Pier Portal II

A Senior Project
presented to
the Faculty of the Mechanical Engineering
California Polytechnic State University, San Luis Obispo

In Partial Fulfillment
of the Requirements for the Degree
Bachelor of Science

by

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June, 2013

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Introduction

The goal of this project was to improve, test and complete the previous Avila Pier Portal project. Cal Poly's Pier Portal project aims to give educators, students, and scientists a new way to observe sea life at the Avila Pier. This camera system is located on a support piling near the end of the pier. Ideally, internet users will be able to manipulate this system to move up and down the piling from the top of the pier all the way to the sea floor.

The previous team successfully built an internal camera system, winch frame, winch motor, camera pod, and pod cart. They also successfully installed the I-beam track for the pod and set up a basic control system for the winch motor and freshwater rinse automation. Unfortunately, the pod failed during pressure testing, and so parts of this project were unable to be fully tested and brought to completion. It is our job to continue where the last team left off. A main goal of our team was to make the Pier Portal require as little maintenance as possible. This meant lots of testing and tuning to get the final product running smoothly, replacing many of the quick fixes for more long term solutions, and adding more safety features within the pod itself to help the components last longer. There is also a lot of room for optimization and integration of different parts of the system.

The current Mechanical Engineering team contributed to the Pier Portal project by completing the following:

- Secured an AC servo motor and motor controller donation from Yaskawa.
- Purchased necessary electrical components (circuit breaker, noise filter, and magnetic contactor) to power the motor controller.
- Purchased a gear reduction drive.
- Sized and purchased a NEMA4X safety enclosure to protect the servo motor and gear reduction drive.
- designed and built a bracket to attach the reduction drive to the winch
- Integrated the winch with the servo system by machining and modifying existing hardware.
- Built a prototype cleaning system.
- Designed a final cleaning system.
- Designed, constructed, and tested a prototype bracket to secure the top of the track to the pier piling.
- Converted the internal pod electronics code from a cooperative multitasking system to a real time operating system.
- Fabricated and tested two different custom printed circuit board revisions to replace the prototype pod electronics.
- Integrated the internal pod electronics control system with the Pier Portal website.

The work presented in this senior project team's report is made up of three mechanical engineering seniors, Misha Balingit, Aaron Jen, and Cory Spieler. In addition, our team includes an

electrical engineering student, Andy Lam, and a computer engineering student, Brian Markwart. However, their contributions to this project are outlined in detail in their own individual senior project reports. The professors overseeing this project are John Ridgely and Bridget Benson. Tom Moylan is the pier manager at the Cal Poly Pier, and is our official sponsor.

Existing Project

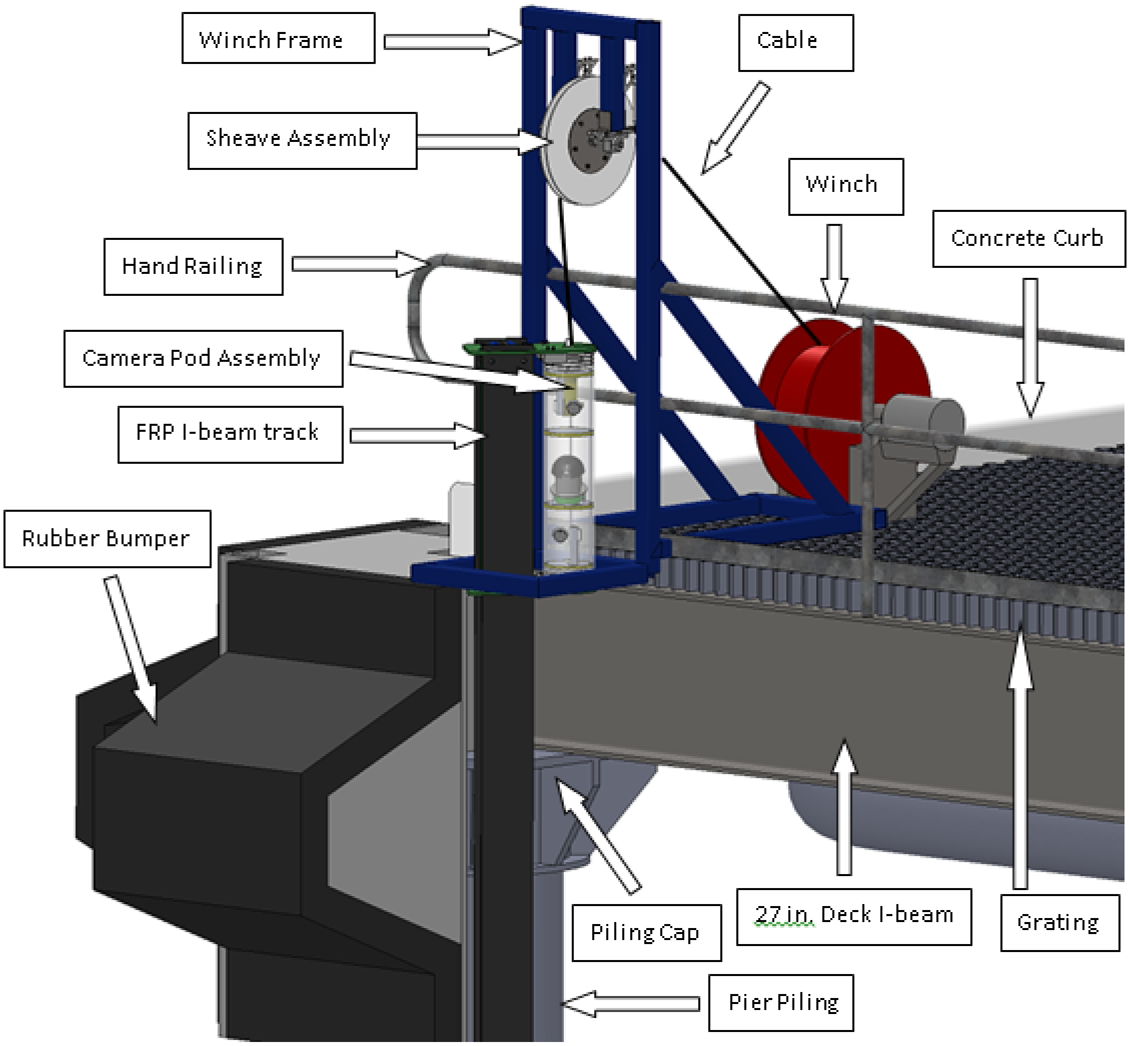


Figure 1. Final design from the previous pier portal group.

Here is an overview of the previous design, including general manufacturing processes. Most of the information in the following sections was taken from the previous Pier Portal team's final report. The purpose of this section is to make it easier for future teams to maintain and improve on the designs of previous teams.

Essentially, the camera pod assembly is moved up and down the I-beam track by a data and power cable which runs through the sheave assembly (pully), and winds around the winch. The winch and winch frame are attached to the pier deck, and the I-beam track runs all the way to the sea floor. Each of the components will be viewed with more detail below. A computer at the top of the deck inside was to be used for high definition storage of video feed while broadcasting a compressed version of the video live.

Winch and Winch Motor Setup

The current winch setup uses a 12 volt DC motor and a gear reduction system that is partially made from bicycle parts. The winch drum system already includes a 12.9:1 reduction. Since the last team needed to reduce the travel speed of the pod even further, they made a custom gear box. This custom gear box will not be reused for the continuation of this project, but further details can be found in the previous Pier Portal report.

