is produced.

Figure 13 Holding Clip

In addition, the assembly contains the fast feed plate as a component, and it is secured to the lower housing through the upper housing by using two fasteners. Not only are the fasteners very small and difficult to handle, they also have the potential to easily get lost, misplaced, or mistakenly installed in an incorrect mounting location. The plate itself seems to be advertising the model of the Oster hair clippers with little other added value. As a thin sheet metal component, it also has a high likelihood of getting damaged over time.

Figure 14 Oster Fast Feed Plate

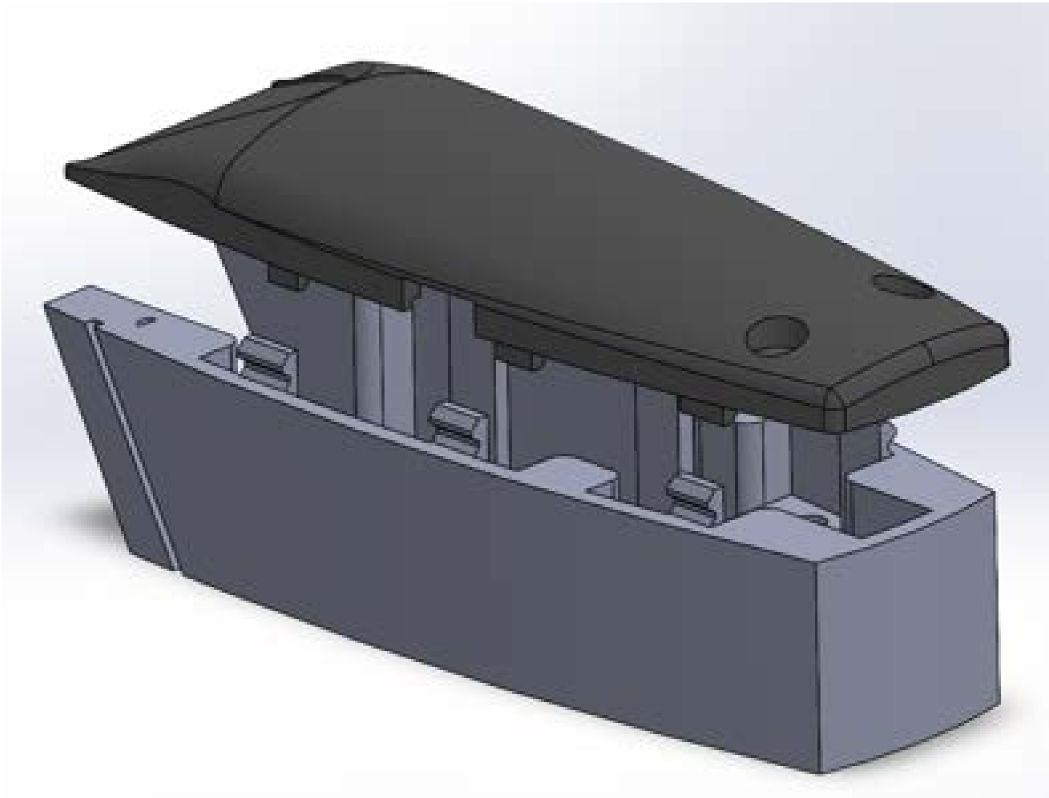
The proposed solution to these design problems is to simply remove the excess parts and include any remaining labeling/non-functional aspects in the remaining materials. The fast feed plate would be replaced by simply having the required letters marked directly on the lower housing. In fact, the required lettering/marking would be incorporated into the injection mold for increased simplicity, decreased overall operations, and increased cost savings.

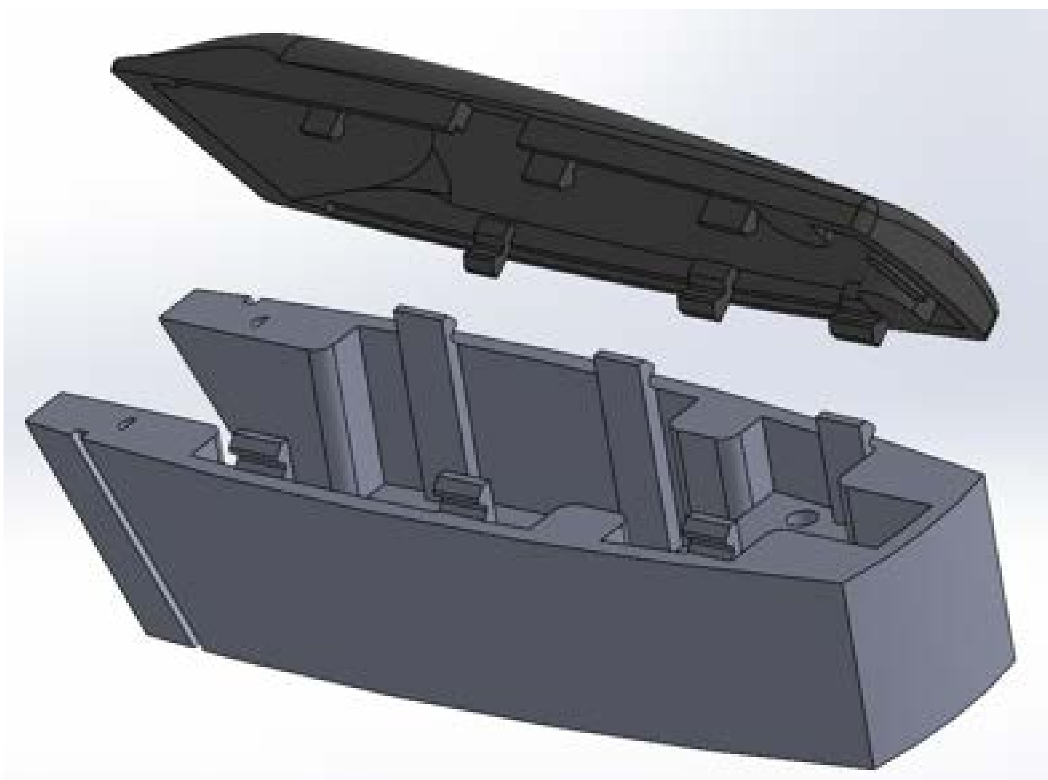
While these changes would necessitate the need for the creation of new molds, with an estimated production of 200,000 units annually, the fast feed clip priced at $0.99 per unit, the holding clip priced at $1.36 per unit, and the cost of a new mold at $100,000, these modifications would result in a net gain of more than $200,000 annually making this design change very worthwhile. The economic analysis of the redesigned product will contain a more thorough accounting of the changes made and help determine whether they were beneficial to the product's value or not.

15.3. Design Change 3

The third proposed change is the use of snap fit features integrated into the upper and lower housing design. The original upper and lower housings are held together with the help of 4 screws as shown in Figure 13. This proposed change, as seen in Figures 14 and 15, would eliminate the need for the four screws that are used to secure the plate and also remove four mounting points features in the lower and upper housing. The removal of the screws would enhance the overall assembly process by minimizing assembly steps, removing unnecessary hardware, and simplifying the product as a whole. This redesign reduces the assembly time from 45 seconds, estimated time to handle, locate and screw, to less than 5 seconds, where the assembler has to just gently push the upper housing over the lower housing until it snaps fit. The triangular feature on the upper and lower housing which works as a snap fit, function such that it can also be disassembled with a sufficient force such that it snaps open in a similar way. That being said, it is sufficiently tight for it to not open while in operation. The same design changes apply to the motor housing using snap fits, eliminating 4 screws.

Figure 15 Original Upper and Lower Housing with 4 screws





Figures 16 and 17 - Redesign of Upper and Lower with snap fit features

16. DFA Analysis for Redesign

DFA Analysis Worksheet

Assembly Name: Hair Clipper **Team:** Group 6 **Date:** 3/6/2024

If the answer is Yes to any of the metrics or questions enter a 1. If the answer is No then enter 0. Each cell must have a number.

Part		DFA Complexity		Functional Analysis / Redesign Opportunity				Error Proofing		Handling			Insertion				Secondary Operations				
Part Number	Part Name 	Number of Parts (Np)	Number of Interfaces (Ni)	Theoretical Minimum Part	Part Can Be Standardized (if not already standard)	Cost (Low/Medium/High)	Practical Minimum Part	Assemble Wrong Part/ Omit Part	Assemble Part Wrong Way Around	Tangle, Nest, or Stick Together	Flexible, Fragile, Sharp or Slippery	Pliers, Tweezers, or Magnifying Glass Needed	Difficult to Align/ Locate	Holding Down Required	Resistance to Insertion	Obstructed Access/ Visibility	Re-orient Workpiece	Screw, Drill, Twist, Rivet, Bend, or Crimp	Weld, Solder, or Glue	Paint, Lube, Heat, Apply Liquid or Gas	Test, Measure or Adjust
	Lower Housing Subassembly																				
008	Lower Housing	1	9	1	0	M	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0
005	Magnet Locating Pin	1	3	1	1	L	0	0	1	0	0	1	0	0	1	0	0	0	0	0	1
~~006~~	~~Holding Clip~~																				
	Drive Lever Subassembly																				
015	Drive Lever	1	7	1	0	M	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1
017	Brass Bushing	1	2	0	1	L	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
013	Drive Lever Internal Part	2	4	0	1	L	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0
016	Magnet	1	3	1	0	L	1	0	1	1	0	0	1	1	1	0	0	0	0	0	1
~~018~~	~~Spring~~																				
	Power Component Subassembly																				
007	Motor housing	1	2	1	0	M	1	0	1	0	1	0	0	1	0	0	0	1	1	0	1
~~106~~	~~Motor housing Screws~~																				
019	Power cord	1	2	1	1	L	1	0	0	1	0	0	0	0	0	0	0	0	1	0	0
003	Switch Extension	3	2	0	0	L	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
	Upper Housing Subassembly																				
004	Upper Housing	1	2	1	0	L	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
~~001~~	~~Fast Feed Plate~~																				
~~101~~	~~Rear Screws~~																				
~~102~~	~~Front Scews Through Plate~~																				
	Inner Blade Subassembly																				
014	Connector Sheet	1	4	0	1	L	1	0	1	0	1	0	0	1	0	0	1	0	0	0	0
020	Inserts for Connector Sheet	2	4	0	1	L	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
103	Connector Sheet Screws	2	4	0	0	L	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
010	Blade 2	1	3	1	0	H	1	0	1	0	1	0	1	1	0	0	0	1	0	0	0
	Outer Blade Subassembly																				
011	Holder	1	5	0	0	M	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0
009	Blade 1	1	4	1	0	H	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0
104	Blade 1 Screws	2	2	0	0	L	0	1	0	0	1	0	1	1	0	0	0	1	0	0	0
002	Blade lever	1	2	1	0	L	1	0	0	0	0	0	1	1	0	0	1	1	0	0	0
105	Blade lever Screws	1	2	0	1	L	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0
012	Comb	1	1	1	0	L	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Totals	26	67	11	7	0	14	3	7	5	6	1	5	8	4	0	3	9	2	0	4
	Design for Assembly Metrics	41.74		42.3%	←Theor. Eff. Pract. Eff.→		53.8%	0.91		1.09			1.55				1.64				
	Targets	40		60.0%			60.0%	1.00		1.00			1.25				1.50				

Table 9 DFA Analysis for Redesigned System

To see if the redesign improved the assembly process, we performed a DFA analysis again and analyzed the results to check if we met the targets or not (see Table 9). Based on the redesigning, we were able to eliminate 5 components which led to a decrease in the total interfaces from 114 to 67. This removal of 5 components also decreased overall part count from 39 parts to 26 parts, equating to a decrease of 33%. Due to this, the complexity factor also decreased from 66.68 to 41.74. Although we had aimed for a complexity factor of 40, we fell short by a short margin. In comparison to the previous numbers of 28.2% Theoretical part efficiency and 41% Practical part efficiency, we were able to improve the efficiencies to 42.3% theoretical and 53.8% practical part efficiency. We believe that, in order to achieve 60% efficiency, there would require a significant redesign of the whole product, which wasn't possible due to time constraints. We were able to achieve the target error-proofing factor by a considerable amount with previous error-proofing of 1.18 which improved to 0.91. Assembly of the Drive lever assembly was difficult before redesigning, the spring was difficult to hold in place and it provided resistance to insertion. Through redesigning the Drive lever and eliminating the spring, we were able to decrease the insertion factor from 1.82 to 1.55. And finally, by redesigning the housing, we were able to eliminate the reorientation and screwing operations while performing the assembly, this improvement led to a decrease in the secondary operation factor from 2.18 to 1.64.

17. Economic Analysis post Redesign

The same form of cost analysis was conducted but with the redesigned parts incorporated. Overall, the redesign resulted in the removal of 8 screws and 4 parts, and the addition of material to some of the existing parts. Since material is typically not as large of a cost driving factor, it was assumed that the removal of parts would outweigh the addition of material from a cost perspective. See Tables 10-12 below for additional information.

Part Number	002	003	004	005	007	008
Part Name	Blade Lever	Switch Extension	Upper Body Housing	Magnet Locating Pin	Motor Housing/Assembly	Lower Body Housing
Manufacturing Process	Injection Molding	Injection Molding	Injection Molding	Lathe	Wire Bending	Injection Molding
Material	ABS	ABS	ABS	Aluminum	Aluminum	ABS
C_M Material cost [$/unit]	$0.003	$0.137	$0.301	$0.036	$3.125	$0.494
C_L Labor cost [$/unit]	$0.50	$0.50	$1.25	$0.71	$0.83	$1.25
C_T Tooling cost [$/unit]	$0.05	$0.05	$0.05	$0.01	$0.00	$0.05
C_E Equipment cost [$/unit]	$0.100	$0.100	$0.167	$0.009	$0.014	$0.250
C_OH Overhead costs [$/unit]	$1.20	$1.20	$3.00	$1.71	$2.00	$3.00
C_U Unit cost [$/unit]	$1.85	$1.99	$4.77	$2.48	$5.97	$5.04
OME Manufacturing cost [$/unit]	$0.008	$0.411	$0.903	$0.107	$9.375	$1.482
OME Price [$/unit]	$0.025	$1.232	$2.709	$0.321	$28.125	$4.446
xometery.com quote price [$/unit]	$2.11	$2.03	$5.87	$2.74	$3.19	$5.52
P Sales price to break even [$/unit]	$1.05	$1.19	$2.10	$0.80	$4.00	$2.29
Break Even Sales Price (Total)	$24.00					
Unit Build Price	$40.86					
Sale Price	$53.07					
% SAVED per Unit	7.61%					
Profit per Unit	$12.21					
% Profit Increase	40.90%					
Annual Profit	$2,441,396.84					
Net Gain	$672,348.63					

Table 10 Cost Analysis Post Redesign Part 1

Part Number	009	010	011	012	013	014
Part Name	Blade 1	Blade 2	Holder	Comb	Drive Lever Internal	Connector Sheet
Manufacturing Process	Milling	Milling	Stamping, sheet bending	Injection molding	Cast	Stamping, sheet bending
Material	High Carbon Steel	High Carbon Steel	Stainless Steel	ABS	Cast Iron	Stainless Steel
C_M Material cost [$/unit]	$0.190	$0.081	$1.240	$0.130	$0.011	$0.048
C_L Labor cost [$/unit]	$0.71	$0.71	$0.50	$0.42	$0.42	$0.21
C_T Tooling cost [$/unit]	$0.15	$0.15	$0.01	$0.05	$0.00	$0.01
C_E Equipment cost [$/unit]	$0.381	$0.571	$0.100	$0.083	$0.001	$0.003
C_OH Overhead costs [$/unit]	$1.71	$1.71	$1.20	$1.00	$1.00	$0.50
C_U Unit cost [$/unit]	$3.15	$3.23	$3.05	$1.68	$1.43	$0.76
OME Manufacturing cost [$/unit]	$0.571	$0.243	$3.720	$0.390	$0.034	$0.144
OME Price [$/unit]	$1.713	$0.729	$11.160	$1.170	$0.102	$0.432
xometery.com quote price [$/unit]	$6.32	$6.06	$10.00	$2.08	$1.00	$8.36
P Sales price to break even [$/unit]	$3.05	$2.95	$2.25	$1.10	$0.44	$0.28
Break Even Sales Price (Total)						

Table 11 Cost Analysis Post Redesign Part 2

Part Number	015	016	017	019
Part Name	Drive Lever	Magnet	Brass Bushing	Screws
Manufacturing Process	Injection Molding	Powder metallurgy	COTS	COTS
Material	ABS	Ferromagnet	Brass	stainless steel
C_M Material cost [$/unit]	$0.142	$0.250	COTS	COTS
C_L Labor cost [$/unit]	$0.33	$0.50	COTS	COTS
C_T Tooling cost [$/unit]	$0.05	$0.01	COTS	COTS
C_E Equipment cost [$/unit]	$0.067	$0.010	COTS	COTS
C_OH Overhead costs [$/unit]	$0.80	$1.20	COTS	COTS
C_U Unit cost [$/unit]	$1.39	$1.97	$0.38	$0.06
OME Manufacturing cost [$/unit]	$0.425	$0.750	COTS	COTS
OME Price [$/unit]	$1.275	$2.250	COTS	COTS
xometery.com quote price [$/unit]	$1.89	$3.76	COTS	COTS
P Sales price to break even [$/unit]	$1.03	$0.81	$0.380	$ 0.06
Break Even Sales Price (Total)				

Table 12 Cost Analysis Post Redesign Part 3

Reviewing the data from the redesigns as a whole indicates very measurable cost savings. Table 8 above shows that annual profit would increase to $2.44 million dollars due to the fact that the overall cost of the part decreased by $3.36. This equates to an annual increase of $672,348.63 in profit. It is important to note that these design modifications would necessitate the creation of new molds for the affected parts 004 - Upper Housing, 008 - Lower Housing, and 015 - Drive Lever, which would decrease profit by $300,000 for the first year. However, for each successive year, since molds are replaced annually, the profit would be back to $672K in value.

18. Human Factors, Safety and Ethical Considerations

The proposed design changes for the hair clippers play a significant role in human factors, safety and ethical considerations along with streamlining the assembly process. The redesigning of the drive lever directly benefits its assembly by reducing the number of components to assemble thus resulting in simplification of assembly and reducing the strain on the assembly workers. The Redesign 3 also plays a significant role in the human factors by simplifying the assembly process for the workers and users will benefit from it as it will make the device more accessible for repair, maintenance and cleaning. Although the team did not redesign the blades, the device had already been designed considering the safety factors. The blades are designed sophisticatedly to minimize the possibility of cuts and nicks. Adjustable blade settings also play an important role in protecting the skin from cuts. Since these hair clippers are a plug-in use device, the hair clippers comply with the safety standards to prevent electrical hazards, the safety instructions are provided in the user manual of the product. These safety factors can be taken into account while marketing the product. With the redesigning, we eliminated components that eventually reduced material use and in turn reduced the waste, this could contribute (though with limited effect) to environmental ethics.

19. Conclusion

In conclusion, the reverse engineering of Oster Fast Feed Hair Clippers led to significant design improvements that enhanced the overall assembly process and decreased costs, while maintaining system performance and functionality. By integrating our first design change, a significant system sub-assembly was simplified and an operation that required precise locating requirements was entirely removed, resulting in decreased assembly time as well as decreased cost. The second design change removed parts that were ultimately functionless, thereby minimizing production time and decreasing system cost. The final design change incorporated snap fit components into the main housing of the product which removed multiple screws, thus decreasing assembly time and secondary operations, while providing cost savings. While our redesign efforts did not result in the achievement of all of our DFA analysis goals, it met a number of them and bettered the product in a noteworthy fashion that would ultimately increase the profitability of the Oster Fast Feed Hair Clipper, while resulting in a higher quality product.

20. Appendix A - BOM and Disassembly Steps

Product Decomposition

Design Organization: Group 6 | **Date: 03/06/2024**

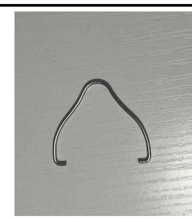
Product Decomposed: Hair Clipper

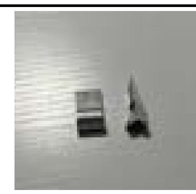
Description: This is an Oster Fast Feed Adjustable Pivot Motor Clipper.

How it works: When the power cord is connected to an AC supply of 120V and 60Hz, the winding in the motor assembly creates a change in the magnetic field, this change in the magnetic field causes the magnet in the drive lever assembly to vibrate at the desired frequency, which in turn oscillates the blade 2 which cause the cutting action.

Parts:

Part #	Part Name	# Req'd	Material	Mfg Process	Image
001	Fast Feed Plate	1	Aluminium 24GA	Metal Stamping	
002	Blade Lever	1	ABS	Injection Molding	
003	Switch Extension	1	ABS	Injection Molding	

004	Upper Body Housing	1	ABS	Injection Molding	
Part #	Part Name	# Req'd	Material	Mfg Process	Image
005	Magnet Locating Pin	1	Aluminum	Turning	
006	Holding Clip	1	Stainless steel	Wire Bending	
007	Motor Housing	1	Aluminum	Wire Bending	
008	Lower Body Housing	1	ABS	Injection Molding	

009	Blade 1	1	High Carbon Steel	Milling	
010	Blade 2	1	High Carbon Steel	Milling	
011	Holder	1	Stainless Steel	Stamping, Sheet bending	
Part #	Part Name	# Req'd	Material	Mfg Process	Image
012	Comb	1	ABS	Injection Molding	
013	Drive Lever Internal Part	2	Cast Iron	Casting	
014	Connector Sheet	1	Stainless Steel	Stamping,Sheet Bending	
015	Drive Lever	1	ABS	Injection Molding	

016	Magnet	1	Ferromagnet	Powder Metallurgy	
017	Brass Bushing	1	Brass	Turning	
018	Spring	2	Stainless Steel	Spring Winding	
019	Power Cord	1	Copper, Rubber		
020	Insert for Connector Sheet	2	Brass	Turning	

Disassembly:

Step #	Procedure	Part #s removed	Image
1	Take Off Comb	012	
2	Take off Blade 1, Remove blade lever	104,009	
3	Slide off Holder and Take off Blade 2	011,010	

Step #	Procedure	Part #s removed	Image
4	Take off Connector Sheet	103,014	
5	Take off Fast Feed Plate	101,001	
6	Remove Upper Body Housing and holding clip	102,004,006	

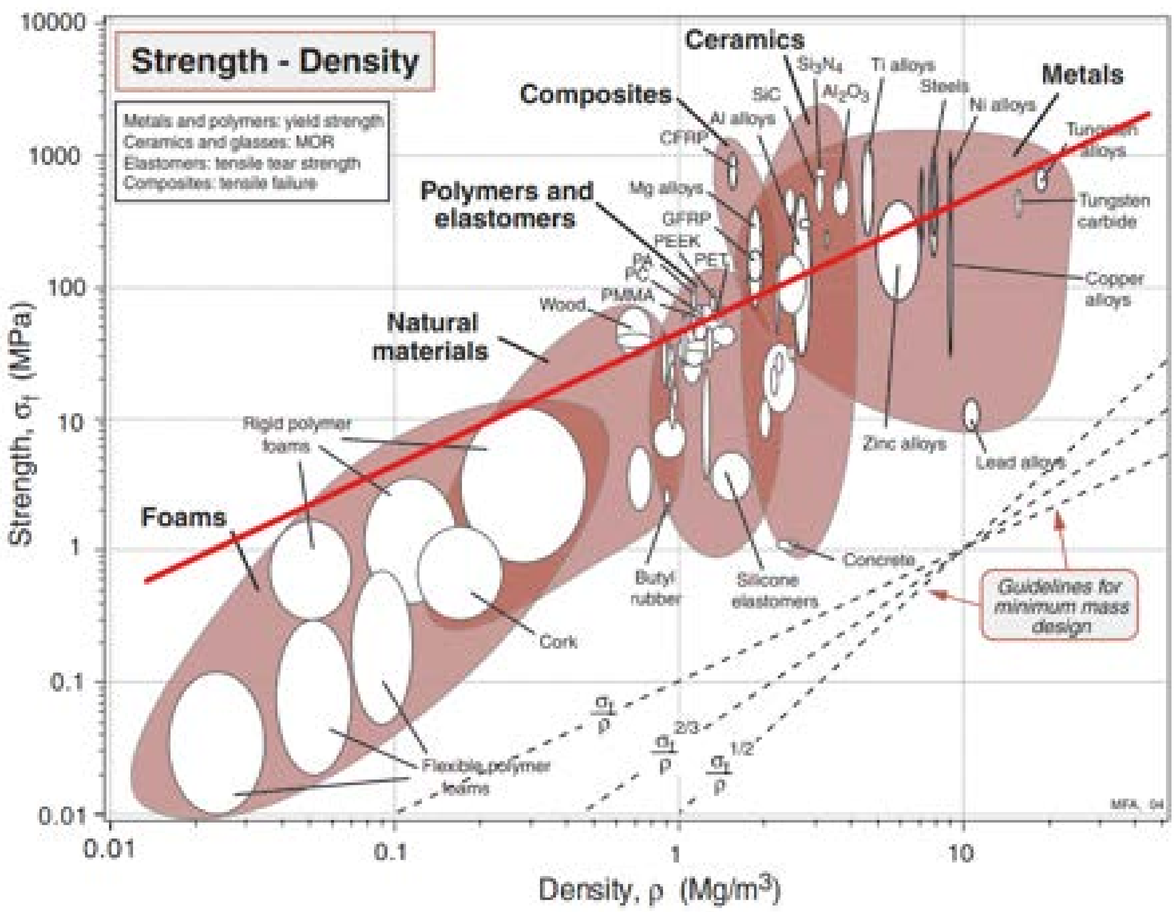
Step #	Procedure	Part #s removed	Image
7	Take off Switch Extension	003	
8	Remove Motor Housing	102,007	

9	Remove Drive Lever Subassembly		
Step #	Procedure	Part #s removed	Image
10	Remove Spring, Magnet, Drive lever internal part and Brass Bushing	018,016,013, 017	

21. Appendix B - Material Selection

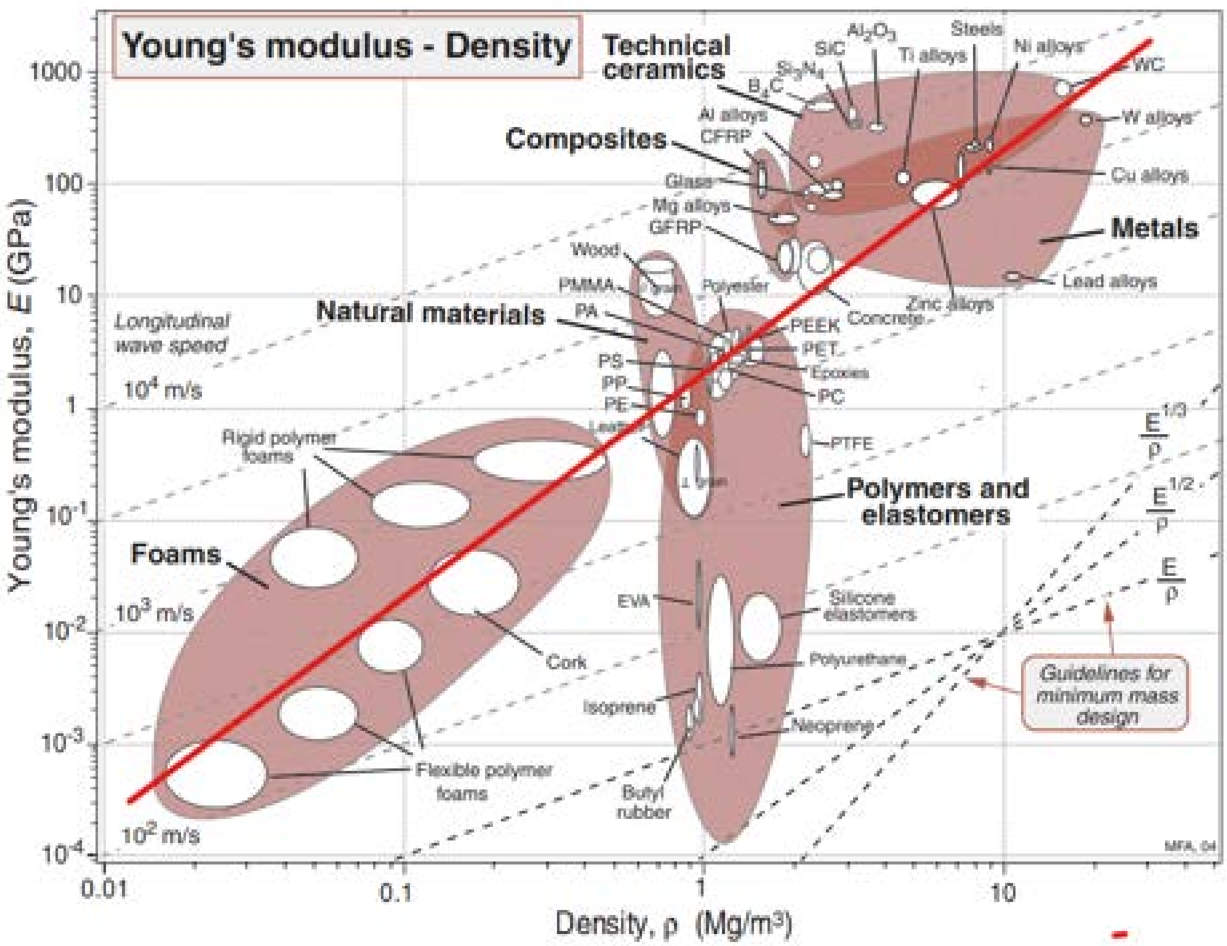
Switch Extension - Part No. 003

The switch extension requires a high level of strength to ensure that it can withstand the repeated tensile and compressive loading conditions that it will be subjected to during operation. When the switch is pressed upward, the arm is in tension, whereas when pushed downward, the arm is in compression. Analyzing this as a bar in tension, where the switch is made out of ABS, an Ashby chart which compares yield strength to density would provide a comparable material. The objective is to keep this light as possible but having enough strength. Lighter material would include some natural materials and polymers. PLA was our selected material because it lies close to ABS on the Ashby chart and is both strong and stiff. PLA is used often in injection molding as well as 3D printing and has desirable properties such as quick biodegradability and a raw vegetable material source.



