BICYCLE MOUNTED IPHONE 5 CASE WITH CHARGING SYSTEM

A Senior Project submitted

In Partial Fulfillment

of the Requirements for the Degree of

Bachelor of Science in Manufacturing Engineering

The Faculty of California Polytechnic State University,

San Luis Obispo

By

Patrick Goebel

June 2013

Graded by:______________ Date of Submission__________________________

Checked by:_____________ Approved by:_____________________________

ABSTRACT

Bicycle Mounted iPhone 5 Case with Charging System

Patrick Goebel

This purpose of this project is to design and manufacture a bicycle handlebar mounted case that will house Apple's iPhone 5 and a charging system that utilizes a charge from a generator hub in the front wheel of a bicycle. The charging system and software for this project will be developed by an Electrical Engineering Graduate student. The case and charging system must be a self-contained unit that is weather-proof and esthetically pleasing. It must allow the user to use all of the features of the iPhone 5 under a wide range of speeds. It must be adjustable between portrait and landscape orientations.

The necessary components of the case, a liner, and handlebar mount were developed, designed, sourced and prototyped to create a functioning prototype using a variety of industrial and manufacturing engineering skills. The designed components were 3D modeled using SolidWorks Computer Aided Design software. These parts were then rapid prototyped using a Stratasys 3D printer. A liner was made by pouring silicone into a wax mold that was machined on a Hass MiniMill. Documents were produced that would aid in the manufacture of this case as a consumer product. A cost analysis was completed that compare multiple manufacturing options for a case, one an injection molded plastic case and the other a machined aluminum case. The breakeven point for these two processes was found to be 266 units with a cost per unit of $73.

Many things were learned though the course of this project. Skills that were learned through many courses taken at Cal Poly were applied to a real problem and then used to solve the problem. Through research and with the guidance of peers and professors I was able to take this project from an idea to a functioning prototype. I learned how to look at the bigger picture when developing ideas and products and to explore all avenues for the best solution. In the future I would obtain more feedback from potential users and peers because they often can offer advice and solutions that may have been over looked. I would recommend that this idea and product be further developed into a consumer product.

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I. Introduction

This report will describe the process of designing and manufacturing a bicycle mounted case for the iPhone 5 with a charging system. This project was undertaken because there is a need for a product that is capable of charging the iPhone 5 while cycling in an easy to use and efficient manner. An Electrical Engineering Graduate student was looking for a Manufacturing Engineering student to design and manufacture a case that could house the electrical charging system and iPhone 5 while creating an electrical interface between the bicycle and the case to obtain a charge. This product would be targeted to cyclists that want to go on long bicycle rides while using GPS, music, and other applications that would normally drain the iPhone 5's battery quickly.

Problem Statement

There are currently no products on the market that function as a protective weatherproof case for the iPhone 5, mount on a bicycles handlebar, and have the capability to charge the phone at a range of speeds. The case must be aesthetically pleasing, easily removable from the handlebars, and able to rotate between portrait and landscape orientations. The case must also house the charging system and have minimal wiring. The power for the charge will come from an external renewable source provided by the bicycle or surrounding environment.

Objectives

- Design a handlebar mounted case to house the iPhone and charging electronics
- Design a liner that will fit in the case to hold the iPhone 5 and separate it from the charging electronics
- Design a handlebar mount to attach the case to the bicycles handlebars and interface the charging system and the charge from the bicycle
- Manufacture a functioning prototype of the above items
- Provide relevant product information for a completed product (product structure, BOM, Etc.)
- Produce engineering drawings of the designed products
- Provide cost analysis

Solution approach

To reach the objectives a case, liner, and handlebar mount will be designed using 3D modeling software. Engineering drawings for these products will be produced using the same software. These designs will take design for manufacturability principles learned in many of the Manufacturing Engineering courses at Cal Poly. Product structure, Bill of Materials, and cost analysis information will be produced based on the design of the product. A functioning prototype will be manufactured using 3D printing, wax molds, and by modifying existing products.

The following section of this report is the literature review which will discuss the importance of the project, current existing products, and processes used to manufacture different parts of this product.

II. Literature Review

The literature review for this project focuses on the design processes and manufacture of a weatherproof bicycle mounted Apple iPhone 5 case and charging system. There are currently no products on the market that function as a protective weatherproof case for the iPhone 5, mount on a bicycles handlebar, and have the capability to charge the phone at a range of speeds. There four are major components to this case/system not including the generator hub and electronics which will be provided by the Electrical Engineering student also working on this project. They are the handlebar mount, the case shell that accommodates the iPhone 5/charging electronics, the liner that separates the phone from the electronics, and the weatherproof touchscreen window. This literature review will cover the different design and manufacturing processes associated with making this system. There are many options for manufacturing this system they depend largely on the size of the market.

Current Options

There are currently many bicycle mounted iPhone 5 cases on the market but none of them have the capability to charge the phone using energy created by cycling without purchasing additional products. Many of the available cases are not weatherproof and offer little protection to the expensive iPhone 5. There are external charging options available but these are big, bulky, and have wiring that needs to be mounted all over the bike. These external charging systems also don't always work with available cases because the charging port on the iPhone 5 is not accessible. The current offerings that are weatherproof don't allow the user to charge the phone, use the headphone jack, or use both the front and rear facing cameras.

Rapid Prototyping

"Rapid Prototyping is a family of fabrication methods to make engineering prototypes in minimum possible lead time based on a computer-aided design (CAD) model of the item. (Groover, 2010, p.787)" Rapid prototyping with 3D printers allows the user to prototype a CAD model to see if a part will function as intended. 3D printers print a part by depositing layers of a material in an x-y coordinate system. Rapid prototyped parts can be made from CAD files in a matter of hours without having to machine or manually fabricate the prototype which can take

weeks. A CAD file can simply be loaded into a 3D printer's software program and the 3D printer will then print the part. There are many different types of rapid prototyping methods and materials (DeGaspari, 2003).

One of the most popular methods of 3D printing is fused deposition modeling(FDM) which was developed by Stratasys in the 1990's (Groover, 2010). During FDM a solid 3D model is exported to the Stratasys FDM program QuickSlice. QuickSlice develops a process plan to print the part and controls the 3D printer's hardware. The 3D printer uses a heating element to heat the print material to a semi-molten state just above the materials melting point. Materials commonly used include ABS, polyethylene, polyamide, and polypropylene. Once the material is at the correct temperature it is then fed through the 3D printer's nozzle while moving around in the x-y coordinates, depositing material on a platform or the previous layer of material. When a layer is complete the platform moves down in the z-direction and another layer of material is deposited until the part is complete. If the layers of material require support a dual nozzle 3D printer that prints support material is used. The support material is later dissolved away. This allows modeling of complex shapes, in some cases enclosed moving parts. (Lee, 2007 and Bakar, 2010). The FDM and 3D printing process is shown in figures 1 and 2.

