The VIBE TR Series: Fit-Widget Bracelet

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Bachelor of Science

By

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Abstract

As our society begins to understand the impact of mental health on human behavior, David Postula saw the need for a product which could help children increase their productivity in the classroom. David imagined the VIBE Bracelet, designed as an anti-anxiety tool that helps young children reduce stress in the classroom and intermittently remind the user of goals or ideas throughout the day. David offered sponsorship for the development of the VIBE Bracelet design project by Cal Poly SLO students. The students designed the VIBE Bracelet to fit David's requirements for a thoughtful reminder bracelet: a fidget element on the band, an interchangeable icon element, and a vibration element to act as a reminder in conjunction with the icon. The following report includes a detailed literature review, conceptual designs, a final prototype design, testing with results, and future recommendations.

I. Introduction

Children with ADHD, anxiety, and autism often experience high levels of stress and difficulty concentrating in important or high-pressure situations, requiring a physical outlet for stress relief. The stakeholders for this project include the V.I.B.E. Team, the project advisor, the sponsor, and all its users. Many therapeutic devices like fidget spinners and weighted blankets function well in these aspects and have been scientifically proven to significantly reduce stress [1]. However, most of these are not something that children can use in their everyday lives. Fidget spinners and several other therapeutic toys tend to become distracting in the classroom. As a result, many schools have gone so far as to ban them [2]. The V.I.B.E. Team has created a bracelet which features the same type of tactile feedback for a soothing effect, has the capability to provide thoughtful reminders throughout the day, and does not interfere with classroom activities to provide its users with stress relief throughout the day. The bracelet also had multiple requirements from our sponsor, which included:

- Low Cost
- A Vibration Reminder
- A Fidget Element
- Comfortable
- Aesthetically Pleasing
- Adjustable
- Interchangeable Icons
- Easy To Use

II. Background

Prior to beginning the design phase of the product, the team conducted a patent and literature search to make sure the product was completely unique and did not violate any current patents. The following paragraphs detail the search conducted by the V.I.B.E. team with respect to the ideas encompassed in the VIBE project and demonstrate that the VIBE bracelet is a new and innovative idea.

i. Similar Projects

a. Revibe Connect

Figure 1: Revibe Connect and System Server [3]

A similar project to the VIBE bracelet is the Revibe Connect vibration reminder watch intended for chhildren with ADHD. However, a patent search regarding the project revealed that the Revibe Connect does not satisfy all the specified customer requirements (listed under Objectives). The Revibe watch relates to the V.I.B.E. Team's ideas in that it is a watch that vibrates to alert children with ADHD to stay focused and remind them of tasks to accomplish [3]. However, the patent states that the product must include storing a response from the user and transmitting user data to a system server [4]. These technologies are not used in the VIBE bracelet design, so the V.I.B.E. Team will not violate this patent. The Revibe Connect also does not fit within the price range of the VIBE bracelet. With a cost of 120 USD, the price far exceeds the target selling price of 5-15 USD for the VIBE bracelet. Upon a further search of patents referenced in the Revibe patent, only one other patent was similar enough to warrant a careful examination. This patent, titled Method of Attention Recovery and Behavioral Modification [5], had claims for providing a sensory input for the user, but also discussed an activity to regain the user's attention, a feature that will not be part of the VIBE project. All other patents found in relation with the Revibe patent search resulted in patented projects that exceeded the basic technological design of the VIBE bracelet, such as tracking user movement or activity levels, telling time, or transmitting data to another device. Many VIBE bracelet elements are much simpler or more general and therefore are not exclusively patentable features found in other patented ideas.

b. Mindful Fidgets

Figure 2: Wearable Fidget [6]

Another patent that concerns the VIBE project relates to the fidget aspect of the bracelet. This pending patent for the Wearable Fidget consists of a spinning mechanism attached to a band placed around a user's wrist [7], pictured above. The patent specifies a particular shape of the spinner, so a different spinner shape is acceptable if a spinning element is part of the VIBE bracelet. There are other fidget options available that are not patented, so the V.I.B.E. Team can incorporate different fidget elements, depending on the mechanics behind it. The price of the Wearable Fidget is 14.75 USD, so the bracelet does fit within the VIBE bracelet price range. The bracelet above is simple, colorful, and looks comfortable, all aspects the VIBE bracelet should include. However, the Wearable Fidget has no vibration element, so it does not cover the reminder aspect of the customer requirements, failing one of the most important criteria.

c. Fidget Spinner

Figure 3: Fidget Spinner [8]

The fidget spinner [9] fidget tool that became very popular among all ages of children and young adults is a similar project geared toward children with ADHD as an energy outlet. The fidget spinner sells for around 12 USD, fitting into the VIBE bracelet requirement. Unfortunately, the size of fidget spinner made it a huge distraction in the classroom. The fidget element of the VIBE bracelet will be on the wristband, making the fidget action more discrete. Also, the fidget spinner fails many criteria, including vibration reminder, interchangeable icons, and wearable around the wrist. Therefore, the fidget spinner in no way satisfies the needs of the sponsor and/or customer.

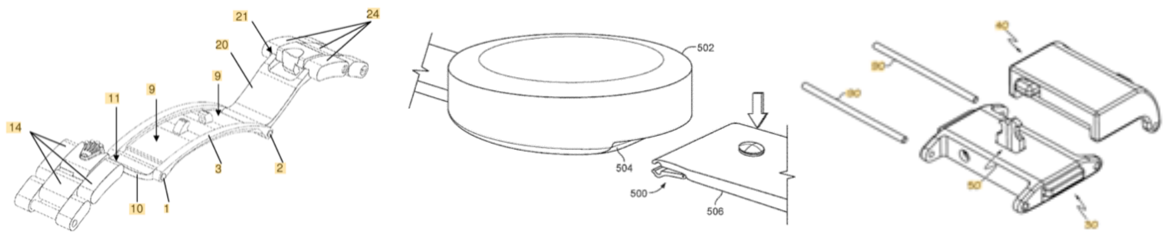
d. Fidget Cube

(a) (b)

Figure 4: Fidget Cube [10]

The fidget cube [11] is a fidget toy that was introduced around the same time as the fidget spinner. This tool is less distracting than the fidget spinner since it is smaller and can be held in the palm of the hand. The fidget cube is a decent product in that there are several fidget elements, satisfying different fidget preferences, yet it does not have a vibration element and is not wearable, so it will not satisfy the criteria for the VIBE bracelet. Like the fidget spinner and cube, almost all fidget toys or devices found in the patent search were stand alone, handheld objects, so fidget elements incorporated into the band of the VIBE bracelet itself is a unique and plausible idea, proving the VIBE bracelet is a new design.

e. <u>Fixation Elements</u>



(a) (b) (c)

Figure 5: fold-over clasp [12] (a), detachable pivot members [13] (b), and spring actuated locking mechanism [14] (c)

Another patentable aspect of the VIBE bracelet is the fixation element of the bracelet band. There is no method the team has decided on, but there are several patents that would restrict the available options for closing the bracelet if the VIBE bracelet requires a more advanced method. These patented designs include fold-over clasps [12], detachable pivot members [13], and spring actuated locking mechanisms [14] (all pictured above). Simpler methods such as Velcro, buttons, or through-holes are not exclusively patented and are possible fixation methods The V.I.B.E. Team may consider.

ii. ADHD and Anxiety Research

The V.I.B.E. Team conducted research related to ADHD in children. One study that proved useful discovered what materials and fidget methods were most popular among children ages 6 to 11 [15]. The study concluded that children were more drawn to squeezing, stretching, clicking, and tapping and preferred materials of plastic or rubber. This research will prove useful when determining the best fidget element for the VIBE bracelet. Another study from 2015 found that appropriate levels of motor activate increased working memory performance for children diagnosed with ADHD [16]. Regarding the VIBE bracelet, this study implies that incorporating a fidget element into the bracelet will allow children with ADHD to not only increase focus but improve performance in the classroom.

The research done by the V.I.B.E. team could find no definitive evidence concluding anxiety is relieved through fidgeting. There was some research stating anxiety levels lowered when hospital patients had stress balls during surgery, but nothing showed fidget tools lowered anxiety in day to day or classroom life.

iii. Power

a. Kinetic Power

The V.I.B.E Team has done research regarding whether it is possible to power the bracelet by kinetic energy. There are watches out there known as kinetic watches. Kinetic watches generate energy through motion using a rotating pendulum which powers an electrical generator. The energy produced by the generator is then stored into a capacitor which discharges over time. On full charge, the watch can last from two weeks to six months [21]. If it is possible, the V.I.B.E. team wants to find a way to make the V.I.B.E. bracelet be able to charge itself kinetically through the motion of fidgeting with the fidget element.

b. Battery Power

Most watches or electronic bracelets use a battery to power any electronics. Lithium-ion batteries are the most popular and are a viable option for powering small circuits such as microcontrollers and vibration motors. Small batteries also have a wide range of provided power, so it is not difficult to find batteries that satisfy small power needs.

iv. Engineering Requirements

When designing this bracelet, the team had to make sure to design around eight customer requirements outlined by the sponsor. These included that the bracelet must be low cost, feature a vibration reminder, feature a fidget element, feel comfortable on the wrist, be aesthetically pleasing, have an adjustable band to accommodate for a wide target age and size range, feature interchangeable reminder icons, and be easy to use. This product is designed with children in mind, so the functions of the bracelet should be intuitive to use. In addition to these customer requirements, the sponsor also wanted to see if it would be possible to feature interchangeable fidget elements as well as power by kinetic energy through that fidget toy. In order to ensure that the design meets the customer requirements, the team developed engineering requirements which needed to be met to reach that goal. These include target requirements for power, weight, cost, size, material selection, and electronics – as seen below in Table 1.

Table 1: Project Vibe Formal Engineering Requirements

Spec. #	Parameter Description	Requirement or Target (units)	Tolerance	Risk	Compliance
1	Power	400 Wh [19]	Min	H	A, T
2	Weight	112 g	Max	M	A, T, S
3	Production Cost	6.00 USD	Max	M	A
4	Area of Wrist	22 cm [17][18]	Max	L	I, S
5	Interchangeable Parts	Yes	N/A	M	T, I
6	Flexibility	Yes	N/A	L	A,T,I
7	Vibration Frequency	160 Hz [20]	Max	H	A, T, S
8	Timing Device	Yes	N/A	H	A, T, S

Legend:

- A – Analysis
- T – Test
- S – Similarity to Existing Designs
- I – Inspection
- H – High
- M – Medium
- L – Low

The reason that these engineering requirements are needed is to ensure the product works, but also to make sure the product is designed without any safety risks. Something an outside observer looking at the engineering requirements might wonder is why there are some maximum tolerances, some minimum, and some that have neither. The requirements that have maximum tolerance restrictions include weight, production cost, area of wrist, and vibration frequency.

- Power – The team determined the bracelet would need about 400 watt-hours of power to function. This requirement was based on the power requirements of similar products to ensure that the VIBE product could compete with other devices on the market. The minimum tolerance for power ensures the bracelet as a long-lasting battery life to reduce replacement or recharging of the battery.
- Weight – The team found that a bracelet with a weight of roughly 112g would weigh most comfortably on a child's wrist. This value was decided based on the average weight of (1) the Revibe Connect Bracelet (250g), (2) a general digital watch for

children found on Amazon (43g), and (3) the maximum weight of an Apple watch (41.7g). Weight has a maximum tolerance limit because if the bracelet gets too heavy, younger children will not be able to easily use it. The risk is listed as “medium” because if the design were too heavy, many children who used the product would be uncomfortable wearing a heavy-weighted object on their arm throughout the day. It could pose as a distraction and potentially cause pain for the user.

- Production cost – The production cost has a maximum limit as well because the sponsor would like to create an easily affordable focus tool so the design should not exceed his desired budget The estimated cost to manufacture each VIBE bracelet was originally 6.00 USD, with its price of unit at 15.00 USD. As mentioned earlier, the product’s cost is one of the more important targets to meet for the project sponsor as the inexpensive feature differentiates it from other competitors on the market. Additionally, the sponsor wanted a 60% gross margin while aiming for a final sale price of about 15 USD. With that retail price, the maximum production cost should not exceed 6 USD. By the end of the design process, the sponsor approved going a bit over the 15 USD target in exchange for a rechargeable battery design, so this maximum tolerance ended up extending to 20 USD.
- Area of Wrist – The area of wrist maximum limit is in place to make sure the bracelet is designed to fit most children, and if it is too large it will be unsuitable for everyday wear. The average circumference of a 15-year-old’s wrist, which would be the maximum band length, is about 22cm. The minimum area of wrist would be that of a 5-year-old, which on average is about 15cm. Since the band is adjustable, the team used the maximum band length for this engineering requirement.
- Interchangeable Parts – The sponsor asked that the bracelet include a thoughtful reminder icon, which can be swapped out for another type of icon of the user’s preference. Additionally, the sponsor wished the fidget element would also be interchangeable in case the user needs a new type of tactile engagement. Since the interchangeable parts are more of “wants” than “needs” for this bracelet’s design and do not contribute to the design for proof of concept, the risk level is considered low in relation the Team’s other engineering requirements.
- Flexibility – The bracelet needed to be adjustable in order to fit children between the ages of 5-15. This means that the bracelet will either feature a band made of a flexible material such as silicone or it will be made with a more rigid material that can be manually adjusted, like Velcro or leather.
- Strength of Vibration – There is a maximum vibration frequency because the bracelet must be classroom friendly and comfortable, so the vibration should not be loud nor too strong. The vibration amplitude of the bracelet is comparable but less than that of a phone. This element creates a strong enough vibration to remind the user, but not strong enough to be a distraction.

- Timing Device – This will allow the user to set a preferred time interval for when the bracelet will vibrate. This will function as an alert for their intended thoughtful reminder.

v. Customer Requirements

Prior to the manufacturing stage of prototype development, the VIBE Team developed a "House of Quality" in Table 2. This table details eight main engineering requirements outlined by the members of the VIBE Team which compare customer with engineering requirements, as well as compare the prototype to three competing products already existing on the market which serve as its benchmarks. This table shows the correlation between the customer and engineering requirements and allowed the team to decide which areas were most important to focus on. As discussed above, the eight engineering requirements listed need to be met to successfully design the prototype. From the table, the most important qualities included the fidget element, vibration reminder, and adjustability, with low-cost, comfort, and ease of use following it.