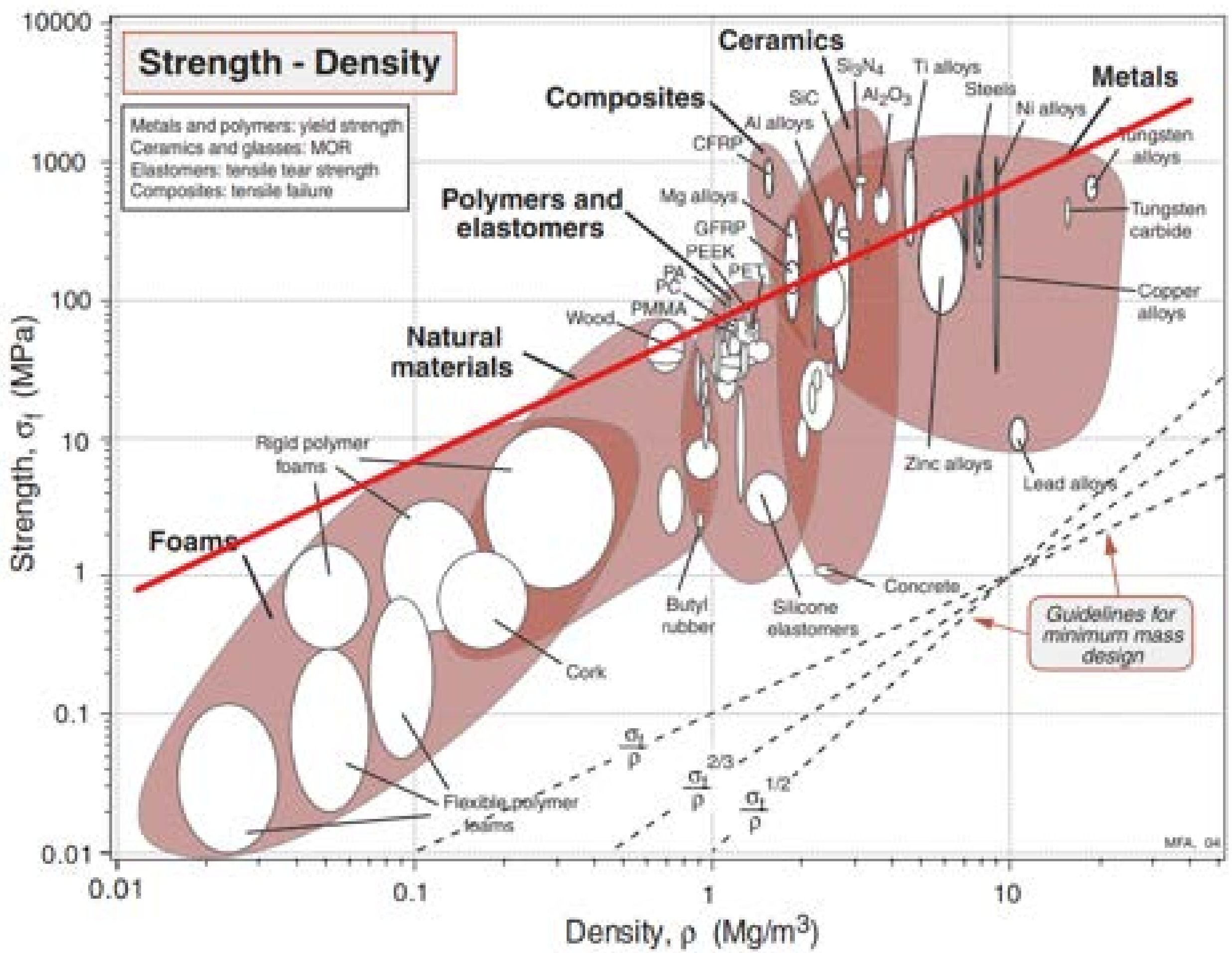
Blade Lever - Part No. 002

The blade lever requires great stiffness to ensure that it can withstand the repeated bending conditions that it will be subjected to during operation. It rotates about a screw in either direction, placing the majority of its loading conditions in bending. It is made out of ABS, which is a stiff and strong plastic, so by analyzing an Ashby chart which compares Young's modulus to density, we can find a comparable material. Objective being less weight and resisting wear at the point of mounting, PET was our selected material because it lies close to ABS on the Ashby chart and is both strong and stiff. It is widely available, easily machinable, and will be able to meet material requirements.



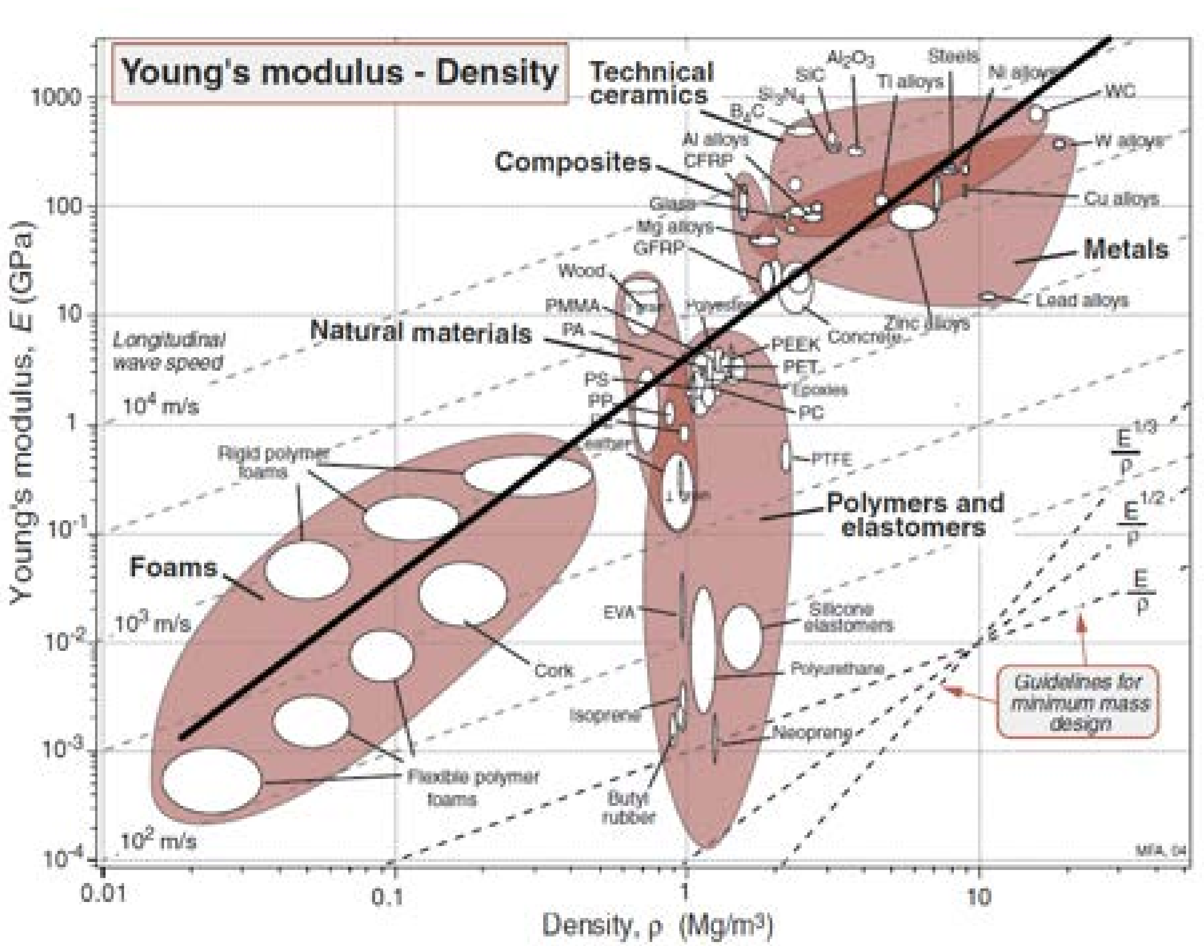
Holding Clip - Part No. - 006

The holding clip is a part which is made from 6063 aluminum and has the function of holding the mass of the clippers when they are suspended from the clip. Thus, when in use, the part can be treated as a bar in tension. When analyzing the strength of the part vs its density on an Ashby chart, stainless steel is an option for a material that is stronger than 6063 Al while still maintaining a similar ratio. 304 Stainless steel would be a good option because of its relatively inexpensive nature and that it can be easily extruded. Al would potentially be more inexpensive to manufacture, but 304 stainless would increase the overall life cycle of the part.



Blade - Part No. 009

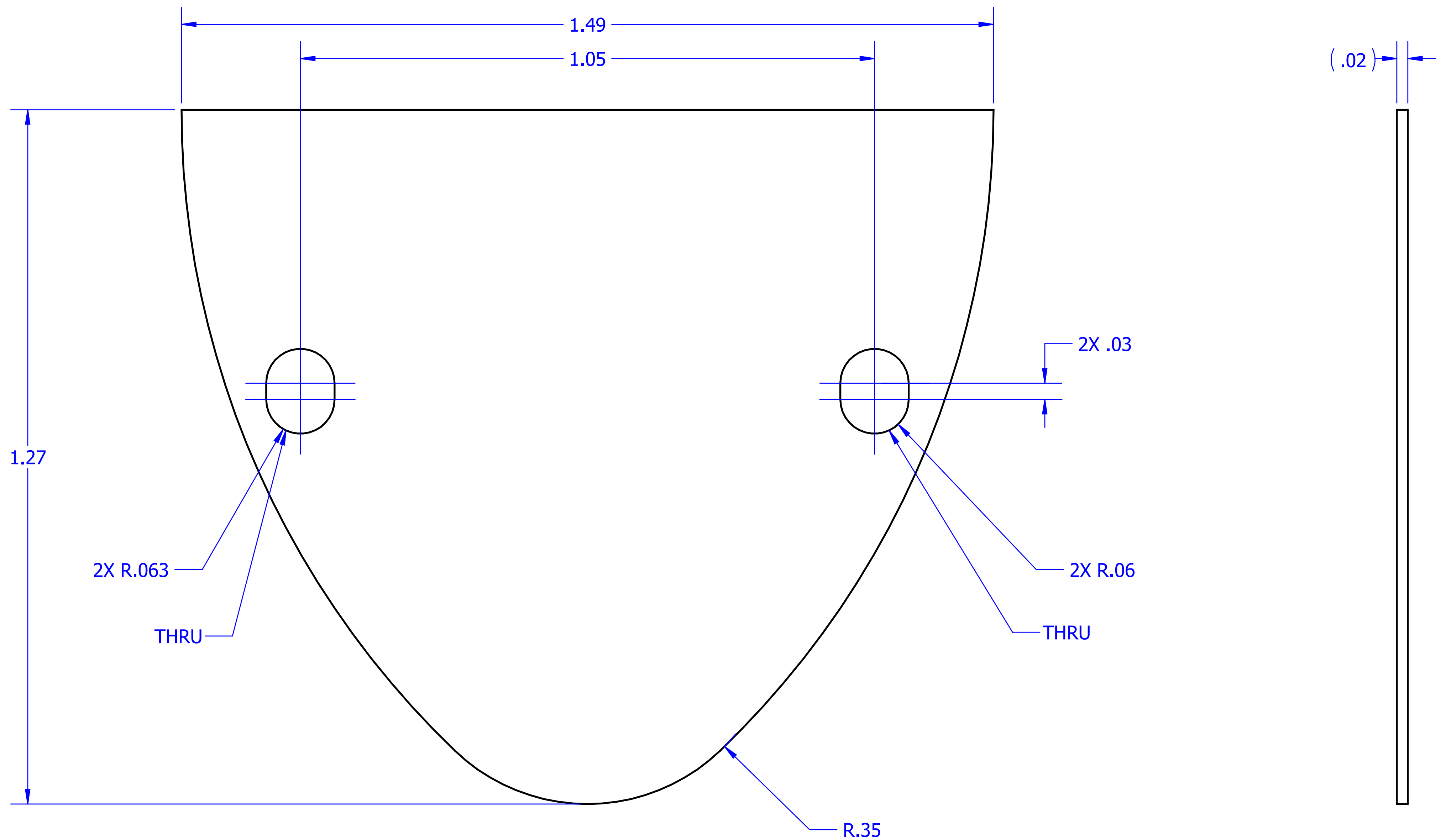
Even though the blade is a plate, its teeth can be considered as a beam. During cutting action, there is a force on the teeth that causes it to go into bending. Looking at the Ashby chart we notice ceramics are the closest option for a blade. Ceramic blades are one of the hardest materials available, however one disadvantage to ceramic blades is that they are brittle, which means they chip or break more easily than stainless-steel blades. Hence stainless steel being ductile and hard does not chip and seems like the most appropriate material.



22. Appendix C - Individual drawings and Assembly Drawing with BOM

Refer drawings below.

REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	1/30/2024



TOLERANCES UNLESS NOTED: UNITS: INCHES	X.X ± .050 X.XX ± .010 X.XXX ± .005 X.X° 1°	UNIVERSITY OF COLORADO BEN ERICKSON 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427	
MATERIAL ALUMINUM 24GA		DESCRIPTION FAST FEED PLATE	
FINISH NONE		PN 001	REV A
			SHEET 1 of 1

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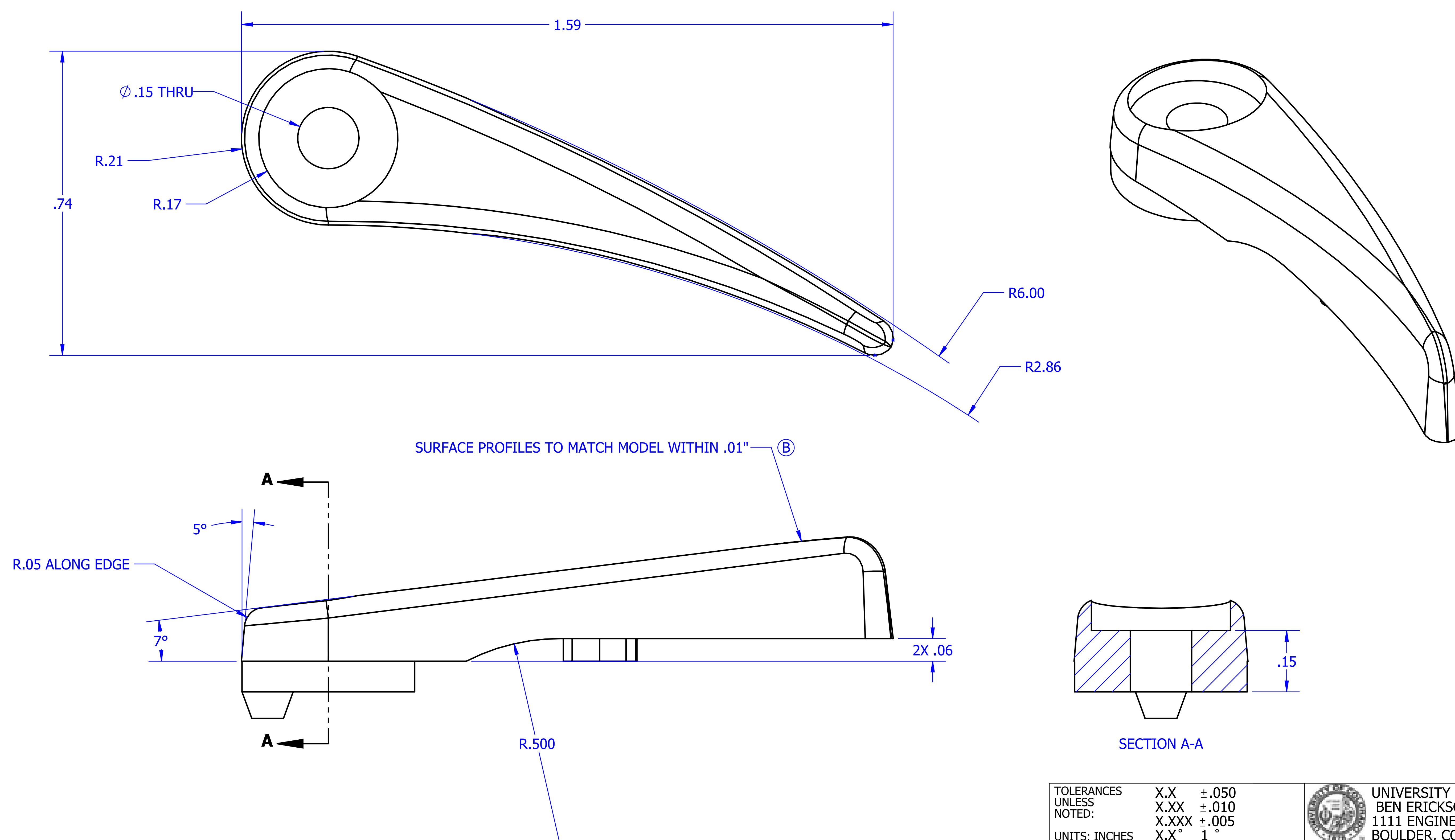
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	2/1/2024
B	MODEL REFERENCE FOR CURVED GEOMETRY	3/7/2024



TOLERANCES UNLESS NOTED:	X.X ±.050 X.XX ±.010 X.XXX ±.005 X.X° 1°	UNIVERSITY OF COLORADO BEN ERICKSON 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427
UNITS: INCHES		
MATERIAL ABS		DESCRIPTION BLADE LEVER
FINISH NONE		PN 002 · REV B · SHEET 1 of 2

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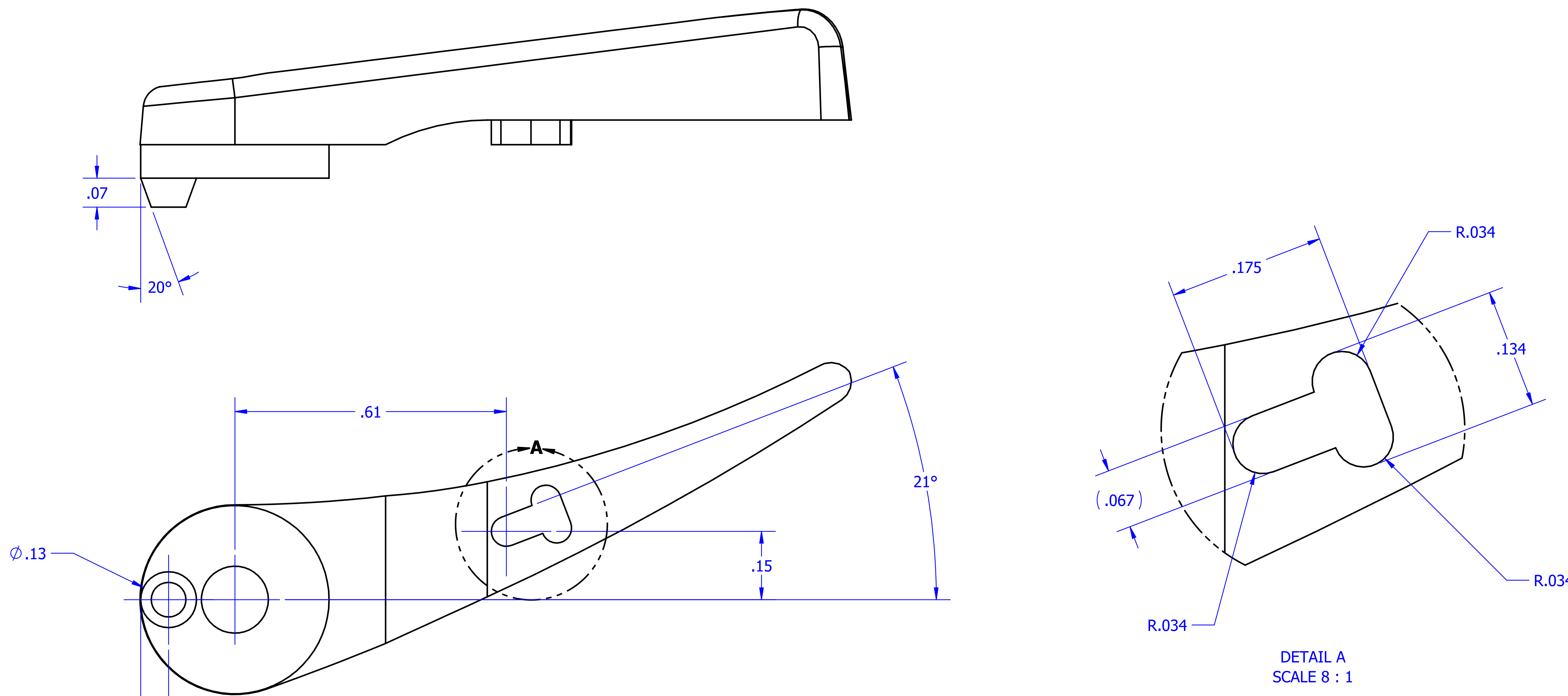

DETAIL A
SCALE 8 : 1

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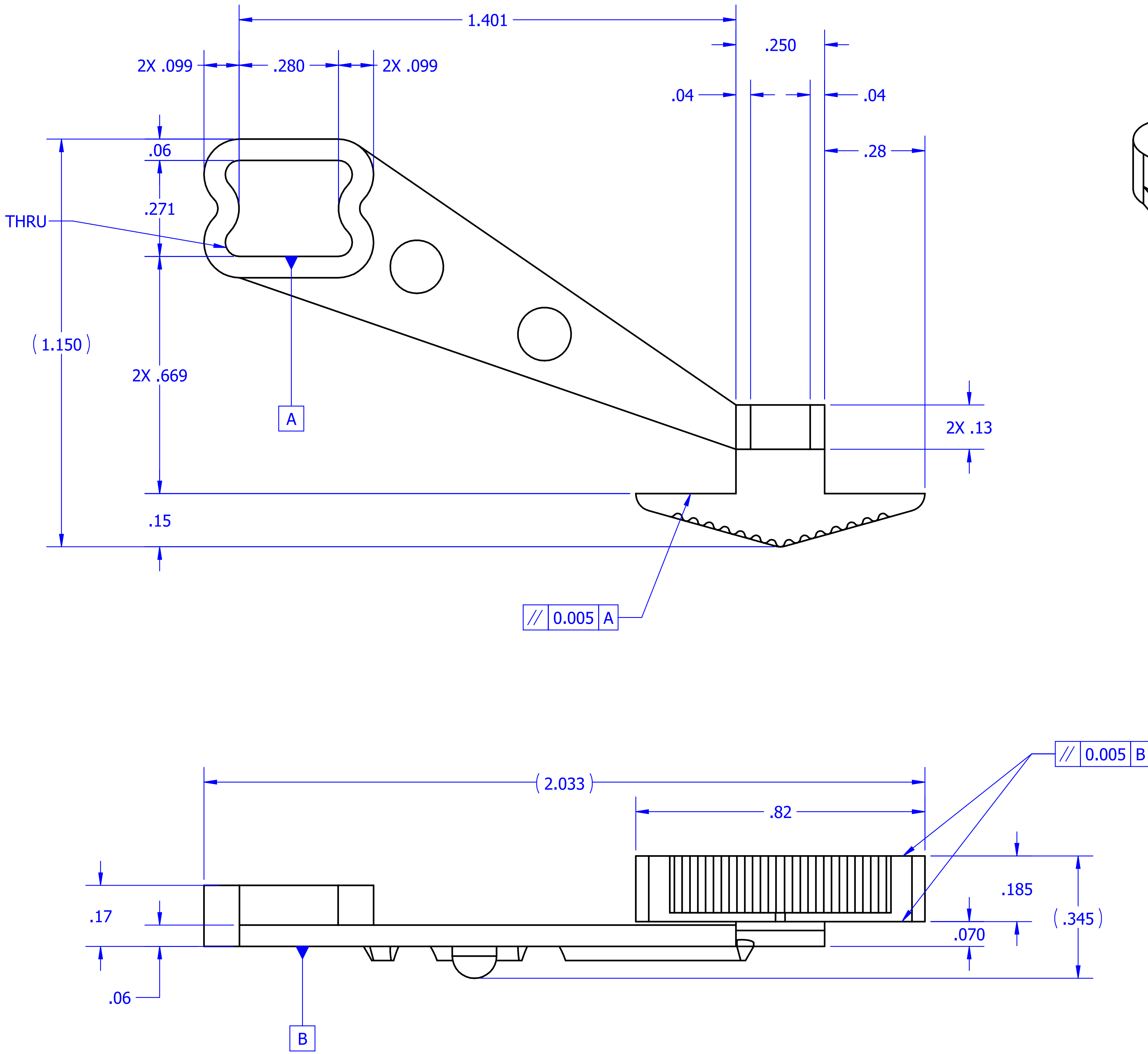
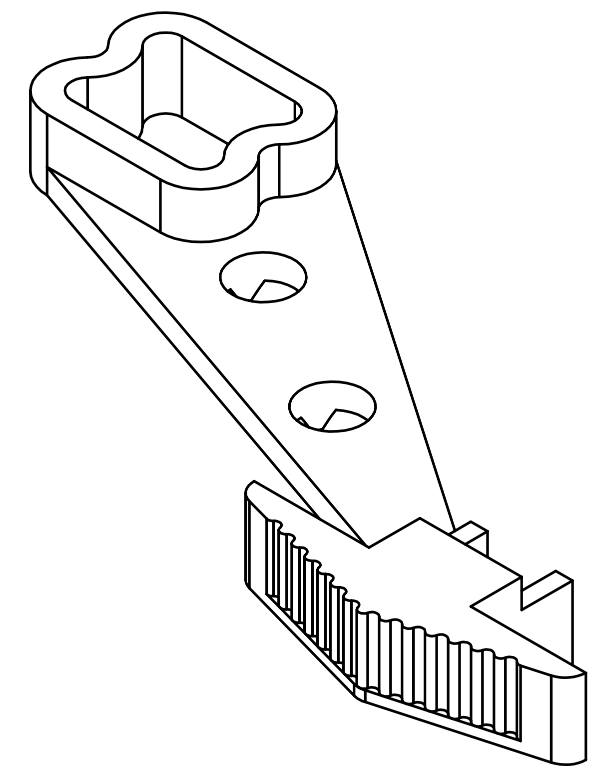
DESCRIPTION		
BLADE LEVER		
PN 002	REV B	SHEET 2 of 2

REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	2/6/2024
B	GD&T ADDED	2/8/2024