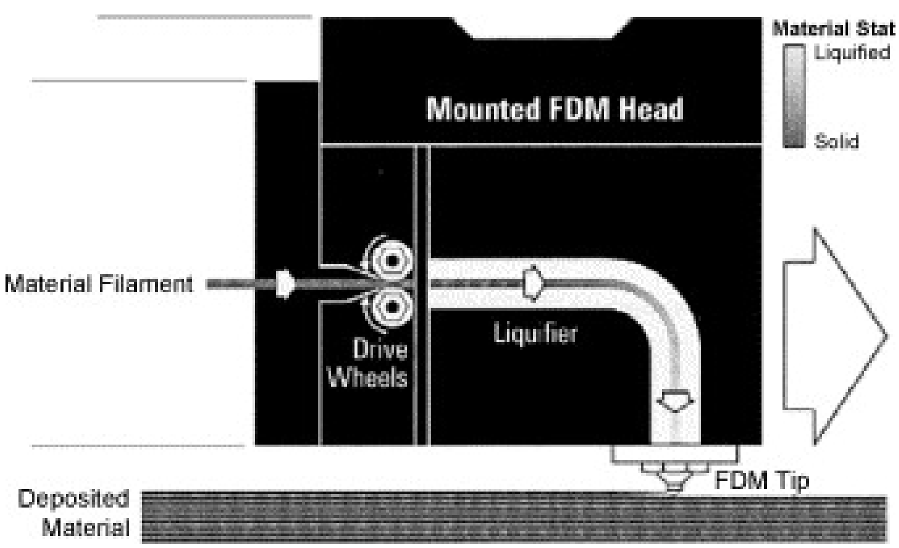


Figure 1. FDM process (Ahn, 2004)

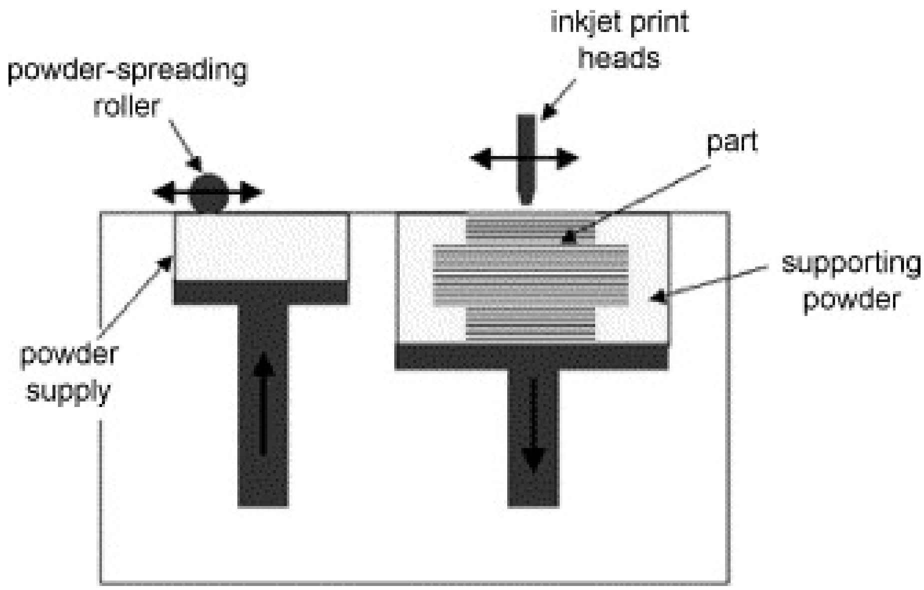


Figure 2. 3D printing process (Lee, 2007)

CNC Machining

CNC machining is a form of material removal using a computer numerical controlled machine. During machining a cutting tool is used to mechanically remove material from a work piece until the desired geometry is achieved. A case for this project could be machined on a 3-axis CNC mill such as the Haas VF-2 machines that are available in the IME advanced machining lab. If the case were to be made of plastic a mold made from aluminum or steel would first need to be machined. I will discuss features that need to be machined for a mold in the injection molding section of this report.

In a 3-axis CNC mill the machine is controlled by code that tells the table holding the workpiece where to move in the x and y planes and tool where to move in the z plane. This code is usually called G-code and it is obtained with software after a programmer has defined the tools and tool path to cut around a solid CAD model. Programmers determine the speed of the tool (rpm), feedrate (ipm), and depth of cut depending on the material being machined and the type of tooling being used (Madison, 1996). There are CNC machines with more than 3-axises which are capable of cutting parts with very complex geometries that can't be cut on a 3-axis mill.

Injection Molding

"Injection molding is a process in which a polymer is heated to a highly plastic state and forced to flow under high pressure into a mold cavity, where it solidifies. The molded part, called a molding, is then removed from the cavity. The process produces discrete components that are almost always net shape (Groover, 2010 p. 286)." With injection molding parts plastic parts can be made in high volumes for little cost, once the system is up and running. Injection molding is the most common molding process for thermoplastic molded parts. The challenges with injection molding are the parts must be removable from the mold. The initial molds are also expensive to design and manufacture. Injection molded parts are typically made for medium to high volume parts.

Injection molding machines typically have a hopper for polymer pellets; these are then fed through the injection molding machine while being heated past their melting temperature with heating elements. The melted polymer is then forced through a nozzle at high pressures and into the mold that is hydraulically clamped against the nozzle. The molds are also heated to help the material flow properly. The material quickly fills the mold and within seconds begins to solidify into the shape of the mold. The material temperature, mold temperature, injection pressure, and clamping force all affect the quality of the part and all must be calculated to ensure that parts are made properly. See figure 3 for a diagram of an injection molding machine.

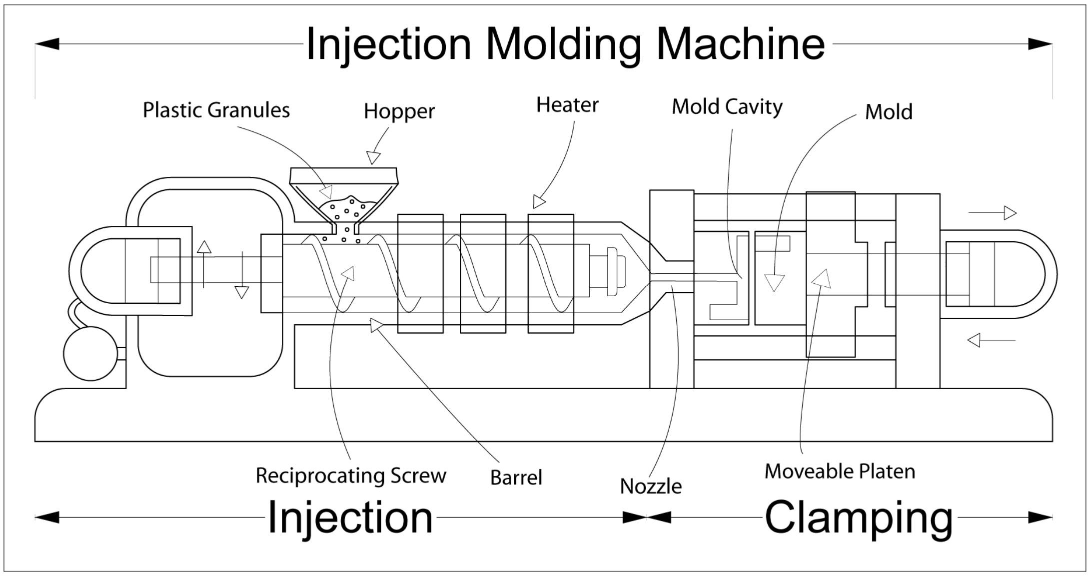


Figure 3: Injection molding machine diagram

The mold is specific to each part and a lot goes into designing and manufacturing a mold. Molds for injection molding are generally machined from aluminum or steel depending on the durability required. Molds typically have two halves, material is removed from each half during machining and when the two halves mate together at the parting line the empty space between them is the mold cavity. This cavity will be filled with the polymer material making the part. Some molds will have multiple cavities so that multiple parts can be injection molded at the same time. For the material to flow from the injection molding machine a spruce, runners, and gates must also be machined into the mold. The spruce mates with the nozzle of the injection molding machine, the runner led from the spruce to the cavity, and the gate constricts the flow of material into the mold. The size of the spruce, runners, and gates all affect the rate and turbulence at which the material flows into the mold and they must be calculated. When the injected polymers start to solidify they shrink a small amount and to help release the finished part from the mold draft angles are often machined into the walls of the molds cavity. Some molds also utilize and ejector system that uses multiple ejector pins to push the finished part out of the mold.