One shortcoming of the 12 volt DC motor is the large amount of current required to run it. The large current creates a higher risk of fire if a short were to occur within the system. In addition, the current DC setup requires a large power transformer. Another problem with the winch setup is that the current gear reduction may not be robust enough. Due to these undesirable factors, the DC motor will be replaced with an AC motor.

Winch frame and Pulley System

The purpose of the winch frame is to hold the pulley that will feed the cable over the edge of the pier. Both items were hand made by the previous team. The pulley has an encoder built into it to keep track of how much cable has been let out. In addition, a clever spring hinge was built into the frame to detect slack in the pod cable. The drawings for these custom parts can all be found in Appendix F.

Figure 2. Winch frame setup.

The winch frame (Figure 2) is made out of three 20ft sections of 3”x 3” x .120” steel box channel. The group used a combination of MIG and TIG welding to put the frame together. The sections were laid out and positioned using magnets and slide squares, and then tacked into place. Each of the seams on the frame were MIG welded. Special care was taken to ensure that there are no gaps in the assembly that would let in corrosive sea air. The L-brackets and spring mounts used to support the sheave and slack detection were cut from a 10gage sheet of steel and then TIG welded together and then TIG welded to the rest of the frame. There are three different sets of holes in the spring mount so that the load switch sensitivity can be adjusted.

Figure 3. Picture of slack detection hardware, taken by the previous pier portal team.

The slack detection hardware (Figure 3) built into the winch frame utilizes a hall-effect switch, a spring, and two hinges to detect if there is slack in the cable. This is important because if there is too much slack in the cable and the motor keeps unwinding, the cable could unseat from the sheave, stopping operation and causing possible damage to the cable. The winch sheave is mounted to the frame via spring-loaded hinges. While there is tension in the cable, a downward force is exerted on the pulley, the hinges are pulled open, the spring is stretched and the system assumes everything is ok. If there is a large wave and the tension in the cable is lost, the spring will be able to pull up on the hinge, and a magnet attached to it will trigger the hall-effect switch, which will signal the system to stop the motor from unwinding until tension returns to the cable. The hall-effect switch is nestled inside a 316 stainless steel 3/8" screw that is bolted to the frame.

In order to further discourage the cable from departing the sheave, a roller guide (Figure 4) was fabricated out of 1.25" x 1.25" x .120" steel box channel and TIG welded to the frame.


Figure 4. Cable roller guide, built and pictured by the previous team.

The encoder (Figure 5) is an absolute encoder that keeps track of what position (0-360 degrees) the pulley rotates through. This allows us to keep track of the height of the pod. Every time the encoder rotates 360 degrees, we know that how much cable we have fed out based on the diameter of the pulley. The pulley also has a spring loaded hinge attached to it so that if the cable were to become loose, the motor will stop.

Figure 5. Sheave assembly created and pictured by the previous team.

The white sheave body (Figure 5) is made from a thick sheet of Ultra High Molecular Weight Polyethylene (UHMWP). It has a curved groove where the cable contacts it. The hub plate material is type 316 stainless steel. They are composed of hub collars and 10-gage plates TIG welded together. A mill was used to add a center hole and the circular patterned mounting holes.

Almost the entire assembly has been painted with Amershield; a polyurethane based industrial marine coating to protect it from rusting. To prime the frame before painting, the frame body was ground with wire brushes and 36grit sand

paper, then chemically etched with Ospho, and subsequently wiped down with mineral spirits. Two coats of Amershield were applied.

I-Beam Track

The I-beam track is made up of Fiber Reinforced Plastic (FRP), and was purchased from Seasafe® along with custom bracket and joint connection plates. This type of composite material was chosen mainly because of its ability to resist corrosive environments, although strength and cost were also factors. The accompanying datasheet for this I-beam and the custom bracket drawings can be found in Appendix F.

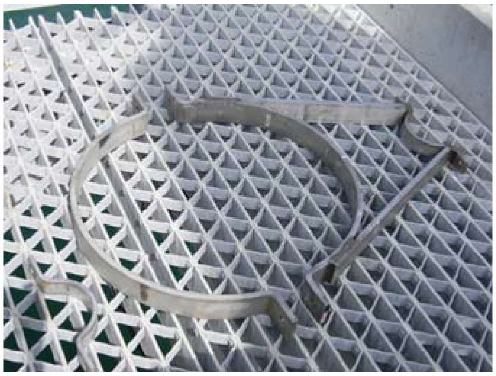


Figure 6. Stainless steel pier piling brackets (taken by the previous team).

The I-beam track is composed of three separate 20ft sections, which are bolted together using midspan brackets (Figure 7). The stainless steel pile brackets (Figure 6) connect the track to the pier piling. The steel pile brackets were given to the previous team by the Cal Poly Pier. Close ups of the track bracket design can be seen in Figure 8 and Figure 9. An overall assembly of the track can be seen in Figure 1. Bracket distances measured from the sea floor up are laid out in Table 1. The installation process for the track is discussed in more detail in the previous pier portal report. Essentially, the track was assembled on the pier deck, a crane was used to lower the track into the water, and diving students attached the track to the piling brackets by drilling directly into the FRP with pneumatic drills. The old installation plan can be found in Appendix G for reference.

Figure 7. Close up of a midspan bracket.

Figure 8. Close up of the track bracket from the front.

Figure 9. Close up of the track bracket from the rear.