Table 2: House of Quality - Quality Function Development Table

Customer Requirements (Step #2)	Engineering Requirements (HOWS)										Benchmarks		
	Weighting (1 to 5)	Power	Weight	Price of Unit	Area of Wrist	Removable Parts	Fixture Element	Flexibility	Strength of Vibration	Timing Device	Revibe Connect	Mindful Fidgets	Fidget Spinner
Low Cost	4	5	-	7	-	4	-	-	-	6	1	8	9
Vibration Reminder	5	7	6	5	-	-	-	-	9	9	9	1	1
Fidget Element	5	-	7	6	-	3	6		-	-	1	9	9
Comfortable	4	-	8	-	8		9	8	8	-	7	8	4
Asthetically Pleasing	3	-	-	-	-	-	6	6	-	-	6	7	6
Adjustable	5	-	-	-	9		9	-	-	-	9	9	1
Interchangable Icons	3	-	8	8	-	9	-	-	-	-	1	1	1
Ease of Use	4	-	-	-	-	8	-	8	-	-	7	8	9
Units		Wh	g	USD	cm	Y/N	Y/N	Y/N	Hz	Y/N			
Targets		0.18	150	15	22	Y	Y	Y	180	Yes			
Benchmark #1		1	5	1	9	5	1	9	5	5			
Benchmark #2		1	3	7	1	1	1	1	1	1			
Importance Scoring		12	29	26	17	24	30	22	17	15			
Importance Rating (%)		40	97	87	57	80	100	73	57	50			

● = 9 Srong Correlation
○ = 3 Medium Correlation
Δ = 1 Small Correlation
Blank No Correlation

III. Design Development

i. Descriptions

In order to make a product that can help the user remember tasks and relieve energy through fidgeting, the team spent some time coming up with ideas for a variety of products besides the original bracelet ideas such as water bottles, keychains, necklaces and more. These product ideas had fidget elements and a reminder unit with icon/text and vibration components. All designs had to include four main components: (1) a base/ casing/ band, (2) a fidget element, (3) a reminder unit (which includes a screen for text or icons, and vibration components), and (4) a power source to operate the reminder.

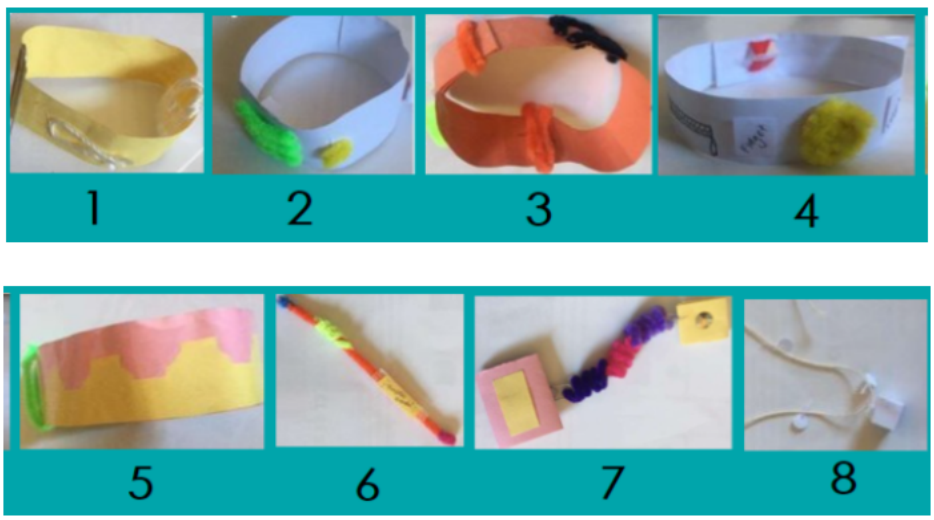


Figure 6: Conceptual Prototypes

ii. Pugh Matrix

The Pugh matrix below ranked all the designs pictured in Figure 6 against a datum, a product which is most similar to the VIBE design called the “Revibe Connect”. The purpose of this matrix was to choose an optimal design for the overall layout of the bracelet, such as where the fidget element and reminder unit would be placed on the bracelet band. The team created other Pugh matrices to rank materials, power sources, and fidget elements to decide on a more detailed design.

Table 3: Decision Matrix

Requirements		Design from Figure 6								Revibe Connect
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	
Low-cost	A	+	+	-	+	+	+	+	+	D
Fidget element	B	+	+	+	+	+	+	+	+	
Sizing	C	-	-	+	S	-	-	+	+	A
Vibration reminder	D	S	S	S	S	S	+	S	S	
Aesthetics	E	+	+	+	+	-	+	+	+	T
Customizable	F	+	+	+	+	+	+	-	-	
Power	G	S	S	+	+	S	S	S	S	U
Σ+		4	4	5	5	3	5	4	4	
Σ-		1	1	1	0	2	1	1	1	M
ΣS		2	2	1	2	2	1	2	2	

Through analyzing each conceptual design in context of cost, adjustability, aesthetics, components, power, and customizability, Design 4 was chosen as the optimal design for the layout of the bracelet. A bracelet design was the best option because bracelets are more classroom-friendly and less likely to be lost, considering the target customer are children from the ages of 5-15 years old.

iii. Conceptual Design

The images, schematics, and tables below detail the layout of the bracelet, describe how the team came to conclusions for bracelet components, and the layout of the internal electronics and software. The team also outlined the safety factors for the bracelet, discussed the methods of production and testing, and presented a layout for the manufacturing plans for Winter 2021.

a. <u>Initial Sketches and 3D Model</u>

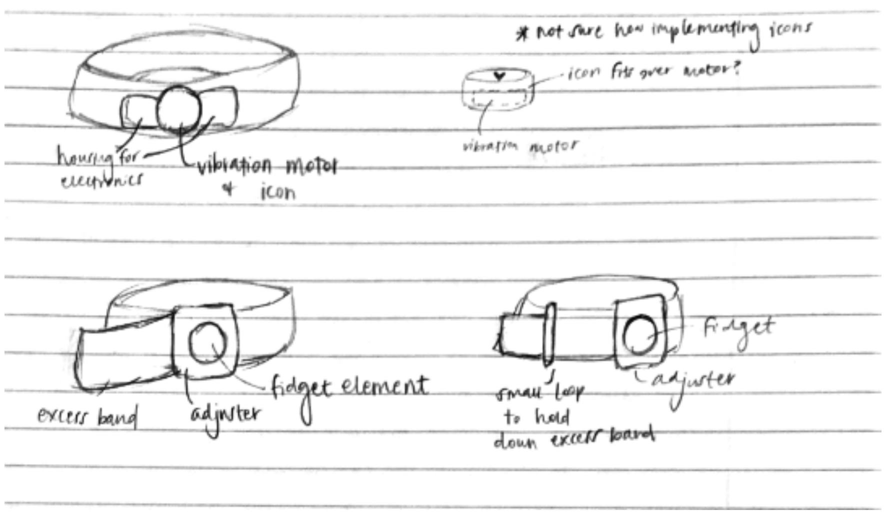


Figure 7: Preliminary Sketches of Conceptual Design

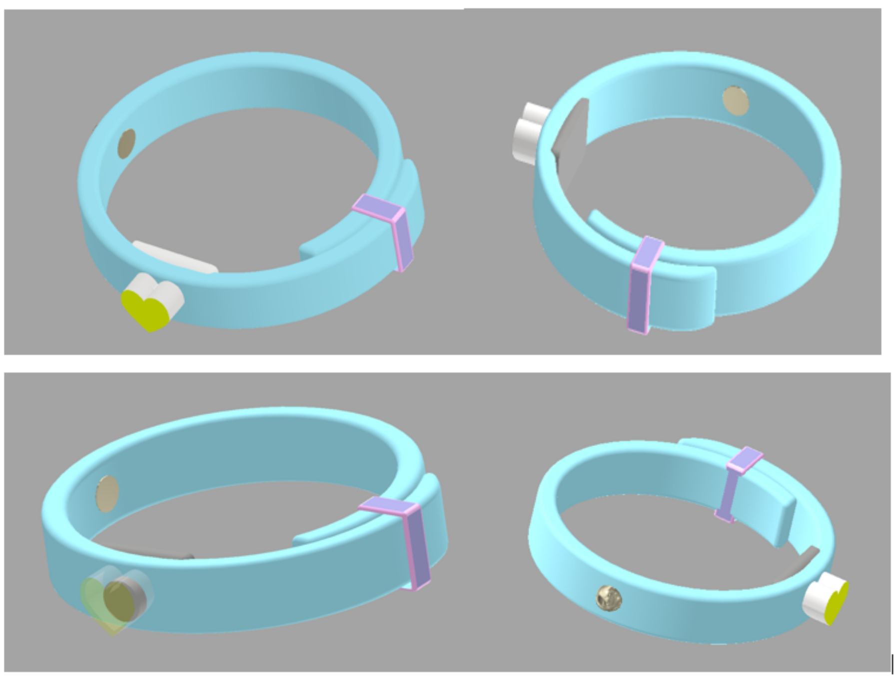


Figure 8: 3D Model of Conceptual Design

b. Sub-Matrices for Further Bracelet Details

As mentioned before, the main components of the VIBE bracelet are the band, fidget elements, and a reminder unit. The following Pugh matrices helped the team decide the best options for each of the bracelet components.

Band Materials

Table 4: Band Material Decisions

Requirements	Soft PLA	TPE	Leather	Revibe Connect (TPU)
Cost	-	-	-	DATUM
Flexibility	+	-	+	
Durability	-	-	-	
Hypoallergenic	S	S	S	
Water Resistance	S	S	-	
Weight	-	S	-	
Σ+	1	0	1	
Σ-	3	3	4	
ΣS	-2	-3	-3	

From Table 4, TPU was compared to three other potential materials and came out as the best option.

Fidget Elements

Table 5: Selection for Fidget Elements

	Joystick	Switch	Button	Roller	Clickable Ball and Socket	Dial	Spinner	Worry Stone	Mech Keyboard	Fidget Cube
Weight	+	+	+	+	+	S	+	-	+	
Size	+	+	+	+	+	-	+	+	-	D
Noise	S	-	-	S	-	S	S	S	-	A
Bulk	+	+	+	+	+	-	+	-	-	T
Satisfaction	S	S	S	S	S	S	S	-	S	U
Ease of Use	+	+	+	+	+	+	+	+	+	M
Σ+	4	4	4	4	4	1	4	2	2	
Σ-	0	1	1	0	1	2	0	3	3	
ΣS	4	3	3	4	3	-1	4	-1	-1	

All the fidget toys that were better than (ΣS positive) the fidget cube had the potential to be used in the fidget element of the product. However, only one design was needed for the prototype. The three toys with the highest ΣS (=4) were the joystick, roller, and spinner. For the prototype design, the fidget element would be a combination of two out of these three toys to offer two ways of fidgeting. The final design that was chosen by VIBE Team for the fidget element of the prototype was a combination of the roller and the spinner.

Reminder Unit

Table 6: Selection for Reminder Unit

	LED screen	LCD screen	Plastic Icons	Velcro icons	Silicon icons	High-tech screen
	1	2	3	4	5	REVIBE
Cost	-	-	+	-	+	D
UI/User Friendliness	+	-	+	-	+	A
Interchangeability	S	S	+	+	+	T
aesthetic appeal	+	+	-	-	-	U
marketability	S	S	+	+	+	M
Compatibility w/ vibration	S	S	+	+	+	-
Σ+	2	1	5	3	5	
Σ-	1	2	1	2	1	
ΣS	3	3	0	0	0	

The reason the team decided to go with the Silicon icons as the reminder element is because it had the most positives and only one negative, which was the aesthetic appeal (which, with the cost constraints on this project, makes sense in comparison with the high-tech screen from the Revibe.

Power Source

Table 7: Selection for Power Source

	Battery	Solar	Kinetic	DATUM
	1	2	3	4
Cost	+	-	-	D
Voltage	+	+	+	A
Duration	S	+	-	T
Complexity	+	-	-	U
Sustainability	S	+	+	M
Replacability	+	-	-	
Σ+	4	3	4	
Σ-	0	3	3	
ΣS	2	0	0	

When choosing the best option for the VIBE Bracelet power source, kinetic, solar, and battery power were compared against the rechargeable battery used in the Revibe Connect bracelet. After researching kinetic and solar power sources used in watches, each design was rated. Looking at the summed totals at the bottom of the table, batteries were the favored method of power. Batteries were the cheapest option (the most important criteria in the table), the least complex, and the easiest to repair or replace. However, the V.I.B.E. Team will continue to investigate the advantages and disadvantages of kinetic power since the project sponsor favors this type of power. Overall, the final project will most likely utilize batteries to keep production cost low.

c. Schematics

The inside electronics of the VIBE Bracelet includes a power source, vibration motor, and a timing circuit, shown in Figure 9. The timing circuit is meant to set the vibration motor to vibrate at different time intervals and should include a timing chip, buttons/switches, and various resistors. The original concepts for the timing circuit utilized a microcontroller and crystal oscillator. After further research into analog circuits, the team determined that a microcontroller would not be necessary since it would make it more complex, more expensive, and require software. Instead, the circuity utilizes a TPL5110 nano-power timer to create the timing circuit. The circuitry surrounding the TPL5110 chip is similar to the circuit schematic for the TPL5110 breakout board by Adafruit. This board was the foundation of the team's schematic as it performed the necessary actions for the bracelet but used extra components and therefore extra space. The board uses less power, less components, and costs less than a microcontroller, therefore making it a better option for the VIBE bracelet final design.

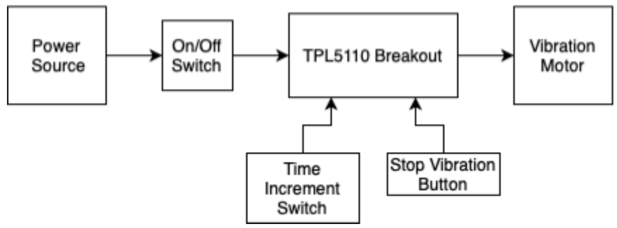


Figure 9: Block diagram for electrical circuitry

d. Satisfaction of Customer Requirements

The customer's main requirements were that the product is an easily affordable thoughtful reminder bracelet, featuring a vibration reminder and a fidget element to help users alleviate stress and anxiety. The V.I.B.E. team's prototype's design incorporates each of these key elements with a classroom-friendly fidget element, a vibration motor, and flexible TPU and PLA materials to create the band and thoughtful reminder icons. Throughout the design process, the team kept the low-cost aspect as the top priority for the customer requirements. The original ideal retail price for the completed bracelet was between $10-15 dollars. With a non-rechargeable battery, the team stayed within this goal. However, the need for a rechargeable battery outweighed the need to keep the bracelet under $15, so with that addition the estimated retail price for the rechargeable version of the prototype design turned out to be about $20. The sponsor also wanted the reminder icon to be interchangeable, so the bracelet was designed to accommodate for this. Additionally, the bracelet was designed to be classroom friendly, meaning non-distracting for others and quiet, which differentiates it from multiple competing products currently on the market. The last customer requirement is that the final product must be aesthetically pleasing and comfortable to wear. Some "wants," or non-essential features, that the team looked into adding to the design included an interchangeable fidget element and power by kinetic energy (making this a fidget-powered bracelet). While the team was able to design interchangeable fidget features, the power by kinetic energy design would have exceeded the budget and affected the retail price.

e. Satisfaction of Engineering Requirements

The VIBE Bracelet design satisfies all the engineering requirements as its power is closest to the desired power. The team was able to make the weight of the bracelet about 140 grams and have an area around the wrist of about 20 centimeters. The following design allowed for interchangeable parts for the reminder and fidget elements, have a clasping element for adjustability, and have flexibility as the bracelet was made from TPU. It also included a timing device that allows the user to set time intervals to vibrate. The vibration was smaller than 160 Hz to be strong enough to remind the user, but not startle them.

f. Safety

The V.I.B.E. team's primary concern for safety with the bracelet is allergies. Some of the materials that could have been used for the final product, such as silicone, had potential to cause bad reactions if said user has allergic reactions to said material. To counter this concern, the team specifically chose materials which have non-allergenic qualities. Another concern would be the icons being too small and being a potential choking hazard. To counteract this, the team recommended putting a warning for consumers on the packaging about this potential issue.