TOLERANCES UNLESS NOTED:
X.X ±.050
X.XX ±.010
X.XXX ±.005
X.X° 1°
UNITS: INCHES

UNIVERSITY OF COLORADO
BEN ERICKSON
1111 ENGINEERING DRIVE
BOULDER, CO 80309-0427

MATERIAL
ABS

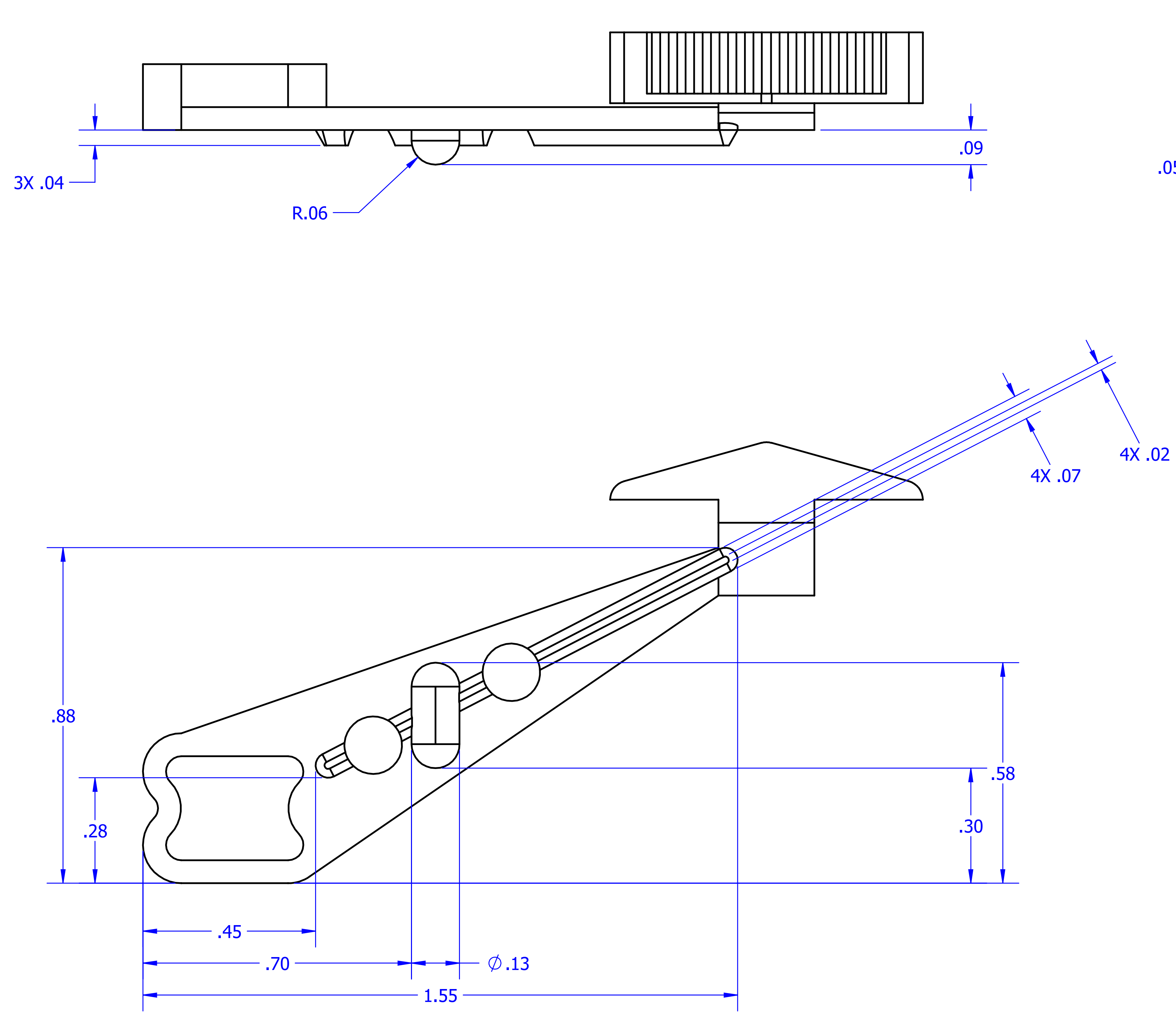
DESCRIPTION
SWITCH EXTENSION

FINISH
NONE

PN
003

REV
B

SHEET
1 of 3



TOLERANCES UNLESS NOTED:	X.X ±.050 X.XX ±.010 X.XXX ±.005 X.X° 1°	UNIVERSITY OF COLORADO BEN ERICKSON 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427	
UNITS: INCHES			
MATERIAL ABS		DESCRIPTION SWITCH EXTENSION	
FINISH NONE		PN 003	REV B
			SHEET 2 of 3

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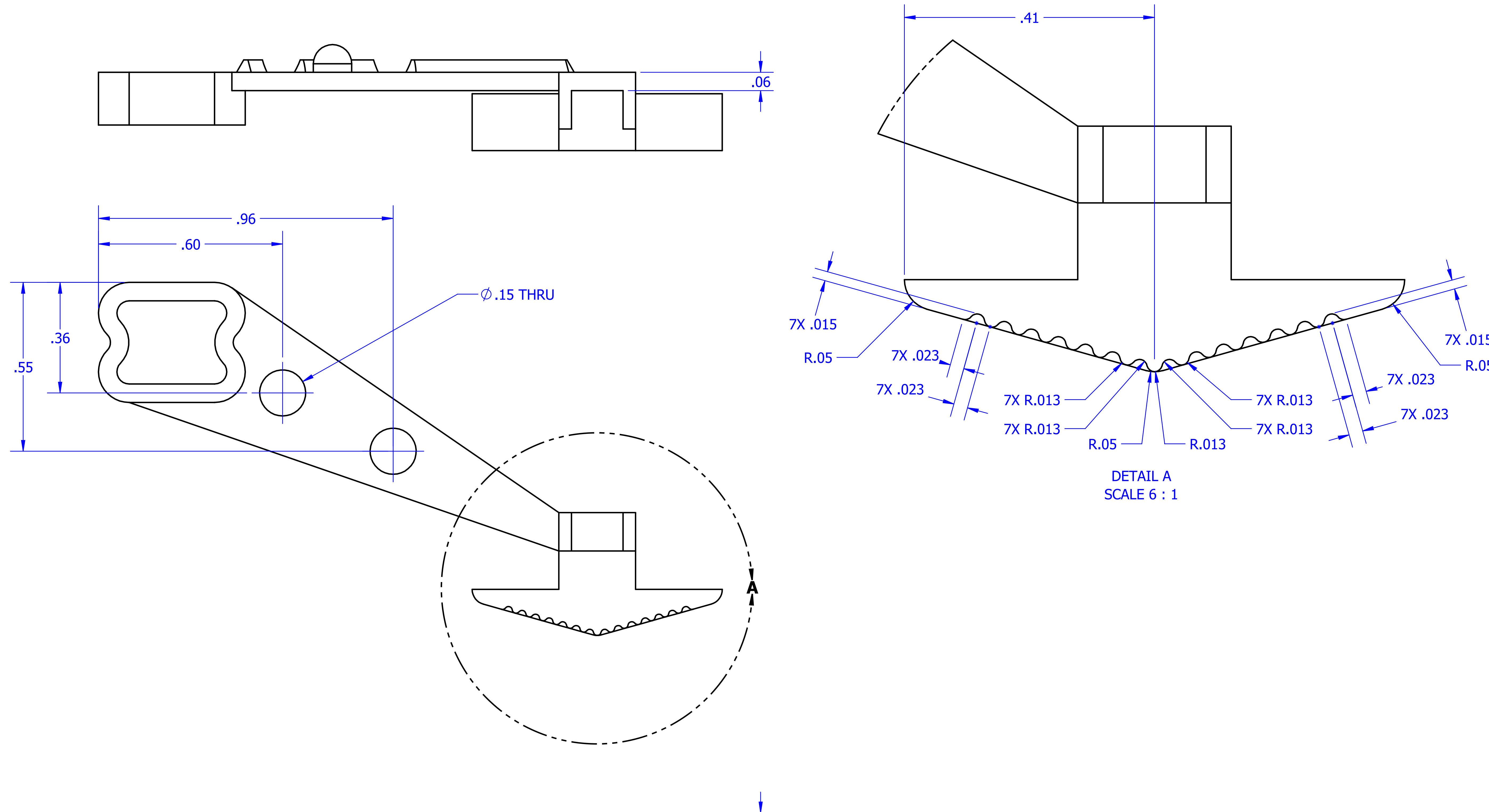

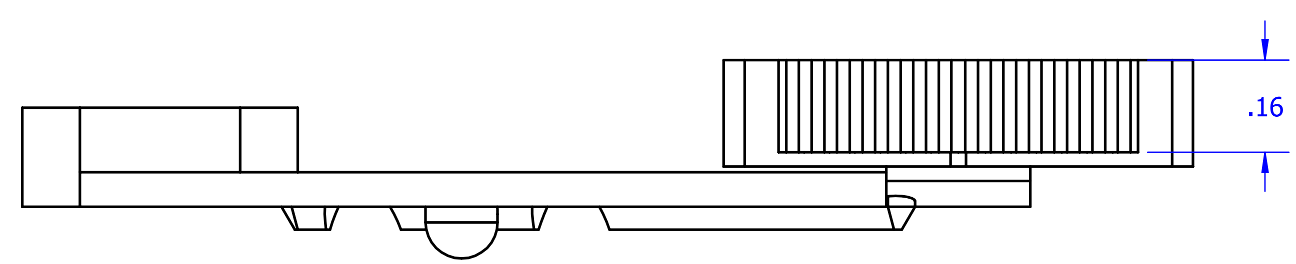

TOLERANCES UNLESS NOTED:	X.X ±.050 X.XX ±.010 X.XXX ±.005 X.X° 1°	UNIVERSITY OF COLORADO BEN ERICKSON 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427	
UNITS: INCHES			
MATERIAL ABS		DESCRIPTION SWITCH EXTENSION	
FINISH NONE		PN 003	REV B
			SHEET 3 of 3

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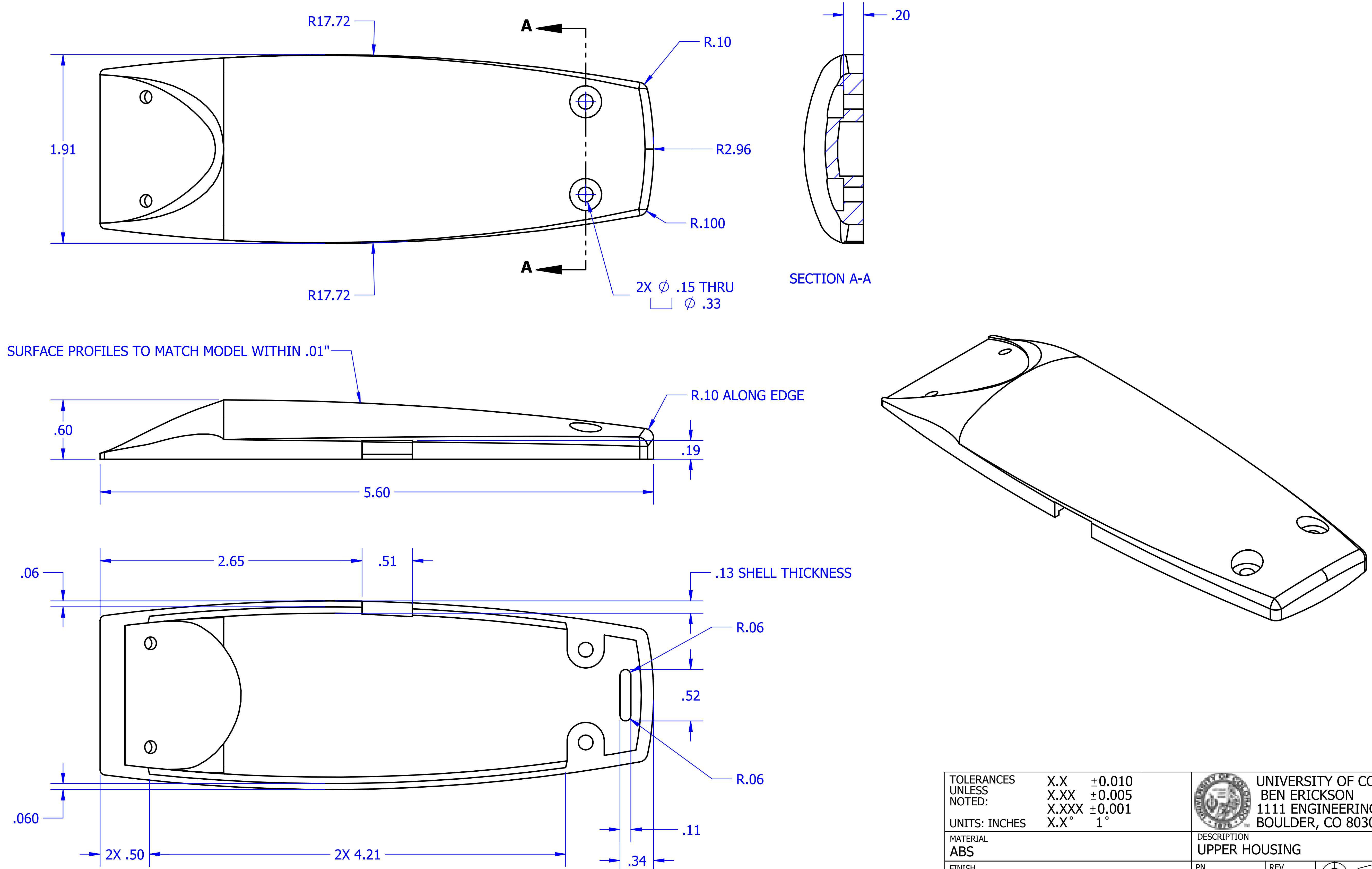
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	3/7/2024



TOLERANCES UNLESS NOTED: X.X ±0.010; X.XX ±0.005; X.XXX ±0.001; X.X° 1° UNITS: INCHES		UNIVERSITY OF COLORADO BEN ERICKSON 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427
MATERIAL ABS		DESCRIPTION UPPER HOUSING
FINISH NONE	PN 004	REV A	SHEET 1 of 2

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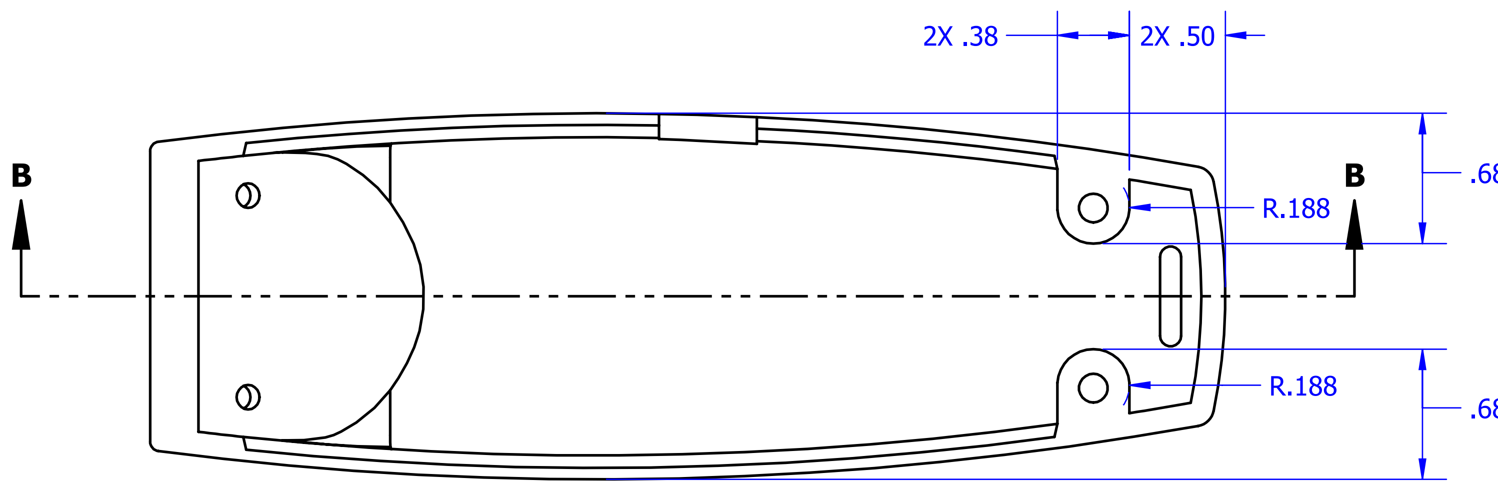
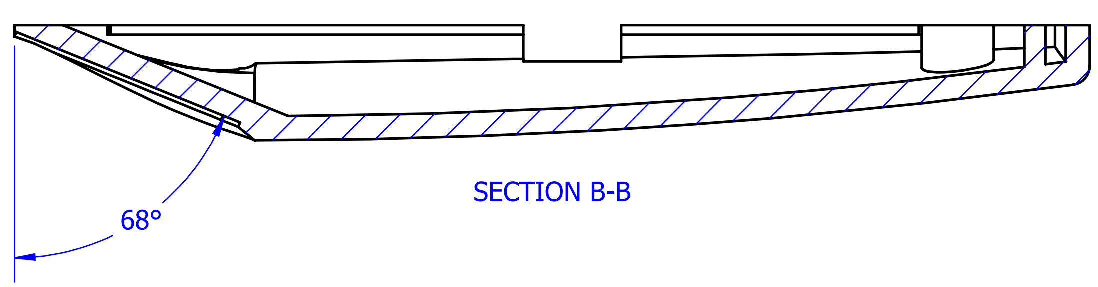
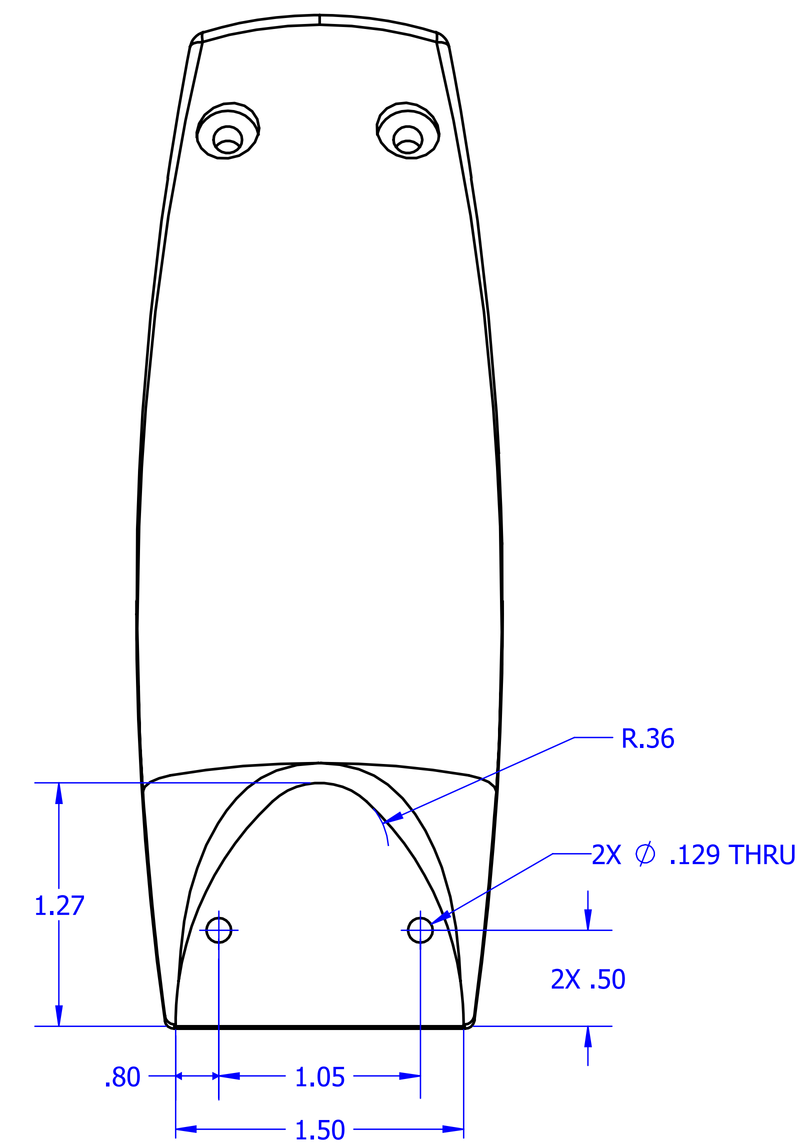




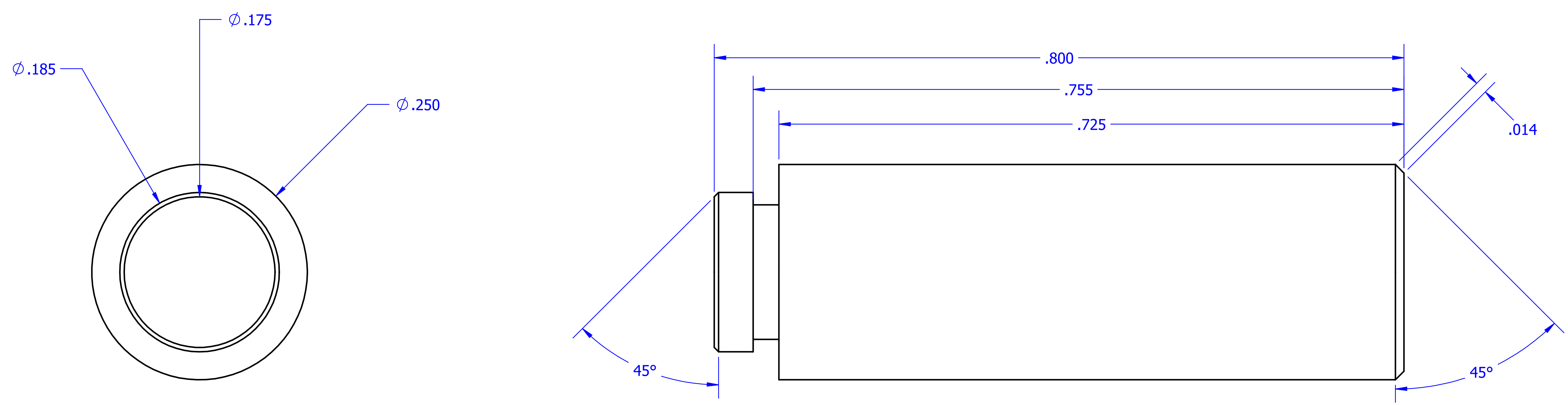
SECTION B-B



68 DEGREE ANGLED OFFSET VIEW

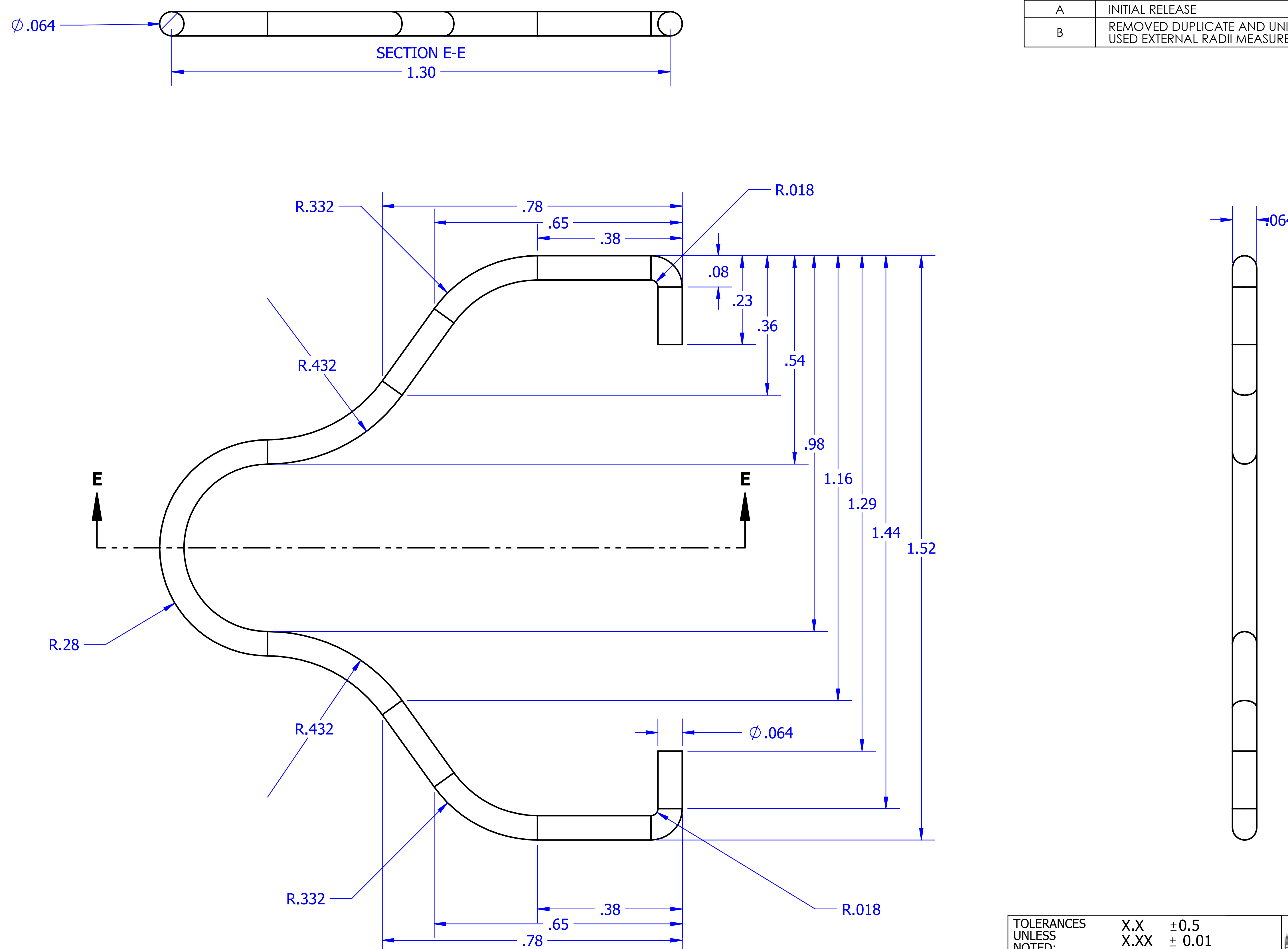
TOLERANCES UNLESS NOTED: X.X ±0.010, X.XX ±0.005, X.XXX ±0.001, X.X° 1°; UNITS: INCHES		UNIVERSITY OF COLORADO BEN ERICKSON 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427	
MATERIAL ABS		DESCRIPTION UPPER HOUSING	
FINISH NONE		PN 004	REV A
SHEET 2 of 2			

REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	1/30/2024
B	ROTATE VIEWS 90 DEG AND INCREASE SCALE	3/7/2024



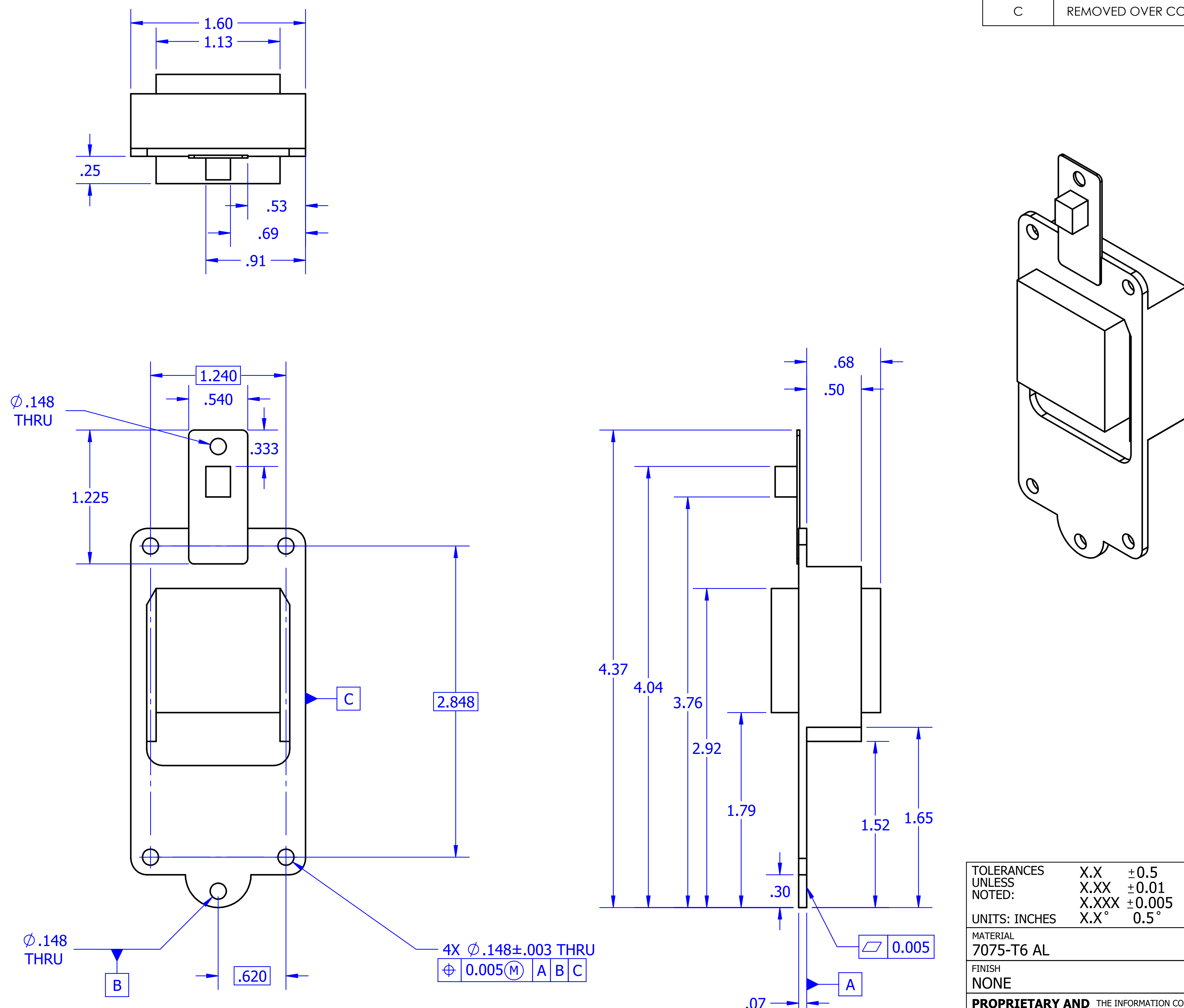
TOLERANCES UNLESS NOTED: X.X ± 0.5; X.XX ± 0.01; X.XXX ± 0.005; X.X° 0.5°; UNITS: INCHES	UNIVERSITY OF COLORADO LUKE SANFORD 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427	
MATERIAL: 316 STAINLESS STEEL	DESCRIPTION: MAGNET LOCATING PIN	
FINISH: N/A	PN: 005	REV: B; SHEET: 1 of 1

REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	2/1/2024
B	REMOVED DUPLICATE AND UNINSPECTABLE DIMS; USED EXTERNAL RADII MEASUREMENTS ONLY	3/7/2024



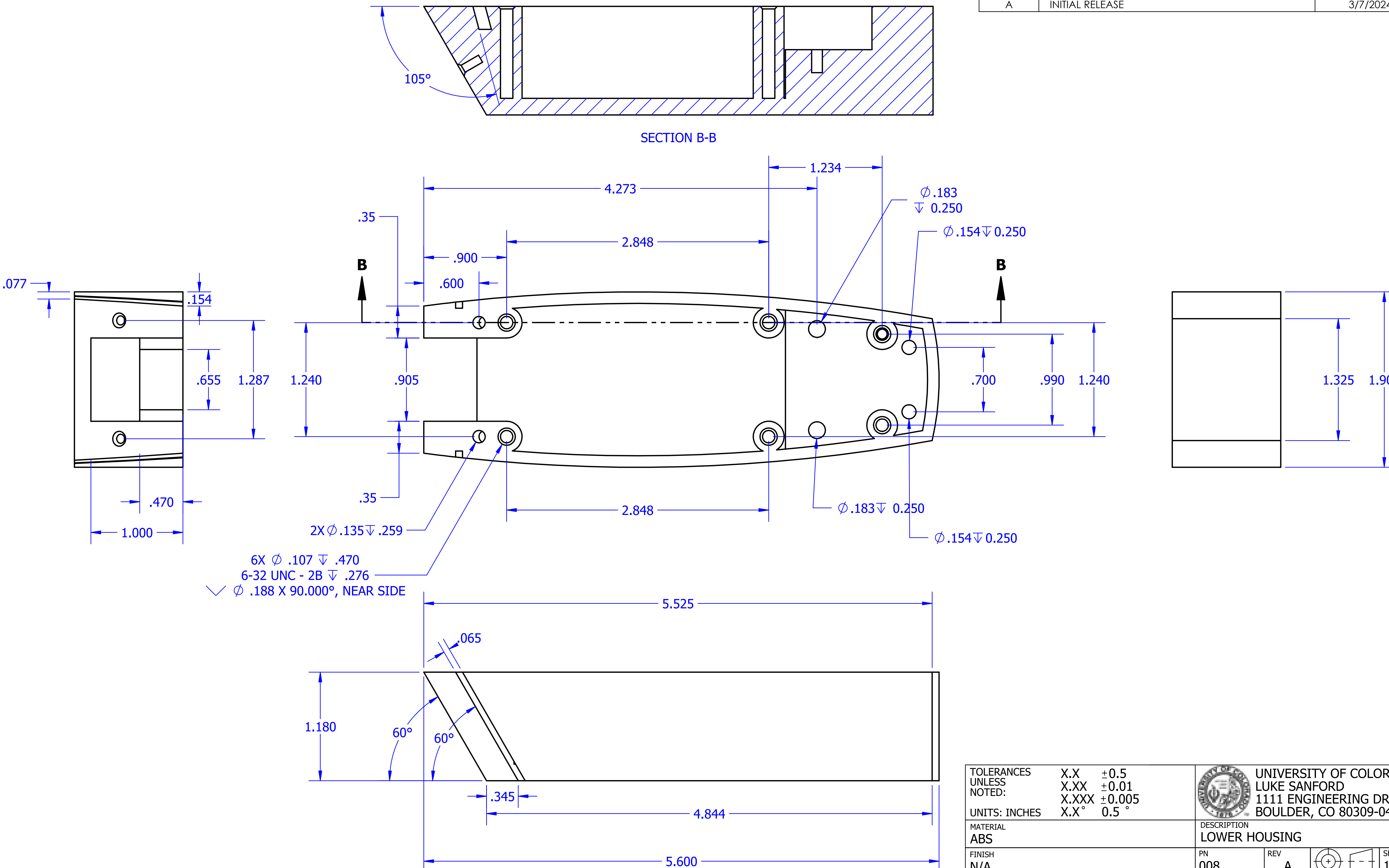
TOLERANCES UNLESS NOTED:	X.X ±0.5 X.XX ± 0.01 X.XXX ± 0.005 X.X° 0.5°	UNIVERSITY OF COLORADO LUKE SANFORD 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427
UNITS: INCHES		
MATERIAL 6063 AL		DESCRIPTION HOLDING CLIP
FINISH NONE		PN 006 · REV B · SHEET 1 of 1

REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	2/6/2024
B	ADDED DATUMS, POSITION, AND FLATNESS CALLOUTS	2/8/2024
C	REMOVED OVER CONSTRAINING DIMENSIONS	3/7/2024

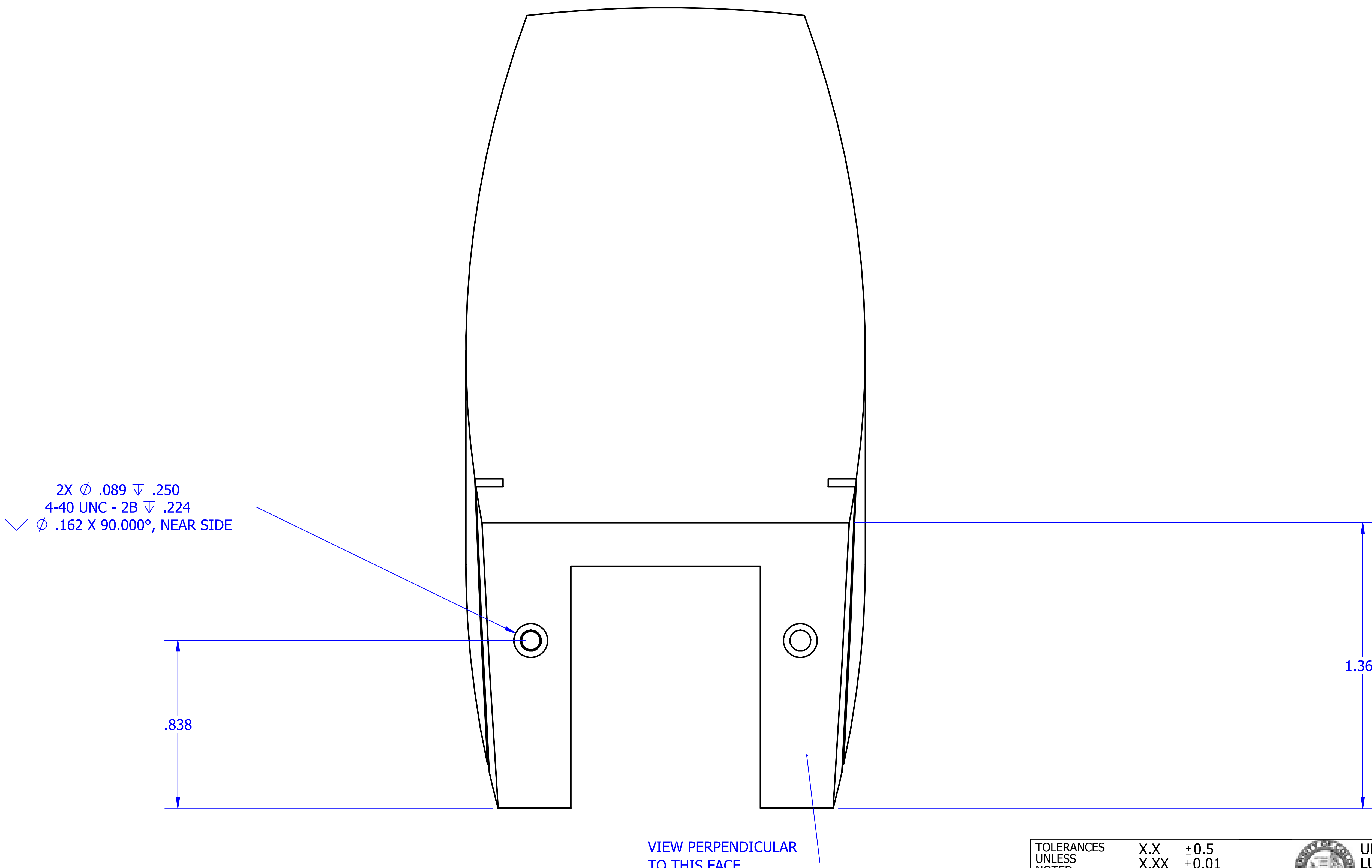


TOLERANCES UNLESS NOTED: UNITS: INCHES	X.X ±0.5 X.XX ±0.01 X.XXX ±0.005 X.X° 0.5°	UNIVERSITY OF COLORADO LUKE SANFORD 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427	
MATERIAL 7075-T6 AL		DESCRIPTION MOTOR MOUNT, ASM	
FINISH NONE		PN 007	REV C
			SHEET 1 of 1

REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	3/7/2024

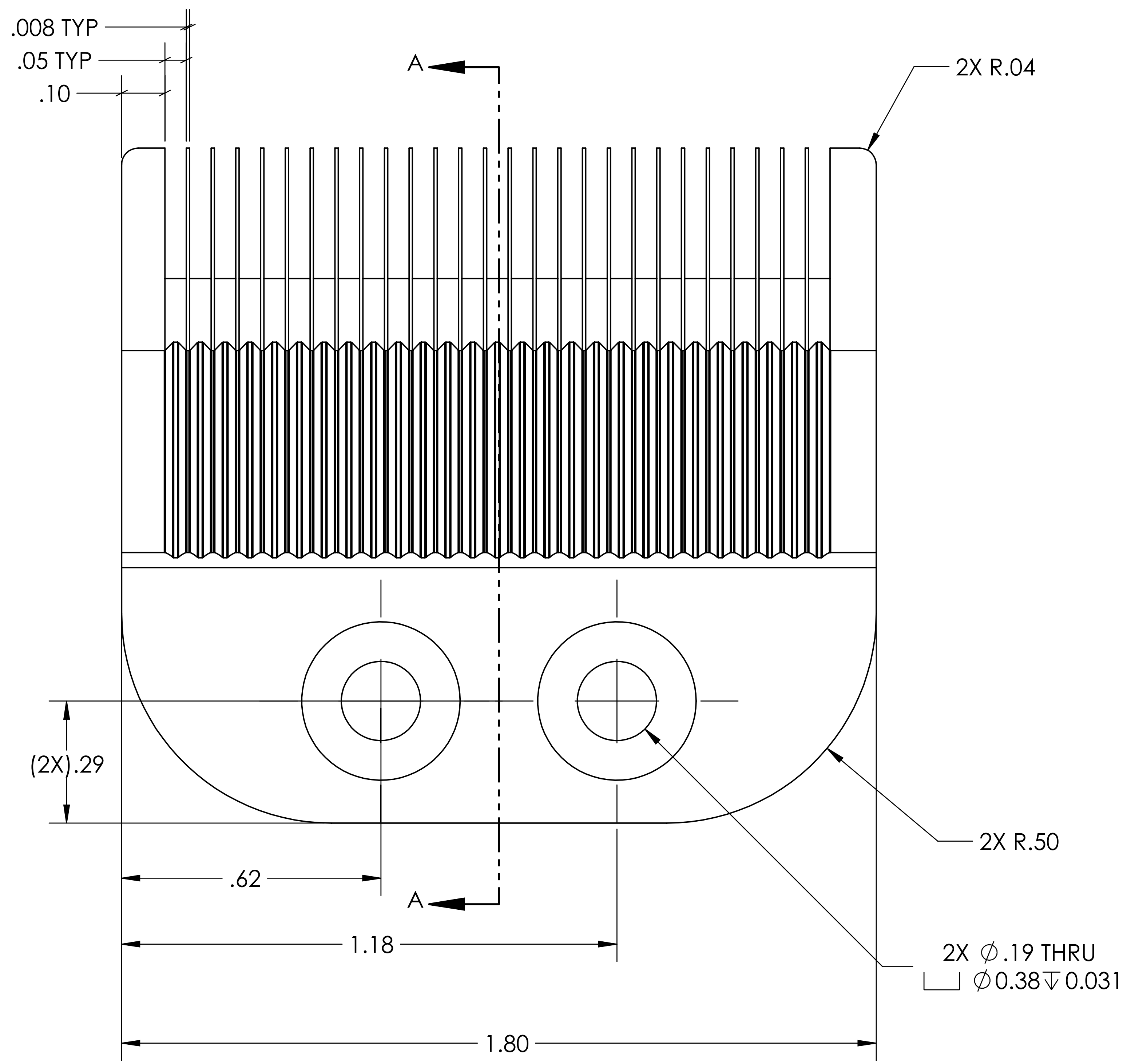


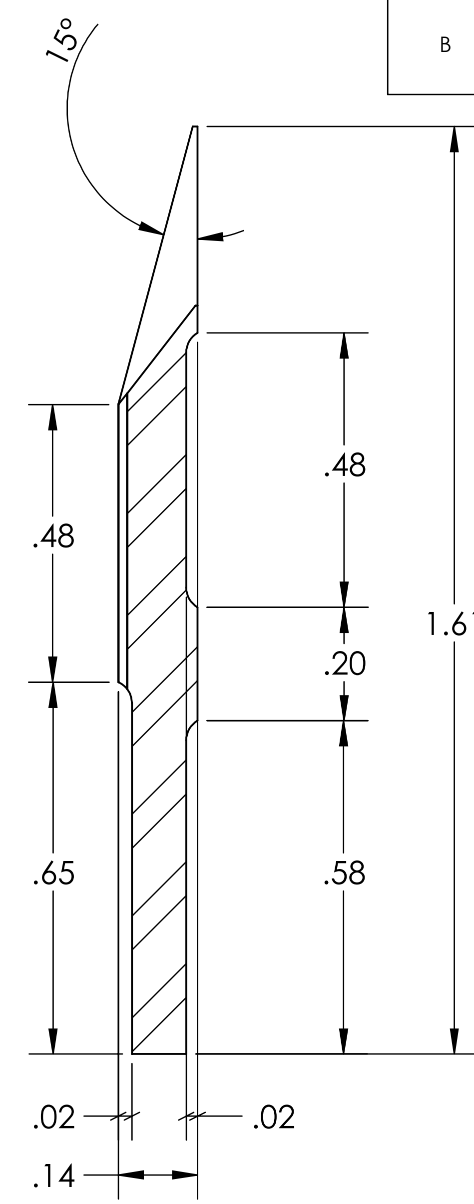
TOLERANCES UNLESS NOTED:	X.X ±0.5 X.XX ±0.01 X.XXX ±0.005 X.X° 0.5 °		UNIVERSITY OF COLORADO LUKE SANFORD 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427
UNITS: INCHES			
MATERIAL ABS		DESCRIPTION LOWER HOUSING	
FINISH N/A	PN 008	REV A	SHEET 1 of 2



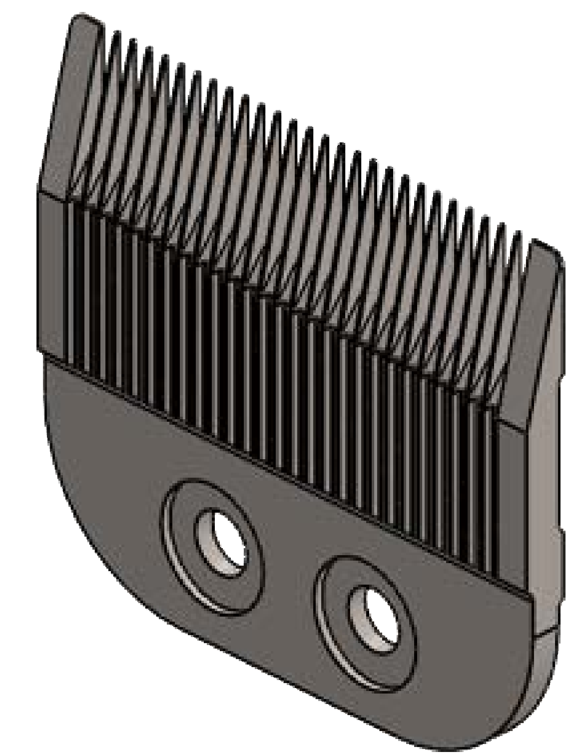
TOLERANCES UNLESS NOTED: UNITS: INCHES	X.X ±0.5 X.XX ±0.01 X.XXX ±0.005 X.X° 0.5 °	UNIVERSITY OF COLORADO LUKE SANFORD 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427		
MATERIAL ABS		DESCRIPTION LOWER HOUSING		
FINISH N/A		PN 008	REV A	SHEET 2 of 2

REVISIONS		
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	1/30/2024
B	ADDED DIMENSIONS, CORRECTION DONE BASED ON COMMENTS	3/5/2024





SECTION A-A



ISOMETRIC VIEW
SCALE: 2:1

NOTES:
1. 26 BLADE CUTS USING GIVEN DIMENSION.
2. UNLESS OTHERWISE SPECIFIED SCALE 3:1
3. REMOVE ALL BURRS
4. REMOVE ALL SHARP EDGES EXCEPT BLADE CUTS.

TOLERANCES UNLESS NOTED: X.X ±0.05; X.XX ±0.01; X.XXX ±0.005; X.X° °0.5 — UNITS: INCHES		UNIVERSITY OF COLORADO MCEN 5045 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427	
MATERIAL HIGH CARBON STEEL		DESCRIPTION BLADE 1	
FINISH GLOSSY	PN 009	REV B	SHEET 1 of 1

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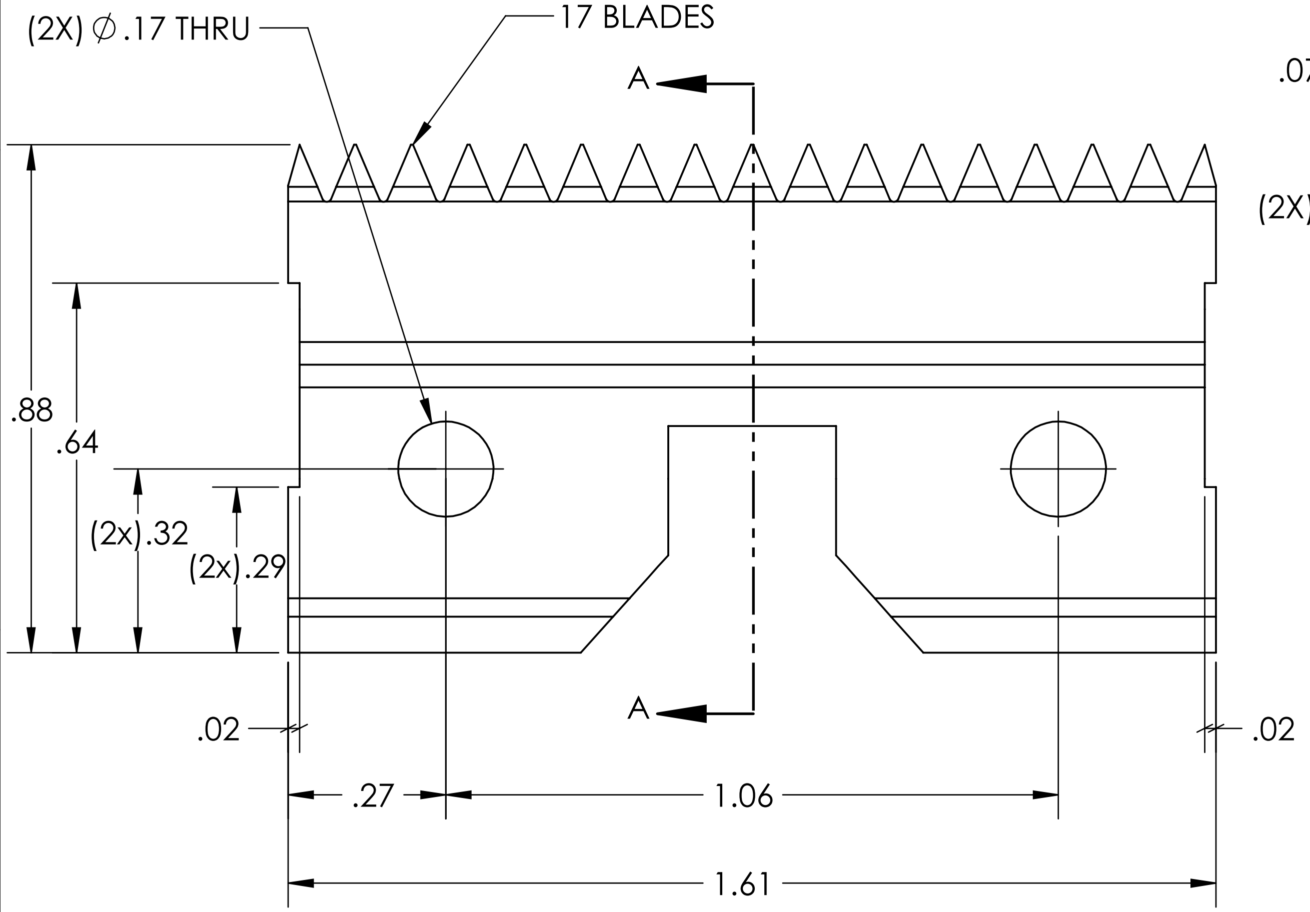
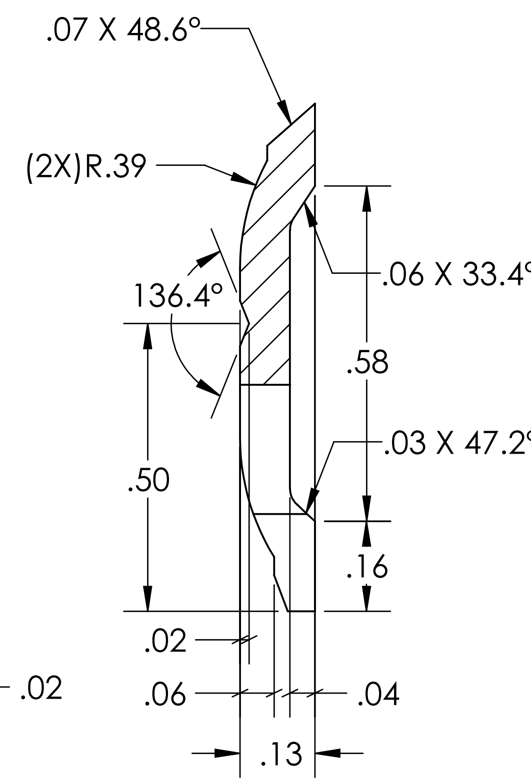
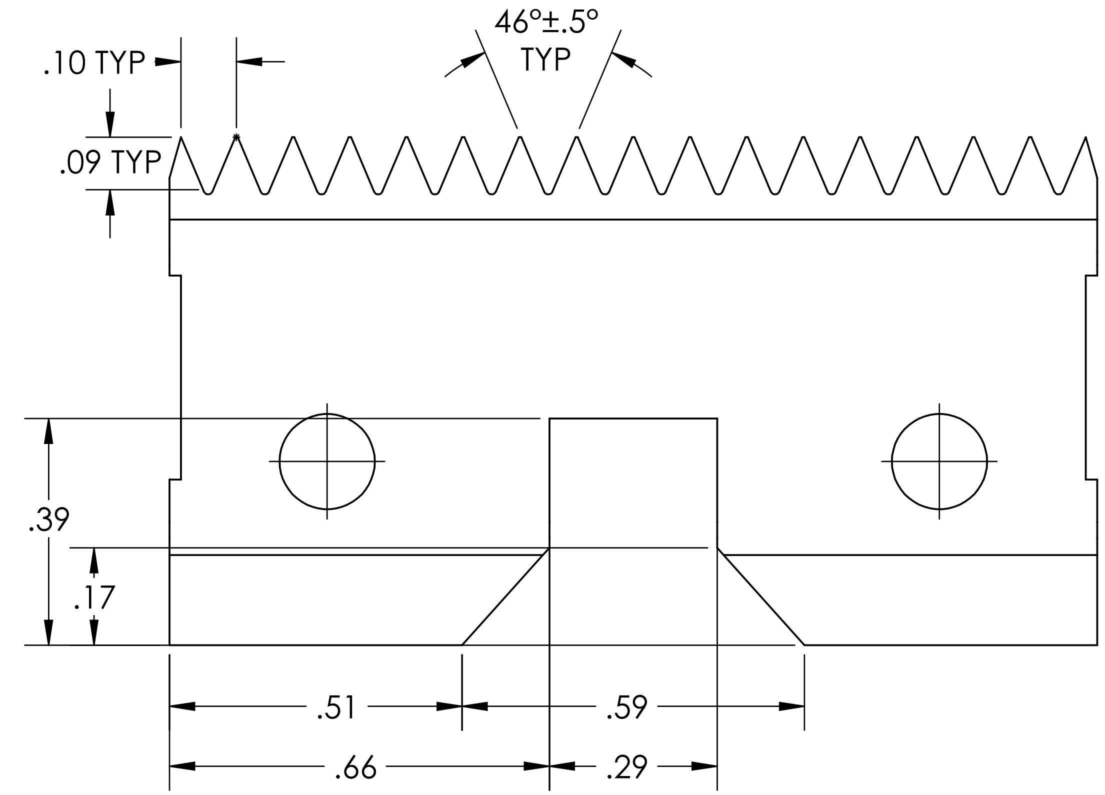
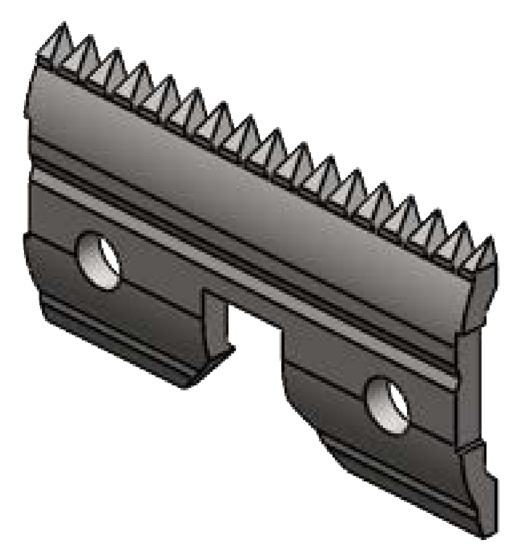
REVISIONS		
REV.	DESCRIPTION	DATE
A	INITAL RELEASE	2/1/2024
B	MISSING DIMENSIONS ADDED	3/5/2024





SECTION A-A





ISOMETRIC VIEW
SCALE: 2:1

NOTES:

1. UNLESS OTHERWISE SPECIFIED SCALE 3:1
2. REMOVE ALL BURRS
3. REMOVE ALL SHARP EDGES EXCEPT BLADE CUTS.

TOLERANCES UNLESS NOTED: X.X ±0.05, X.XX ±0.01, X.XXX ±0.005, X.X° °0.5; UNITS: INCHES	UNIVERSITY OF COLORADO MCEN 5045 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427		
MATERIAL: HIGH CARBON STEEL	DESCRIPTION: BLADE 2		
FINISH: GLOSSY	PN: 010	REV: B	SHEET: 1 of 1