There are many problems that can occur with injection molded parts and they all must be taken into account during the design and manufacture of the mold and parts. The major problems that can occur are shrinkage, sinks/voids, flashing, and short shots. Part shrinkage must be taken

into account when designing a mold otherwise the final parts may be smaller than the required dimensions (Zheng, 2011). To calculate part shrinkage the following equation can be used:

$$D_c = D_p + D_pS + D_pS^2$$

Where D_c is the dimension of the cavity, D_p is the dimension of the final part, and S is a standard shrinkage value that can be found in the table 1. below:

TABLE 13.1 Typical values of shrinkage for moldings of selected thermoplastics.

Plastic	Shrinkage, mm/mm (in/in)	Plastic	Shrinkage, mm/mm (in/in)
ABS	0.006	Polyethylene	0.025
Nylon-6,6	0.020	Polystyrene	0.004
Polycarbonate	0.007	PVC	0.005

Table 1. Shrinkage values for common thermoplastic polymers (Groover, 2010)

Sinks and voids generally occur in thicker molded sections. The material on the surface of the part will solidify and the internal material will contract and form a depression in the part. Voids occur for the same reason and leave a void inside of the molded part. Sinks and voids can be prevented by increasing the molding pressure or designing a mold with thin or uniform sections (Groover, 2010).

Flashing is when material flows out of the cavity at the parting line of the mold. This can occur if the mold halves don't sit flush together on the mating surface, if injected materials temperature is too high, if the clamping force isn't high enough, or if the injection pressure is too high (Groover, 2010).

Short shot occurs when the material doesn't properly fill the mold. This happens when the material begins to solidify before the mold is completely full. It can happen if the mold isn't heated to the proper temperature, if the material being injected isn't hot enough, if the spruce/runners/gates aren't the correct size, or if the injection pressure isn't high enough (Groover, 2010).

Silicone Rubber Liner

Silicone rubber has many properties that make it a good liner for electronics like phones. Silicone rubber has a flexible network structure which makes it elastic and shockproof. Silicone rubber is thermally stable and waterproof (Chiu, 2003). These properties are important because the iPhone must be able to function properly even if there is rough terrain. The iPhone can reach temperatures of near 100 degrees Fahrenheit; silicone rubber is stable at temperatures up to 190 degrees Fahrenheit so it will easily be able to dissipate the heat produced by the phone. The waterproof properties of silicone rubber will create a good seal between the outer case and the phone.

Touchscreen Window

Thermoplastic polyurethane is a suitable choice for the touchscreen window on the case. Polyurethanes have good mechanical strength, low thermal conductivity, are chemically inert, and are hydrophobic (Fu, 2012). These properties are ideal for an iPhone cases touchscreen window. Polyurethane will withstand the elements while still allowing the user to utilize the touchscreen with their fingers. iPhone 5 touchscreens are capacitive (Zeman, 2012) which means that they are coated with a transparent conductor like indium tin oxide (Kable, 1986). The human body is an electrical conductor so when a capacitive touchscreen is touched it can be controlled. Thermoplastic polyurethane is a capacitive material so the capacitive touchscreens that iPhones use will still be useable through a polyurethane window. Thermoplastic polyurethane can be easily manufactured into the desired window size by simple cutting processes then attached to the case with weatherproof adhesives.

In conclusion, making a weatherproof bicycle mounted Apple iPhone 5 case and charging system will require many manufacturing processes. There are multiple ways to go about making this case and they largely depend on the size of the market and the desired materials. Further research and customer feedback should be obtained to determine which features the case should have and what it should be made of. If manufactured this case would provide a unique product like no others currently available.

In the following section of this report the design approach and constraints are presented.

III. Design

The design section of this report focuses on the approach taken to design or source each component of this product. It details the constraints and requirements of the product. Detailed drawings of the major components are included in this section.

Constraints

- The case must house the Apple iPhone 5 and charging system electronics
- Obtain a charge from a generator hub in the front wheel of the bicycle
- Mount on a bicycles handlebars securely
- Have the ability to rotate between portrait and landscape orientations
- Allow the user to access the headphone port
- Be weather resistant (water, sweat, sunlight)
- Aesthetically pleasing
- Durable

Brainstorming

With the constraints and problem statement clearly outlined a brainstorming session was held with the Electrical Engineering Graduate student to generate potential ideas for the product. Mind mapping techniques were used to put ideas down on paper. Suggestions and ideas from cyclists and iPhone users were obtained and added to the pool of ideas. From the large list of ideas the best and most feasible ones were targeted and 3D modeling of the major components began.

3D Modeling

The major components of the case were modeled in SolidWorks. There were four components that needed to be modeled. They were the liner, case top, case bottom, and clamp arm. The dimensions and a solid model for the Apple iPhone 5 were obtained from GrabCAD.com.

Liner:

Using these dimensions and double checking them with calipers the liner was the first to be modeled. The liner absorbs road vibrations and separates the phone from the electronics. The

liner also creates a weatherproof seal when the case is closed. Given these requirements the thickness of the liners walls were modeled at 0.20 inches. This satisfies the requirements of the liner. A window cutout was modeled so the rear camera could be used while the phone is in the case. Groves were modeled on the tops and sides of the liner to accommodate the power and volume buttons on the phone. Cut outs were modeled on the bottom of the liner where the power cord and headphone cords are plugged into the phone. A solid 3D model of the liner can be seen below.

Figure 4. Solid 3D model of liner

Case bottom:

The case bottom has to accommodate the electronic charging system and the liner. The electronic charging system consists on a battery, a circuit board, and wiring. The circuit board and battery dimensions were obtained from the Electrical Engineering Graduate student. The dimensions of the case bottom were base of the liner and the circuit board. Standoffs were modeled for the circuit board to be mounted on. A window cutout was modeled so the rear camera could be used while the phone is in the case. Surrounding the window cut out a slot was modeled where a window can be glued in place. A hinge was

modeled on the top left side of the case bottom where the top and bottom of the case will be held together by a 1/16 inch rod. A 1/16 hole was modeled through this hinge to accommodate the rod. On the right side on the case bottom mounting points were modeled where the clamp arm will be mounted. 1/16 inch holes were modeled through these mounting points where a 1/16 rod will hold the clamp arm in place. On the underside of the case bottom an extrusion was modeled that will slide into the handlebar mount. Holes were modeled through the base of the case and this extrusion to create a path for the electrical contacts. A hole was modeled on the bottom of the case bottom for the headphone plug. Radii were modeled on some edges for aesthetic reasons and to remove sharp edges. A solid 3D model of the case bottom can be seen below.