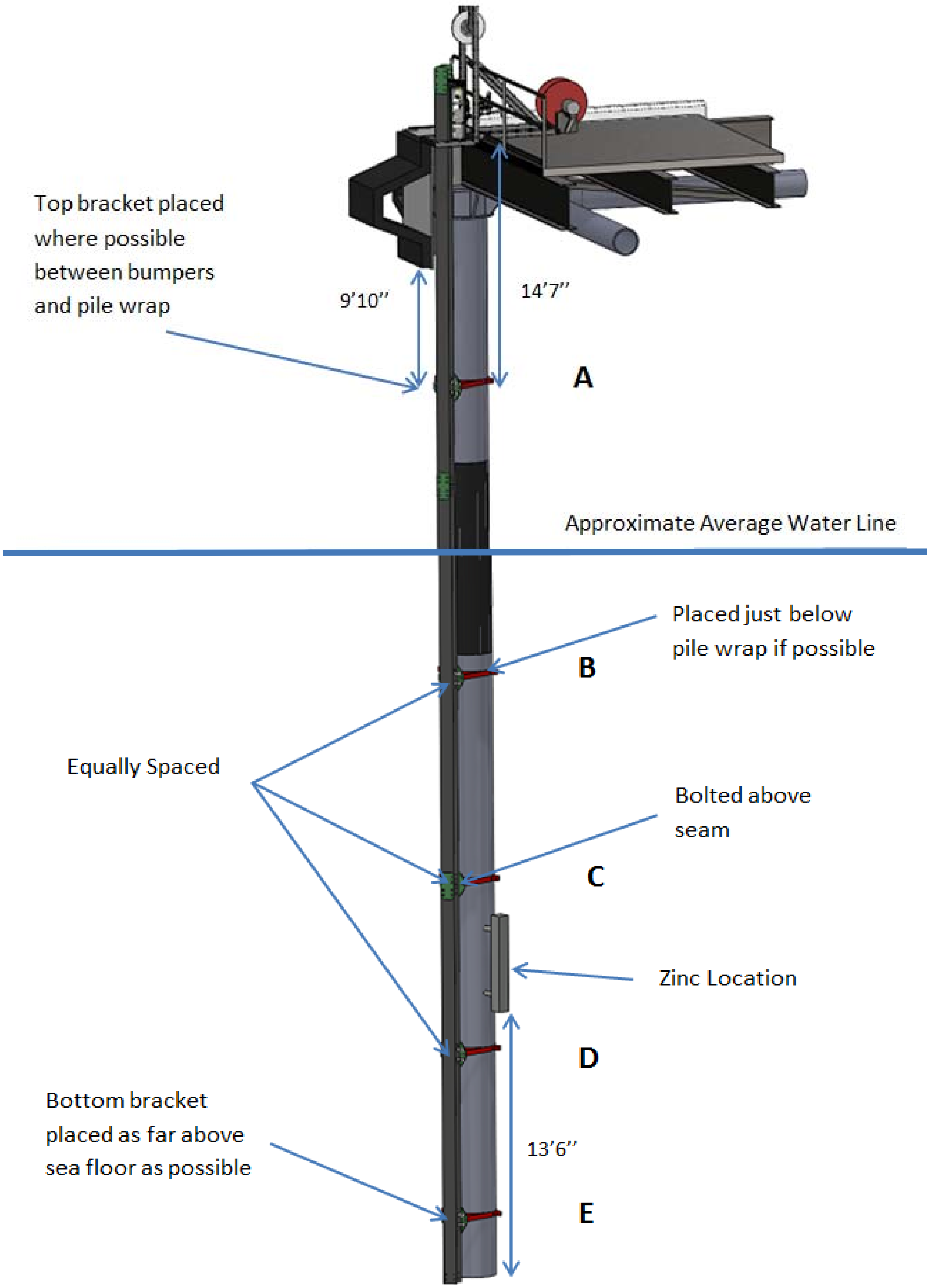


Figure 10. Overall pier installation layout from previous team's installation plan.

Table 1. Bracket Distances laid out by previous pier portal team.

Brackets	Distance above seafloor (approximate)	Notes
Deck	687in (57'3'')	Defined as top of grating
A	539in (44'11'')	Placed where possible above pile wrap
B	366in (30'6'')	Placed just below pile wrap
C	252in (20'1-1/2'')	Bolted above seam
D	139in (11'7'')	Equally spaced
E	39in (3'3'')	Placed as above seafloor for ease of installation

Pod

The purpose of the pod is to enclose the electronics, camera, and lights. It is designed to keep water out while being transparent enough to allow the camera to get a clear view of the ocean. The pod walls are made out of an eight inch outer diameter, .25" thick, cast acrylic tube. The top cap is glued with acrylic glue and the bottom cap is removable so that the components inside can be accessed. The inside of the pod is split up into four different levels, each separated by Delrin® platforms. The pod communicates via a waterproof cable connection to the deck computer. Two caps, installed on the top and bottom of the pod are made out of acrylic like the pod walls so that the thermal expansion coefficients are as similar as possible, which will minimize leakage through the O-rings due to thermal expansion. Each cap is approximately 2.5" thick. They were machined from a solid 50lb, 2ft long acrylic rod. Rough cuts were made with a band saw and then cleaned up a bit with a table saw and large diameter end mill. A Clausing lathe with a large radius cutter at the Cal Poly Hangar was used to bring the caps to their specified dimensions. The cavities in the center were created using a combination of a rotary table and an end mill. The lathe was used with a square shaped cutter to make the grooves for the O-rings. The O-ring design guide used to spec these grooves can be found in Appendix F. The previous team also documented two accidents that occurred during fabrication of the bottom caps. The bottom most groove was cut too deep, and one of the corners of a groove was damaged because a lathe was accidently shifted into auto-feed.

Figure 11. Center of inner pod structure (taken by previous team).

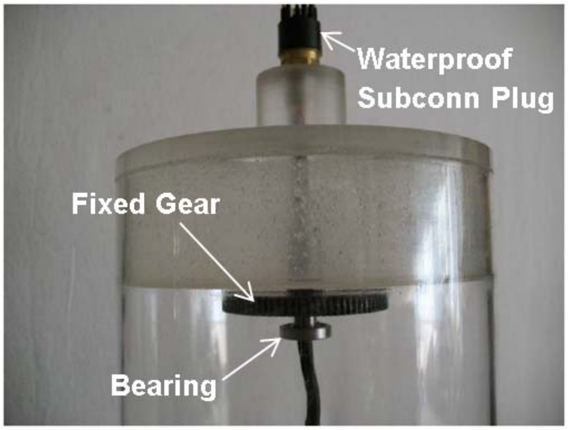


Figure 12. Top cap (taken by previous team).

More specifically, the top cap (Figure 12) has a hole through the center so that the data and power cable can access the pod. The hole is tapped as the waterproof Subconn plug requires. Below that, a shaft was press-fit into the hole with a 0.001” interference. There is also a gear and bearing fixed to this shaft inside the pod with the same 0.001” interference. Both the gear and bearing are used for the internal rotation system. The bearing sits in a groove cut into the uppermost Delrin® platform and limits the distance the internal pod structure can be pushed into the pod, so that the upper fixed gear and motor pinion gear are aligned. There is also a magnet installed in the top cap. This magnet is used in combination with a Hall Effect switch to limit the rotation of the pod. A standard printer cable was repurposed to function as the transition cable between the pod electronics and the main winch cable. This cable is described in more detail in the cable section.

The lower cap (Figure 13) has a Lazy Suzan bearing installed for the internal pod structure to rotate on. In addition, the lower cap has a vent plug. This is necessary so that air has somewhere to escape when the pod caps are pushed into place. If there was no vent plug, we would have to compress the air inside the pod, and there would be a constant pressure force trying to detach the bottom cap from the pod. Furthermore, the previous team said that if any fogging issues are encountered, the air inside the pod can be replaced with a moisture free gas such as nitrogen, to address the problem. The last component of the lower cap is the leak detection circuit pocket. A hole was drilled through the cap in the radial direction so that leak detection leads could be threaded through from the inside. Then, the holes were filled with acrylic epoxy so that in the event of a breach, the water didn’t have an easier pathway to travel to penetrate the pod.

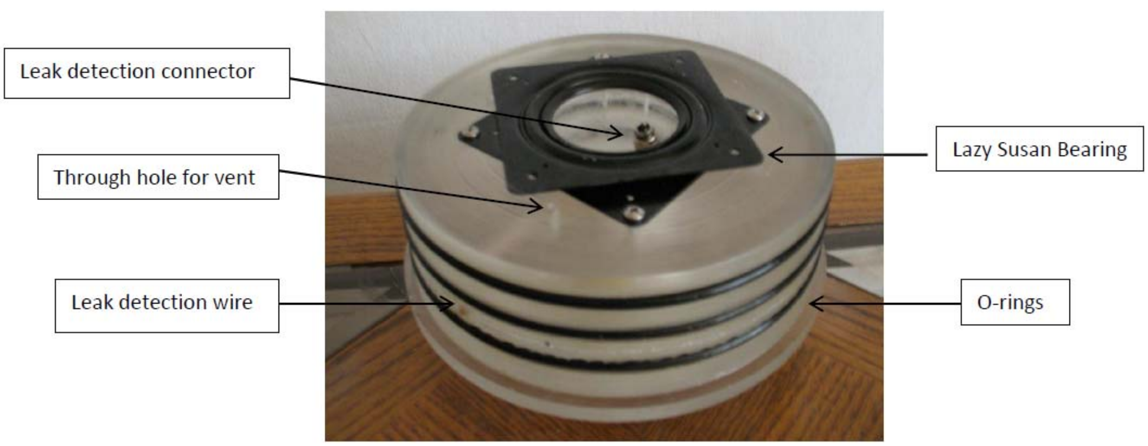


Figure 13. Lower cap assembly created and pictured by the previous team

Each of the Delrin® platforms is .5” thick, with a 7.38” diameter. Three 30” threaded support rods are spaced out to the left, right, and directly behind the camera so that there is sufficient support for the pod structure, but the field of vision of the camera is not blocked. Two nuts threaded onto each rod above and below each Delrin® disk hold the platform in place (Figure 14). The machining process for the platforms is similar to the cap machining process. The team used a vertical band saw for rough cuts, a lathe to turn the rough cuts down to specified dimensions, a mill and drill press for holes, and a Dremel tool to smooth all rough edges.