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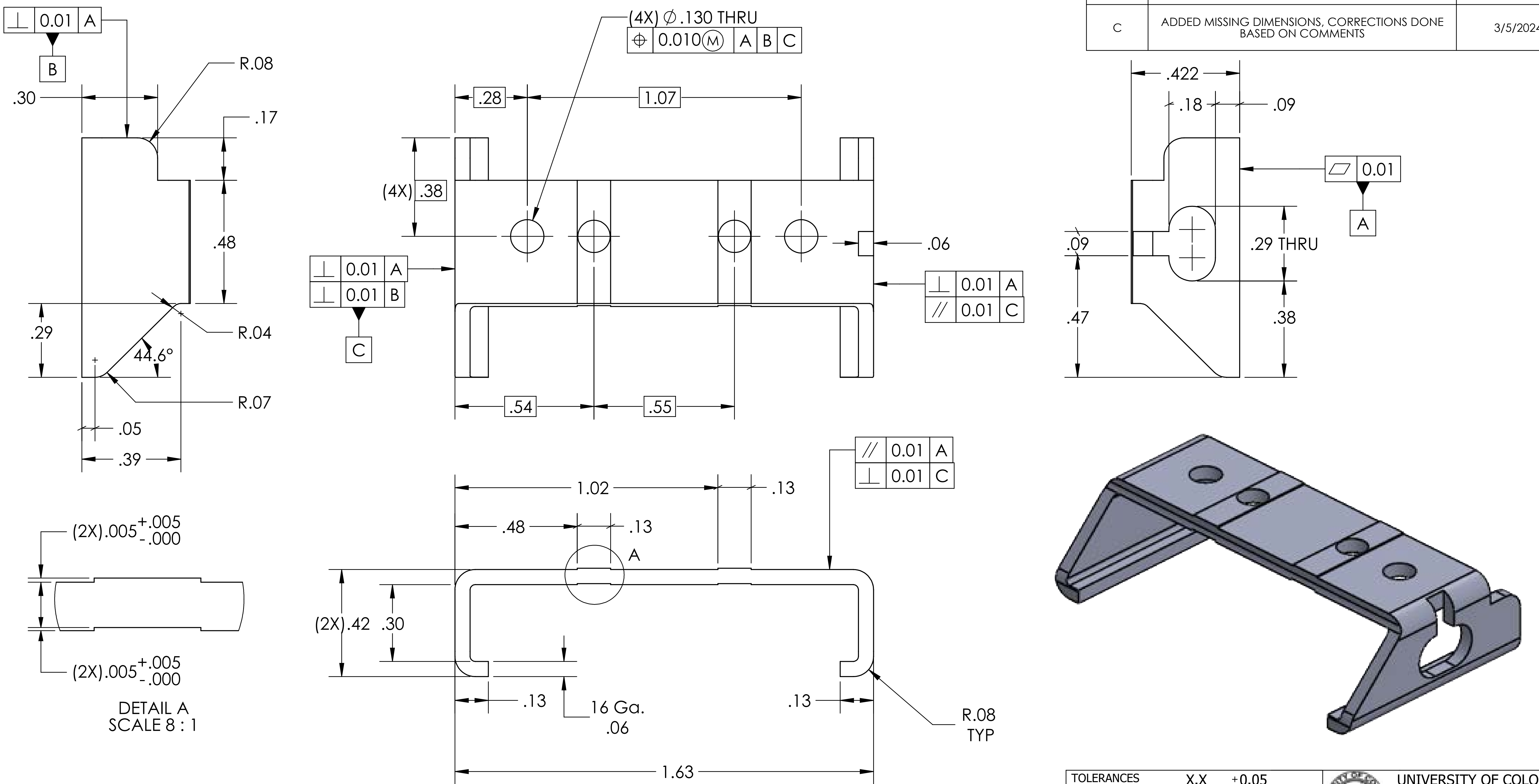
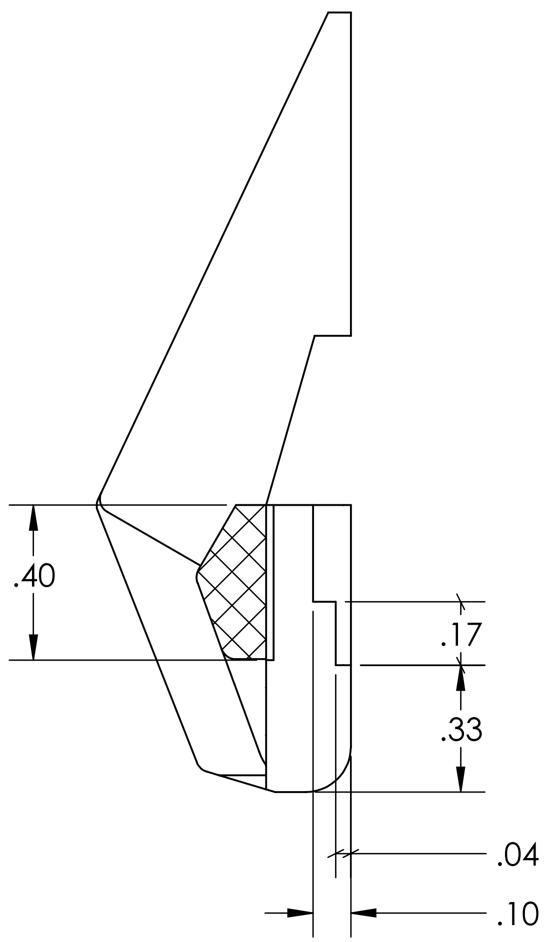
REVISIONS		
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	2/6/2024
B	GD&T INCLUDED	2/8/2024
C	ADDED MISSING DIMENSIONS, CORRECTIONS DONE BASED ON COMMENTS	3/5/2024



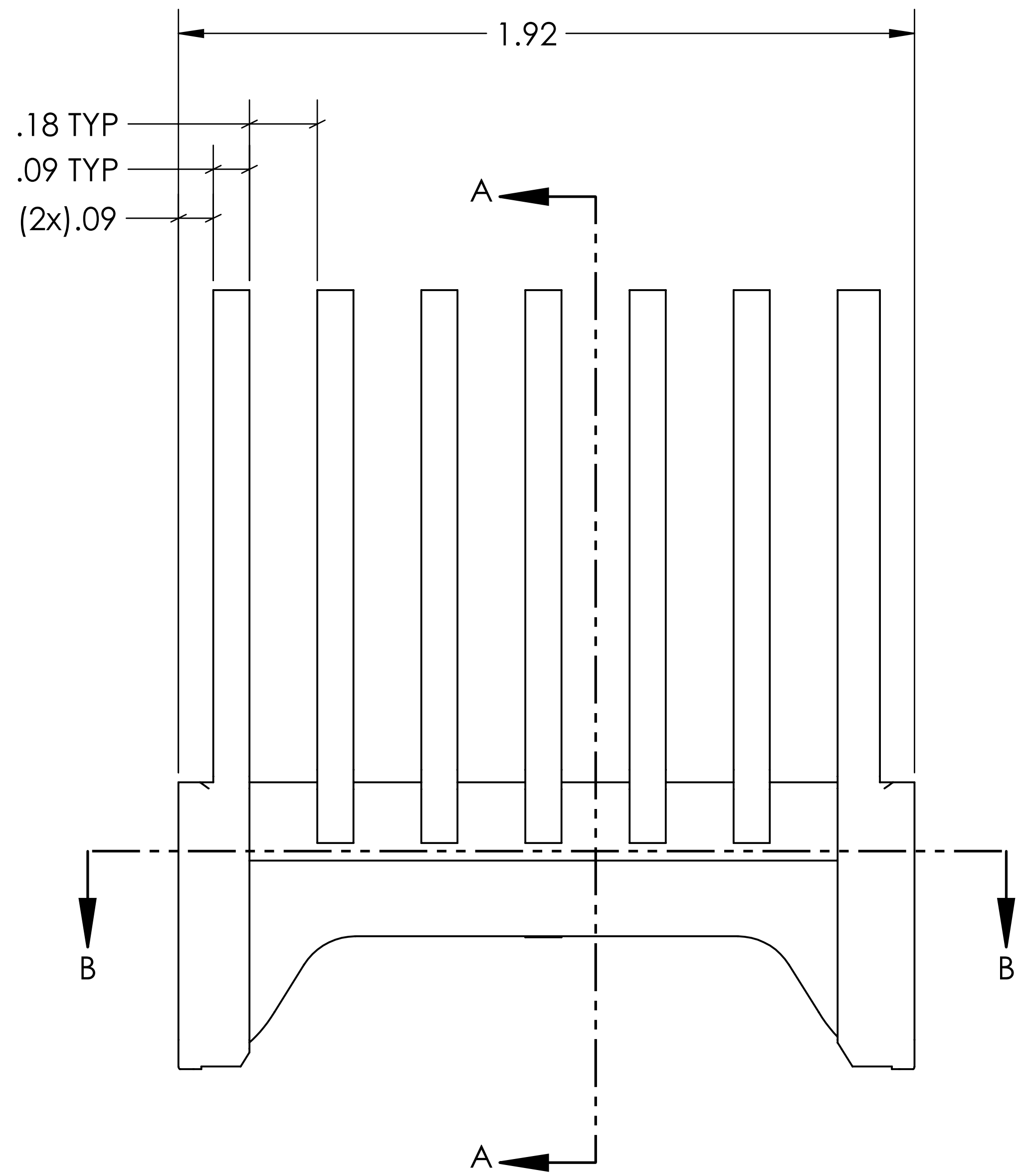
NOTES:
1. UNLESS OTHERWISE SPECIFIED SCALE 5:2
2. REMOVE ALL BURRS
3. REMOVE ALL SHARP EDGES

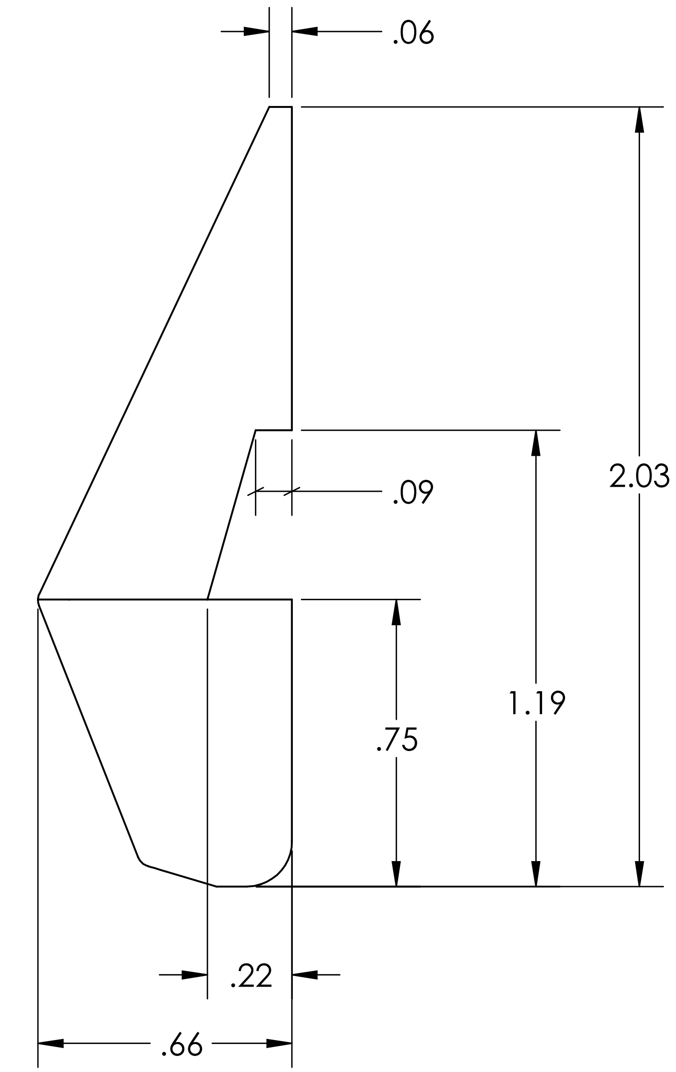
TOLERANCES UNLESS NOTED: UNITS: INCHES	X.X ±0.05 X.XX ±0.01 X.XXX ±0.005 X.X° °0.5	UNIVERSITY OF COLORADO MCEN 5045 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427
MATERIAL STAINLESS STEEL		DESCRIPTION HOLDER
FINISH -		PN 011 · REV C · SHEET 1 of 1
PROPRIETARY AND CONFIDENTIAL	THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF . ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT WRITTEN PERMISSION IS PROHIBITED.	

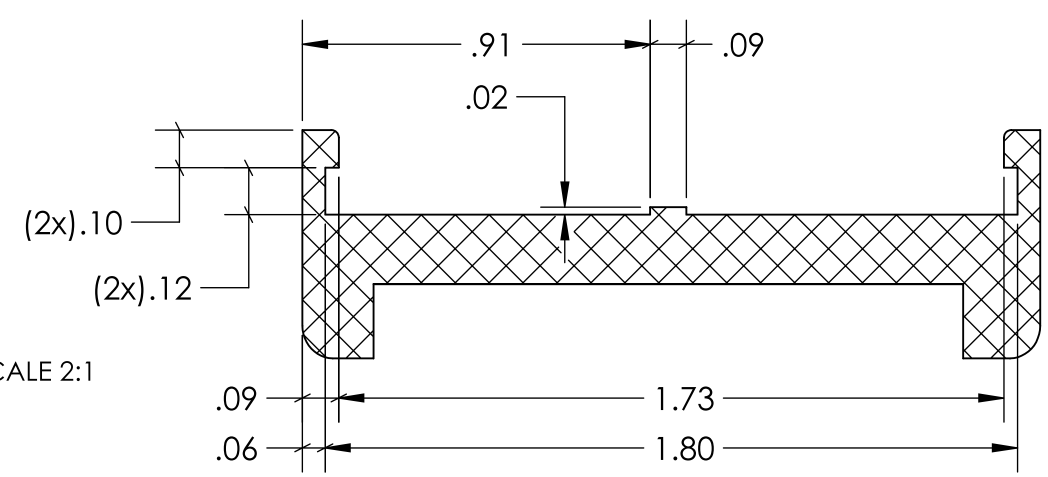
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	3/5/2024



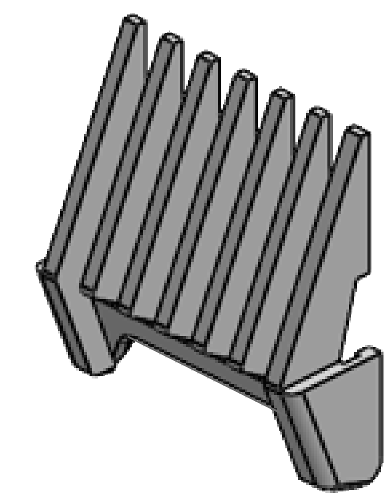
SECTION A-A







SECTION B-B



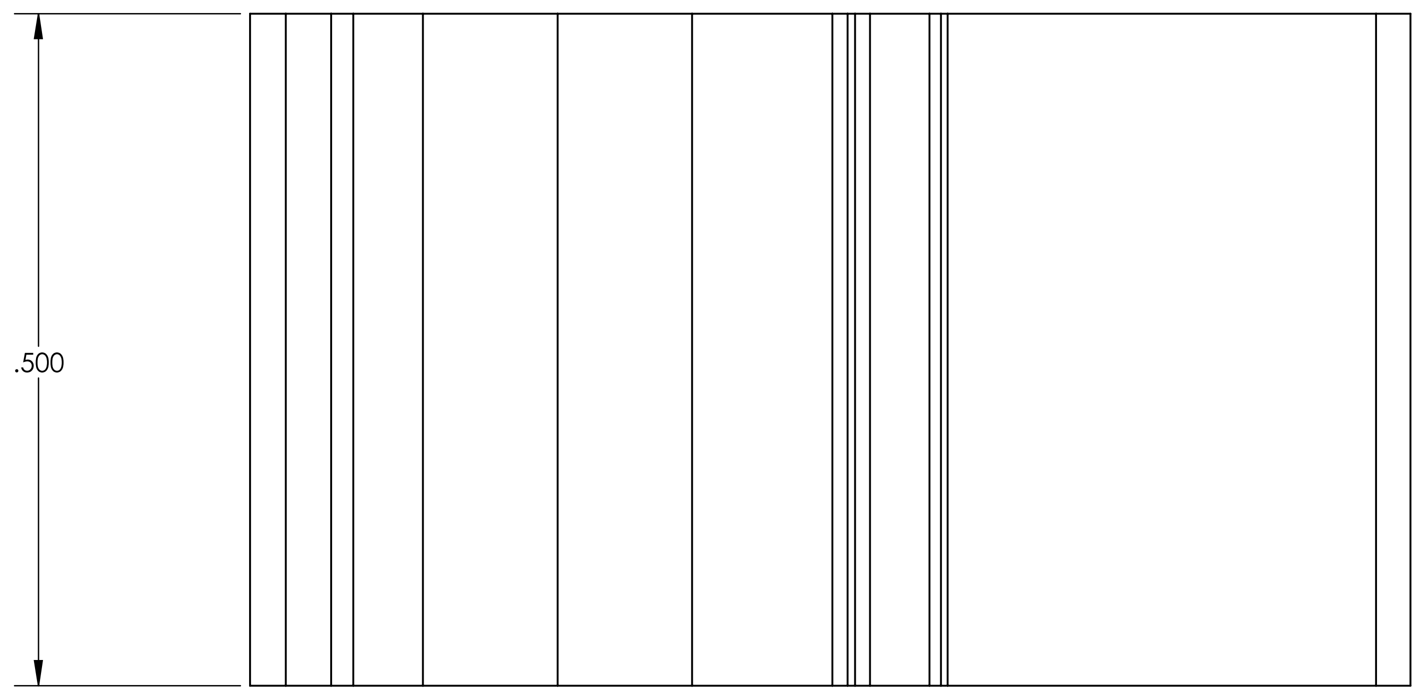
ISOMETRIC VIEW
SCALE: 1:1

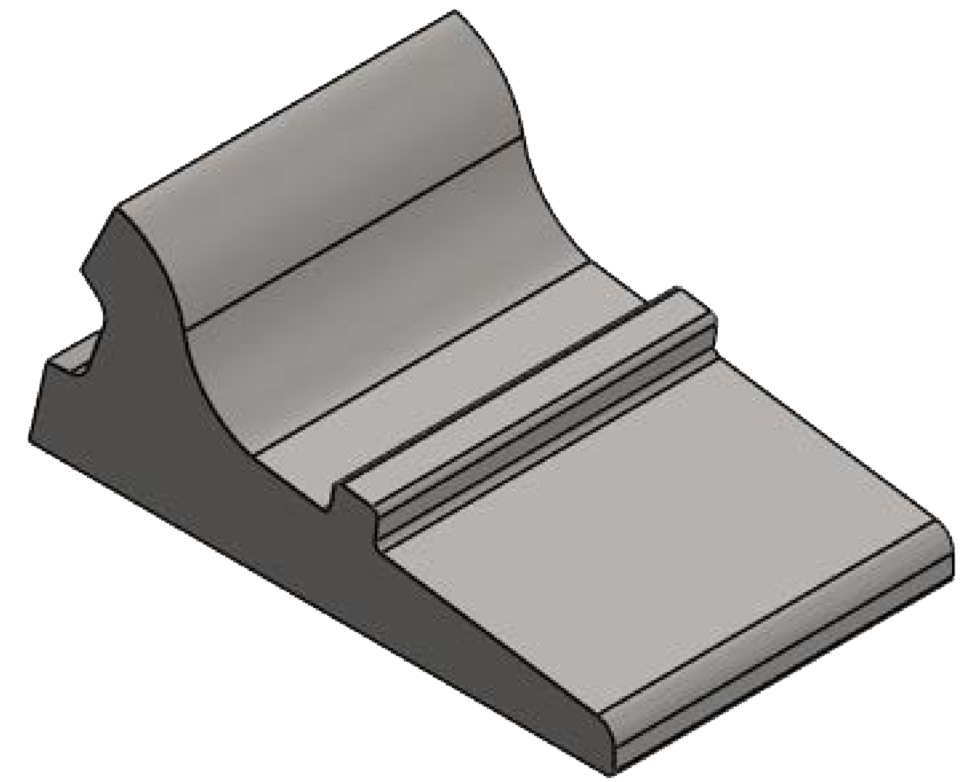
NOTES:
1. UNLESS OTHERWISE SPECIFIED SCALE 2:1
2. REMOVE ALL BURRS

TOLERANCES UNLESS NOTED:	X.X ±0.05 X.XX ±0.01 X.XXX ±0.005 X.X° °0.5		UNIVERSITY OF COLORADO MCEN 5045 1111 ENGINEERING DRIVE BOULDER, CO 80309-0427
UNITS:			
MATERIAL ABS		DESCRIPTION COMB	
FINISH -		PN 012	REV A · SHEET 1 of 1

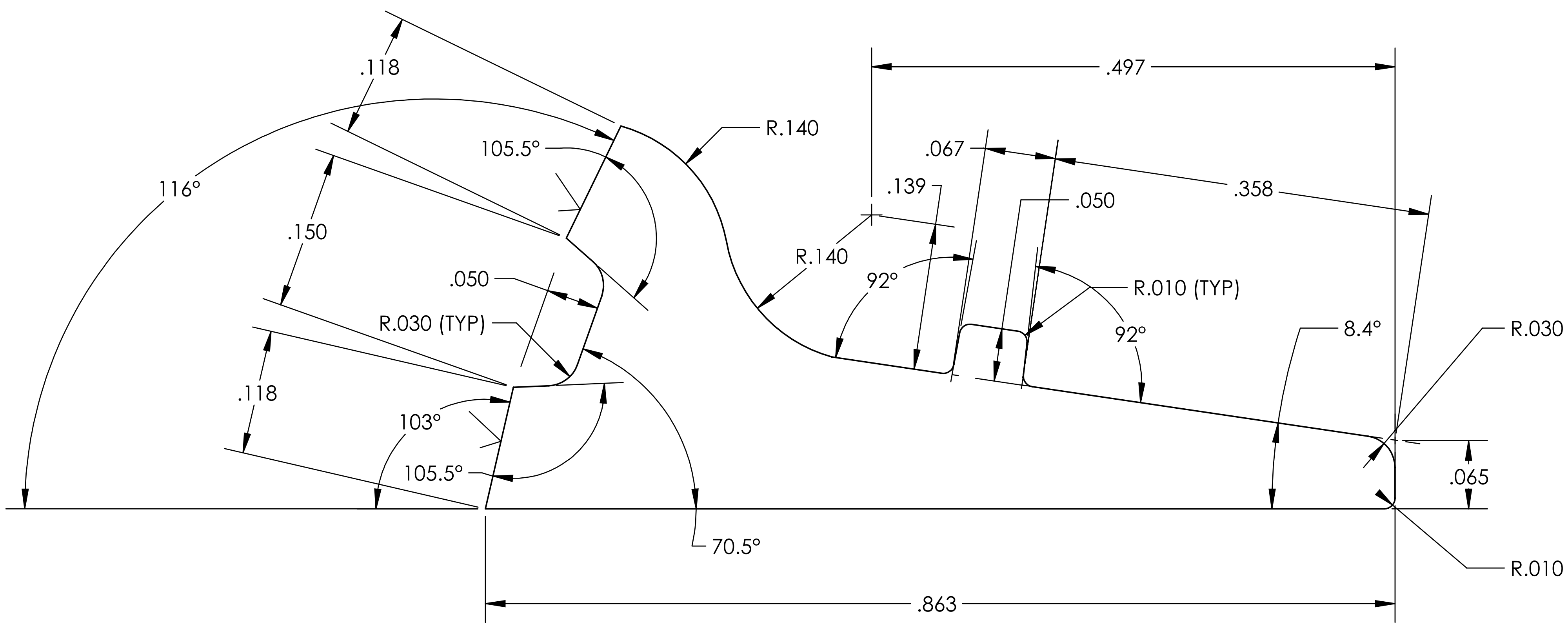
PROPRIETARY AND CONFIDENTIAL THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF . ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT WRITTEN PERMISSION IS PROHIBITED.

REVISIONS		
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	1/30/2024
B	UPDATED DESCRIPTION, UPDATED DIMENSIONS TO OUTSIDE PART CONFINES, REVISED PER COMMENTS	3/4/2024





ISOMETRIC VIEW
SCALE 5:1

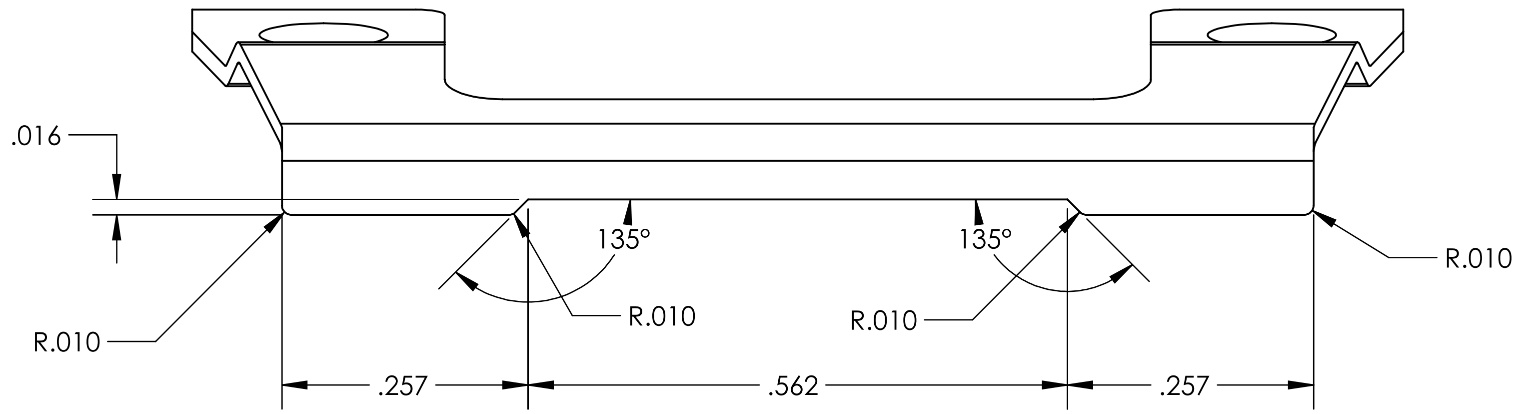


NOTES:
1. QUANTITY REQUIRED: TWO (2)
2. SURFACES MARKED SHALL HAVE SURFACE FINISH OF 125 AARH OR BETTER.
3. UNLESS OTHERWISE SPECIFIED SCALE 7:1

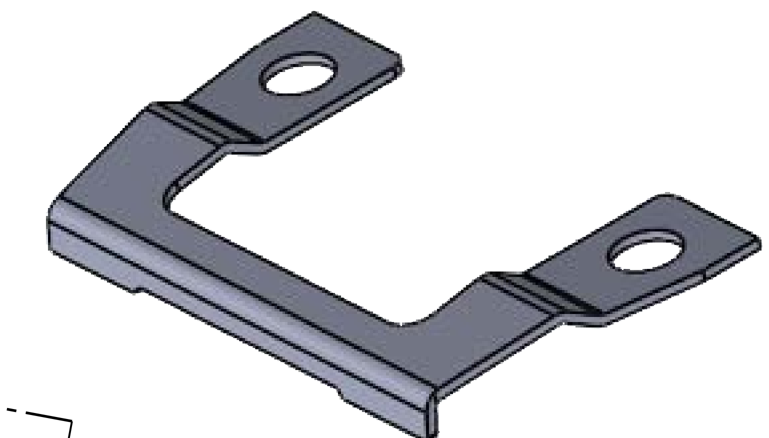
TOLERANCES UNLESS NOTED: X.X ± 0.05, X.XX ± 0.01, X.XXX ± 0.005, X.X° ± 0.5° UNITS: INCHES		UNIVERSITY OF COLORADO MCEN 5045 1111 ENGINEERING DRIVE BOULDER, CO 80309
MATERIAL CAST IRON		DESCRIPTION DRIVE LEVER INTERNAL PART
FINISH NONE (EXCEPT AS NOTED)	PN 013	REV B — SHEET 1 of 1