Other concerns that had come up for safety with the bracelet are the potential of sharp objects and choking hazards. Since the chosen fidget in the end was a gear mechanism, it was possible for the gears to be too sharp and cut the user. In order to resolve this problem, the gears were rounded out to protect the user while maintaining full functionality. The band includes some small parts making choking a safety concern. The team will design to keep small parts contained and attached, decreasing the probability of choking hazards. Another design concern was potential hazardous material in the battery. In extreme conditions, batteries may break down and be hazardous. The team will include a warning to the consumers to tell them to be careful with the battery in extreme conditions.

IV. Final Design

i. Prototype Overall Design

After a lot more research was done, the conceptual design was adjusted to achieve a better (for pricing and complexity) solution. Figure 10 shows the final design for the prototype.

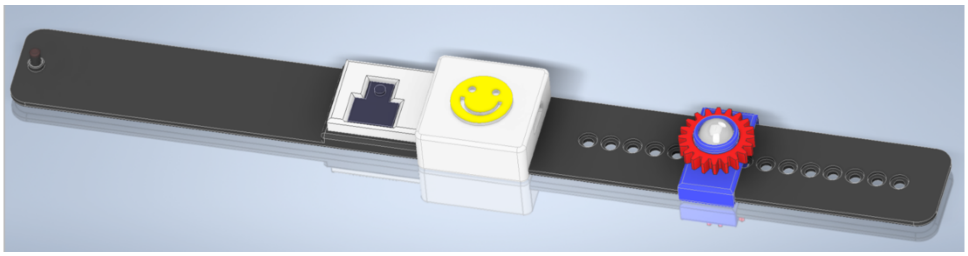


Figure 10: Overall Design for Prototype

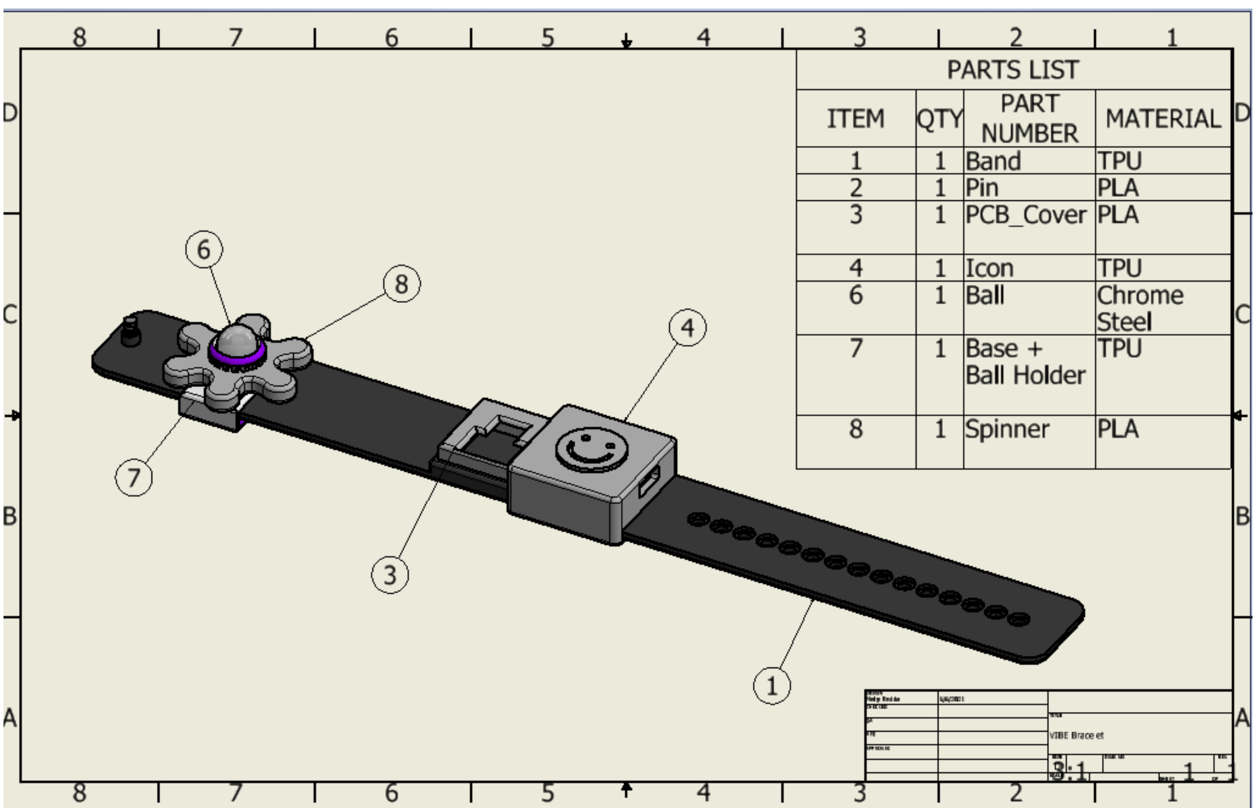


Figure 11: 2D Drawing of the VIBE Bracelet without Electrical Parts

The fidget element was a combination of the spinner toy and the roller ball toy. The electric components, an intermittent vibration unit and battery, would be placed under the icon. The vibration would go off within a certain time interval (chosen by the user) to remind the user of the meaningful message from the icon. This function promotes the users' focus and improves their productivity. The wristband would be adjustable in a large size-range to accommodate the largest to the smallest wrist sizes of children from the age of 5 to 15.

ii. Mechanical Design

Table 8: Comparing Mechanical Design with Mechanical Engineering Requirements

Engineering Requirements	Target Value	Actual Value
Weight	Lighter than 112 g	39 g
Circumference of Wrist	22 cm	23.4 cm
Interchangeable Parts	Yes	
Flexibility	Yes	

a. Bracelet Band

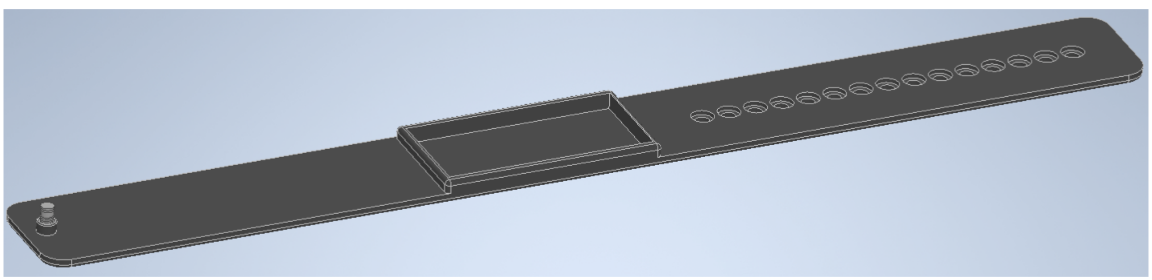
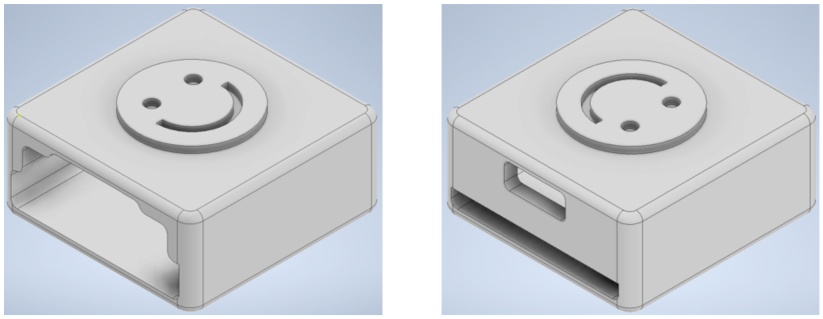


Figure 12: Prototype's Band Design

From the conceptual design, the material used for the band was TPU. During the process of the band and icon's design, these three aspects were considered critical: (1) high flexibility to fit broad range of sizing; (2) method of assembly between the icon and the band (screws, adhesives, magnets, etc.); and (3) inter-changeable function of parts. The band has 15 holes to fit multiple sizes with (6 millimeters distanced) in between the largest wrist size and the smallest wrist size. As shown in Figure 11, the closure of the band was a pin-connection using a PLA pin.

b. Icon

The connection between the band and the icon was sleeve-sliding. This method of assembly is chosen because it does not require any extra components (screws, adhesive, etc.) which simplifies and reduce the cost of the product.

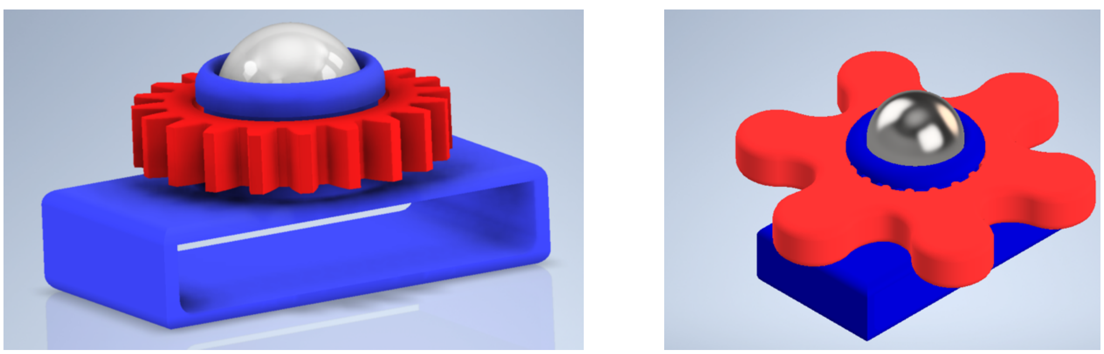


(a) (b)

Figure 13: (a) Left-View and (b) Right-View of the Icon

The icon was designed as a hollow shell that slide along the band and covered the battery [Figure 12]. On the right side of the icon, there was a port made for rechargeable battery. As shown in Figure 10, there was another part of the icon that covered the PCB broad and the vibration motor. This part [Figure 13] was not inter-changeable and made of PLA, a rigid, common, and inexpensive material. Because PLA is rigid, as the bracelet is worn, this part will not bend and thus, will protect the PCB underneath the cover.

c. <u>Fidgeting Element</u>



(a) (b)

Figure 14: (a) Smooth Spinner and (b) Haptic Spinner Gear

As discussed in the conceptual design, the fidget element was a combination of spinner and roller toys. The fidget element also included a sleeve base to help it movable along the band for the interchangeable purpose. The first version of the fidget element was a PLA gear spun smoothly on the outside and a roller ball in the middle.

The sponsor's feedback mentioned that haptic feedback in the spinner was preferable. Thus, the second version of the fidget element was created with a PLA spinner that gave haptic feedback as it was spun and the roller ball in the middle. The outer shape of the spinner was adjusted to be less pointy to improve the user's comfort while using it. The haptic feedback of the spinner was designed based on the interference between the spinner the outer layer of the roller ball holder. Two different interferences of 0.25 mm and 0.10 mm were made for the haptic feedback spinner. The 0.25 mm interference version offered more satisfying haptic feedback for teenagers from age of 12 to 15; while the 0.10 mm interference version was considered more suitable for children from 5 to 11 years old.

iii. Electrical Design

The components included in the electrical design of the bracelet are a TPL5110 nano-power system timer chip from Texas Instruments, a vibration motor, a battery, a charger adapter from Tiny Circuits, 2 switches, a button, and various resistors/capacitors. The following descriptions detail the specifications and uses of each component.

a. TPL5110 Nano-Power System Timer

The TPL5110 Nano-Power System Timer is a low power timer meant for power gating (shutting off power to part of a circuit). The timer only draws 35nA when the circuit is not powered, making the chip an outstanding option for reduced battery size. The TPL5110 has many possible timing intervals, set by a resistor and ranging from 100ms to 2 hours (Table 8), well exceeding the desired time intervals of 30 minutes and 1 hour. The timing interval is set by connecting a resistor to the DELAY pin. For the VIBE bracelet, 2 resistors connected to the DELAY pin and to a single-pole-double-throw switch allow the user to switch between 2 different time intervals. When the allotted time passes, power is supplied to the DRV pin, powering the vibration motor connected to that pin. The board then waits to receive a signal from the DONE pin to tell the TPL5110 to disconnect power from the DRV pin.

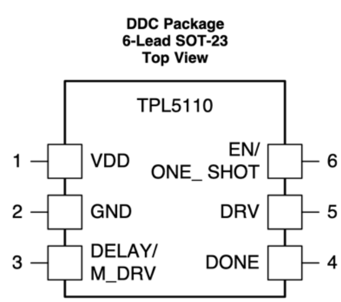


Figure 15: TPL5110 Timer Pinout Diagram [24]

Table 8 below shows the different resistor values that correspond to each time interval. The VIBE bracelet has two different time intervals of 30 minutes and 1 hour, so the design requires resistors of values 92.43ohms and 124.91 ohms.