Figure 14. Image of mid section of the pod taken by the previous team.

The top level is dedicated to one of two light arrays as can be seen in Figure 11, and a 24V DC motor (provided to the previous Pier Portal Team at a discounted price from Ametek®) which rotates the entire *internal* pod assembly to increase maneuverability and scope of the camera. Each light array is composed of three Cree XML warm white LEDs with a spotlight lens attached. There are also aluminum heat sinks attached to help dissipate heat. Each array is also attached to a servo, which allows the lights to be rotated up and down 90 degrees. Each LED array has a tower-mount made from 0.12” stainless steel sheet metal. These towers were bent into shape using a brake machine and a vise with wooden jaws.

The second level houses the camera, which is capable of rotating in the vertical and horizontal directions. This camera is a Triton A1IPPTZ10X2MP, specified for high resolution in low lighting situations, and allows pan, tilt and zoom control through Ethernet commands. One Ethernet cable plugged into the camera assembly is used for power, while the other is used for communication. The camera can stream 1920x1080 video with up to 10x optical zoom. A phototransistor is located at the front of the camera so that the amount of light seen by the camera can be measured by the electrical system for automation of the LED brightness. The camera mount is made from two pieces of stainless steel 0.020” sheet metal, each bent into shape using a hand brake machine and then TIG welded together. A square hole was cut in the center so that wires from the pod board could reach the camera with a Dremel tool. There is also a cable routing block located near the rear threaded rod, used to

The third level houses the second LED, and the electronic boards required to run the internal system of the pod. Felt strips are glued to the Delrin® platforms in order to block light reflections from the LEDs from interfering with the camera.

Finally, the fourth level of the pod includes the removable plug and water leak detection circuit. This plug relies on three different O-rings to help keep the pod sealed. In the event of a leak, the water will act to complete the simple circuit, set off an alarm in the

system, and cause it to immediately extract the camera pod from the water to avoid further leakage and damage to the internal components.

Cable

The main winch cable is 100ft long with a 0.62" diameter, fabricated and donated by Remote Ocean Systems. It has a 1000lbf breaking strength due to the Kevlar braid just beneath a waterproof polyurethane jacket. It also has a minimum bend radius of 10" and weighs 28lbf (280lbs/mft). An Amtec cable grip distributes stresses placed on the cable closest to the pod to a steel cable sheathed in vinyl plastic which is part of the pod cart. This ensures that the Subconn connector, which is much more sensitive than the Kevlar reinforced cable, will not see the forces that the rest of the cable is subjected to. As cleverly explained by the previous group, this cable grip works very much in the same way that a Chinese finger trap does. The datasheet for this cable and the cable grip can be found in Appendix F.

Essentially, there are 21 conductors inside the main winch cable, split into 6 different legs. A breakdown of each leg in table format is presented below in Table 2. The original cable only had six 16AWG data lines. The previous team asked Remote Ocean Systems to split (or branch) two 16AWG data lines in two, creating eight total 16AWG data lines. Essentially, the data lines in Leg #2 are connected to two data lines in Leg #1 for the purpose of the temperature & humidity sensor.

Table 2. Breakdown of main winch cable wires.

LEG	INTENDED LEG USE	WIRES			Notes
		TYPE	QTY	USE	
#1	connects to pod	16AWG	4	Power	*Custom/Doesn't match data sheet
		22AWG	8	Data	
#2	Temp/Pressure sensor	16AWG	2	Power	Currently plugged by MCDC4M micro series dummy plug
		22AWG	2	Data	
#3	-	16AWG	2	-	Currently plugged by Subconn Poly Plug
		22AWG	2		
#4	-	Coaxial- TYPE RG-59/U	1	-	Currently plugged by Subconn Poly Plug
#5	-	Coaxial- TYPE RG-59/U	1	-	Currently plugged by Subconn Poly Plug
#6	-	Coaxial- TYPE RG-59/U	1	-	Currently plugged by Subconn Poly Plug

The main winch cable connects to the pod via large waterproof Subconn MCBH12M & MCBH12F (for 'M' male and 'F' for female) micro series bulk head connectors located outside of the pod. The smaller HIROSE connectors are at the end of the printer cable, which is meant to be threaded through the Delrin® platforms down to the bottom level

where the pod board is located. More information on both of these cables can be found in the Pod section. The previous team created **Error! Not a valid bookmark self-reference.** and Figure 15 to define the pin outs for each of these connectors. The “Nuclear Cable” refers to the main winch cable.

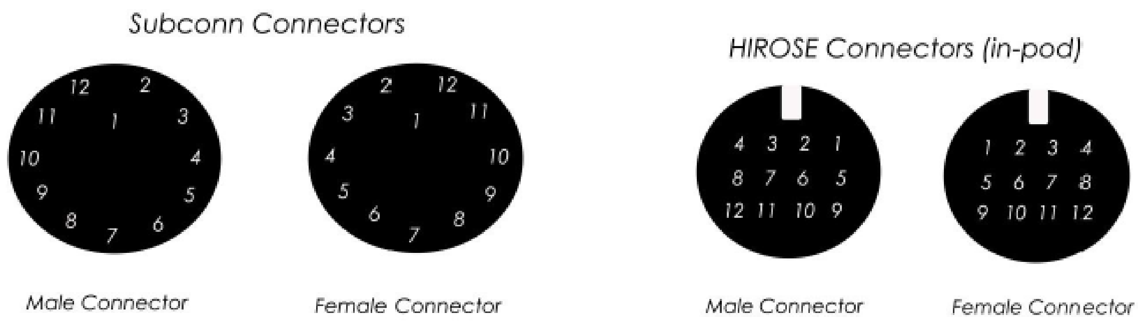


Figure 15. Connector Pin Configurations from the previous team.

Table 3. Wire color and connector pin definitions created by the previous team.

Conductor Name	Subconn Connector pin #	Hirose Connector pin #	Nuclear Cable wire color	In-pod Cable wire color
Cam1	1	5	Bk	Y, Y/Bk
Cam2	2	6	W	W, Bk/W
Cam3	3	9	R/Bk	B, B/Bk
Cam4	4	8	G	Br, Br/W
RS485 "B"	5	10	O	Gy, Gy/Bk
RS485 "A"	6	7	B	Pi/R, Pi/B
x	7	1	W/Bk	many
x	8	2	R	many
+24 volt	9	3	G/Bk	R, R/W, R/Bk
+24 volt	10	4	O/Bk	O, O/W, O/Bl
Gnd	11	11	B/Bk	G, G/W, G/Bl
Gnd	12	12	Bk/W	P, P/W, P/Bk

Table 4. Color abbreviations key created by previous team.

B	blue
Br	brown
Bk	black
G	green
Gy	gray
O	orange
P	purple
Pi	pink
R	red
W	white
Y	yellow

Electronic boards

The previous team successfully created a working prototype of the electronics inside the pod. The purpose of the pod electronics is to support the camera. This included hardware and supporting code necessary to control two LED arrays mounted on servos for maximum visibility underwater, a DC motor for panning, fans to help cool the LED arrays, and a leak detection circuit. Their prototype assembly will be replaced with a custom

printed circuit board (PCB), and the code will be converted from a cooperative multitasking system to a real time operating system (RTOS).