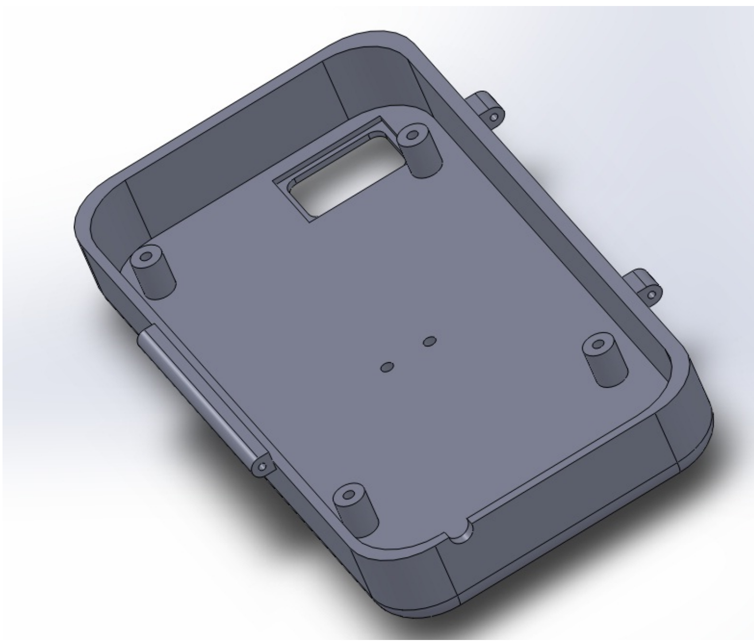


Figure 5. Solid 3D model of case bottom

Case Top:

The case top was modeled to mate with the case bottom and the liner. There is a slight interference between the liner and the case top when the case is closed and this creates a weather resistant seal between the liner and the case. A window was modeled on the top of the case top so that the user can visibly see the phones screen, has access to the home button on the phone, and so the front facing camera can be used. A hinge was modeled on the left left side of the case top where the top and bottom of the case will be held together by a 1/16

inch rod. A 1/16 hole was modeled through this hinge to accommodate the rod. A hole was modeled on the bottom of the case bottom for the headphone plug. A slot was modeled on the top right side of the case top where the clamp arm locks into place. Radii were modeled on some edges for aesthetic reasons and to remove sharp edges. A solid 3D model of the case top can be seen below.

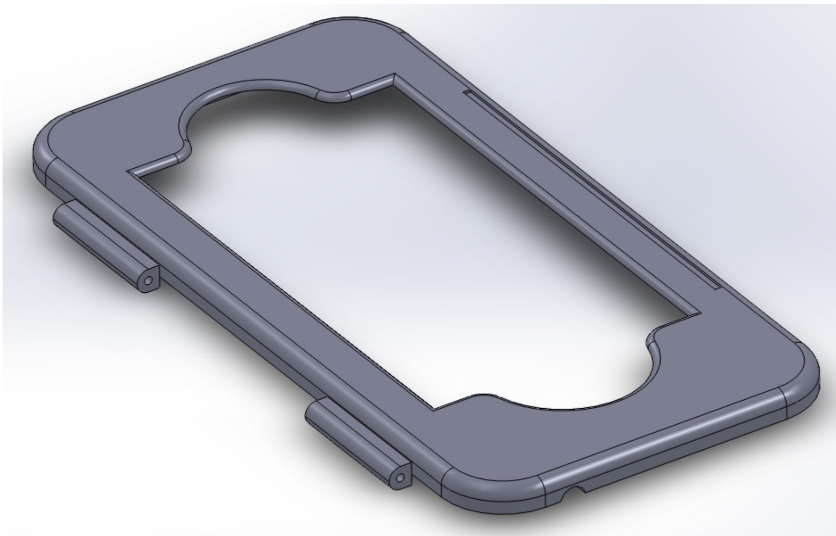


Figure 6. Solid model of case top

Clamp Arm:

The clamping arm was modeled to attach to the case bottom using 1/16 rod. A 1/16 inch hole was modeled through the mount point where a 1/16 rod will hold the clamp arm in place. An extrusion was modeled on the arm to fit into the slot on the case top and hold the case closed. Radii were modeled on some edges for aesthetic reasons and to remove sharp edges. A solid 3D model of the clamp arm can be seen below.

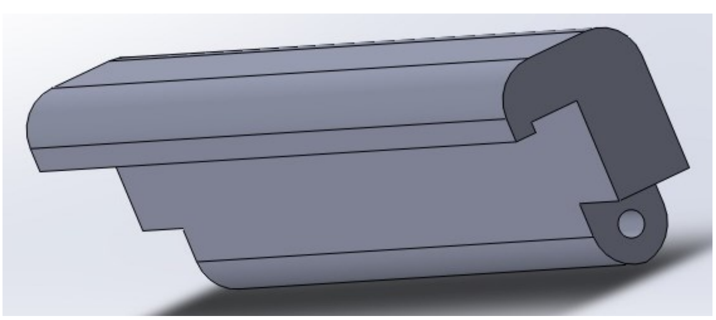


Figure 7. Solid model of clamp arm

Purchased Components

A number of the components used in the product are to be purchased to reduce manufacturing costs. These components are standard sizes that can be purchased of the self from a number of distributors. These components include 1/16 inch metal rod in 3 inch and 4 inch length for the case and clamp arm hinges. The rear window is 3/4 inch x 1 inch, 0.1 inch thick piece of clear plastic. The front window is a 2.5 inch x 5 inch piece of thin polyurethane film. The electrical contacts, wiring, and mounting screws are all standard sizes.

Handlebar mount

The handlebar mount is a combination of two purchased products. It is modified to combine these products which allows for a ball and socket type joint so that the case can rotate between landscape and portrait orientations. It is also modified to add electrical contact points when the case is attached. The mount includes two clamp diameter pieces to accommodate the standard 25.4mm and 31.8mm bicycle handlebar diameters. A picture of the mount can be seen below.

Figure 8. Ball and socket style handlebar mount

See the appendix for complete engineering drawings of the 3D molded components

The following section describes the methods used to prototype the product

IV. Methods

When the design of the components was completed the fit was tested by creating and assembly in the 3D molding software. This assembly included a 3D model of the iPhone 5, the liner, and the circuit board (without components installed). This assembly can be seen below.

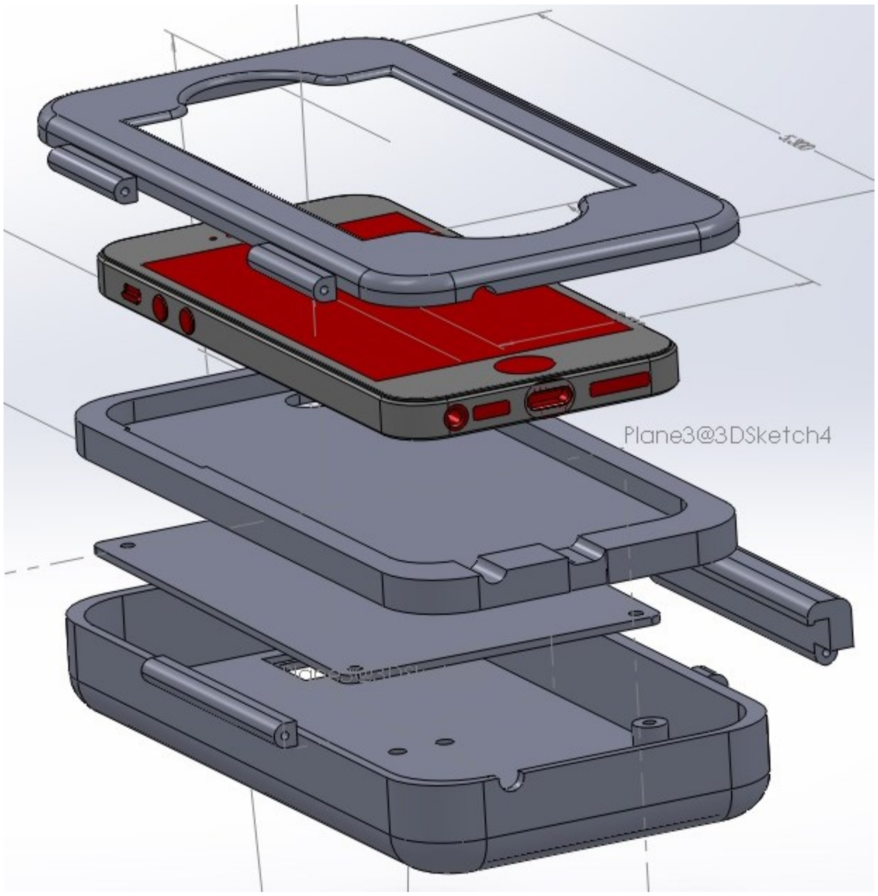
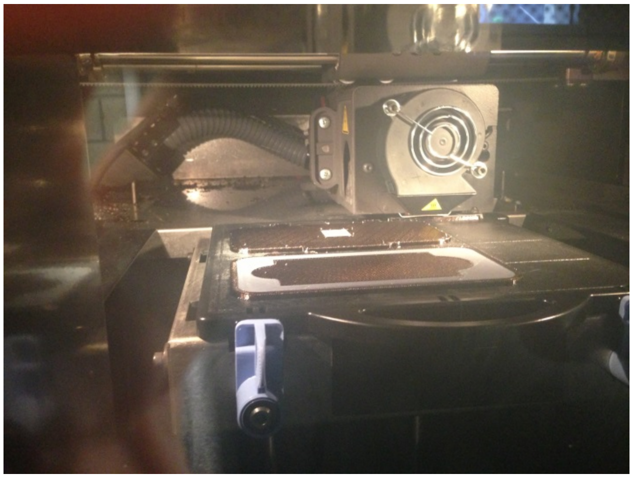