Table 9: Timer intervals with corresponding resistor values

t_{IP}	Calculated Resistance (kΩ)	Closest Real Value (kΩ)	Parallel of Two 1% Tolerance Resistors,(kΩ)
1min	22.02	22.021	40.2 // 48.7
2min	29.35	29.349	35.7 // 165.0
3min	34.73	34.729	63.4 // 76.8
4min	39.11	39.097	63.4 // 102.0
5min	42.90	42.887	54.9 // 196.0
6min	46.29	46.301	75.0 // 121.0
7min	49.38	49.392	97.6 // 100.0
8min	52.24	52.224	88.7 // 127.0
9min	54.92	54.902	86.6 // 150.0
10min	57.44	57.437	107.0 // 124.0
20min	77.57	77.579	140.0 // 174.0
30min	92.43	92.233	182.0 // 187.0
40min	104.67	104.625	130.0 // 536.00
50min	115.33	115.331	150.0 // 499.00
1h	124.91	124.856	221.0 // 287.00
1h30min	149.39	149.398	165.0 // 1580.0
2h	170.00	170.00	340.0 // 340.0

b. Vibration Motor

The vibration motor, running on 2-5V power, can produce the highest frequency of 183Hz. The current draw of the motor ranges from 40mA at 2V and 100mA at 5V. The project is designed to run on 3V, with a current draw of 60mA.

c. Battery and Charging Adapter

The battery chosen for this circuitry is a 750mAh rechargeable battery from Tiny Circuits. With a consistent current draw of 60mA, the battery life is approximately 12.5 hours. The current of the TPL5110 Timer is not included in this calculation since the current draw is negligibly low when compared to the 60mA. With the assumption of a 30-minute timer running and resetting for 12 hours of the day, and the vibration motor drawing 60mA of current for 5 seconds each time the timer is set off, the battery will run out of charge after about 16 days. The purpose of choosing a battery with a longer battery life is to ensure that the VIBE bracelet can last some time without needing a charge, reducing the need for daily or even weekly charges.

d. Switches and Button

The designed PCB has 2 switches: one meant for turning power on and off, and the second meant for switching the time intervals. These switches will be easily accessible so the user can quickly switch between states. For the time interval, if the user switches to the second choice once the circuit has already been powered, power must be disconnected again before the change is made. The button on the board is meant to turn off the vibration motor once it has been powered. The motor will vibrate until the user presses the button, so if the button is not pressed, the motor will run until the button is pressed or the battery has died.

e. Circuit and PCB Overview

The diagram in Figure 17 details the circuit design for the VIBE bracelet electronics system. The details of the components in the figure are listed in the BOM further down in the document.

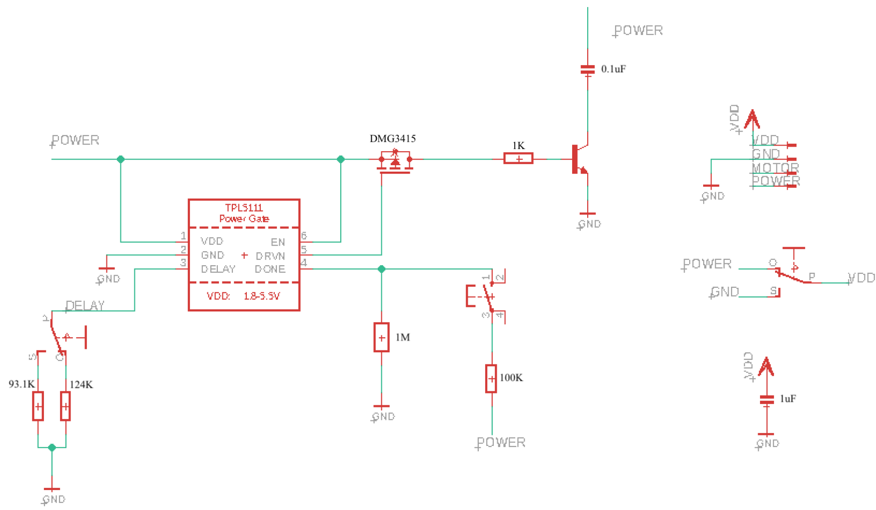


Figure 16: VIBE Bracelet Schematic with Part Values

The foundation of the VIBE circuitry is based on the Adafruit TPL5110 Breakout Board shown in Figure 17. Because the board has several features that the VIBE team was not taking advantage of, the final design does not utilize the breakout board itself. However, the basic function of the breakout board (namely the TPL5110 power gate and pin connections) suits the VIBE bracelet's needs, and therefore Adafruit's breakout board design was helpful in creating a circuit that fits the customer requirements for the bracelet.

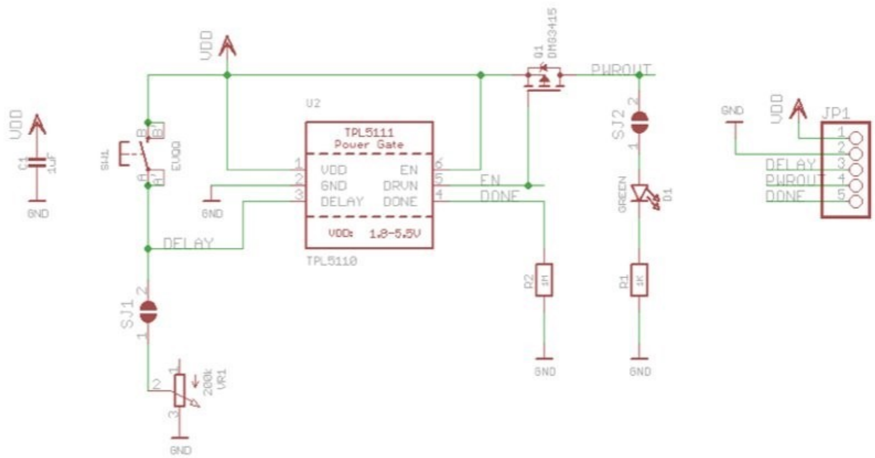


Figure 17: Detailed circuity of Adafruit TPL5110 breakout board

Table 10: Comparison of Engineering Requirements and Final Design

Parameter Description	Required or Target (units)	Expected Tolerance	Current Design	Design Tolerance
Power	400 Wh	Min	3000 Wh	Max
Vibration Frequency	100 Hz	Min	183 Hz	Max
Time Interval	15 min	Min	2 Hr	Max

The table above demonstrates that the circuitry design of the VIBE bracelet holds up to the engineering requirements laid out in the design process. As shown, each aspect of the final design exceeds the minimum requirements necessary for a satisfactory product.

iv. Prototype Cost Breakdown

David, the project's sponsor, specified that he wanted the VIBE Bracelet to be an affordable item on the market. This is one of the main qualities that set it apart from many other competing products. Ideally, he wanted the final project to be sold in stores for around $10-15 USD per unit with a 60% gross margin. While designing the prototype, the team accommodated for this goal by making low cost a high priority in selecting materials for the band, thoughtful reminder, and the battery power source. In the beginning phase of product design, the sponsor wanted to see if it were possible to power this bracelet purely with kinetic energy from the fidget element. Unfortunately, during their research stage, the team found that the feature would come at a high cost. This feature would have been a unique addition to the product, but due to the importance of keeping the product inexpensive, they decided to rule it out. David allotted a budget of $50-100 USD for just the prototype development. The team developed a cost-estimating Excel spreadsheet which helped with budgeting spending on the prototype, as well as an estimate for the sponsor for how much this prototype will cost when mass-produced. The total cost to create the prototype was $115.36. That amount includes all the components currently used and several electronics components which were used in earlier iterations but are no longer being used for the current design. The Bill of Materials shown in Table 9 lists the final parts, the manufacturers for each part, quantity of each per component, and the costs for each item used in the final design. Each manufacturer listed below had the parts in stock, so there were no long lead times which helped ensure the final working prototype would have been created on time.

Table 11: Bill of materials for prototype part

Bill of Materials - Parts used to make Rechargeable VIBE Bracelet

BOM Level	Part Number	Part Name	Description	Manufacturer	Manufacturing ID	Qty	Ordering Costs
1		**VIBE Bracelet**	Base product				
2		**Vibration**	Vibration feature for Reminder				
3	1597-1244-ND	Vibration Motor	Vibration ERM Motor 3V	Seed Technology Co.,	316040001	1	$ 0.12
3	474-COM-00097	Push Button	SparkFun Accessories Mini Pushbutton Switch	SparkFun	COM-00097	1	$ 0.35
3	80-C0805C104M3R	0.1uF Capacitor	Multilayer Ceramic Capacitors MLCC - SMD/SMT 25V 0.1uF	KEMET	C0805C104M3RACTU	1	$ 0.13
3	80-C0805C105Z4VACLR	1uF Capacitor	Multilayer Ceramic Capacitors MLCC - SMD/SMT 16V 1uF Y5V 0805 -20%,+80%	KEMET	C0805C105Z4VAC7210	1	$ 0.12
3	603-RC0201FR-7D100KL	93.1 kOhms	Thick Film Resistors - SMD 93.1 kOhms 50 mW	Yageo	RC0201FR-0793K1L	1	$ 0.12
3	603-RC0201FR-07124KL	124 kOhms	Thick Film Resistors - SMD 124 kOhms 50 mW	Yageo	RC0201FR-07124KL	1	$ 0.10
3	612-EG1218	Pin Slide	Slide Switches PC MNT 3 PIN	E-Switch	EG1218	2	$ 0.49
3	621-DMG3415UQ-7	MOSFET	MOSFET BVDSS: 8V 24V SOT23 T&R 3K	Diodes Incorporated	DMG3415UQ-7	1	$ 0.43
3	595-TPL5110DDCT	Timer	Timers & Support Products Ultra Lw Pwr Timer	Texas Instruments	TPL5110DDCT	1	$ 0.95
3	652-CR0201AFW1001GLF	ResA 0201 1k 1% 50mW	Thick Film Resistors - SMD ResA 0201 1k 1% 50mW TC200	Bourns	CR0201AFW-1001GLF	1	$ 0.10
3	652-CR0201-JW-104GLF	100K 1% 250 ppm	Thick Film Resistors - SMD 100K 1% 250ppm	Bourns	CR0201-JW-104GLF	1	$ 0.14
3	652-CR0201-JW-105GLF	1000k 5% 50mW	Thick Film Resistors - SMD Res 0201 1000k 5% 50mW TC200	Bourns	CR0201-JW-105GLF	1	$ 0.12
3	406-ASL2112	Addapter	Power Management IC Development Tools Tiny Battery	TinyCircuits	ASL2112	1	$ 5.22
3	406-ASR00003	Battery pack	Battery Packs Lithium Ion Polymer Battery - 3.7V 150mAh	TinyCircuits	ASR00003	1	$ 2.46
3	N/A	PCB	Custom PCB	Advanced Circuits		1	$ 0.66
2		**Band**	3D printed with TPU	Xometry		1	Free
2		**PCB Cover**	3D printed with PLA	Xometry		1	Free
2		**Fidget Gear**	3D printed with PLA	Xometry		1	Free
2		**Reminder Icon**	3D printed with TPU	Xometry		1	Free

Total Cost	**$ 11.51**

v. Prototype Manufacturing

a. Mechanical Parts

For the prototype, the band, icon, and fidget element were custom made on SolidWorks. The team 3D printed all the renditions of these parts using the Cal Poly Sandbox and personal 3D printers. The icon and band were made from TPU, while the fidget element was made from PLA. The list of mechanical parts for the product prototype is shown in Table 10. Luckily, both sources of printing were free to use so it did not contribute to the overall VIBE project spending budget.

Table 12: Mechanical Components of the Prototype

Primary Parts	**Bracelet**		**Reminder Icon**		**Fidget Element**		
Secondary Components	Band	Pin	Interchangeable Icon	PCB Cover	Base + Ball Holder	Spinner	Roller Ball
Material	TPU	PLA	TPU	PLA	TPU	PLA	Chrome Steel
Method of Building	3D Printing						Buying Ready-Made Products

b. <u>Electrical Parts</u>

Below is the list of electric parts needed to build the prototype:

- Custom PCB
- Switches and buttons
- Vibration motor
- Rechargeable Battery
- Micro-USB charging adapter
- Various capacitors and resistors

For manufacturing, the Eagle CAD documentation for the custom PCB will be sent to JLCPCB for fabrication. Once the boards were printed, shipped, and received, the team will assemble all components onto the board by hand. The switches, button, motor, battery, and adapter will all be ordered pre-made from Mouser.

vi. Specification Verification Checklist and Testing Plan

After the prototype is built, tests will be performed on the product to ensure it passes all the required specification shown in Table 11 on the next page. In manufacturing the prototype, the team utilized 3D printing to produce the band and reminder icon, and order parts for the vibration motor, power source, and fidget element. As listed in the GANTT in Appendix B, manufacturing and assembly was the primary focus of winter quarter 2021, while testing, retesting, and finalizing the prototype was focused on during spring quarter.

Table 13: Specification Checklist for Testing

Specification or Clause Reference	Testing Description and Condition to Pass	Testing Equipment	Assigned to
Mechanical Assembly	The icon must fit into the band as designed.	None	Molly
	The icon can (1) cover the electric component and (2) ensure the aesthetic beauty of the product.	None	Molly
	The pin should fit into sizing holes.	None	Molly
Sizing	The band should fit 95% of children's wrists from the age of 5 to 15.	None	Molly
Intermittent Vibration	Time interval is controlled by the switch and resistor.	Oscilloscope	Emma
	Vibration goes off at given time interval.	Oscilloscope	Emma
	Vibration strength must meet the engineering requirement (Minimum strength is 100Hz).	Oscilloscope	Emma
	While the motor vibrates, the vibration can only stop when the user turns it off by pressing the button.	Oscilloscope	Emma
	The vibration-timing system can be turned off anytime by the users.	Oscilloscope	Emma
	Measure current output from breakout board	Multimeter	Emma
Fidgeting Element	Gears should be able to turn smoothly.	None	Molly
	Haptic feedback must be satisfying and comfortable when being used.	None	Molly
	Fidget cannot get stuck on itself or other objects.	None	Molly
	Roller ball must stay in after at least 10 drop tests at 5 ft above the ground.	None	Molly
	Fidget should be silent while turning for classroom compatibility.	None	Molly
	Fidget toy's size must fit in aesthetically with the band (Not too big, too bulky, or too small).	None	Molly
Battery Life	Battery must be able to sustain long term use.	Multimeter/ Oscilloscope	Emma
Interchangeability	Icon must be interchangeable.	None	Molly
Comfort and convenience for users	Users must feel comfortable while wearing the band.	None	Molly/ Emma
	The band must stay secured on the users' wrist under strong impacts (for example: sport activities)	None	Molly
	The band must be able to sustain rough impact (such as scrapes, drops and collisions).	None	Molly
	The whole prototype must be weighted less than 112g.	Scale	Molly

V. Product Realization

i. Prototype Manufacturing Results

a. Manufacturing of Mechanical Parts

All of the mechanical parts (except the roller ball) of the bracelet were 3D printed from the printer shown in Figure 18.