The winch control system is also in the prototype stage, as it was never able to be installed onsite and put to the test. Documentation shows that there are still some major kinks to work out, and the freshwater rinse valve, hall-effect load sensor, and position reset button still need to be integrated into the system.

More information on their prototype pod and winch control system can be found in the previous Pier Portal's report.

Cart

The purpose of the cart (Figure 16) is to hold the pod and allow it to move up and down on the I-beam. The frame is made out of two FRP (fiber-reinforced plastic) end plates that are held together with two FRP connecting supports. FRP was chosen because it is both strong and will resist the corrosive environment of saltwater. Lead ballasts have been added to the cart to overcome the buoyancy from the hollow acrylic tube. The cart rolls up and down with eight roller blade wheels that sandwich the I-beam. The original design included roller blade wheels to help facilitate smooth movement. In addition, pod stops and strapping are used to hold the pod in place on the cart.

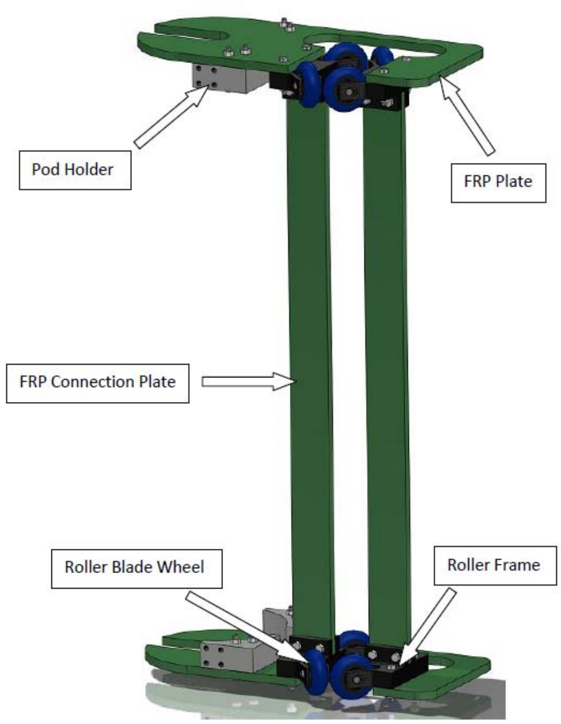


Figure 16. Pod cart modeled and labeled by the previous team.

FRP plates were donated by Rob Brewster, who also heavily aided the fabrication process of the plates. Fabrication of these FRP pieces was very tricky due to the layered

nature of the FRP material. All cart plates were cut using a water jet. However, the water jet was only able to cut the material when it approached from an edge rather than starting in the middle of the material. Attempting to cut a profile from the middle of the anisotropic FRP causes the water to explode into the plate, fracturing and damaging the material rather than cutting straight through it cleanly. Holes in the plates were pre drilled, cut to diameter with the water jet, and then reamed to specifications.

The pod stops were made from leftover UHMWPE instead of Delrin to reduce costs while the pod straps are ¼" thick and made of neoprene. Both pod stops are identical and were machined on a manual mill with a turntable. The holes for the pod strap assembly are 5/16" and threaded. The straps are kept in place because they are pinched between a Delrin plate and the pod stops with four fiberglass reinforced polyurethane bolts. Acetal spring washers help keep the bolts tight while causing minimal damage to the surrounding materials.

The weights used to counteract the buoyancy force of the pod are 1/8" x 32" x 2.5" lead sheets. These strips were cut out of a larger sheet with a shear, while the 3/8" holes were punched into the material. They are cut into strips so that they can be attached to the long, thin connection brackets of the FRP pod cart.

All holes in the cart are 5/16", and all fasteners (besides the pod strap fasteners) are type 316 stainless steel. Medium strength Loctite was used to keep the nuts in position.

Codes and Standards

Our standards will be exactly the same as in the previous project. The system will be assembled and maintained manually, so an understanding of OSHA codes applies. We must ensure the system is safe to assemble, use, and maintain.

Since the system will operate outdoors in a marine environment it must not violate EPA standards or any other applicable environmental regulations. This particularly applies to the release of fluids and chemicals into the ocean cited by the EPA to be hazardous to the environment. As a result, our material selection for components like fasteners or gears is a challenge. We will also make sure the paints we use will not contain harmful chemicals such as tributyltin and copper.

According to the previous Pier Portal Project, one option is to use stainless steels such as AISI 316L/ASTM CF3M or 2205/2507. There are also other options to protect materials in marine environments. These include applying a current to the material, coating the material, or using sacrificial galvanic anodes such as zinc. Specific coatings mentioned were epoxy, vinyl rubber, and polyurethane. Sacrificial anodes such as zinc are commonly added to steel structures underwater. In the types of conditions present at the pier, we can expect a zinc depletion rate of 25-48 mm per year.

The previous Pier Portal project suggests that 316 stainless is only marginally successful in marine environments. It also states that 316 is not commonly used anymore, and the only commercially viable form of stainless steel are the duplex grades. Most common forms of this steel are 2205 and 2507 alloys. A basic cost analysis yielded that duplex stainless variations are twice as expensive as commonly found 316 variations. Other non-ferrous options include composites and plastics that are known to last in marine environments.

Technical & Engineering Specifications Research

Barnacles and other sea life grow on underwater surfaces- especially porous composite surfaces like the I-beam track. There are various ways to prevent barnacles from growing: UV light, vibrations, and physical removal. For the UV light method, each portion of the beam will need to be exposed to UV light for a few seconds each day. For the vibration method, there will need to be a device that will send vibrations out along the track as it moves up and down. For the physical method, the cart will need to physically scrape or scrub the surface on a daily basis. Previous pier portal research shows that 6 N of shear force is enough to remove growth. Another way to prevent barnacles from growing is rinsing the surface with fresh water. For the camera pod and cart, using fresh water is easiest method of prevention since physically scrubbing it would be difficult and ineffective.

Barnacle growth rates are affected by many factors making it hard to predict. However, peak spawning season is in late winter and early spring and growing season is in the summer. However, it is difficult to predict how much barnacles will grow because it depends on time of the year and sea depth. Barnacle growth can also vary from year to year. Regardless of how quickly barnacles or other sea life are growing, the track cleaning system needs to be able to prevent any kind of growth. To over design the track cleaner, it will be assumed that it will always be cleaning/preventing during the late spawning and early growing season.

Another obstacle for the camera pod is the external pressure it experiences at the maximum depth of 30 feet. To be safe, the pod will be designed to withstand approximately 45 psi, or the equivalent of 100 feet in seawater. According to the previous project, this is a factor of safety of approximately 2.5.

The force required to move the whole camera system upwards through the water is a combination of the weight of the pod, cart and cable and the drag force experienced when moving. Since the drag force is dependent on the speed the pod moves and the geometry of the system, it is difficult to calculate the total force. Instead, this drag force will be tested to get a ballpark number of how much total force the motor needs to exert to move the system.

There are some safety considerations that the entire system has to make. The biggest one is that the motor needs to automatically shut down if it tries to pull up too much weight. This prevents the motor from pulling up any seaweed that may have gotten caught or even a person hanging onto the cart. Another safety consideration is automatically slowing the cart when it approaches the seafloor. Slowing it down will

prevent it from crashing into the ground and damaging itself. There are various ways to sense the seafloor. One way is to use an encoder to measure the cable length and use that to approximate when it reaches the seafloor. However, one thing to consider with this method is that the seafloor depth may change from time to time. Another method is to use sensors to see when it will approach the ground. These sensors can vary from infrared to sonar to tactile.