Figure 9. 3D model of case assembly

Prototyping

The case bottom, case top, and clamp arm components of the case were rapid prototyped using a Stratasys 3D printer. To print these components the solid 3D model files were converted into the standard STL format that the 3D printer can read. The run time for the printing of the three components was approximately 5.5 hours. Pictures of the 3D printer in progress and the completed print can be seen below.



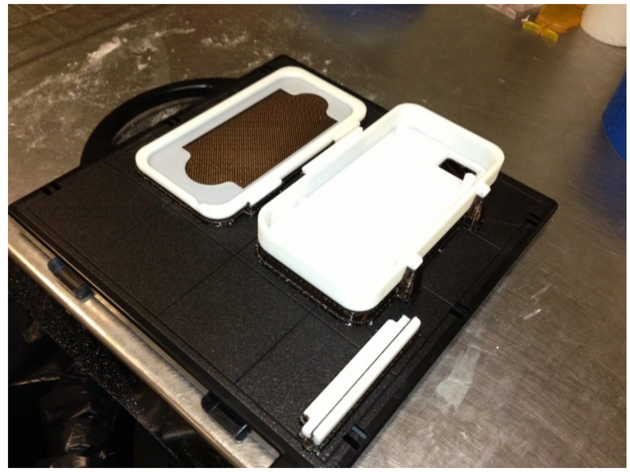


Figure 10. 3D printer in action Figure 11. Completed 3D print

The liner for the case was prototyped by making a wax mold and pouring liquid silicone into the mold to cure. To make the mold a mold was designed around the liner 3D model in the 3D molding software. A 3D model of the mold can be seen below.

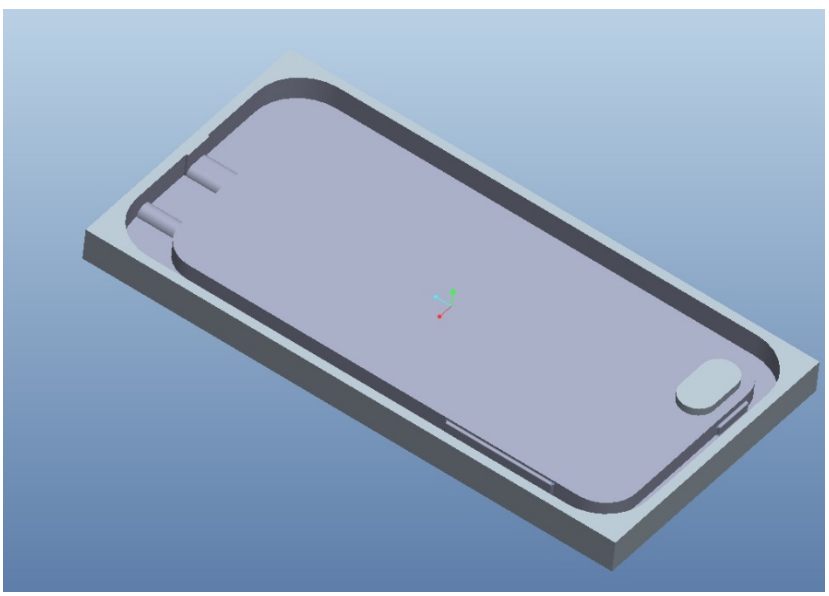


Figure 12. 3D model of the liner mold

Using Mastercam software the cut paths and correct cutting tools to machine the mold were programed. The G-code, technical term for machining program, was obtained and loaded on the Hass MiniMill. A wax mold and the Hass Minimill were chosen to make this mold because it could made very quickly due to the capabilities of the machine and the soft properties of wax.

The machining cuts on the mold were made at 25,000 revolutions per minute and 200 inches per minute. The wax mold took approximately 10 minutes to machine. Photos of the machine and wax mold can be seen below.

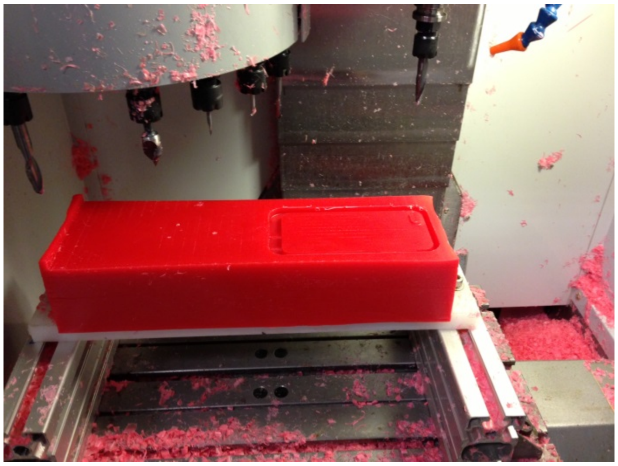


Figure 13. Wax mold being machined


Figure 14. Completed wax mold

A Moldstar 15 two part silicone mixture was poured into the mold and allowed to cure. Photos of the prototyped liner can be seen below.


Figure 15. Prototyped silicone liner


Figure 16. Prototyped silicone liner

The following section discusses the outcomes of the work completed for the project and suggestions for changes that should be made for future prototypes and products.

V. Results and Discussion

The result of this project is a functioning prototype case that mounts to a bicycles handlebar and allows the user to utilize the iPhone 5's features while cycling. The circuit board mounts into the case and everything fits together as intended. The quality of the prototype is better than expected and gives a good representation of the fit and function of a production product. A product structure, Bill of material and a cost analysis with multiple production options were compiled. Images of the functioning prototype utilizing some of the phones features can be seen in figures 17 through 20 below.

Figure 17. Functioning prototype

Figure 18. Functioning prototype

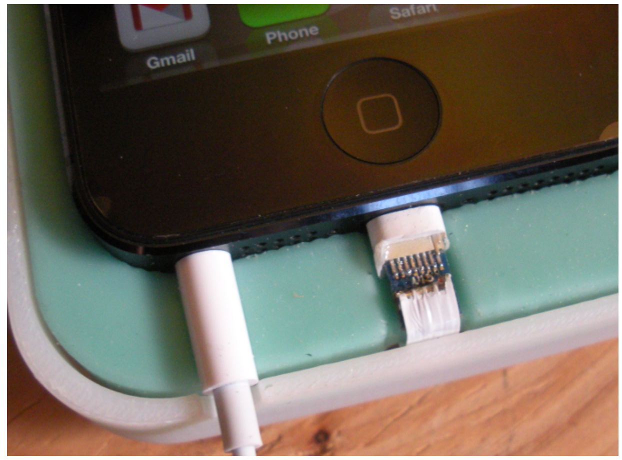


Figure 19. Functioning prototype

Figure 20. Functioning prototype

Some problems that were revealed with this prototype and that should be addressed for future prototypes and a final product are the clamp mechanism and a lower profile handlebar mount. A two piece clamping mechanism might be a good solution because it could lock into place offering a more secure clamp. This would require more pieces and would increase the costs. A better handlebar mount could be designed and manufactured but it would increase the costs significantly compared to slightly modifying off the shelf products.