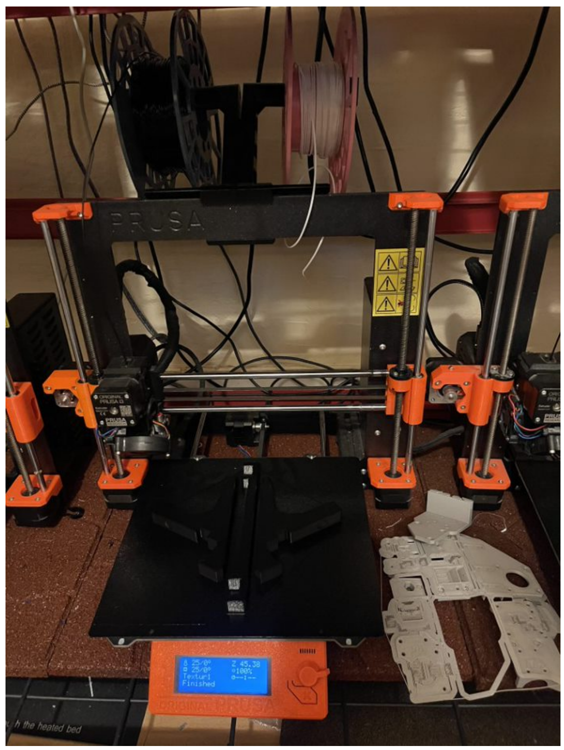
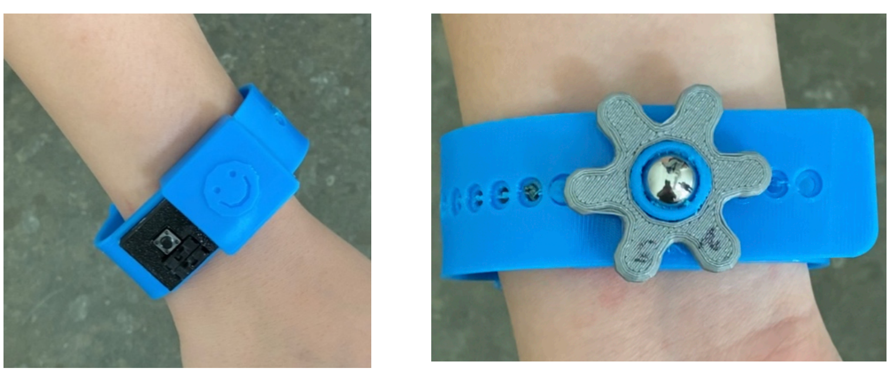


Figure 18: 3D Printer Used to Made Mechanical Parts



(a) (b)

Figure 19: (a) Front View and (b) Back View of the Prototype on User's Wrist

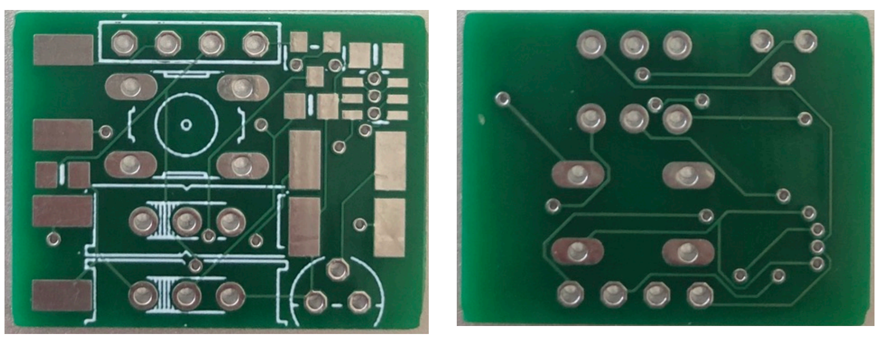
One of the biggest disadvantages for using TPU in 3D printing was that any small errors in printing speeds and temperatures can result in material clogs in the extruder and cause failure. This problem occurred more often with small and thin details (dimensions smaller than 3 mm). To avoid this problem, some changes in the dimensions were made and took note in Table 12.

Table 14: Change in Dimensions to Avoid Failure in 3D Printing.

Part	Dimensions	Original Value	Adjusted Value
Pin	Top thickness	0.5 mm	1 mm
Icon	Thickness	1 mm	2 mm
Base + Ball Holder	Base Sleeve	1 mm	2 mm
	Ball Holder Thickness	0.75 mm	1 mm

b. Manufacturing of Electrical Parts

The electrical components of the band were manufactured through a third-party venue, JLCPCB, where the custom PCB was fabricated. The board was then soldered and wired by the VIBE team using previously owned equipment including a soldering iron and multimeter.



(a) (b)

Figure 20: (a) PCB Top View and (b) PCB Bottom View

ii. Prototype Assembly

a. Electrical Assembly

The fully assembled PCB is shown in Figure 20 below. The first part of the assembly process was soldering on the smaller components (such as the TPL5110 timer, MOSTFET, and capacitors) since it would be difficult to solder the small pads with other components on the board. Next were the larger resistors, and last of all were the through hole components. It should be noted that the 1Mohm resistor in the top right should have been sized the same as the other resistors.

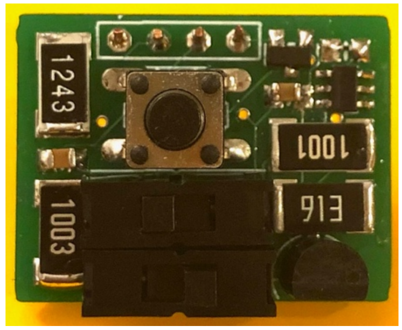
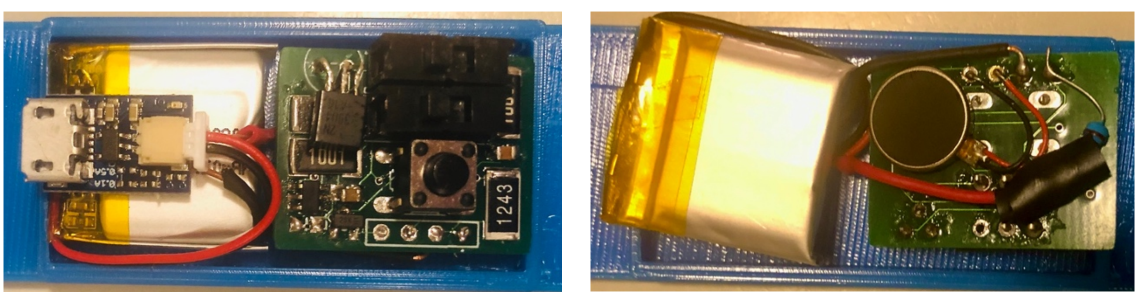


Figure 21: Completed PCB Assembly

After the PCB was completely assembled, the vibration motor and battery were wired to the board, pictured in Figure 20. The battery plugged into the charging adapter through a micro JST SH connector which pre-wired to the battery by Tiny Circuits. All of the wires connected to PCB are routed on the backside of the board. The vibration motor, pre-made with a sticker-like backing, is placed on the back of the PCB board as well. Although it is not pictured in the photos below, the back of the PCB board was insulated with a layer of electrical tape to provide a layer of separation between the PCB pads and the wires/motor attached to the back. This was meant to eliminate any chances of accidental shorting by either bare wires or the metal back of the motor.



(a) (b)

Figure 22: (a) Electronics Top View and (b) Electronics Bottom View

b. Mechanical Assembly

After having all the mechanical components mentioned in Table 12 available, the assembly started with (1) super glued the PLA pin onto the TPU band; (2) put the PLA spinner onto the fidget base, over the ball holder; (3) put the chrome steel roller ball into the ball holder. Once the roller ball was in, the outer surface of the ball holder would expand enough to keep the

PLA spinner from slipping out. (4) At this point, the fidget element was fully assembled and would be slide onto the band (from the left side- the side with the PLA pin) using the sleeve of the fidget element base. (5) The PCB with two switches and a button on top, and the motor underneath was put under the PCB cover made of PLA. (6) The PCB and the cover were then super glued onto the slot (on the left side) in the middle of the band that was reserved for electrical part. This step also resulted in the placement of the battery which was connected to the PCB on the band. (7) The icon slid on the band and went over the battery and its charger and fit snuggly on top. After this step, the product was considered fully assembled.

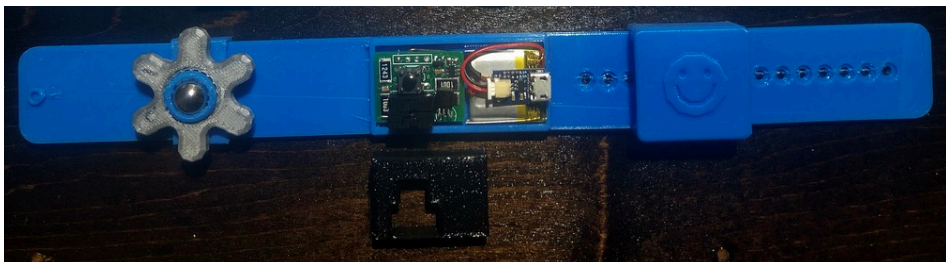


Figure 23: Open View of Assembled Prototype

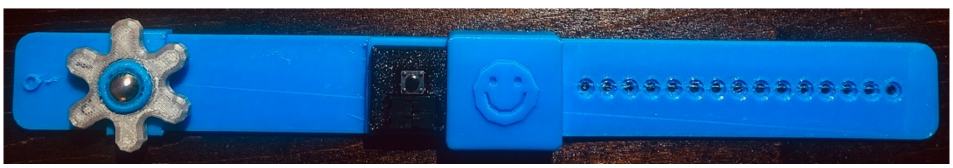


Figure 24: Enclosed View of Assembled Prototype

iii. Manufacturing Conclusions and Future Recommendations

a. <u>Mechanical</u>

To avoid failure in TPU 3D printing, some dimensions were increased, thus, led to the product overdesigned. The original values of these dimensions (shown in Table 14) can be used for future manufacturing which uses injection molding method.

b. <u>Electrical</u>

Since the PCB was assembled by hand, many of the components placed on the board were large for easier assembly. For future manufacturing, these components may be switched out for smaller options to decrease the overall size of the PCB. Reducing the size of the PCB would allow the band icon/electronics to fit better on the wrist, especially for children of younger ages. In regards to PCB components, the ON/OFF switch is currently a SPDT slide switch, but a small rocker switch may prove to be a better component to distinguish between the 2 switches. Also, for final manufacturing, the switches should be labeled to increase ease of use for the customer. For printing the circuit board, the company used (JLCPCB) was best for ordering only a few boards, however if the boards are ordered in large quantities, a different company may be a better option for cost and shipping.

iv. Cost Estimation for Mass Future Production

Once the prototype is handed over to the sponsor, David, he plans to produce about 10,000 bracelets for initial sales. The VIBE Team developed two cost estimates for producing that volume for rechargeable as well as non-rechargeable designs of the bracelets. They did so by researching cost per units based on high order quantities. For the electrical components, most parts on the manufacturer's website listed prices for 10,000+ units. In addition to that, the team communicated with a company called Xometry that calculated some production quotes for the PLA and TPU components including the band, PCB cover, fidget gear, and reminder icons. As mentioned previously, the team determined that injection molding would be the most effective method for creating the PLA and TPU components, so the quote from Xometry was for producing such parts using those methods. Some problems that the team encountered in this part of the process included incomplete cost estimates. There were a few electrical parts which did not include costs for ordering 10,000 units, so the listed unit costs for those parts are noted as being the lowest cost listed by the manufacturer. In addition, the final quote for injection molding 10,000 units of the PLA and TPU components was incomplete; the quote for the TPU components was completed, but the team eventually estimated the cost of the PLA components based on material cost and part size because those values were never disclosed.

The rechargeable VIBE Bracelet design surpassed the upper limit of $15 selling price per unit in this estimate, but the non-rechargeable design stayed under that limit. After talking to the sponsor about the pros and cons of each design, it was decided that the rechargeable design was more effective for customer use, so the higher cost was approved in return for the more functional and longer-lasting design. The total production cost per unit when producing 10,000 units of the rechargeable bracelet would be about $8.11 USD, while the non-rechargeable design would have cost $5.73 USD, as shown below in Figures 24 and 25 respectively. The selling price for the chosen design would be about $20.29 USD, but since the sponsor is using a different company that value is going to vary in the sponsor's future production of the bracelet.

Bill of Materials - Rechargeable VIBE Bracelet

BOM Lev	Part Numb	Part Nam	Description	Manufactur	Manufacturing ID	Qty	Qty 10,00	Unit cos	Total Co	
1		**VIBE Bracelet**	Base product							
2		**Vibration Circutry**	Vibration feature for Reminder Icon							
3	1597-1244-ND	Vibration Motor	Vibration ERM Motor 3V	Seed Technology Co.,	316040001	1	10000	$ 0.90	$ 9,000.00	* Price is for 1000 units
3	474-COM-00097	Push Button	SparkFun Accessories Mini Pushbutton Switch	SparkFun	COM-00097	1	10000	$ 0.35	$ 3,500.00	* Price is for 100+ units
3	80-C0805C104M3R	0.1uF Capacitor	Multilayer Ceramic Capacitors MLCC - SMD/SMT 25V 0.1uF X7R 0805 20%	KEMET	C0805C104M3R ACTU	1	10000	$ 0.01	$ 117.00	
3	80-C0805C105Z4VACLR	1uF Capacitor	Multilayer Ceramic Capacitors MLCC - SMD/SMT 16V 1uF Y5V 0805 -20% +80%	KEMET	C0805C105Z4VA C7210	1	10000	$ 0.02	$ 170.00	
3	603-RC0201FR-7D100KL	93.1 kOhms	Thick Film Resistors - SMD 93.1 kOhms 50 mW	Yageo	RC0201FR-0793K1L	1	10000	$ 0.00	$ 40.00	
3	603-RC0201FR-07124KL	124 kOhms	Thick Film Resistors - SMD 124 kOhms 50 mW	Yageo	RC0201FR-07124KL	1	10000	$ 0.00	$ 40.00	
3	612-EG1218	Pin Slide	Slide Switches PC MNT 3 PIN SLIDE	E-Switch	EG1218	2	20000	$ 0.30	$ 6,060.00	
3	621-DMG3415UQ-7	MOSFET	MOSFET BVDSS: 8V 24V SOT23 T&R 3K	Diodes Incorporated	DMG3415UQ-7	1	10000	$ 0.13	$ 1,310.00	
3	595-TPL5110DDCT	Timer	Timers & Support Products Ultra Lw Pwr Timer	Texas Instruments	TPL5110DDCT	1	10000	$ 0.38	$ 3,830.00	
3	652-CR0201AFW1001GLF	ResA 0201 1k 1% 50mW	Thick Film Resistors - SMD ResA 0201 1k 1% 50mW TC200 AEC-Q200	Bourns	CR0201AFW-1001GLF	1	10000	$ 0.00	$ 40.00	
3	652-CR0201-JW-104GLF	100K 1% 250 ppm	Thick Film Resistors - SMD 100K 1% 250ppm	Bourns	CR0201-JW-104GLF	1	10000	$ 0.01	$ 140.00	
3	652-CR0201-JW-105GLF	1000k 5% 50mW	Thick Film Resistors - SMD Res 0201 1000k 5% 50mW TC200	Bourns	CR0201-JW-105GLF	1	10000	$ 0.01	$ 130.00	
3	406-ASL2112	Addapter	Power Management IC Development Tools Tiny Battery Charger	TinyCircuits	ASL2112	1	10000	$ 2.82	$ 28,200.00	* Price is for 1000 unit
3	406-ASR00003	Battery pack	Battery Packs Lithium Ion Polymer Battery - 3.7V 150mAh	TinyCircuits	ASR00003	1	10000	$ 1.28	$ 12,800.00	* Price is for 100 units
3	N/A	PCB	Custom PCB	Advanced Circuits		1	10000	$ 0.56	$ 5,600.00	* Quote here is for 1000
2		**Band**	3D printed with TPU	Xometry		1	10000	$ 0.66	$ 6,600.00	
2		**PCB Cover**	3D printed with PLA	Xometry		1	10000	$ 0.22	$ 2,200.00	*Estimate
2		**Fidget Gear**	3D printed with PLA	Xometry		1	10000	$ 0.11	$ 1,100.00	*Estimate
2		**Reminder Icon**	3D printed with TPU	Xometry		1	10000	$ 0.33	$ 3,300.00	

[green] = quote is not at lowest value for producing 10k units

[blue] = estimate -- This is based on previous quote, cost of PLA, and amount of material used. Xometry never gave me a quote for this component.