A minor problem is the pod fogging up in the inside. Since the inside of the pod will be warmer than the outside (surrounded by cold seawater), the air inside will condense and obstruct the camera view. This can be prevented by vacuuming out as much air as possible. Another method would be to insert silica gel beads into the pod. These silica gel beads are made to absorb moisture from their surroundings. They are typically used to prevent spoilage and degradation of foods.

Existing solutions

One of the largest challenges of this project will be to implement a cleaning system that will keep the track barnacle free. This challenge is also faced by anyone who keeps a boat in the ocean. The solution used most by boat owners is painting the bottom of the hull with a special paint that helps keep it clean. Then, every season, the bottom of the boat is pressure washed to get any algae or barnacles off. This solution is somewhat similar to our freshwater rinse for the pod, but will not work for the track because the composite I-beam is already installed in the water, preventing us from painting or pressure washing it. Scrubbing an unpainted surface clean at least every month is another method that would better fit our situation. We will be experimenting with different cleaning methods and materials to see which one works the best.

There have been similar projects and solutions for observing underwater life such as ROVs and fixed water cameras. Even though an ROV is an excellent competitive solution, it lacks in image stabilization and has a lot of unnecessary qualities which would only add to the cost of our system. Another type of competitive solution is a fixed water camera. These cameras give video and, sometimes, audio feedback to the user just like the Pier Portal, but they lack the ability to move and remain clean, which leads to a shorter lifespan. The previous project compared itself to an underwater camera system used in the Olympics. This system involved installing a sealed air chamber with an internal track which the camera could move up and down on to visually track drivers. However, these types of systems are not meant to be long term solutions and are also not typically installed in harsh saltwater environments. All of these systems will still be looked at as competition and will be used to benchmark our pod's performance.

Since this is a continuation of the previous Pier Portal, it is difficult to find an alternative solution for monitoring sea life. With a track and camera pod already built, implementing an entirely new system is out of the question. However, research was done on existing solutions for the fresh water rinse and track cleaning systems, as these are the places for the most innovation.

Objectives

Goals

The most important goal of the Pier Portal II project is to allow users to observe the sea life around the Cal Poly Pier. Not only will the project give users underwater visuals but also audio via a hydrophone. Since getting visual and audio footage to the public is the main goal, this project's success is dependent on the quality of the footage. The best result would have smooth video, clear audio, and live updates.

With the potential of having many viewers, the Pier Portal II will need to have the longest life possible and the least amount of down time. The project will include self-sustaining systems, such as automatic track cleaning and the fresh water rinse system, to lengthen its life time.

More specific requirements include switching the current DC motor out with an AC motor. Also, the motor needs a different gear train to provide the proper torque to lift the camera pod.

Engineering specifications

Below is a table that summarizes the engineering specifications with a method to verify the requirement is met:

Spec. #	Parameter	Requirement	Risk	Compliance
1	External pressure	45 psi (or 100 ft)	M	T
2	Shear force on track	6 N	L	T
3	LED brightness	900 lm	L	I
4	External impact	3.6 kN	M	T
5	Max internal temp.	72°C	M	A, T
6	Distance above floor triggering slowdown	7 ft	L	T
7	Distance above floor triggering stop	3 ft	M	T
8	Max resisting force	150	H	T
9	Fresh water rinse surface area	95%	M	T
10	Hydrophone range	1 mi	L	T, I
11	Jerk	$0.1 ft/s^3$	L	A, T

Below are notes and/or further description of the engineering specifications:

- Spec. #1- At the max pressure, the camera pod should not leak or have any physical deformation. The inside of the pod will also not fog up.
- Spec. #2- This value is the minimum recommended value to remove growing sea life from surfaces.
- Spec. #5- This value is based on the max temperature of electronics inside the pod.
- Spec. #6- If the pod is within seven feet of the seafloor, the motor will automatically slow down. And if within three feet, the motor will automatically stop.
- Spec. #9- The fresh water rinse system will rinse at least 95% of the pod casing
- Spec. #10- The hydrophone range is estimated based on the area of the bay. A one mile radius will cover the entire bay. This was measured based on an image from Google Satellite.
- Spec. #11- The army suggests this maximum value to avoid motion sickness.

Most of the engineering specifications listed above were from the previous team's research and specifications. We reviewed their research, data, and specifications and concluded that they are still valid. However, Pier Portal II has additional sponsor requirements such as adding a hydrophone and a fresh water rinse system.

These new requirements have certain engineering specifications of their own such as the range of the hydrophone and the surface area washed by the fresh water rinse. The sponsor has expressed concern that sea life will begin to grow on the camera pod itself if it is not maintained regularly. One way to keep the pod casing clean is a daily fresh water rinse. Since the wash is planned to occur daily, it is estimated that if approximately 95% of the pod is washed each day, sea life will not be able to grow.

Quality Function Deployment

A list of customer/sponsor requirements was created for the QFD. This list contains the goals and expectations from our sponsor. Each requirement has a weight of importance. The ones that absolutely need to be met were marked with an '*'. Other requirements were given a number that measured its importance. For example, being able to replace the video cable got a 1 while being able to see underwater got a 7. All these values totaled to 100.

Another step was to fill in the engineering requirements that would help meet the customer requirements. Each engineering requirement value was either researched or estimated based on basic engineering knowledge. At least each engineering requirement helped solve multiple customer requirements.

The QFD can be found in Appendix A.

Gantt chart

A Gantt chart, or timeline for our project can be found in Appendix B. This chart outlines each task that must be done to complete this project, and visually indicates the due dates and dependence of each task.

Design Development

There are three main components of the Pier Portal that were worked on over the quarter: the track cleaning system, the motor, and the pod/deck electronics. These components are the most crucial to the entire system, so they were put as a top priority. Designing these parts also will take the most time to troubleshoot, so having them designed first will give the most time to fix any unseen errors. There are also a few tests that need to be done: pressure test, drag/wheel test, and sink test. These tests are to see if the current system is suitable for real use. However, these tests would give the most accurate data if done on the track. Currently, the track has a lot of barnacle and sea life on it so it is impossible to test it on the track. These tests will be done as soon as the track is cleaned, which will have to be pushed to next quarter due to scheduling conflicts.

Track Cleaning System

There are three ways to prevent barnacles and other sea life from growing on the I-beam track (as mentioned previously): UV light, vibrations, and physical removal. However, not all three methods will work in this specific system.

The UV light method is a quick and effective method since it can easily cover a lot of surfaces of the track and is easy to implement. However, the big downside is the installed track is UV light sensitive. If this method is used, the UV lights will start damaging the track. Since the cart is run up and down daily, the track will receive too much damage, and the lifetime of this system will be shortened dramatically.

There are various ways to implement the vibration method such as physically vibrating the track or even inducing local vibrations through sound. Many studies have been done to see if vibration is a good way to inhibit barnacle growth, the most notable one by P. V. Murphy and M. Latour of Lectret S. A. of Switzerland the University of Science and Technology of Languedoc, France. Their study has shown that most fouling species dislike a low range of high frequencies. This would be easy to implement into the system-- a constant frequency would be applied wherever the cart is. However, even though the vibrations will prevent some sea life, there is a chance that it will not prevent all forms of sea life. For example, the same frequency that bothers a starfish may be quite enjoyable to a barnacle. There are also other problems that come with vibrations such as causing the camera to shake, or inducing too much movement in the system, which would be bad for the FRP I-beam. If the beam is vibrated too much, it may cause damage in the form of microfractures and decrease the projected lifetime. A sound system or any type of vibrations might also interfere with the hydrophone. Overall, this method will not be used because it is not 100%

Figure 17. The chosen brush to use in the track cleaning prototype. Image from Home Depot website.

reliable.