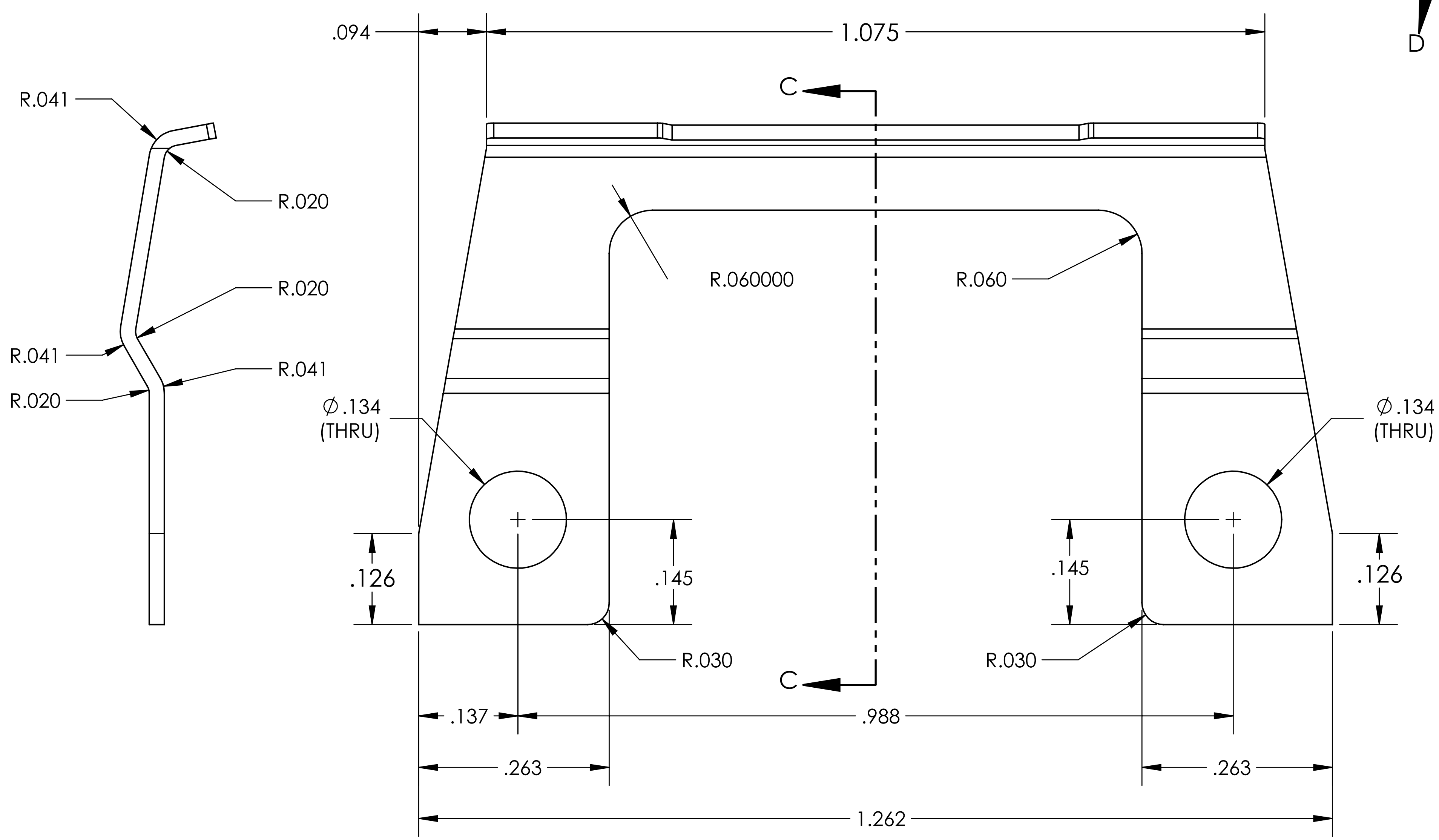
PROPRIETARY AND CONFIDENTIAL

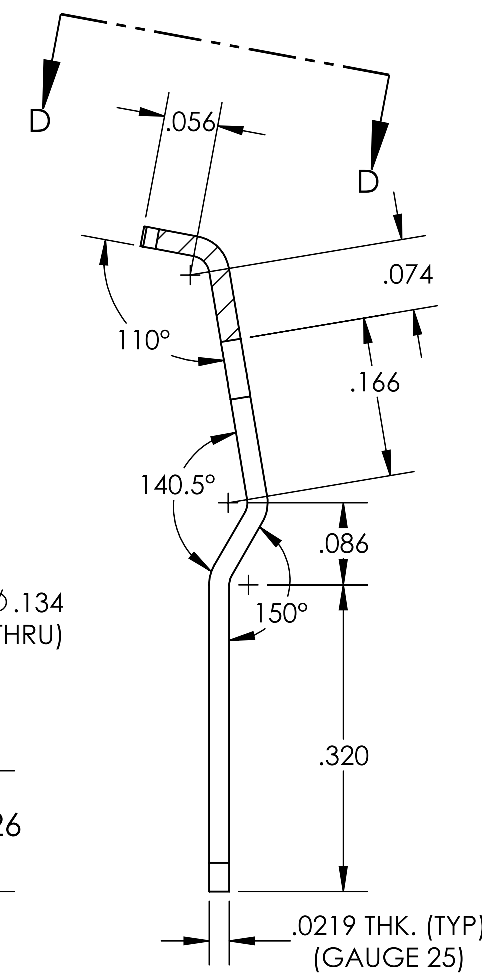
REVISIONS		
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	2/1/2024
B	ADDED CENTER MARKS, ADDED SHEET METAL THICKNESS GAUGE, REVISED PER COMMENTS	3/4/2024



VIEW D-D (⌒ 100.500°)







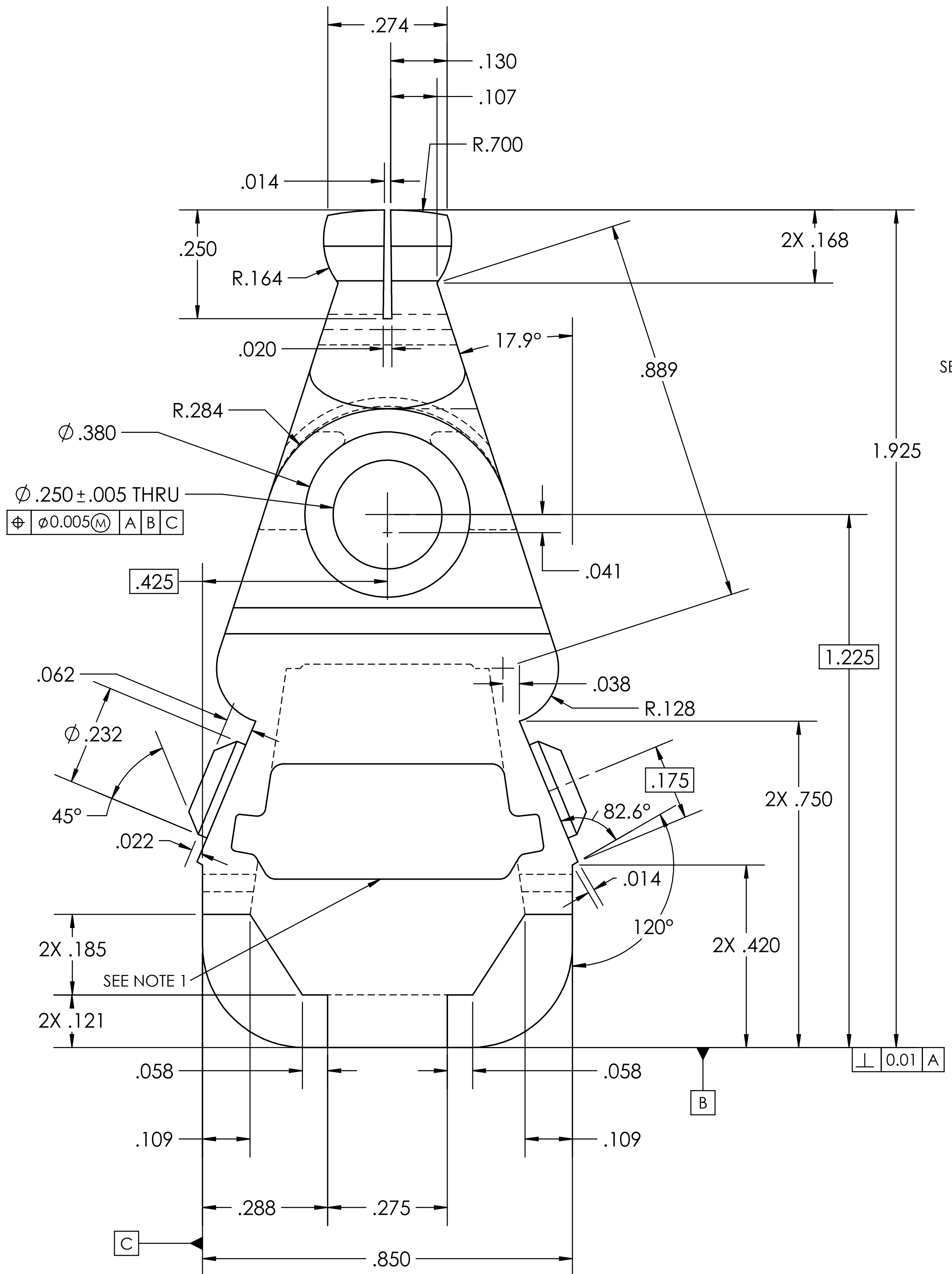
SECTION C-C

NOTES:

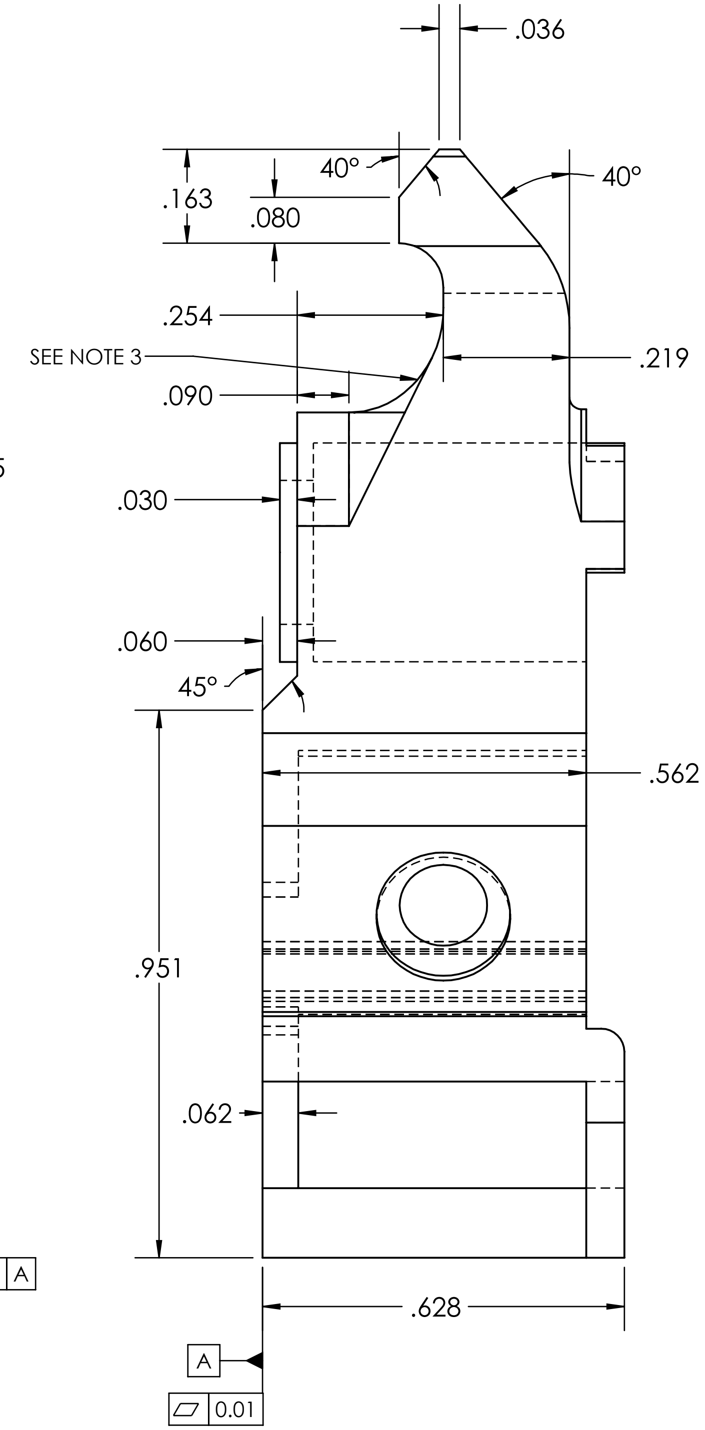
1. UNLESS OTHERWISE SPECIFIED SCALE 5:1

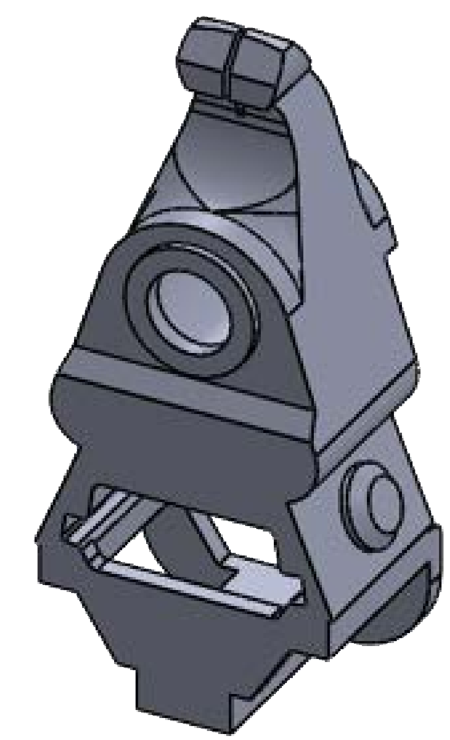
TOLERANCES UNLESS NOTED: X.X ± 0.05, X.XX ± 0.01, X.XXX ± 0.005, X.X° ± 0.5° UNITS: INCHES		UNIVERSITY OF COLORADO MCEN 5045 1111 ENGINEERING DRIVE BOULDER, CO 80309
MATERIAL STAINLESS STEEL		DESCRIPTION CONNECTOR SHEET
FINISH NONE	PN 014	REV B — SHEET 1 of 1

REVISIONS		
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	2/6/2024
B	ADDED GD&T AND REVISED PER COMMENTS	2/8/2024
C	ADDED SECTION VIEW ON SHEET 3 FOR HIDDEN FEATURE DIMENSIONS, UPDATED TOLERANCE PER COMMENTS	3/4/2024



FRONT VIEW
SCALE 3:1





ISOMETRIC VIEW
SCALE 2:1

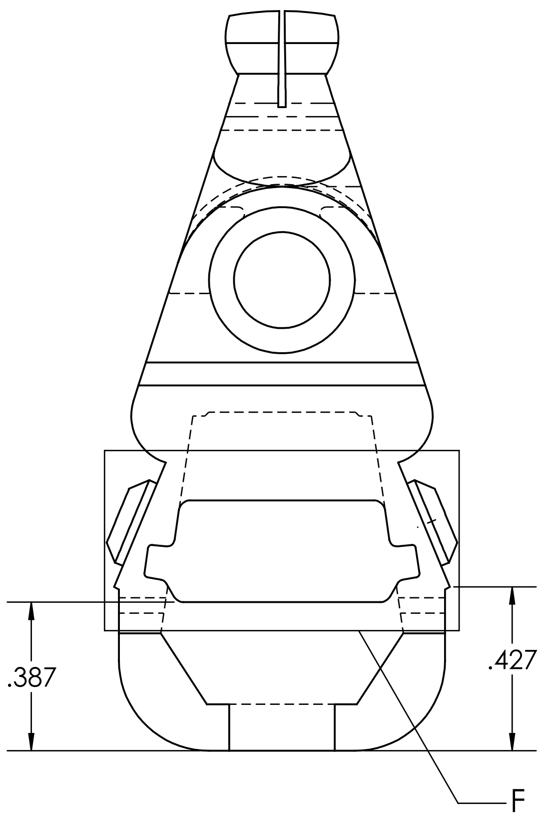
NOTES:
1. SEE SHEET 2 FOR THROUGH HOLE PROFILE DIMENSIONS
2. SEE SHEET 3 FOR REAR VIEW FEATURES AND DIMENSIONS
3. UNLESS OTHERWISE SPECIFIED SURFACE PROFILES TO MATCH MODEL 'DRIVE LEVER.SLDPRT' WITHIN 0.03
4. DIMENSIONS FOR FEATURES ARE SYMMETRIC AND APPLY TO THE OTHER SIDE OF VERTICAL CENTER LINE THROUGH THE HOLE FEATURE IN THE FRONT VIEW.

TOLERANCES UNLESS NOTED: X.X ± 0.05, X.XX ± 0.01, X.XXX ± 0.005, X.X° ± 0.5° UNITS: INCHES	UNIVERSITY OF COLORADO MCEN 5045 1111 ENGINEERING DRIVE BOULDER, CO 80309	
MATERIAL ABS PLASTIC	DESCRIPTION DRIVE LEVER	
FINISH N/A	PN 015	REV C · SHEET 1 of 3

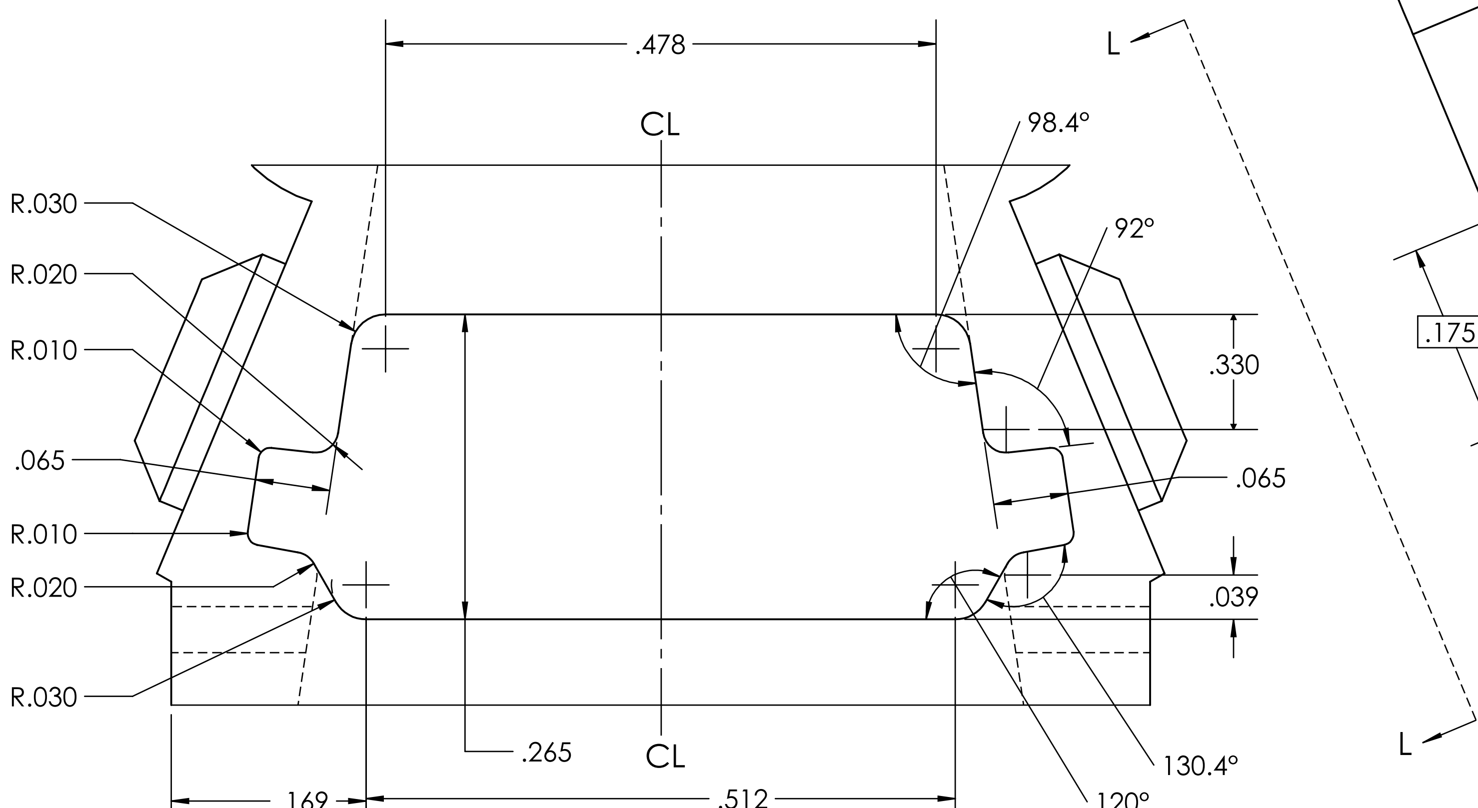
NOTES:

1. DETAIL F IS DETAIL VIEW OF THE PROFILE WHICH IS A THROUGH HOLE.
2. THE FILLET AND ANGULAR DIMENSIONS IN DETAIL F ARE SYMMETRIC AND ALSO APPLY TO THE OTHER SIDE OF CENTER LINE "CL".

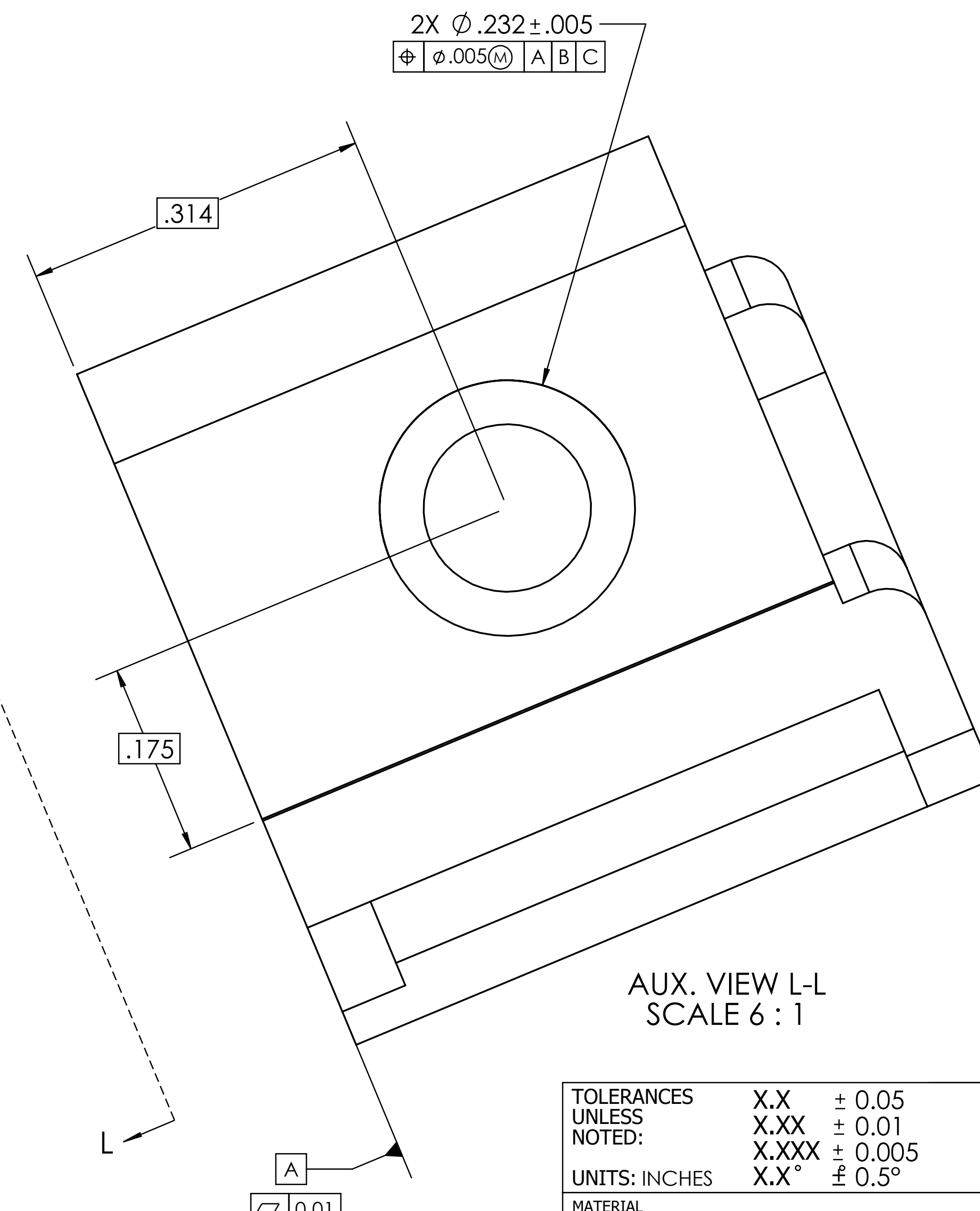
REVISIONS		
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	2/6/2024
B	ADDED GD&T AND REVISED PER COMMENTS	2/8/2024
C	ADDED SECTION VIEW ON SHEET 3 FOR HIDDEN FEATURE DIMENSIONS,UPDATED TOLERANCE PER COMMENTS	3/4/2024



FRONT VIEW
SCALE 2:1



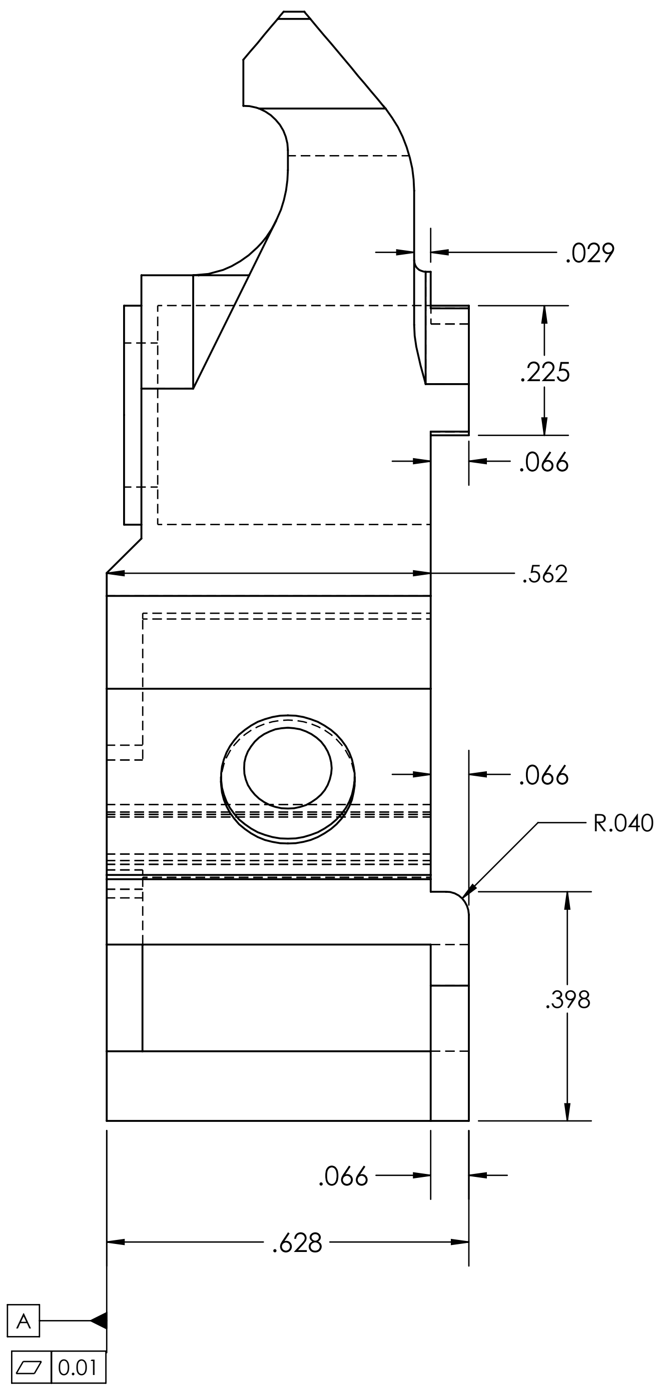
DETAIL F
SCALE 6 : 1

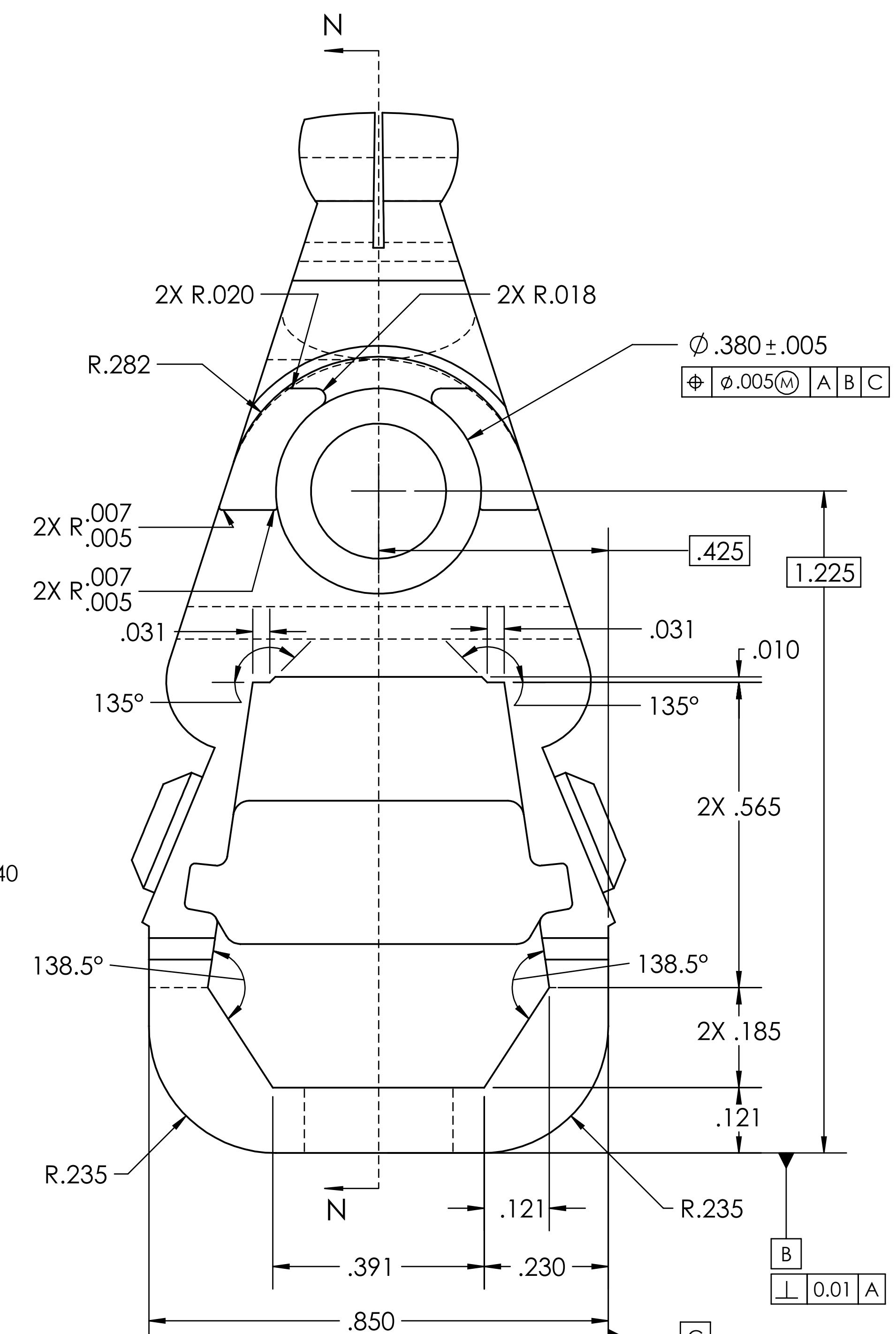


AUX. VIEW L-L
SCALE 6 : 1

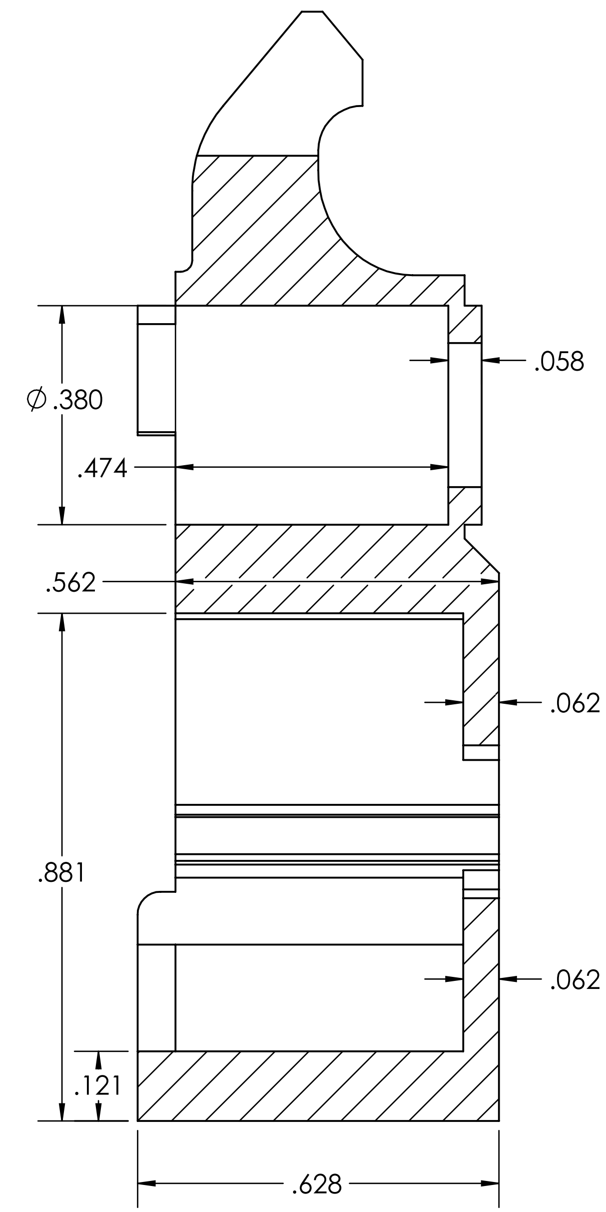
TOLERANCES UNLESS NOTED: UNITS: INCHES	X.X ± 0.05 X.XX ± 0.01 X.XXX ± 0.005 X.X° ± 0.5°	UNIVERSITY OF COLORADO MCEN 5045 1111 ENGINEERING DRIVE BOULDER, CO 80309
MATERIAL ABS PLASTIC		DESCRIPTION DRIVE LEVER
FINISH N/A		PN 015 · REV C · SHEET 2 of 3