The product structure shown below in figure 21 shows the breakdown of all of the components that make up this product. It shows the level for each component and each components parent. The product bill of materials show in table 2 also shows each component and its parent but includes more detailed information including part number, part description, quantity, and whether the component is manufactured or purchased. The cost analysis show in table 3 gives a brief description of two different product options. The first option is for an injection molded case and the second option is for a CNC machined aluminum case. The cost analysis shows the quantity and cost for both options with a breakeven point of 266 units. For the detailed cost analysis see the spreadsheet in the appendix.

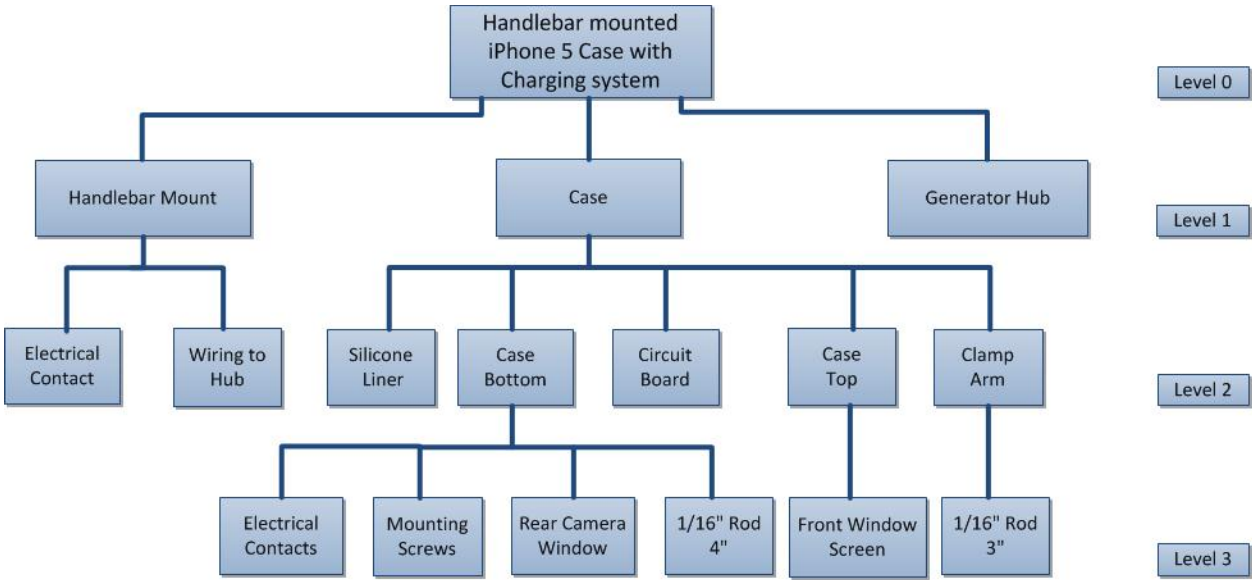


Figure 21. Product structure

Level	Part Number	Description	Quantity	Purchased/Manufactured
0	1001	Bicycle mounted iPhone 5 Case w/ Charging	1	
1	1002	Handlebar Mount	1	Manufactured
2	EC1001	Electrical Contact	1	Purchased
2	W244	Wiring to hub, 3 feet	1	Purchased
1	GH1001	Generator Hub	1	Purchased
1	1003	Case	1	Manufactured
2	CB20012	Circuit Board with components installed	1	Purchased
2	1004	Silicone Liner	1	Manufactured
2	1005	Case Top	1	Manufactured
3	WS555	Front window screen	1	Purchased
2	1007	Clamp Arm	1	Manufactured
3	SR116-3	1/16 steel rod for attaching clamp arm, 3"	1	Purchased
2	1006	Case Bottom	1	Manufactured
3	EC5005	Spring Electrical Contact	2	Purchased
3	SR116-4	1/16 steel rod for attaching top/bottom, 4"	1	Purchased
3	W4455	Rear Camera Window	1	Purchased
3	SC#46	Screws for mounting board	4	Purchased

Table 2. Product bill of materials

Option 1-	Quantity	Cost per case
Injection Molded case	100	$154.72
	200	$89.72
	266	$73.59
	300	$68.05
	1000	$37.72

Option 2 -	Quantity	Cost per case
CNC machined case	100	$89.22
	200	$76.72
	266	$73.62
	300	$72.55
	1000	$66.72

Table 3. Cost analysis summary

The final section concludes this report. It summarizes what has been covered thus far and addressed what has been accomplished and it implications. It describes what was learned. It also offers recommendations for the future.

VI. Conclusions

There are currently no fully contained products on the market that can use a charge from a generator hub on a bicycle to power the iPhone 5 while allowing the user to access all of the phones features. This project set out to change that by designing and manufacturing a functioning prototype case that could be mounted on a bicycles handlebars, be weather resistant, and charge the iPhone 5 at a range of speeds. A variety of design and prototyping techniques discussed earlier in this report were used to design and manufacture a functioning prototype that addressed the problem while staying within the project constraints. All of the deliverables were addressed and completed.

The most important take away from this project is that the functioning prototype proves that this system will work as function as intended and offers users a sustainable way to use and charge their iPhone 5's while cycling under varying conditions.

Many things were learned though the course of this project. Skills that were learned through many courses taken at Cal Poly were applied to a real problem and then used to solve the problem. Through research and with the guidance of peers and professors I was able to take this project from an idea to a functioning prototype. I learned how to look at the bigger picture when developing ideas and products and to explore all avenues for the best solution. In the future I would obtain more feedback from potential users and peers because they often can offer advice and solutions that may have been over looked. I would recommend that this idea and product be further developed into a consumer product.

Literature Review Bibliography

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Figures and Equations

Fig. 1 S.H. Ahn, C.S. Lee, W.B. Jung. “Development translucent FDM parts by post-processing.” Rapid Prototyping J., 10 (4) (2004), pp. 218–224

Fig 2. CADCAMNET website. http://www.cadcamnet.com/Sections/rapid%20prototyping/For%20beginners.htm.

Fig 3. Rockey, Brenden. "*Injection Molding Wikipedia article*" http://en.wikipedia.org/wiki/File:Injection_moulding.png 2009