The final method of physical removal is the safest and simplest design. Even though it will be a bit harder to implement, it is the most reliable out of all three. To physically remove any small growth, the track needs to be brushed/scrubbed on a daily basis. There are many different kinds of brushes and sponges that can be used. However, not all are suitable for this system. For example, some brushes have harder bristles that will scratch and damage the track. To eliminate options, a mold test was done by soaking the sponges and brushes in clean water and let out to dry. None of them had any mold after a week. However, in the end a fairly soft, blue brush (Figure 17) was chosen based on its ability to cover a large surface and that it is easy to attach to the cart.

The brushes will be mounted on the bottom of the cart. This will allow the cleaning system to reach the entire length of the track. Placing the brushes on the bottom of the cart will also give the cart a bumper when it approaches the sea floor.

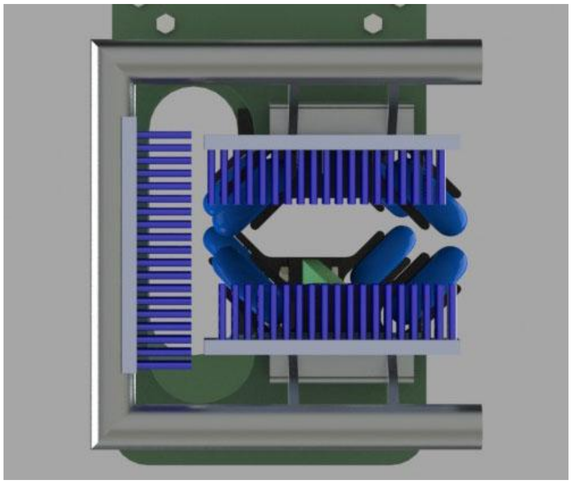


Figure 18. Bottom view of how the brushes will be attached to the U-bracket.

The prototype design for the track cleaning system can be seen in Figure 18. Multiple brushes will be attached to a U-bracket which will be attached to the bottom of the cart. This prototype bracket will be made out of aluminum, because it is easier to work with and cheaper. For the final project, changing from aluminum to stainless steel will be considered to increase lifespan and durability. The brushes will be held to the bracket with nuts and bolts that go through the solid backing of the brush. The bracket will be attached to the cart with long bolts that will go through already existing holes on the cart (Figure 19). This will take out the need for drilling new holes into the cart and possibly damaging the FRP.

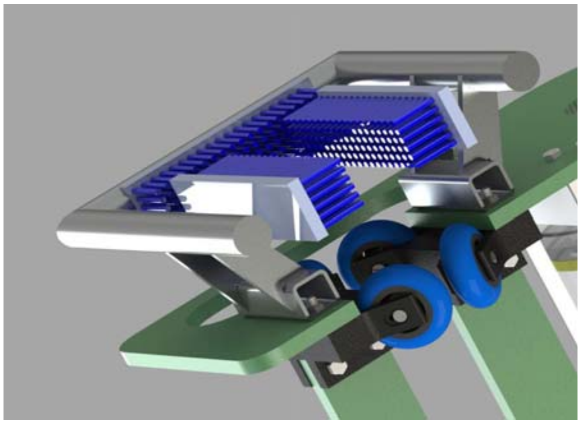


Figure 19. Side view of how the U-bracket will be attached to the cart.

The prototype is designed to scrub most of the surface of the track. The only side that it will not reach is the mounting side. However, the brushes will touch all other surfaces, even the corners inside the I-beam. For initial cleaning (without the motor) the cart will need to be hand-fed down the track and then pulled back up. This will only need to be done daily, just like the final project.

AC Motor

Our motor must be able to lift 150 lbs at a rate of 1 ft/s. This specification takes into account our predictions for extra force due to large waves and debris such as kelp that may become snagged on the cart. Based on our calculations (see Appendix C) a 1 horsepower motor will be able to provide sufficient power and give the system a factor of safety of 1.2.

After getting in contact with Yaskawa America, Inc., a representative said that they are interested in possibly donating a motor. Their only concern was that their motor is not suited for the Pier Portal project conditions and the outdoor environment. If Yaskawa donates a motor, it needs to be safe from ocean environmental hazards such as ocean spray, humidity, and sunlight/heat. This motor donation would be very beneficial not only because of the low cost but also because of their high quality motors. With their motor, we would be able to control and move the cart with great precision. Another benefit noted by a representative is that Yaskawa would also donate a motor driver along with the motor.

In the event that we do not receive a donation from Yaskawa America, Inc., the next best option is a motor that runs on 240 volt, three phase alternating current. These motors are more efficient, provide better starting torque, and are more precise than DC motors. If we are unable to get this type of electricity at the pier, we will select a single phase motor that runs on standard 120 VAC.

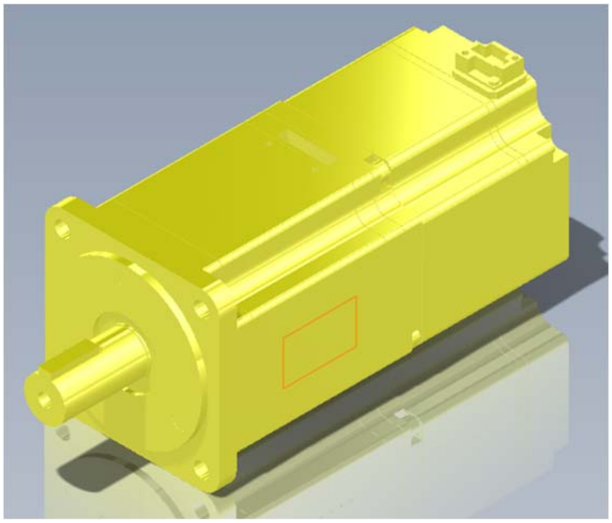


Figure 20. Yaskawa Motor CAD Drawing.

The motor needs to be robust enough to hold up in the damp marine environment of the pier. Three types of AC motor enclosures are open drip proof (ODP), totally enclosed fan-cooled (TEFC), and totally enclosed non ventilated (TENV). ODP motors have vents that allow air to be circulated inside the motor for cooling. These types of motors are best for use in clean, dry, and indoor environments. TEFC and TENV motors offer more protection because they are sealed from the outside air but TENV motors provide less power because they are not fan cooled. For this application, a TEFC motor will be best because it will offer protection to the moist air while still providing enough power.

Gear Reduction

If we receive a servo motor from Yaskawa we will need to use a gear reducer to get the correct speed and torque for our winch drum. Assuming a maximum speed of 1 ft./s for our pod cart we will need a total gear reduction of around 129 to 1.

The current winch has a two stage reduction implemented into it. The first stage provides a gear reduction of 12.9:1. It is made up of a large sprocket attached directly to the winch drum and heavy duty chain that connects it to the smaller sprocket. The second stage of the gear reduction is made out of bicycle sprockets and chain. In order to get the large gear reduction we need for our servo motor we will be combining the current first stage chain/sprocket reduction with a gear reduction drive. The gear drive will need to have a gear reduction of 10:1 which will combine with the existing first stage gear reduction (12.9:1) to provide a total gear reduction of 129:1.

Table 5. Required Gear Reduction.

Drum Diam. (in)	Max speed (ft/s)	Max Cable Force (lbf)	Nom. Motor Speed (rpm)	Required Power (W)	Required gear reduction
20	1	150	1500	260	129

Variable Frequency Drive

If we use an AC motor, we will be implementing a variable frequency drive (VFD) like the one seen in Figure 21 to control it. Variable frequency drives control an AC motor's speed by changing the frequency of the current being delivered to the motor.