REVISIONS		
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	2/6/2024
B	ADDED GD&T AND REVISED PER COMMENTS	2/8/2024
C	ADDED SECTION VIEW ON SHEET 3 FOR HIDDEN FEATURE DIMENSIONS,UPDATED TOLERANCE PER COMMENTS	3/4/2024

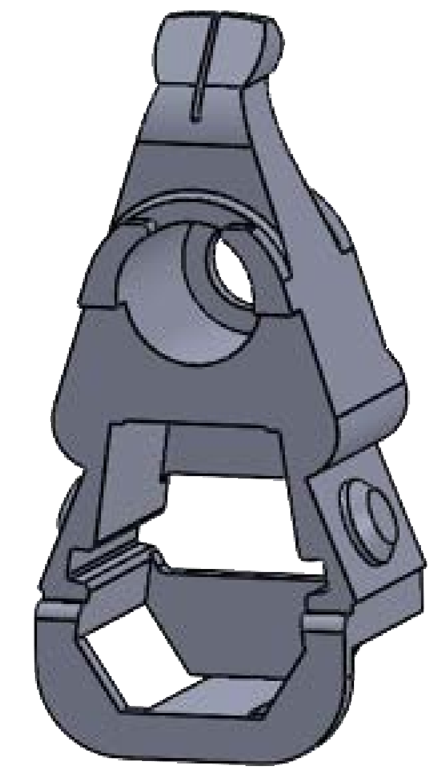




REAR VIEW
SCALE 3:1



SECTION N-N
SCALE 3 : 1



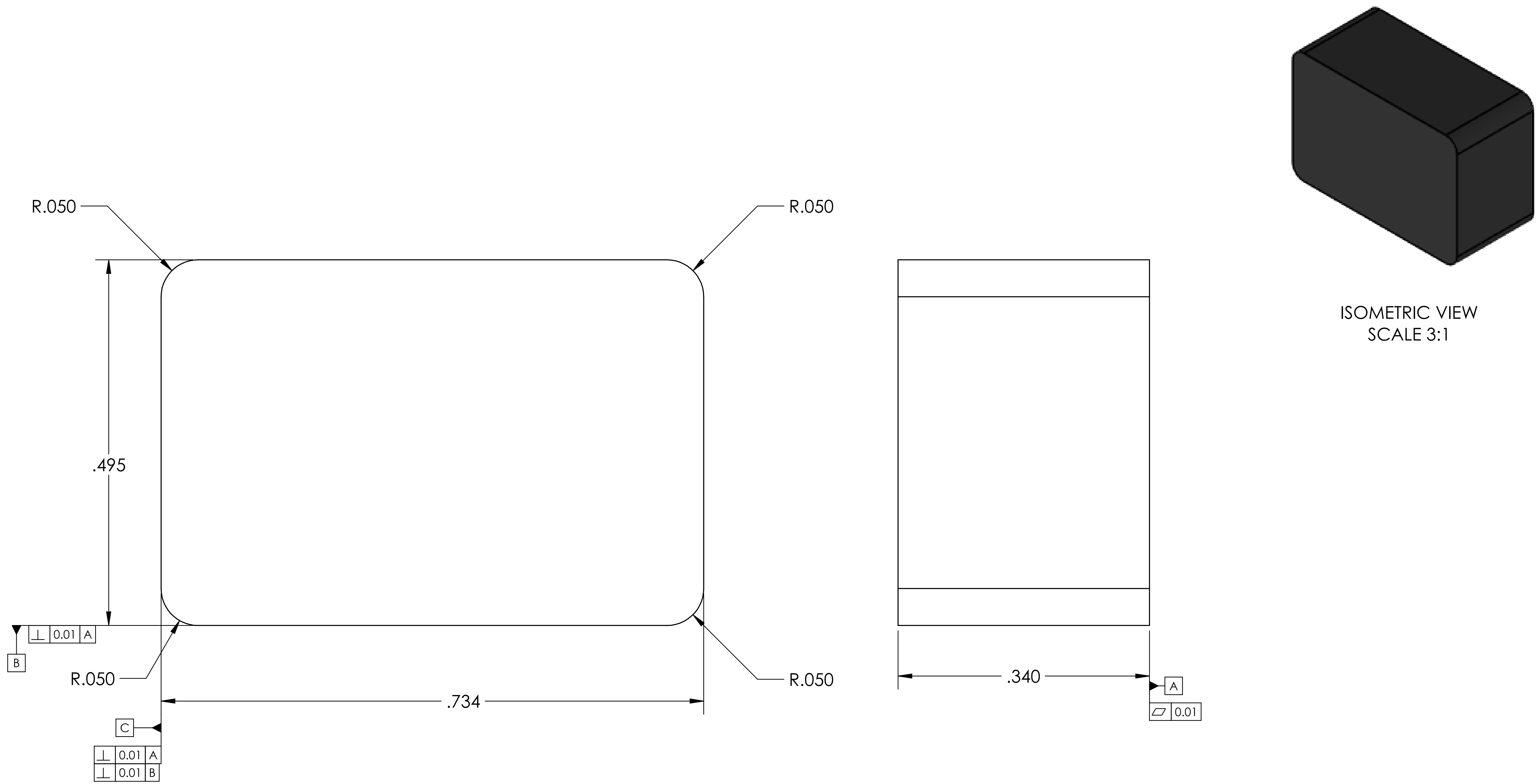
ISOMETRIC VIEW
SCALE 2:1

NOTES:

1. UNLESS OTHERWISE SPECIFIED SURFACE PROFILES TO MATCH MODEL 'DRIVE LEVER.SLDPRT' WITHIN 0.03

TOLERANCES UNLESS NOTED: X.X ± 0.05; X.XX ± 0.01; X.XXX ± 0.005; X.X° ± 0.5° UNITS: INCHES		UNIVERSITY OF COLORADO MCEN 5045 1111 ENGINEERING DRIVE BOULDER, CO 80309
MATERIAL ABS PLASTIC		DESCRIPTION DRIVE LEVER
FINISH N/A	PN 015	REV C · SHEET 3 of 3

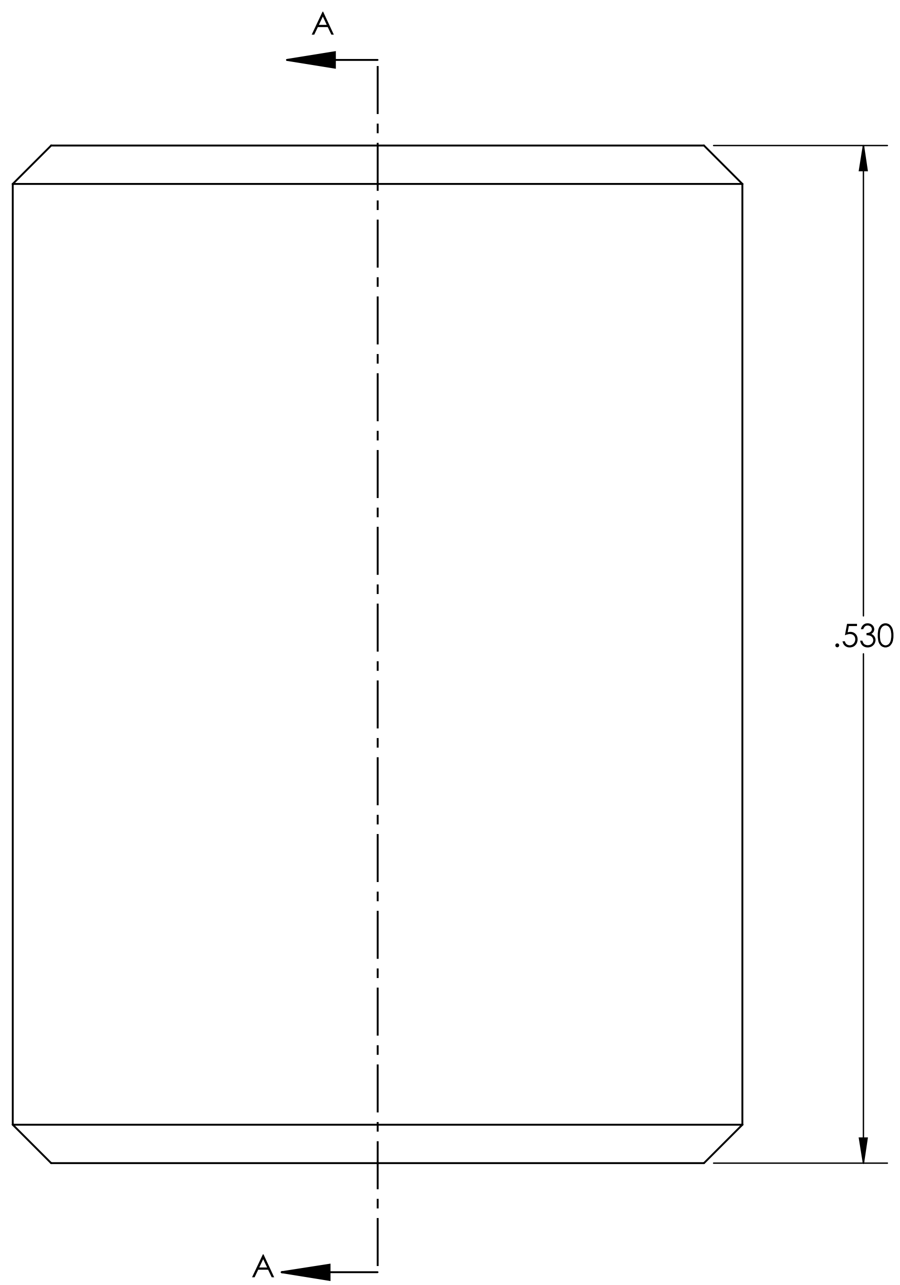
REVISIONS		
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	3/2/2024

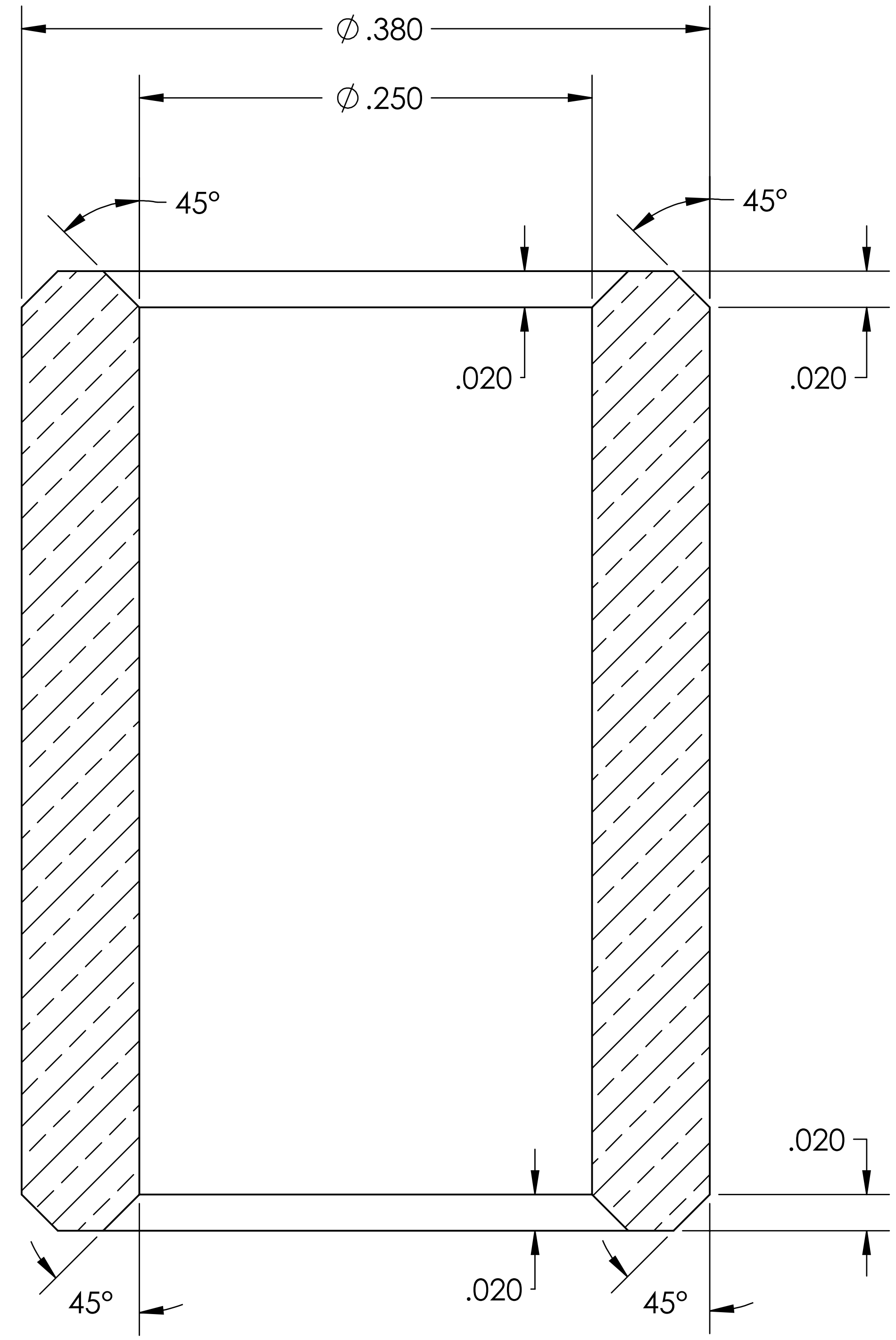


NOTES:
1. UNLESS OTHERWISE SPECIFIED SCALE 6:1

TOLERANCES UNLESS NOTED:	X.X ± 0.05 X.XX ± 0.01 X.XXX ± 0.005 X.X° ± 0.5°		UNIVERSITY OF COLORADO MCEN 5045 1111 ENGINEERING DRIVE BOULDER, CO 80309
UNITS: INCHES			
MATERIAL FERROMAGNET		DESCRIPTION MAGNET	
FINISH NONE		PN 016	REV A · SHEET 1 of 1

REVISIONS		
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	3/2/2024





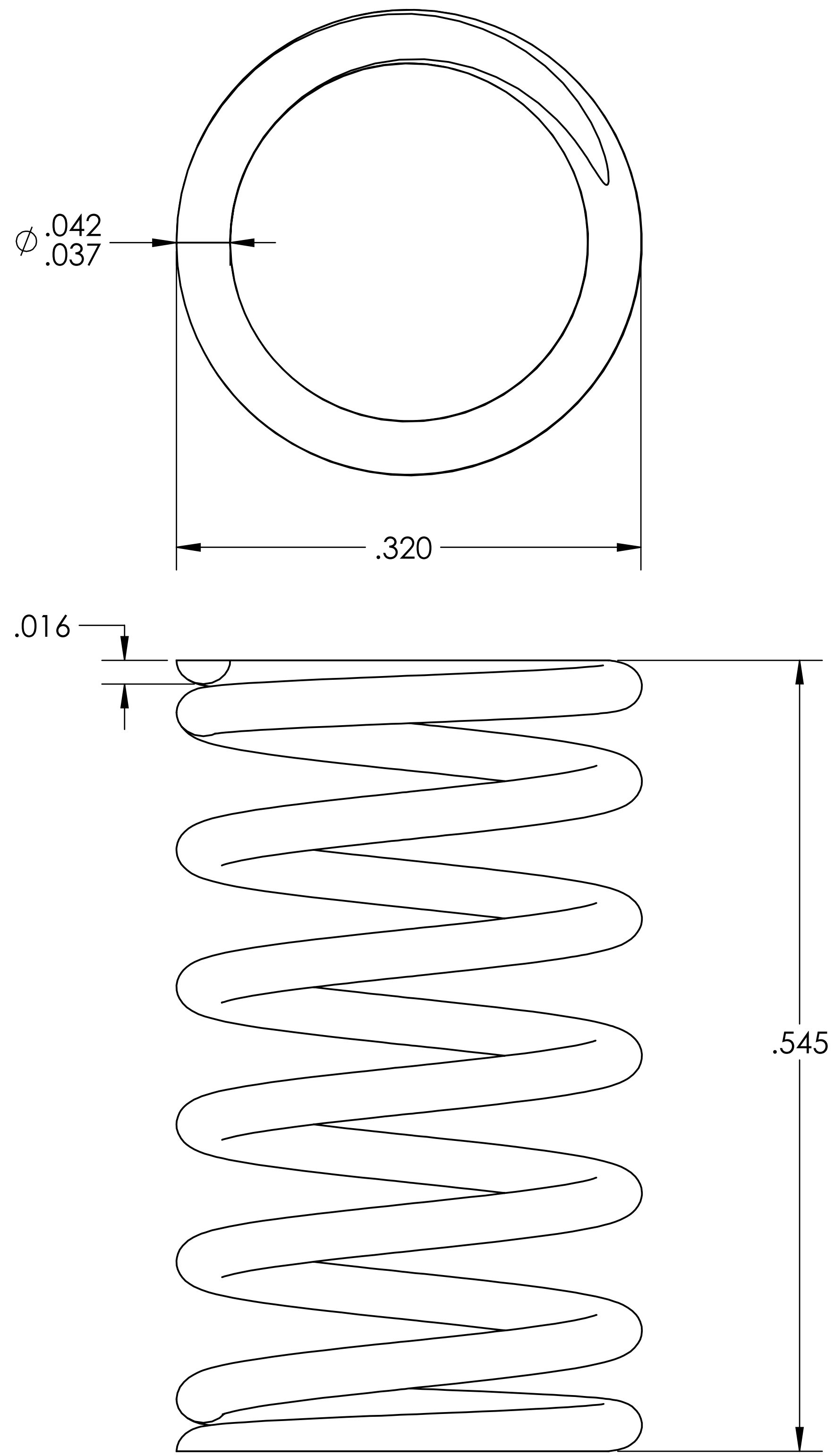
SECTION A-A

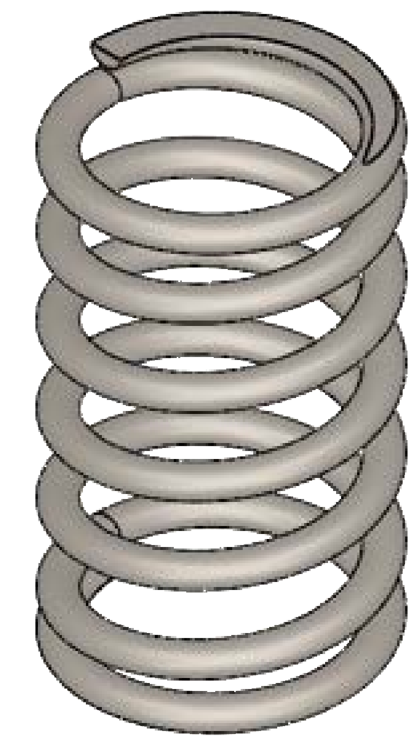
ISOMETRIC VIEW
SCALE 4:1

NOTES:
1. UNLESS OTHERWISE SPECIFIED SCALE 10:1

TOLERANCES UNLESS NOTED: X.X ± 0.05; X.XX ± 0.01; X.XXX ± 0.005; X.X° ± 0.5°; UNITS: INCHES	UNIVERSITY OF COLORADO MCEN 5045 1111 ENGINEERING DRIVE BOULDER, CO 80309	
MATERIAL: BRASS	DESCRIPTION: BRASS BUSHING	
FINISH: NONE	PN: 017	REV: A; SHEET: 1 of 1

REVISIONS		
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	3/3/2024





ISOMETRIC VIEW
SCALE 6:1

NOTES:
1. QUANTITY REQUIRED: TWO(2)
2. SPRING PITCH 0.085 INCHES
3. MEAN COIL DIAMETER 0.283 INCHES
4. SPRING CONSTANT SHALL BE BETWEEN 10-14 LBS/IN

TOLERANCES UNLESS NOTED: X.X ± 0.05; X.XX ± 0.01; X.XXX ± 0.005; X.X° ± 0.5°; UNITS: INCHES		UNIVERSITY OF COLORADO MCEN 5045 1111 ENGINEERING DRIVE BOULDER, CO 80309	
MATERIAL: STAINLESS STEEL		DESCRIPTION: SPRING	
FINISH: NONE		PN: 018	REV: A; SHEET: 1 of 1

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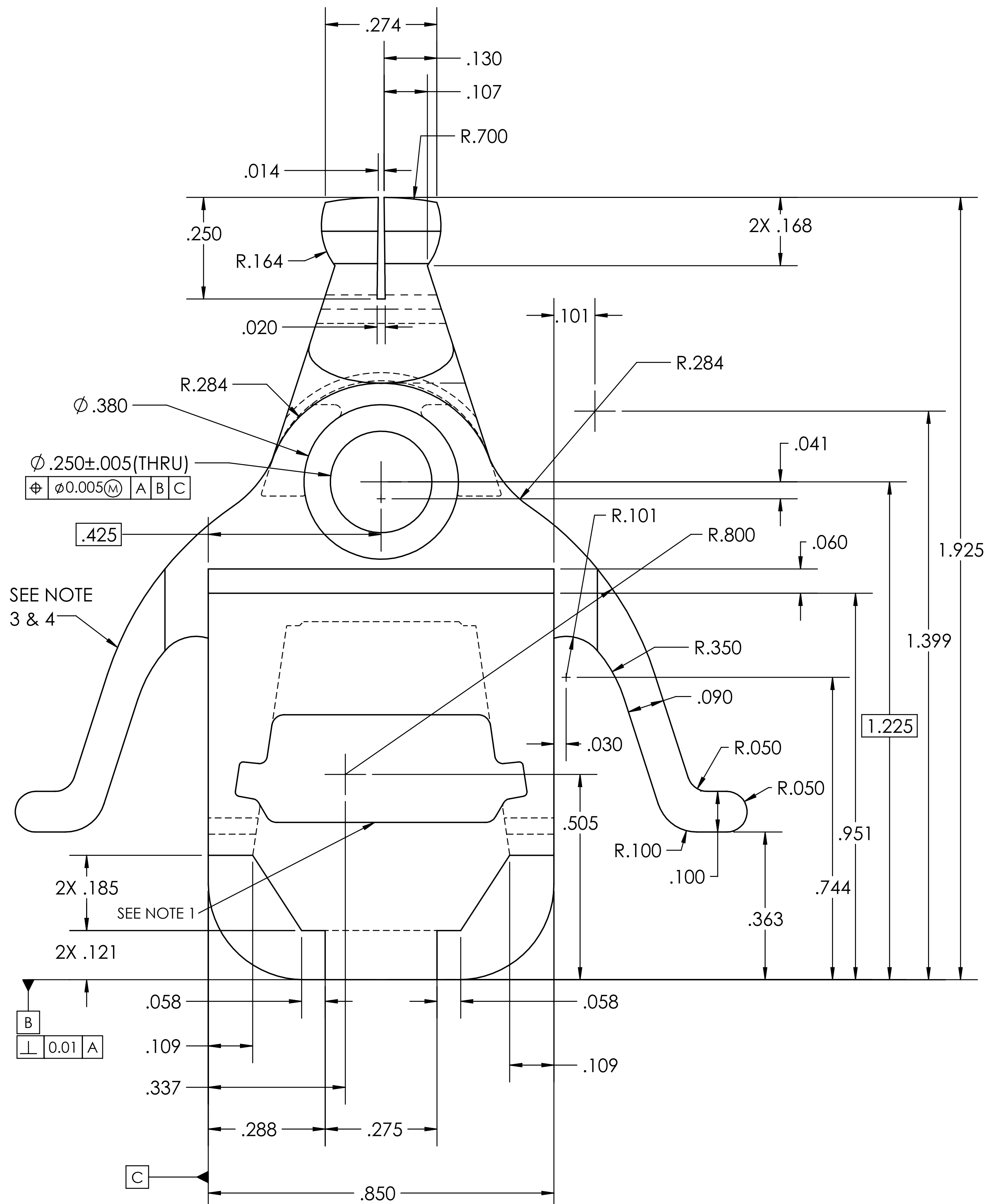
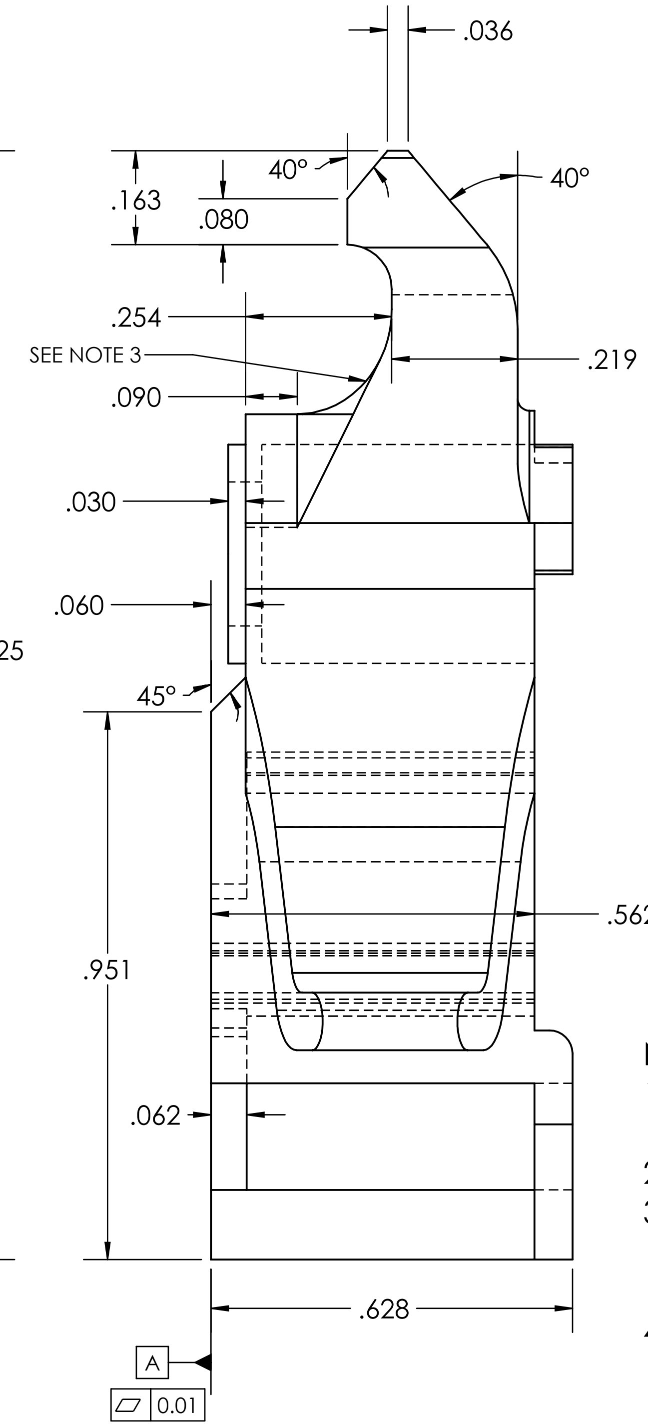
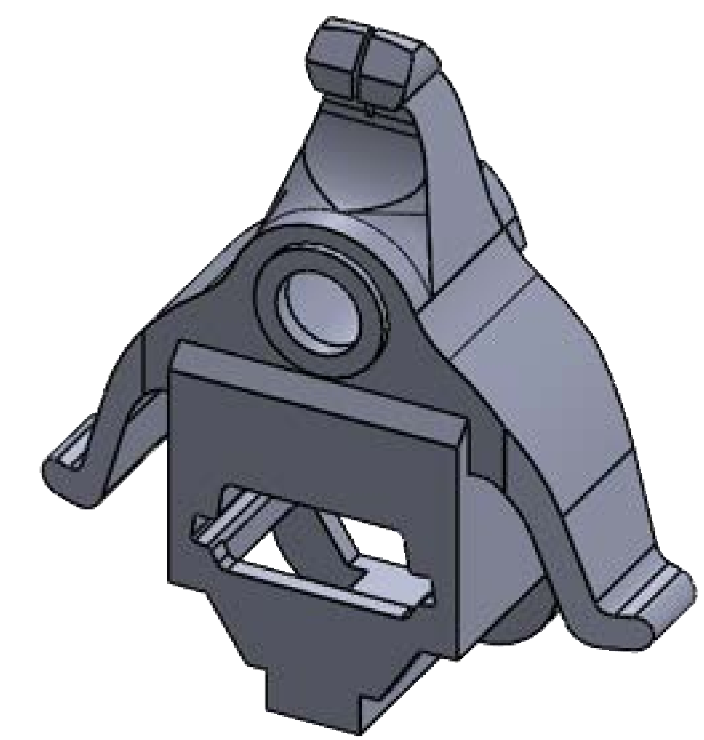
REVISIONS		
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	3/5/2024