Gross Margin
60%

	Per Unit	Per 10,000 Units
Part Count	20	190000
Total Cost	$ 8.11	$ 79,777.00
Selling price	$ 20.29	$ 202,867.50
Total Profit	$ 12.17	$ 121,720.50
Total for charity	$ 1.22	$ 12,172.05

Figure 25: Rechargeable VIBE Bracelet costs for future production

Bill of Materials – Non-rechargeable VIBE Bracelet

BOM	Part Number	Part Name	Description	Manufacturer	Manufacturing ID	Qty	Qty: 10,000 Unit	Unit	Total Cost	
1		**VIBE Bracelet**	Base product							
2		**Vibration**	Vibration feature for Reminder Icon							
3	1597-1244-ND	Vibration Motor	Vibration ERM Motor 3V	Seed Technology Co., Ltd	316040001	1	10000	$ 0.90	$ 9,000.00	*price is for 1000 units
3	474-COM-00097	Push Button	SparkFun Accessories Mini Pushbutton Switch	SparkFun	COM-00097	1	10000	$ 0.32	$ 3,200.00	*price is for 100+ units
3	80-C0805C104M3R	0.1uF Capacitor	Multilayer Ceramic Capacitors MLCC - SMD/SMT 25V 0.1uF X7R 0805 20%	KEMET	C0805C104M3RACTU	1	10000	$ 0.01	$ 117.00	
3	80-C0805C105Z4VACLR	1uF Capacitor	Multilayer Ceramic Capacitors MLCC - SMD/SMT 16V 1uF Y5V 0805 - 20% +80%	KEMET	C0805C105Z4VAC7210	1	10000	$ 0.02	$ 170.00	
3	603-RC0201FR-7D100KL	93.1 kOhms	Thick Film Resistors - SMD 93.1 kOhms 50 mW	Yageo	RC0201FR-0793K1L	1	10000	$ 0.00	$ 40.00	
3	603-RC0201FR-07124KL	124 kOhms	Thick Film Resistors - SMD 124 kOhms 50 mW	Yageo	RC0201FR-07124KL	1	10000	$ 0.00	$ 40.00	
3	612-EG1218	Pin Slide	Slide Switches PC MNT 3 PIN SLIDE	E-Switch	EG1218	2	20000	$ 0.30	$ 6,060.00	
3	621-DMG3415UQ-7	MOSFET	MOSFET BVDSS: 8V 24V SOT23	Diodes Incorporated	DMG3415UQ-7	1	10000	$ 0.13	$ 1,310.00	
3	595-TPL5110DDCT	Timer	Timers & Support Products Ultra Lw Pwr Timer	Texas Instruments	TPL5110DDCT	1	10000	$ 0.38	$ 3,830.00	
3	652-CR0201AFW1001GLF	ResA 0201 1k 1% 50mW	Thick Film Resistors - SMD ResA 0201 1k 1% 50mW TC200 AEC-Q200	Bourns	CR0201AFW-1001GLF	1	10000	$ 0.00	$ 40.00	
3	652-CR0201-JW-104GLF	100K 1% 250 ppm	Thick Film Resistors - SMD 100K 1% 250ppm	Bourns	CR0201-JW-104GLF	1	10000	$ 0.01	$ 140.00	
3	652-CR0201-JW-105GLF	1000k 5% 50mW	Thick Film Resistors - SMD Res 0201 1000k 5% 50mW TC200	Bourns	CR0201-JW-105GLF	1	10000	$ 0.01	$ 130.00	
3	490-18652-ND	3V Battery - 500mAH	Battery Lithium 3V Coin 24.5MM 500 mAH	Murata Electronics	CR2477W	1	10000	$ 1.16	$ 11,589.80	
3	BS-2450	Battery Holder	Battery Holder Coin PC Pin	MPD (Memory Protection Devices)	BS-2450	1	10000	$ 0.52	$ 5,192.20	
3	N/A	PCB	Custom PCB	Advanced Circuits		1	10000	$ 0.63	$ 6,300.00	* Quote here is for 1000,
2		**Band**	3D printed with TPU	Xometry		1	10000	$ 0.66	$ 6,600.00	
2		**PCB Cover**	3D printed with PLA	Xometry		1	10000	$ 0.22	$ 2,200.00	*Estimate
2		**Fidget Gear**	3D printed with PLA	Xometry		1	10000	$ 0.11	$ 1,100.00	*Estimate
2		**Reminder Icon**	3D printed with TPU	Xometry		1	10000	$ 0.33	$ 3,300.00	

[green] = quote is not at lowest value for producing 10k units

[blue] = estimate -- This is based on previous quote, cost of PLA, and amount of material used. Xometry never gave me a quote for this component.

Gross Margin
60%

	Per Unit	Per 10,000 Units
Part Count	19	200000
Total Cost	$ 5.73	$ 53,759.00
Selling price	$ 14.33	$ 143,322.50
Total Profit	$ 8.60	$ 85,993.50
Total for charity	$ 0.86	$ 8,599.35

Figure 26: Non-rechargeable VIBE Bracelet costs for future production

VI. Design Verification

The testing of the VIBE bracelet was conducted in an unprofessional environment, within the homes of the VIBE team members, due to COVID-19 restrictions. Therefore, some of the tests do not have precise measurements due to lack of reliable or good quality testing equipment. The most important tests performed on the VIBE Bracelet are described in detail below. For a complete list of tests conducted, refer to Appendix D for the Design Verification Plan and Report (DVP&R) Table.

i. Drop Test

The drop test of the VIBE Bracelet consisted of 10 drops from 5ft onto hardwood floors, carpet, and concrete. Table 13 below details the results of the drop test on the different surfaces.

Table 15: Result of the Drop Test

Surface Material	Height	Number of Tests Passed	Number of Tests Failed
Hardwood	5 ft	9	1
Carpet	5 ft	10	0
Concrete	5 ft	8	2

The only part that was considered failed during some drop tests was the fidget element. In some drop tests over hard surfaces like hardwood and concrete, the chrome steel roller ball fell out at around the 8^{th} and 9^{th} drops but was easily placed back into the fidget element. The roller ball by itself is consider as a choking hazard for children, making the failure of the fidget element a safety concern. Apart from the roller ball dislodging from the fidget element, there was no damage to the fidget, icon, or electrical components of the VIBE Bracelet.

ii. Electronics Functionality Test

The electronics functionality test required that all functions of the PCB worked well and consistently. Outside of the PCB functionality, the test required that the vibration motor run reliably when triggered by the set time interval, as well as ensure that the motor was strong enough to feel when in the band and not too noisy. Other testing consisted of running the PCB off of battery power, and charging the battery using the charging adapter and a micro-USB cable plugged into a wall outlet.

Table 16: Result of the Electronics Functionality Test

Function Tested	Pass or Fail
Vibration when time interval occurs	Pass
Switch turns power ON/OFF	Pass
Button turns off vibration	Pass
Switch changes selected time interval	Pass
Battery provides sufficient power	Pass
Adapter charges battery when plugged into wall outlet using micro-USB cable	Pass
Vibration of motor strong enough to provide user with physical feedback	Pass
Vibration motor not exceedingly noisy	Pass

With the initial tests with the vibration motor, the motor would turn off without pressing the button, a flaw that would make the bracelet design defective. To solve this problem, a 10ohm resistor was placed between the battery and the PCB power soldering pad to reduce the current sent to the vibration motor. This fixed the problem, creating a properly functional system. With this in mind, it may be beneficial to increase the size of the resistor at the gate of the NMOS transistor to reduce the current sent to the motor.

iii. Fidget Toy Functionality Test

All three versions of the fidget elements were put together on the band to compare as shown in Figure 25.

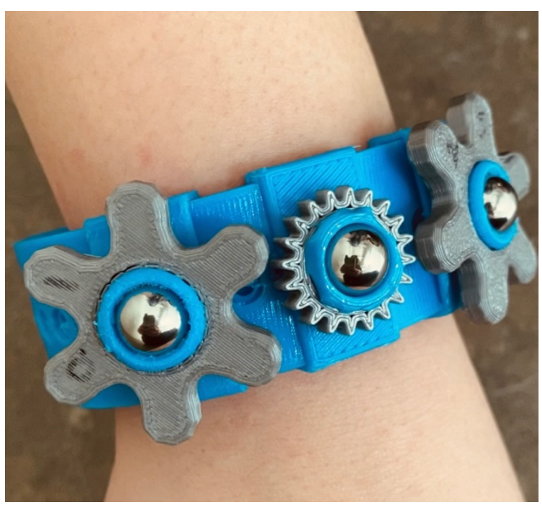


Figure 27: All Three Fidget Elements on the Band

The result of the fidget element test was summarized in Table 15. This table can be used in the future to help customers find out which version fit their needs.

Table 17: Result of Fidget Element Test

Criteria	Version 1	Version 2	Version 3
Noise	Light	Light	Medium
Smooth Movement	Yes	No	No
Haptic Feedback	No	Light	Medium
Interchangeable	Yes	Yes	Yes

<u>Legend:</u>

- Version 1 - Smooth Gear Spinner (In the middle in Figure 15)
- Version 2 - 0.1 Interference Spinner (On the left in Figure 15)
- Version 3 - 0.25 Interference Spinner (On the right in Figure 15)
- Noise
  - Light - insignificant, neglectable noise
  - Medium - slightly noticeable but less loud than pen clicking noise
  - High - noticeable noise that is as loud as or louder than the pen clicking noise.
- Smooth Movement - The spinner can spin without giving any feedback.
- Haptic Feedback- Clicking feedback when the spinner is spun
  - Light - light resistance overcome by using just one finger to spin
  - Medium - significant resistance overcome by using two or more fingers to spin.
- Interchangeable - The fidget element can be placed and replaced easily by the user.

iv. Sizing and Comfortability Test

In order to satisfy the sizing and comfortability test, 15 holes we put on the right side of the bracelet for the pin to fit through. This allows the bracelet to be adjusted to the user's wrist size. To satisfy the comfortability test, we made the bracelet out of TPU, a soft and flexible material which will not irritate or injure the user. The bracelet is also only 39 grams, which is lighter than both the Apple Watch (41.7 grams) and the Revibe Connect (250g), making it light and not heavy on a children's wrist.

VII. <u>Conclusion and Recommendations</u>

The final design of the VIBE Bracelet protype was successfully completed by the end of Spring Quarter 2021. The design features a vibration reminder with two timing settings, interchangeable reminder icons, interchangeable fidget elements with a hybrid rollerball and haptic gear element, a rechargeable battery, as well as an adjustable band. The bracelet is lightweight, comfortable to wear, and flexible. The vibration reminder has an on-off switch, a switch that allows the user to choose how often they want a reminder, and a button that stops the vibration. After weeks of testing and redesign, the team's final prototype is fully functional and ready to be sent off to the sponsor for further development.

While the team and sponsor are happy with the current iteration of the design, there are always some aspects that the design can be improved. While the current design of the bracelet functions well and is not distracting in the classroom, the members of the VIBE team could not test the bracelet out with children during the design phase of production.

One concern that the team had was that the design could be minimized in size. Though the bracelet would not seem bulky on older users of the product, it might be too wide on a younger child's wrist. Since this design is meant to accommodate those aged 5-15, this is one area that can be improved in future development. This can be done by finding smaller components for the PCB and a smaller battery. Smaller components for the PCB would easily fit within the VIBE Bracelets cost constraints, but a smaller cost-efficient battery may prove challenging to find. However, either of these changes would significantly reduce the overall size of the electronics within the band.

One last important note for the sponsor in future designs of fidget elements is to avoid sharp or pointy designs in the fidget component, because it might cause discomfort for the users after a significant amount of time. This disadvantage showed in the test of spinning the gear in the smooth gear spinner version. The team designed a smoother edged version of this part when sending the sponsor the final product files to preemptively address such an issue.

VIII. Acknowledgements

We would like to express our gratitude to several individuals who supported our team throughout our senior project.

First, we would like to thank David Postula, our project's sponsor, for providing our team with the opportunity to work on a senior project that will help thousands of children. This was an invaluable experience, and we cannot wait to see where this project will go from here.

We also could not have completed this project without of Karla Carichner, our senior project advisor, for her expert advice and support throughout the year-long design process. Her experience with previous interdisciplinary projects helped our team to run smoothly and kept us on track to create a complete, functional prototype.

In addition, we would like to thank Dr. Vladimir Prodanov for providing insight into the electrical components best suited for our project and pointing us in the direction of an analog solution, eliminating the need for complex systems and software. Along with Dr. Prodanov, we would like thank Dr. Jim Widmann, the other interdisciplinary senior project advisor, for providing the students with expert knowledge on how to work in the field as an engineer.