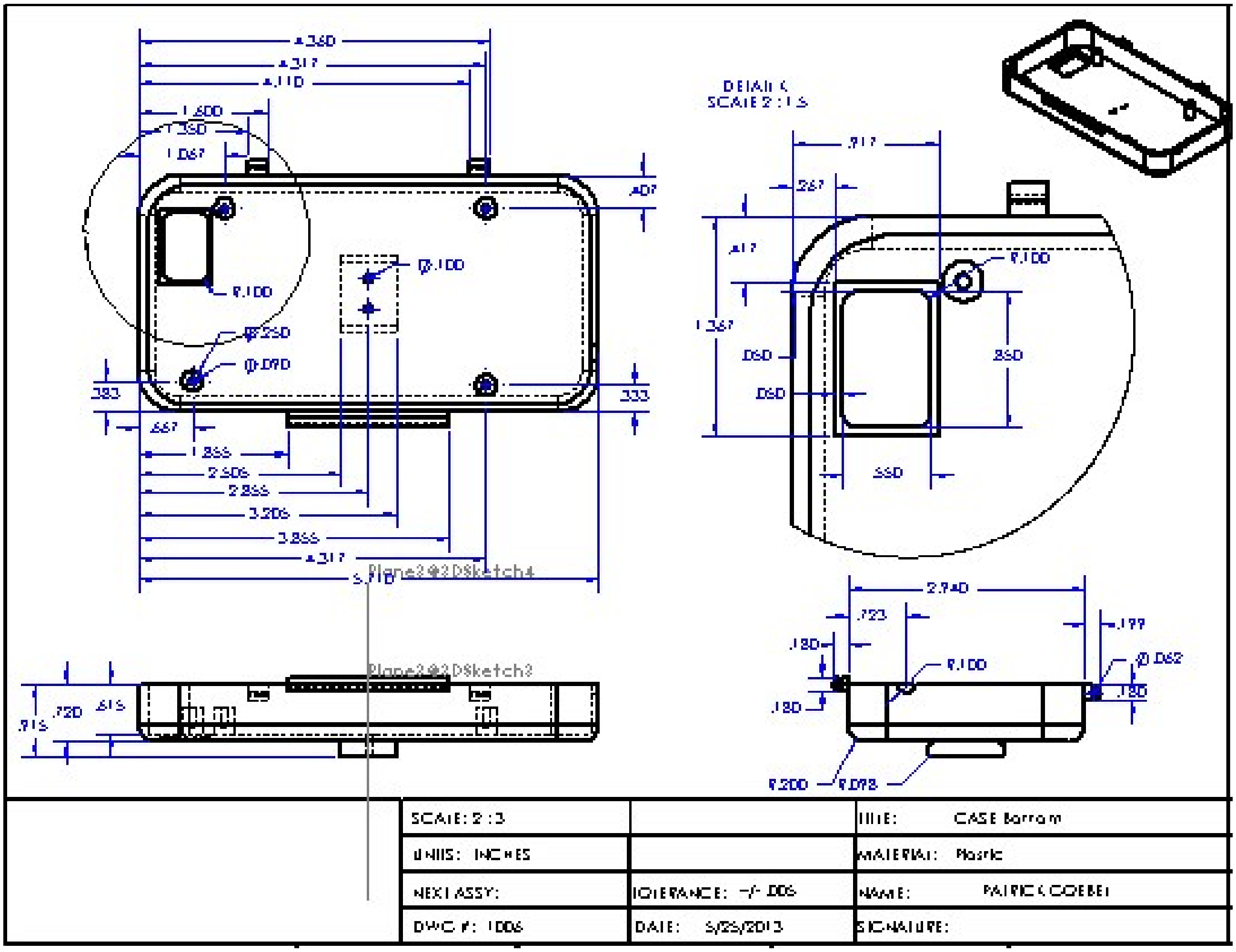
Eq. 1 Rubin, I. I. *Injection Molding: Theory and Practice*. John Wiley & Sons, New York, 1973.

Other

Solid Model and drawing for iPhone 5. GrabCAD.COM
http://grabcad.com/library/iphone-5-for-case-design-and-photo-rendering

Appendix

Engineering drawings:



DETAIL C
SCALE 2 : 1.5
SCALE: 2 : 3
UNITS: INCHES
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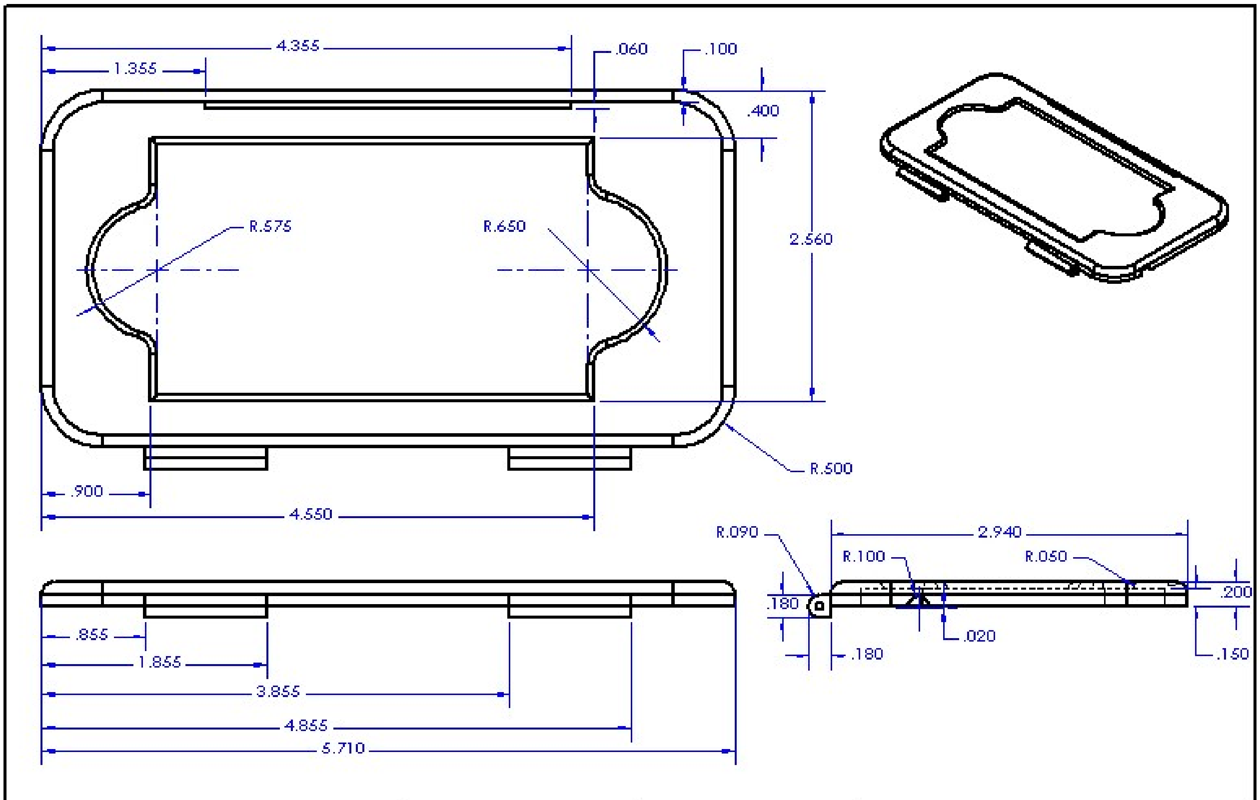
DWG #: 1006
TOLERANCE: +/- .005
DATE: 5/25/2013
TITLE: CASE Bottom
MATERIAL: Plastic
NAME: PATRICK GOEBEL
SIGNATURE:



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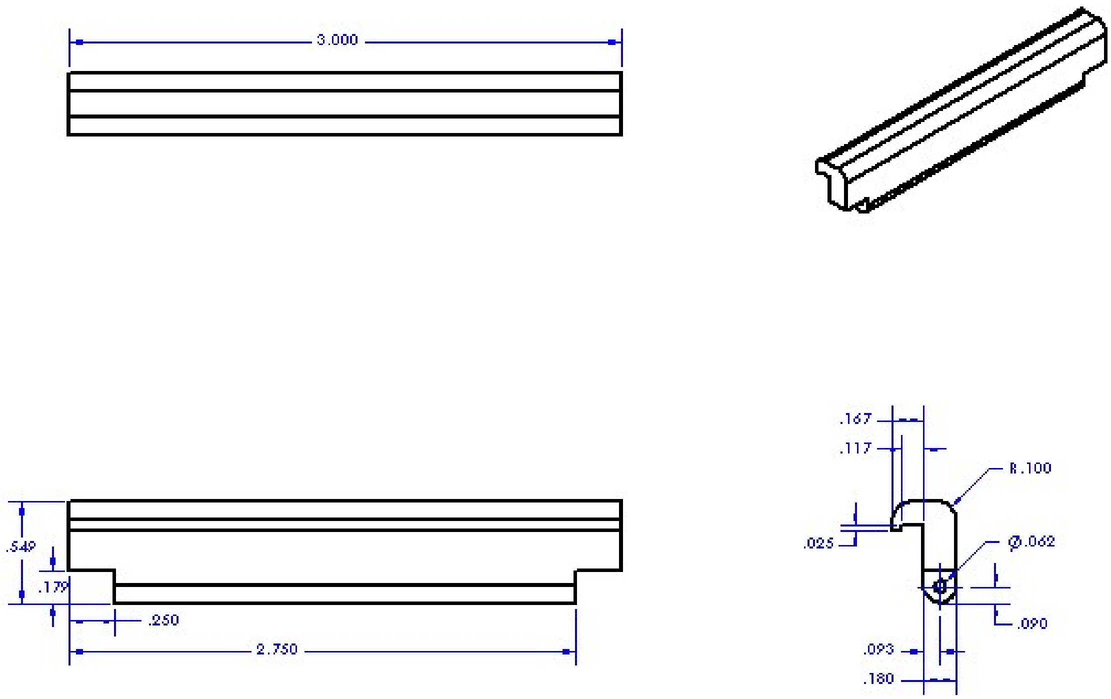

	SCALE: 3 : 2		TITLE: CLAMP ARM
	UNITS: INCHES		MATERIAL: PLASTIC
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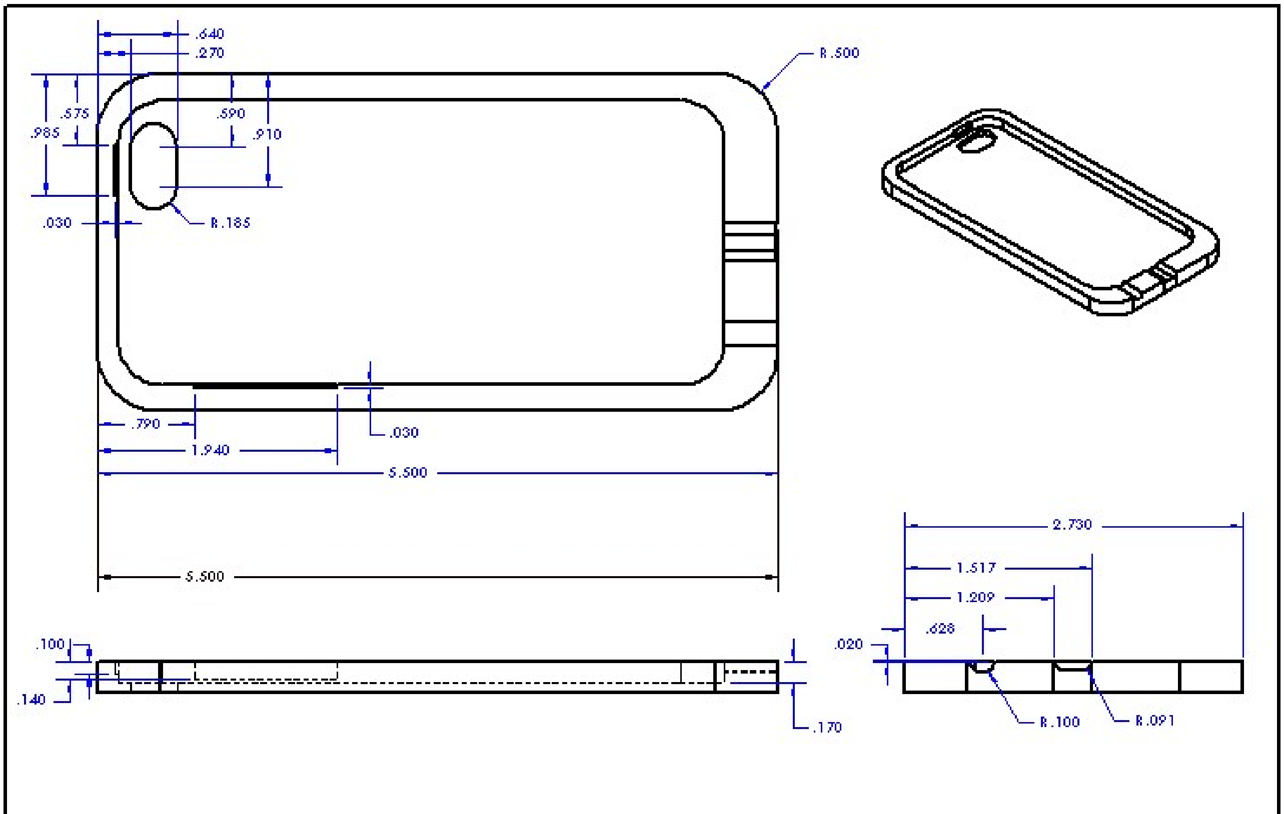

	SCALE: 1 : 1		TITLE: CASE LINER
	UNITS: INCHES		MATERIAL: SILICONE RUBBER
	NEXT ASSY:	TOLERANCE: +/- .005	NAME: PATRICK GOEBEL
	DWG #: 1004	DATE: 5/25/2013	SIGNATURE:

Detailed Cost Analysis:

Option 1- Injection molded case						
Purchased items		Quantity	Cost	Extended cost		
	Handlebar mount	1	2	2		
	Wiring to hub, 3 ft	1	0.1	0.1		
	Circuit board w/ components	1	10	10		
	Front window screen	1	0.1	0.1		
	1/16 steel rod, 3 in	1	0.08	0.08		
	1/16 steel rod, 4 in	1	0.09	0.09		
	Electrical contacts	2	0.07	0.14		
	Rear camera window	1	0.11	0.11		
	Circuit board mounting screws	4	0.01	0.02		
Manfactured items						
	Injection molding labor, $45/hr	10 min/part	7.5	7.5		
	Material - plastic	5 in^3	0.25	0.25		
	Material - silicone	1.5 in^3	0.33	0.33		
	Case assembly labor, $30/hr	8 min/part	4	4		
					24.72	
Mold Costs						
	Mold for case top	1	4000	4000		
	Mold for case bottom	1	5000	5000		
	Mold for clamp arm	1	1500	1500		
	Mold for liner	1	2500	2500	13000	
Option 2- CNC Machined case						
Purchased items		Quantity	Cost	Extended cost		
	Handlebar mount	1	2	2		
	Wiring to hub, 3 ft	1	0.1	0.1		
	Circuit board w/ components	1	10	10		
	Front window screen	1	0.1	0.1		
	1/16 steel rod, 3 in	1	0.08	0.08		
	1/16 steel rod, 4 in	1	0.09	0.09		
	Electrical contacts	2	0.07	0.14		
	Rear camera window	1	0.11	0.11		
	Circuit board mounting screws	4	0.01	0.02		
Manfactured items						
	Machining molding labor, $60/hr	40 min/part	40	40		
	Injection molding liner labor $45/hr	3 min/part	2.25	2.25		
	Material - Aluminum	35 in^3	5	5		
	Material - silicone	1.5 in^3	0.33	0.33		
	Case assembly labor, $30/hr	8 min/part	4	4	64.22	
	Mold for liner	1	2500	2500		
Option 1- Injection Molded case	Quantity	Cost per case		**Option 2 - CNC machined case**	Quantity	Cost per case
	100	154.72			100	89.22
	200	89.72			200	76.72
	266	73.59			266	73.62
	300	68.05			300	72.55
	1000	37.72			1000	66.72
	Breakeven point: 266 units					