FRONT VIEW
SCALE 3:1





ISOMETRIC VIEW
SCALE 2:1

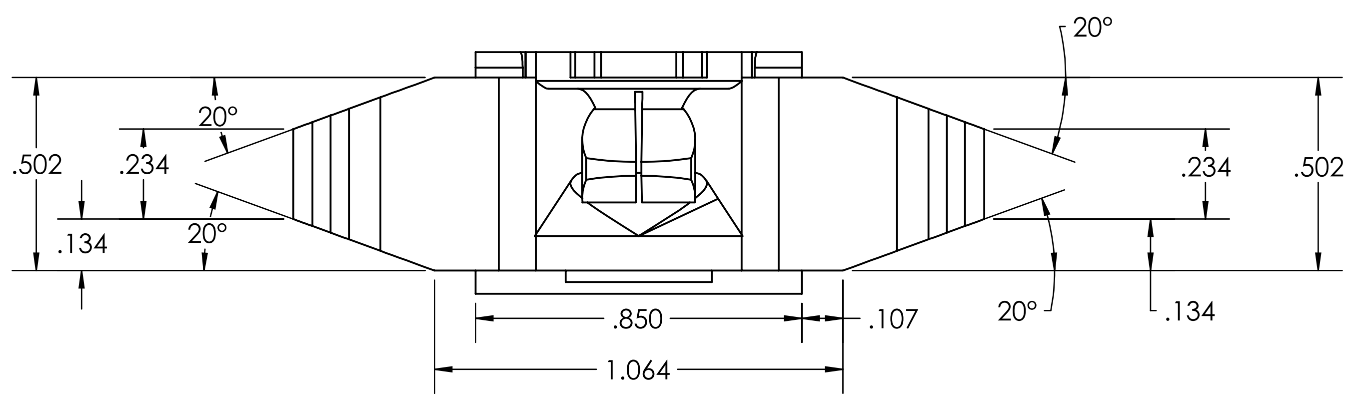
NOTES:

1. SEE SHEET 2 FOR TOP VIEW AND THROUGH HOLE FEATURE PROFILE DIMENSIONS
2. SEE SHEET 3 FOR REAR VIEW FEATURES AND DIMENSIONS
3. UNLESS OTHERWISE SPECIFIED SURFACE PROFILES TO MATCH MODEL 'DRIVE LEVER REDESIGN.SLDPRT' WITHIN 0.03
4. DIMENSIONS FOR FEATURES ARE SYMMETRIC AND APPLY TO THE OTHER SIDE OF VERTICAL CENTER LINE THROUGH THE HOLE FEATURE IN THE FRONT VIEW.

TOLERANCES UNLESS NOTED: X.X ± 0.05; X.XX ± 0.01; X.XXX ± 0.005; X.X° ± 0.5° — UNITS: INCHES		UNIVERSITY OF COLORADO MCEN 5045 1111 ENGINEERING DRIVE BOULDER, CO 80309
MATERIAL ABS PLASTIC		DESCRIPTION DRIVE LEVER REDESIGN
FINISH N/A		PN 015R — REV A — SHEET 1 of 3

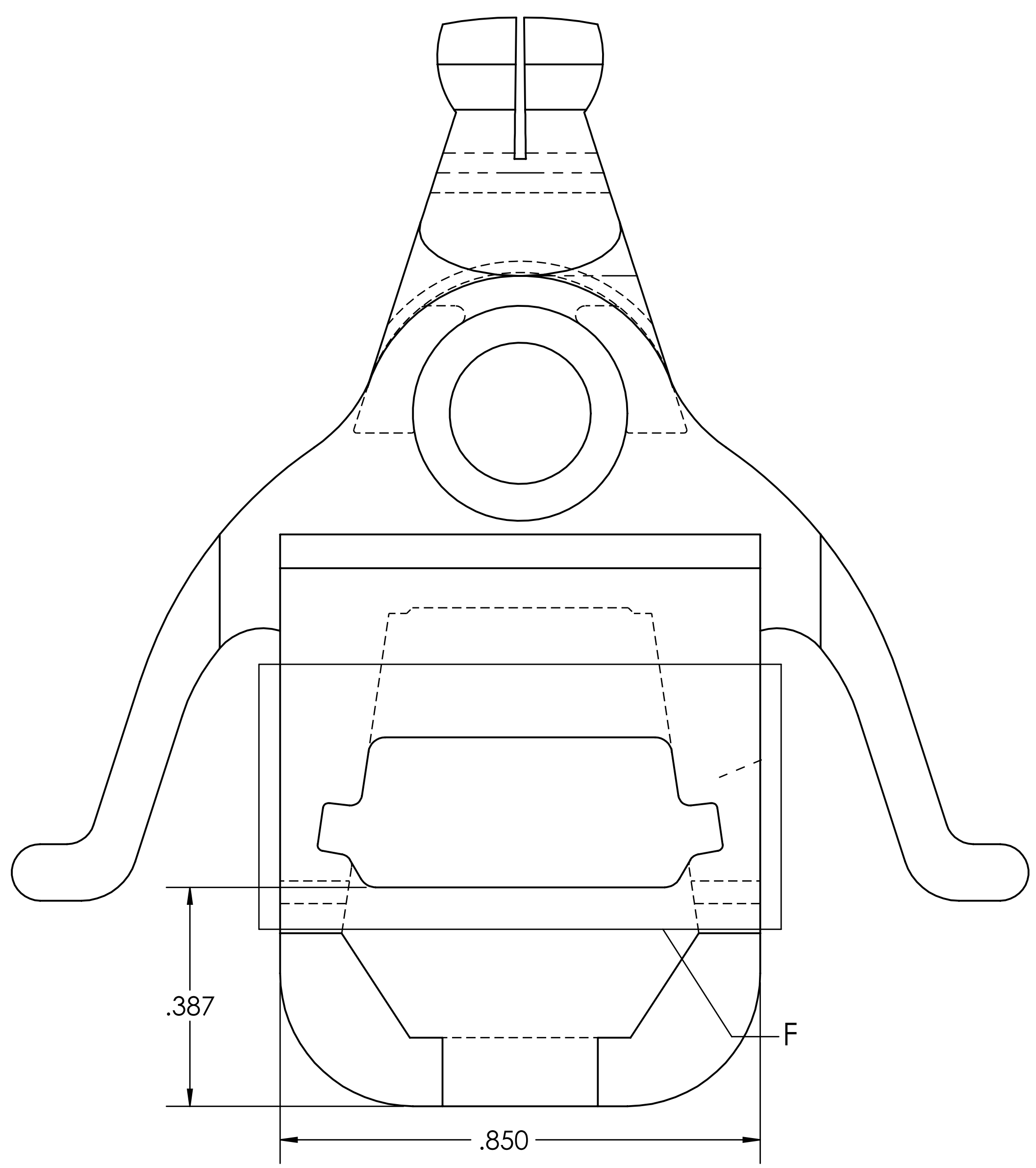
6 5 4 3 2 1

REVISIONS		
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	3/5/2024

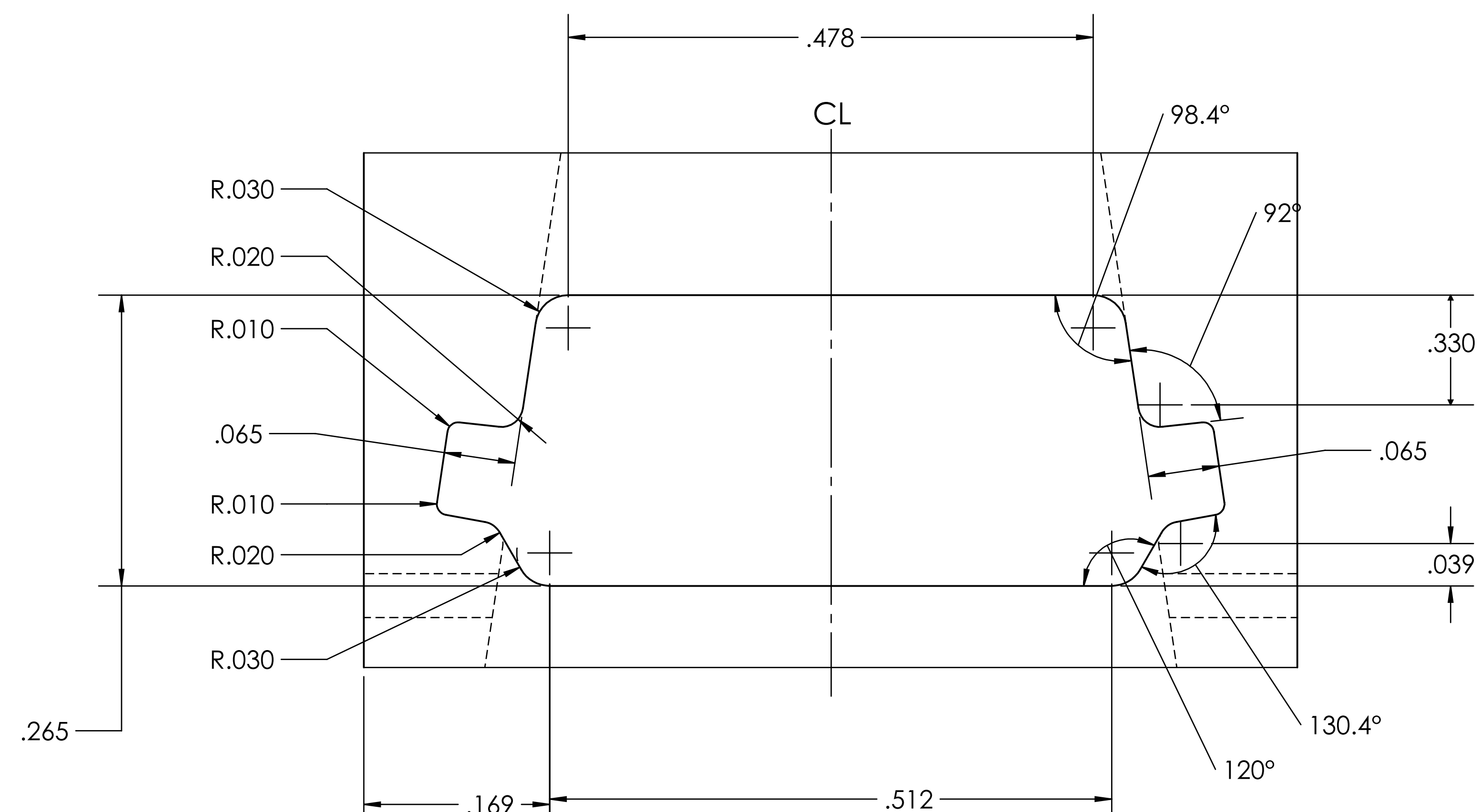


TOP VIEW
SCALE 3:1

NOTES:
1. DETAIL F IS DETAIL VIEW OF THE PROFILE WHICH IS A THROUGH HOLE.
2. THE FILLET AND ANGULAR DIMENSIONS IN DETAIL F ARE SYMMETRIC AND ALSO APPLY TO THE OTHER SIDE OF CENTER LINE "CL".



FRONT VIEW
SCALE 3:1

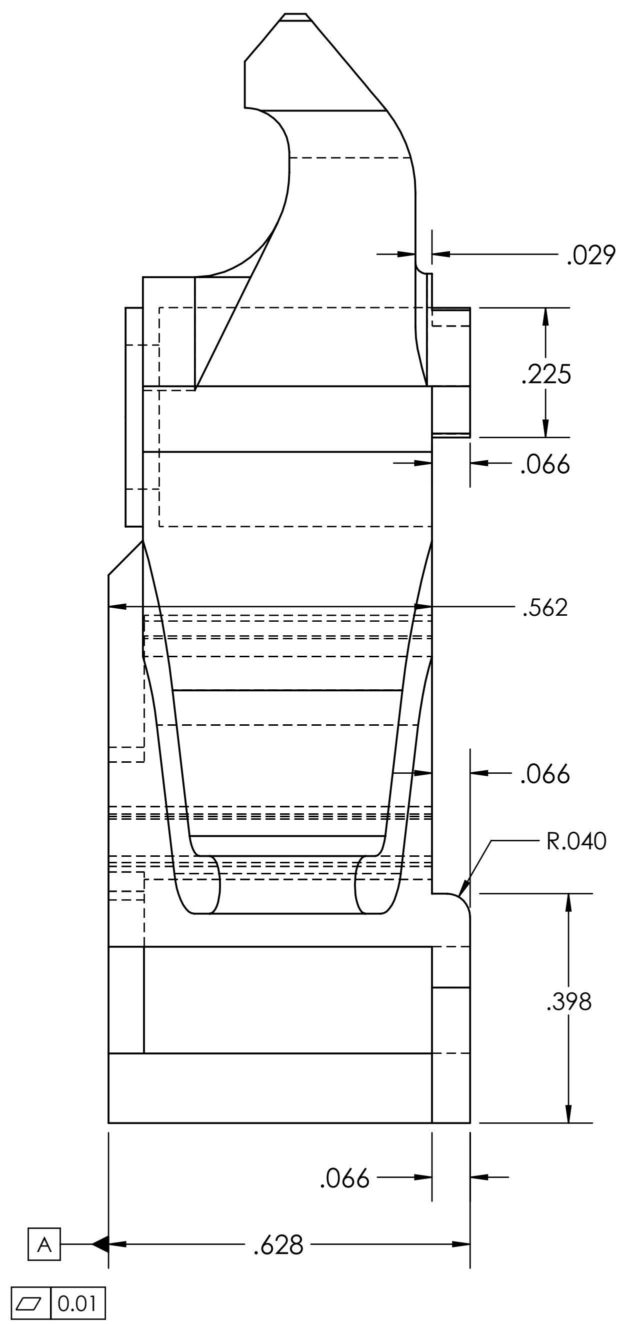


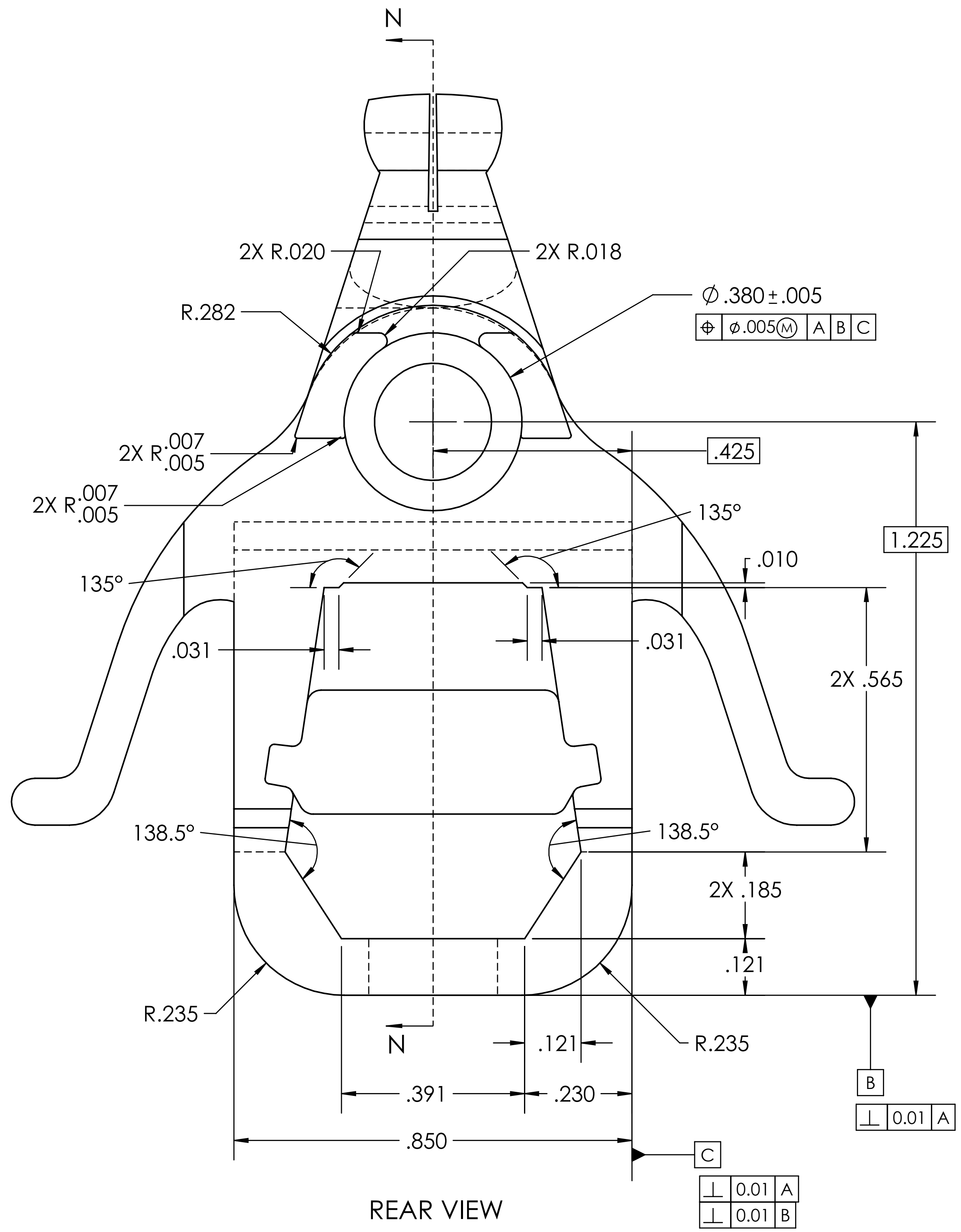
DETAIL F
SCALE 6 : 1

TOLERANCES UNLESS NOTED:	X.X ± 0.05 X.XX ± 0.01 X.XXX ± 0.005 X.X° ± 0.5°		UNIVERSITY OF COLORADO MCEN 5045 1111 ENGINEERING DRIVE BOULDER, CO 80309
UNITS: INCHES			
MATERIAL ABS PLASTIC			DESCRIPTION DRIVE LEVER REDESIGN
FINISH N/A		PN 015R	REV A	SHEET 2 of 3

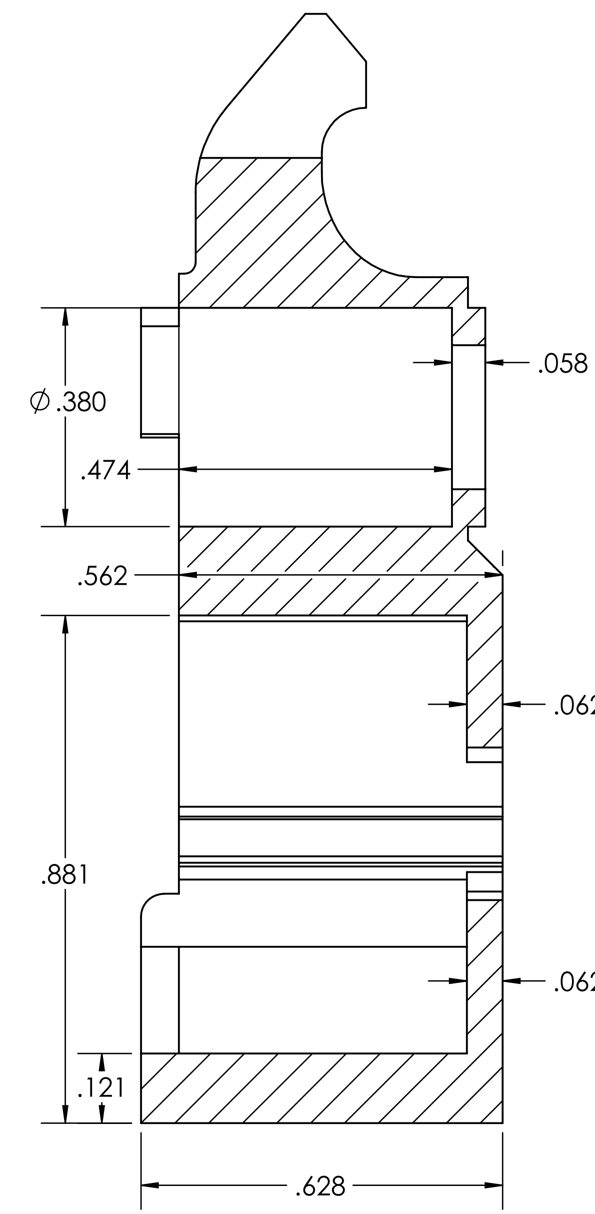
6 5 4 3 2 1

REVISIONS		
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	3/5/2024





REAR VIEW
SCALE 3:1



SECTION N-N
SCALE 3 : 1

ISOMETRIC VIEW
SCALE 1:1

NOTES:

1. UNLESS OTHERWISE SPECIFIED SURFACE PROFILES TO MATCH MODEL 'DRIVE LEVER REDESIGN.SLDPRT' WITHIN 0.03

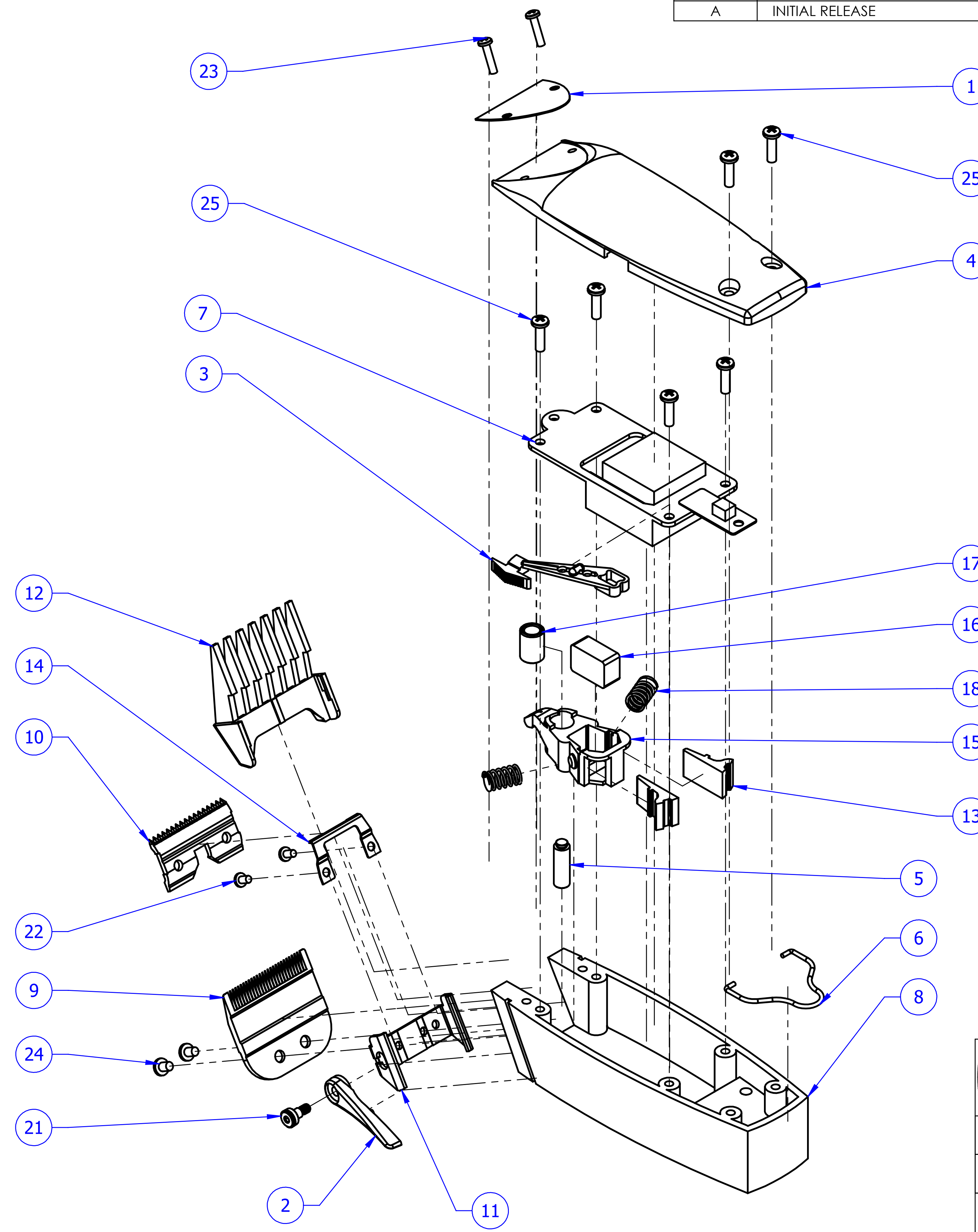
TOLERANCES UNLESS NOTED:		
	X.X	± 0.05
	X.XX	± 0.01
	X.XXX	± 0.005
UNITS: INCHES	X.X°	± 0.5°

UNIVERSITY OF COLORADO
MCEN 5045
1111 ENGINEERING DRIVE
BOULDER, CO 80309

MATERIAL	DESCRIPTION			
ABS PLASTIC	DRIVE LEVER REDESIGN			
FINISH	PN	REV		SHEET
N/A	015R	A		3 of 3

REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	3/7/2024

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	001	FAST FEED PLATE	1
2	002	BLADE LEVER	1
3	003	SWITCH EXTENSION	1
4	004	UPPER HOUSING	1
5	005	MAGNET LOCATING PIN	1
6	006	HOLDING CLIP	1
7	007	MOTOR HOUSING	1
8	008	LOWER HOUSING	1
9	009	BLADE 1	1
10	010	BLADE 2	1
11	011	HOLDER	1
12	012	COMB	1
13	013	DRIVE LEVER INTERNAL PART 1	2
14	014	CONNECTOR SHEET	1
15	015	DRIVE LEVER	1
16	016	MAGNET	1
17	017	BRASS BUSHING	1
18	018	SPRING	2
19	019	POWER CORD	1
20	020	INSERT FOR CONNECTOR SHEET	1
21	97345A111	316 Stainless Steel Shoulder Screw	1
22	CR-PHMS 0.112-40x0.188x0.188-N		2
23	CR-PHMS 0.112-40x0.5x0.5-N		2
24	CR-PHMS 0.138-32x0.188x0.188-N		2
25	CR-PHMS 0.138-32x0.5x0.5-N		6



UNIVERSITY OF COLORADO
BEN ERICKSON
1111 ENGINEERING DRIVE
BOULDER, CO 80309-0427

DESCRIPTION
HAIR CLIPPER

PN	REV	SHEET
200	A	1 of 1