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X. <u>Appendices</u>

i. Appendix A: V.I.B.E Team Contract

Mission

The mission of the V.I.B.E. is to create an affordable bracelet for children aged 5-15, specifically targeted towards children with ADHD, ADD, and/or Anxiety. This bracelet provides its users with the ability to set thoughtful reminders for themselves, has a fidget feature to alleviate stress and function as an energy outlet.

Section 1- Name

This organization shall be known as V.I.B.E. (Very Intellectual Bracelet Engineering).

Section 2 - Membership

A. Members of the team include Angela Colabella, Emma Neal, Joey Chen, and Molly Rodda.
B. No member shall purport to represent the team unless so authorized by the team.
C. Each member shall be provided a copy of the team contract.

Section 3 - Statement of Commitment

A. Members of the team commit to invest adequate amount of time to the group project. This means that all members will attend lab activities (TR 12-3pm) and scheduled team meetings unless they have an approved excuse from advisor and/or team.
B. Members of the team guarantee to complete assigned tasks by the due date. If a member has some emergencies come up, he/she needs to notify the group as soon as possible or within 24 hours, and any changes in the plan need to be agreed upon by every member in the group.
C. If team member does not complete work by the necessary deadline, the said team member must pick up extra duties for the next week. If they continue to fail in completing tasks, the team advisor will be contacted to discuss their short-comings and possible consequences.

Section 4 - Decision Making

A. By Consensus
   a. Use matrix table to determine best proposed solution.
   b. If matrix results in a 3 against 1 disagreement, the team will agree to the top idea, but an effort will be made to include some aspect of the 4th member's ideas.
   c. If matrix results in a 2 against 2 disagreement, put down everyone's ideas and try to come up with a compromised solution. If no compromise is possible, pause on this and come back to it.
   d. If coming back to the issue does not result in a compromise, look for potential other solutions that all team members can agree upon.
B. Voting Methods
   a. Propose all ideas.
   b. Narrow down to one selection.
   c. To vote:
      i. Write down individual preferences in the team one-note.
      ii. If 3-1, refer to Section 4-A.b.
      iii. If 2-2, refer to Section 4-A.c.
   d. Confirm final vote orally and record on paper/electronically.
C. Voting Outcomes
   a. Majority wins.

Section 5 - Team Interactions

A. All affairs of the team shall be governed by professional behavior with respect given to all team members.
B. Meetings shall be held Thursdays, 11am-12pm (UU Hour).
C. Unless otherwise noticed, all meetings will be held via Zoom.
D. Special meetings of the team may be called by communicating through text message or email.
E. Attendance is mandatory unless provided with an approved excuse: illness, family emergency, or technical difficulties (power or Wi-Fi outage).
F. Meeting discussions will be conducted in a conversational format with special regard for a dialogue that is respectful and considerate of all members in attendance.
G. A meeting agenda, distributed 2 days in advance, will guide meeting topics and timing.
H. The length of meetings shall be stated in advance.
I. All team members are expected to be punctual, with a 5-minute grace period.
J. All meetings will be publicized to members using phone calls, team websites, e-mail, and texting.
K. Notices shall be distributed no less than 12 hours before the meeting date.

L. Violation of team rules will result in a strike. Three strikes result in reporting to advisor. Extra work decided by other team members can eliminate the strike.

Section 6 - Conflict Resolution

A. Conflict is defined as an issue that continuously affects the team dynamic
B. Call a conflict resolution meeting for all members:
   a. Write down each side of the conflict in Team One Note.
   b. Discuss issue thoroughly, everyone MUST be respectful and consider the other side's perspective.
   c. Draw up guidelines for future behavior.
   d. If a member violates these guidelines, conflict moves up to discussion with Advisor.

Section 7 - Roles and Responsibilities

A. Sponsor Contact: Angela Colabella
   a. This team member will be the single point of contact for the sponsor to avoid any confusion regarding communication to/from the sponsor. The sponsor contact must communicate in a timely and professional manner with the sponsor

Section 8 - Amendments

A. Add new articles that have the ability to cancel rules from these sections.
B. All team members must come to unanimous decision when voting on new articles.

Section 9 - Effective Date

A. This contract of the V.I.B.E. Team shall become effective on October 1, 2020.
B. Dates of amendment must be recorded in minutes of meetings at which amendments were approved, together with a revised set of bylaws.

Section10 - Signatures

   

Angela Colabella	Molly Rodda	Emma Neal	Joey Chen
10/1/2020	10/1/2020	10/1/2020	10/1/2020

ii. Appendix B: Gantt Chart

Task	Progress	Start	End
▾ **Initial Planning** (100%)		9/24/20	10/13/20
▾ **Literature Review** (100%)		10/1/20	10/12/20
Anxiety and ADHD Research	100%	10/1/20	10/12/20
Research Kinetic Power	100%	10/1/20	10/12/20
Research Patents	100%	10/1/20	10/12/20
Research Similar Projects	100%	10/1/20	10/12/20
Logo Design	100%	9/24/20	10/1/20
Team Contract		10/1/20	10/1/20
First Sponsor Meeting		10/1/20	10/1/20
Gather Needs and Wants	100%	10/1/20	10/6/20
Detailed Problem Statement	100%	10/6/20	10/8/20
QFD Table	100%	10/6/20	10/13/20
Project Requirement Document		10/13/20	10/13/20
▾ **Brainstorm and Design** (100%)		10/15/20	1/15/21
Brainstorm Project Ideas	100%	10/15/20	10/23/20
Construct Rough Prototypes	100%	10/26/20	10/30/20
▾ **Fidget Element** (100%)		10/29/20	1/5/21
Research Effective Fidgets	100%	10/29/20	11/12/20
Choose Fidget Element	100%	12/1/20	1/5/21

Task	Start	End
▾ **Reminder** (100%)	10/29/20	1/5/21
100% Research Effective Vibration Elements	10/29/20	11/12/20
100% Research Icon Material	10/29/20	11/12/20
100% Choose Optimal Reminder Element	12/1/20	1/5/21
▾ **Power** (100%)	10/27/20	1/5/21
100% Research Kinetic Power	10/29/20	11/12/20
100% Research Solar Power	10/29/20	11/12/20
100% Research Battery Options	10/29/20	11/12/20
100% Calculate Voltage/Power Requirements	10/27/20	11/5/20
100% Choose Optimal Power Method	12/1/20	1/5/21
▾ **Bracelet Band** (100%)	10/29/20	1/5/21
100% Research Band Materials	10/29/20	11/12/20
100% Determine Optimal Band Sizing	10/29/20	11/12/20
100% Choose Band Material	12/1/20	1/5/21
◆ Pugh Matrix	11/10/20	11/10/20
◆ Conceptual Design Review Presentation	11/19/20	11/19/20
◆ Conceptual Design Report	11/23/20	11/23/20
▾ **Final Design** (100%)	1/4/21	1/15/21
100% Determine Overall Detailed Bracelet Design	1/4/21	1/8/21
◆ Final Design Report	1/12/21	1/12/21
100% Incorporate Sponsor Feedback	1/12/21	1/15/21

Prototype (23%)		2/11/21	6/4/21
Order Parts (100%)		2/11/21	2/26/21
100%	Order Batteries/Power Components	2/11/21	Friday
100%	Order Vibration Motor	2/11/21	Friday
100%	Order Parts for Timing Device	2/11/21	Friday
Manufacturing (40%)		2/11/21	3/5/21
50%	3D Print/Manufacture Band	2/11/21	3/5/21
50%	3D Print/Manufacture Fidget Element	2/11/21	3/5/21
50%	3D Print/Manufacture Reminder Icon	2/11/21	3/5/21
0%	Construct Power and Timing System	2/18/21	3/5/21
Testing (0%)		2/22/21	4/23/21
0%	Test Power Source	Yesterday	3/5/21
0%	Test Effectiveness of Vibration	Yesterday	3/5/21
0%	Test Power and Vibration Together	Thursday	3/5/21
0%	Test Timing of Reminder	Thursday	3/12/21
0%	Test Band Sizing	Yesterday	3/5/21
0%	Test Adjustability	Yesterday	3/5/21
0%	Test Effectiveness of Fidget	Yesterday	3/5/21
0%	Test Placement of Elements on Band	3/5/21	3/12/21
0%	Ensure Compatibility Between Parts	3/29/21	4/16/21
0%	Test for Full Functionality	4/1/21	4/16/21

0%	Test Durability	4/19/21	4/23/21
	Assembly (0%)	3/29/21	4/30/21
0%	Assemble Power, Timing, Vibration	3/29/21	4/16/21
0%	Assemble Parts on Band	4/16/21	4/30/21
	Make Improvements (0%)	5/3/21	6/4/21
0%	Document Successes and Failures	5/3/21	5/14/21
0%	Gather Sponsor Feedback	5/17/21	5/21/21
0%	Retest and Reassemble	5/17/21	5/28/21
0%	Arrive at Final Design	5/31/21	6/4/21

iii. Appendix C: 2D Detailed Drawings

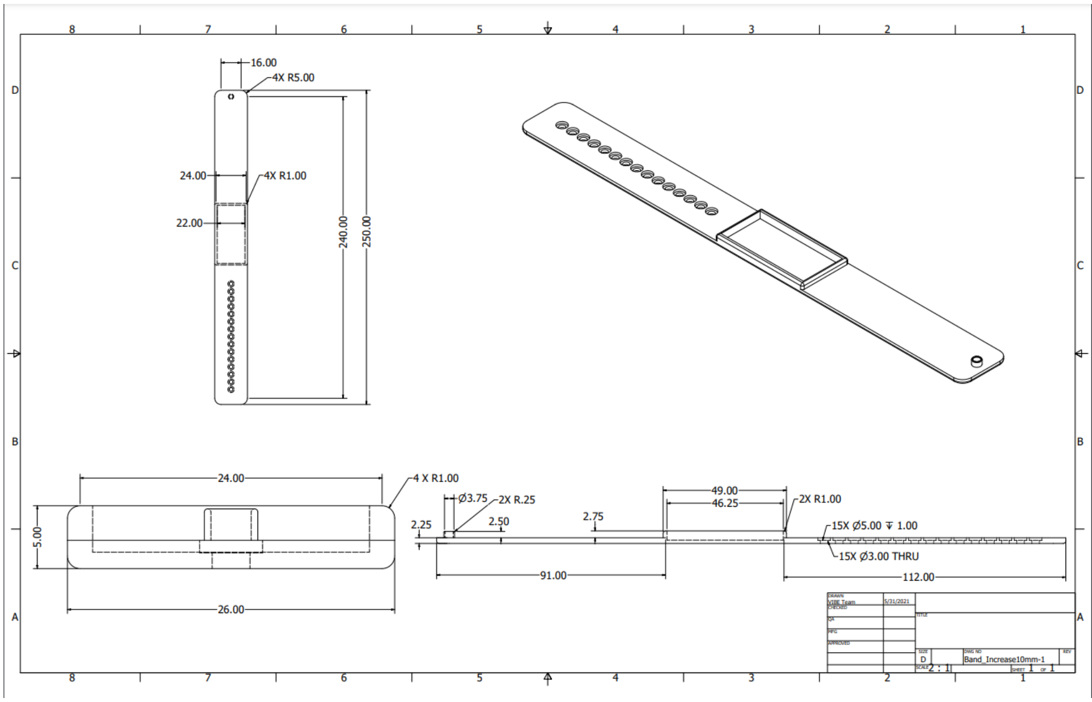

Figure 28: Band Detailed Drawing

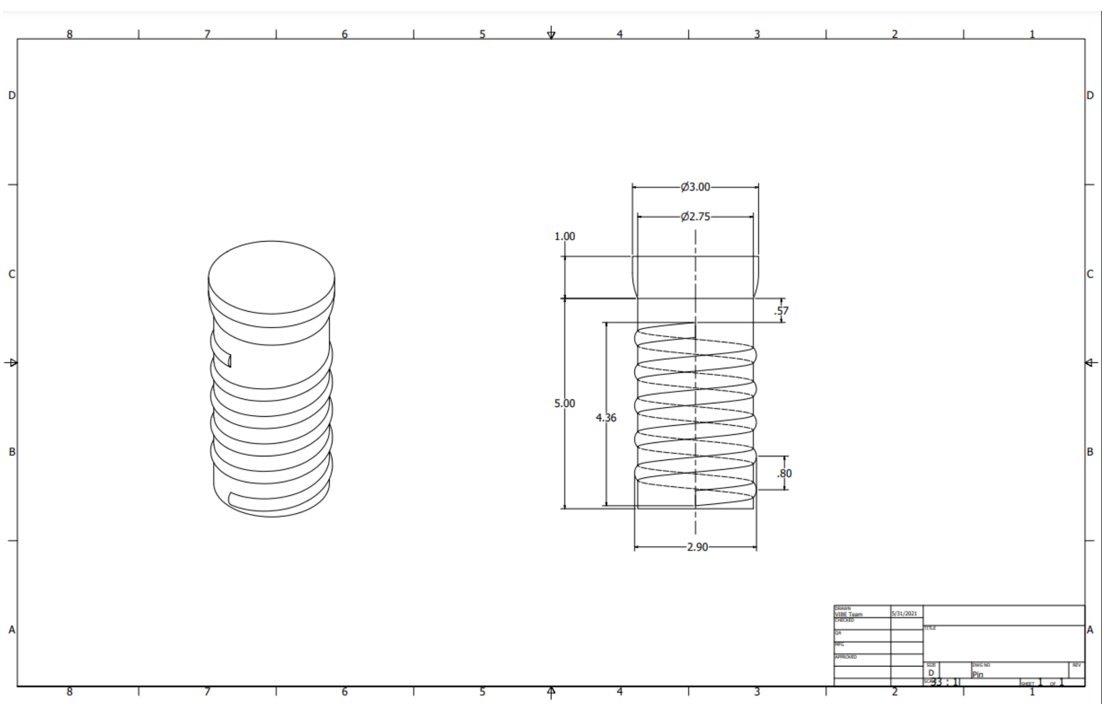

Figure 29: Pin Detailed Drawing

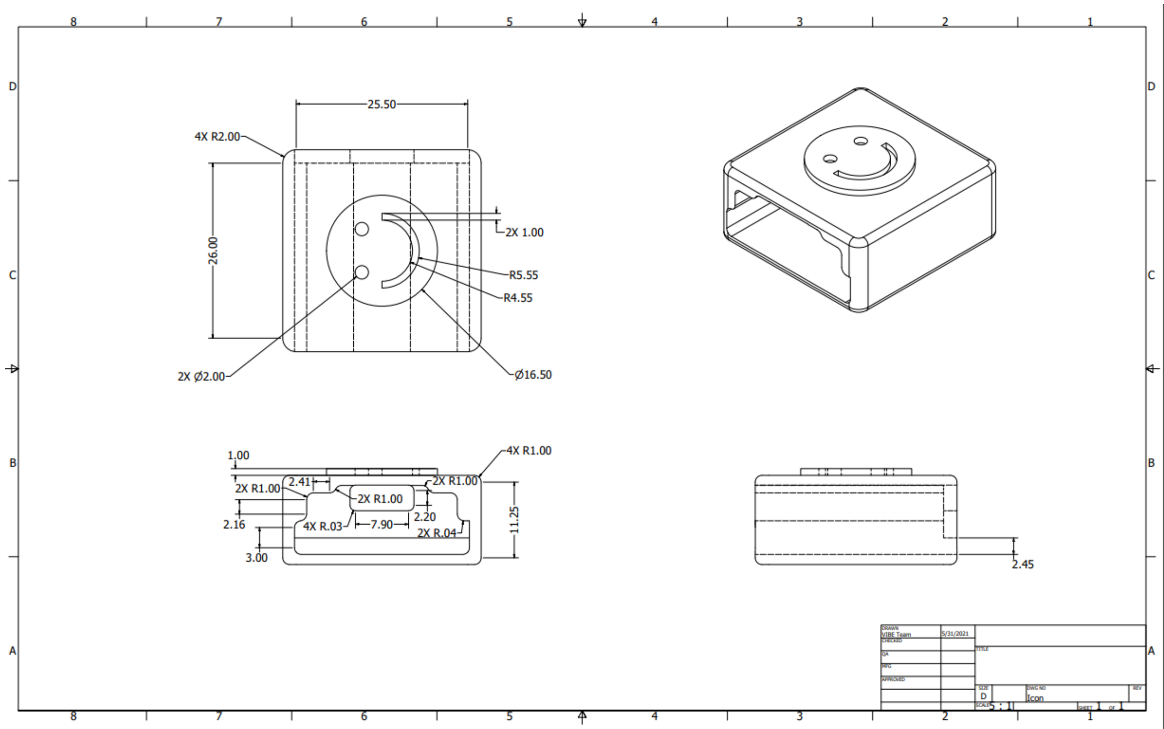

Figure 30: Icon Detailed Drawing

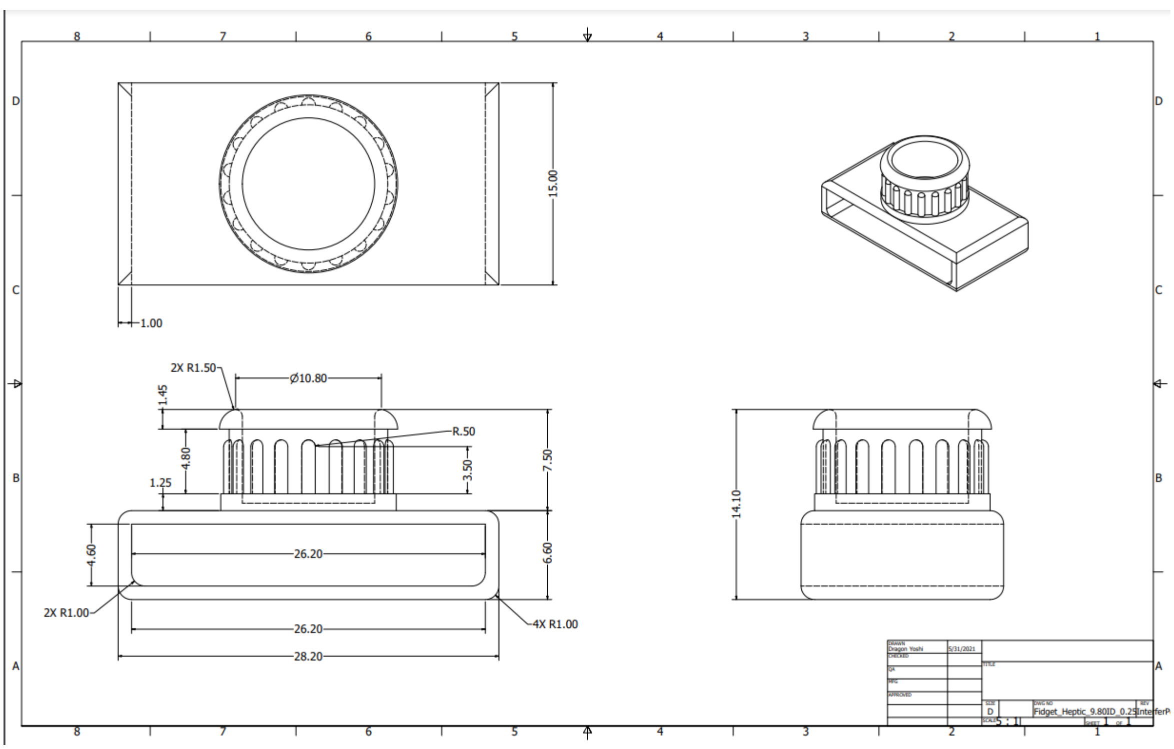

Figure 31: Base and Ball Holder Detailed Drawing

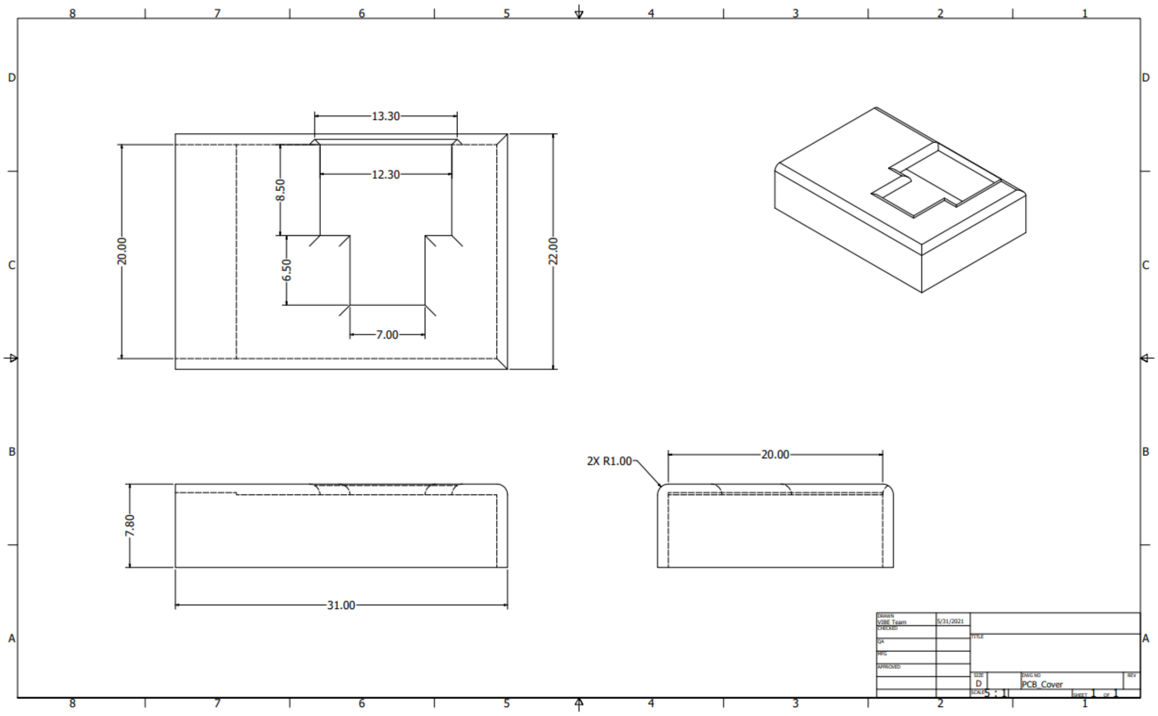

Figure 32: Switch and PCB Cover Detailed Drawing

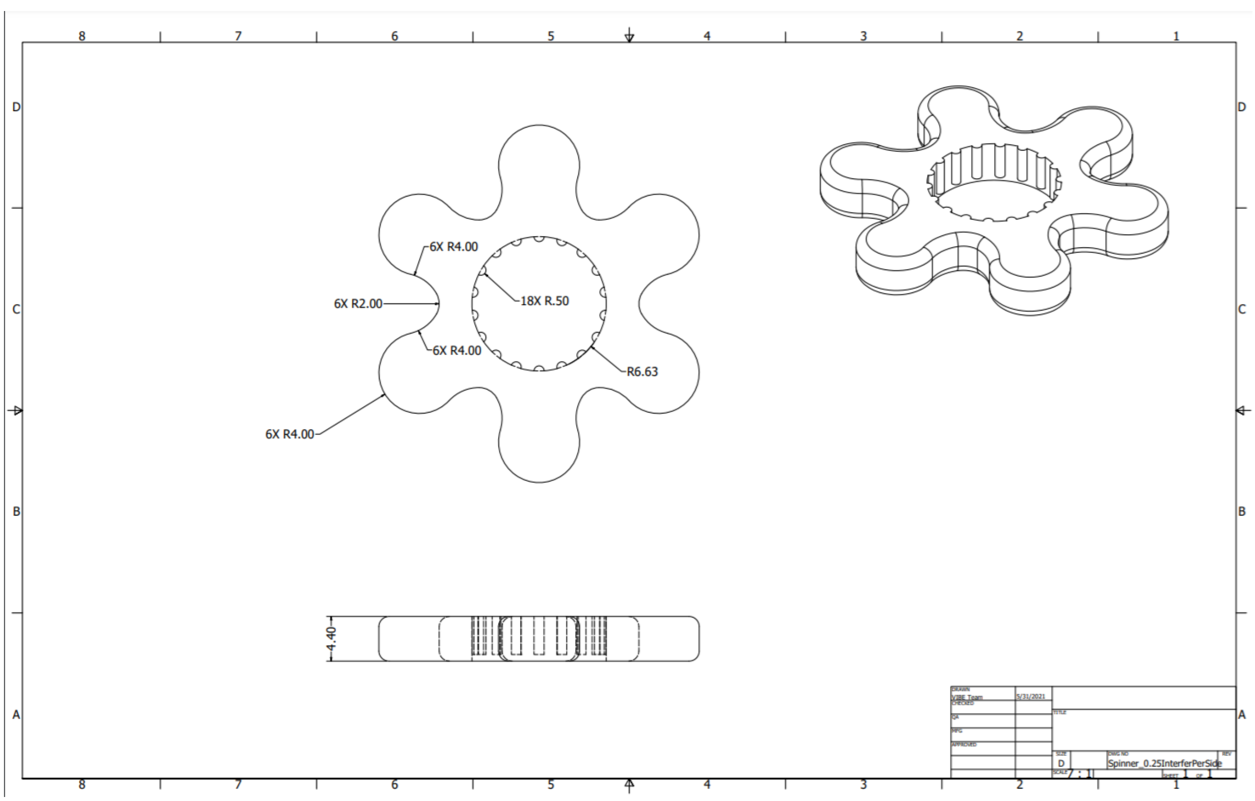

Figure 33: 0.25 Interference Spinner Detailed Drawing

iv. Appendix D: DVP&R Table

DVP&R												
Report Date			Sponsor									
TEST PLAN								TEST REPORT				
Item No	Specification or Clause Reference	Test Description	Acceptance Criteria	Test Responsibility	Test Stage	TIMING		TEST RESULTS				NOTES
						Start date	Finish date	Test Result		Quantity Pass	Quantity Fail	
1	Mechanical Assembly	Complete housing of electronics	All electronic components covered by icon/switch cover	Molly	Complete	3/22/2021	3/31/2021	Fit over the PCB Broad with switches and button		30	0	
		Pin at end of band can fit in holes	Pin does not fall out with bending of band	Molly	Complete	3/22/2021	3/31/2021	Pin fit through the sizing hole and stay put		24	6	
2		Placing icon on band	Icon fits snuggly over electronics while still being interchangeable	Molly	Complete	3/22/2021	5/15/2021	Icon fit snuggly without damage electric parts and stay put while the bracelet is worn		30	0	
3		Placing fidget element on band	Fidget element fits on band, can move along band, and holds down excess band length	Molly	Complete	3/22/2021	5/21/2021	Fidget element can be move back and forth on the band, and also removed easily by the user		21	9	
4	Sizing	Fits range of wrist sizes from 15cm to 22cm	Comfortable fit on children ages 5-15	VIBE Team	Incomplete	3/22/2021	-	-		-	-	COVID-19 restrictions kept the team from doing any human testing
5	Intermittent Vibration	Vibrates consistently on both 30 minute and 1 hour time intervals	vibration turns on at appropriate time after running for several hours	Emma	Complete	4/5/2021	5/27/2021	Vibration consistent and on time		30	0	
6		Vibration stops when button is pressed	Vibration stops immediately after button press	Emma	Complete	4/5/2021	5/27/2021	Vibration stops when button pressed		30	0	
7		Motor runs continuously until button is pressed	Motor does not turn off without button press after running for several minutes	Emma	Complete	4/5/2021	5/27/2021	Motor runs until button pressed		20	10	
		Vibration noise	Vibration cannot be heard outside of a 1ft range	Emma	Complete	4/5/2021	5/27/2021	Quiet vibration		25	5	
8		Vibration frequency	Vibration strong enough for user to acknowledge quickly	Emma	Complete	4/5/2021	5/27/2021	Vibration felt by user		25	5	
12	Battery Use	Battery life	Rechargable battery lasts at least 10 hours	Emma	Complete	5/10/2021	5/27/2021	Battery lasts more than 10 hours		5	0	
9	Fidget Element	Fidget element is appropriately quiet	All fidget toys are not heard outside of a 1ft range	Molly	Complete	3/22/2021	5/21/2021	No sound or insignificant sound (less loud than the sound of clicking pen)		24	6	
10		Gear moves smoothly and satisfactory	Gear easily turned by user	Molly	Complete	3/22/2021	5/21/2021	Quiet in the smooth version, and produce haptic feedback in the haptic version		28	2	
11		Roller ball moves smoothly and easily	Roller ball moves with only slight pressure from user	Molly	Complete	3/23/2021	5/22/2021	Ball moves easily by the user's finger		19	11	
15	Icon Element	Icon is interchangeable	Icon can be place/ replaced by kids from 5-15 themselves	Molly	Complete	3/23/2021	5/22/2021	Icon slid on/off the band easily		30	0	
17	Comfort and Convenience	Bracelet Weight	Lighter than 112 g	Molly	Complete	3/23/2021	5/22/2021	Bracelet weight 39g		2	0	