The variable frequency drive can be used for a single phase or three phase motor. Some VFDs are specifically rated for single phase or three phase input, but according to the buying guide, "*the rule of thumb for sizing the single phase input on a three-phase drive is to use a VFD rated for 2 times the FLA (*Full Load Amps) *of the motor."*

There are two nonstandard, major requirements that our VFD will need to meet. One of these requirements is that the VFD will need to have linear voltage following capabilities. A voltage follower will allow us to control the motor with our deck electronics control system. Essentially, the microcontroller at the heart of our deck electronics will be able to change the speed of the motor by sending different voltages to the VFD. Many of the VFDs that meet this requirement can also be current controlled in the same manner.

Figure 21. Variable frequency drive example, taken from McMaster-Carr.

The second requirement is that the VFD be specified for variable torque applications. According to the buying guide on vfds.com, "variable torque operation allows the motor to apply only the torque needed resulting in reduced energy consumption." In our case, there will be a big difference in necessary torque when the pod cart is in and out of the water. In the water, the buoyancy force of the pod will help alleviate the weight that the motor must lift. However, in the air, the motor will feel the full weight of

the cart. Since our project will have such a large difference in necessary torque, this specification will also help us stay under the current rating.
We will also need to be weary of overvoltage, overcurrent, and thermal overload. Many VFDs come with built in protection for all of these factors. We will also be taking precautions by setting up our control system with these concerns in mind. For example, the buying guide notes that an AC motor should not be run at a speed less than 20% of its maximum speed without external cooling, otherwise the motor will overheat. When setting up our control system, we will be sure to set the minimum speed accordingly. If the user tries to slow down any more than that, we will automatically turn off the motor and let the friction from the gearing effectively hold the cart in place. Overvoltage, or running a motor at a higher voltage than it is rated for, will be accounted for by purchasing an AC motor that will work with the power options we will have at the pier. For overcurrent protection, we need to look at the National Electrical Code book (Article 430, Part C), to determine how much overcurrent protection we need for our motor. It seems that most VFDs come with overcurrent protection built in. However, there are other ways to help protect from overcurrent, such as a current sense input to the deck board proportional to the current the motor is experiencing, or a fuse.

Deck Electronics

In addition to controlling the freshwater rinse, the deck electronics will control the position of the cart along the pier. During this process, the control system will have an automatic slow-down feature and an automatic stop feature. The sea floor height generally varies a couple of feet over the year. Ideally, we will want to be able to slow the cart down before it reaches the bottom so that it doesn't smash into the sea floor at full speed. By using the encoder to track the position of the cart, we will be able to tell when we get close to the bottom and instruct the cart to lower its maximum speed. For example, we know that our sea floor is approximately 60 feet below the deck (40 feet of water, 20 feet of air). Once our encoder tells us that we are 50 feet below the deck, we will slow down the motor so that it is prepared for impact. This will prolong the life of the system.

The second system safety feature that will be included in the system is an automatic stop. If a swimmer were to decide to hang off the pod as it was being raised, or the cart became hopelessly entangled by seaweed and couldn't move, the motor could become overloaded, and something might break. In the event of such occurrences, the motor will shut off if it sees more than 150 lbs of weight resisting it.

Pod Electronics Initial Design (v1.2)

During fall quarter (2012), a small mechatronics team was subcontracted to help with the pod electronics. This team included one of the Pier Portal team members, Misha, and two other freelance mechatronics students Chris Gaul and Nate Jones. The objective of this project was to condense the existing Pier Portal's pod electronics hardware and software setup into a more sophisticated and streamlined design. This included converting the software to a real time operating system (RTOS) instead of cooperative multitasking and creating a custom printed circuit board (PCB) for the project. After ordering the first version of the custom PCB, we started working on the code for the project on an ME405 board. This project board was setup with an ATmega128 (a microcontroller that functions as the brain of the pod) and various supporting components for general project use in mechatronics classes. The main difference between this prototype board and our custom board is that our custom board utilizes an ATmega1281, which features more memory and more PWM ports necessary for the control of various components in our system.

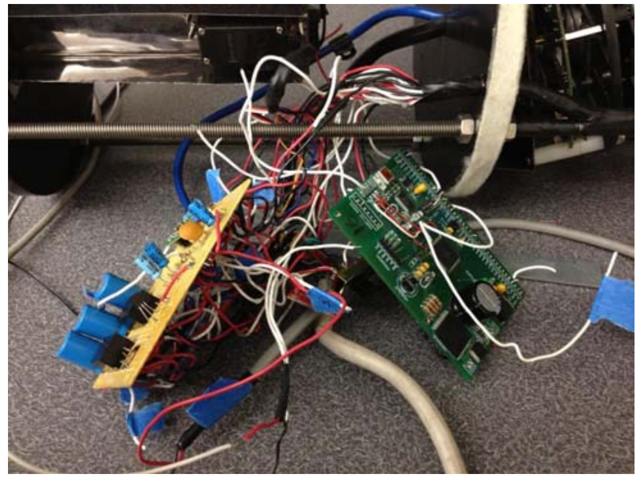


Figure 22. Pod electronics from the previous team.

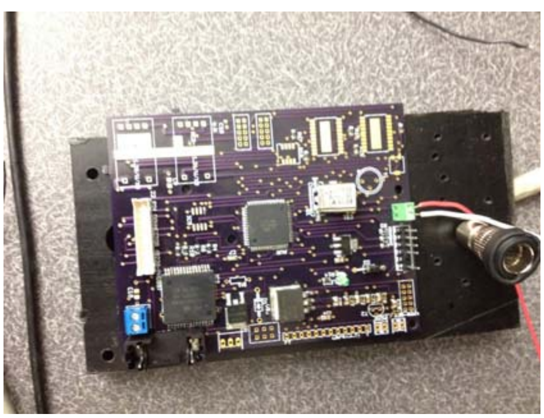


Figure 23. Pod electronics streamlined design (without connectors installed).

Here are before (Figure 22) and after (Figure 23) pictures of the previous pod setup and the newer pod setup (v1.2). Moving to a custom printed circuit board minimized the rats nest wires, messy soldered connections, and makes replacement much easier. The new design will allow pod hardware such as the fans, camera, motor, and servos to be grouped together and plugged into the new board via a few neat connectors. Furthermore, the custom PCB excludes unnecessary components such as the MiRF Radio breakout pins or FT232 chip (used for a serial port connection) and instead allows us to include hardware specifically for the Pier Portal, and eliminates the prototype-quality board. After the first version of the custom PCB was created, tested for functionality, and many lessons were learned, it was time to start creating the next version of the board.

At the conclusion of the quarter, most functionality had been put back into the software. Communication with the software was possible via a user interface, which allowed the user to control the fans, lights, read from the phototransistor (light-detection sensor), and yaw motor manually. Unfortunately, there were not enough PWM ports on the 128 to run all of the hardware, but the team made do with what was available. Some control, such as yaw motor position control and fan speed control based on variable temperature, was already in place on the pod and only needed to be tuned with the actual hardware. Most of the drivers used to run this code needed to be changed in order to successfully transfer from the prototype ME405 board with an ATtmega128 to the custom PCB with an ATmega1281.

In terms of system safety, a leak detection circuit will still be included in the pod. In addition to that, a temperature & humidity sensor will be installed to make sure that the electronics are not overheating. The fans included in the pod will help distribute heat away from the LEDs and spread evenly throughout the pod so that the ocean water surrounding the pod can cool the system more efficiently. In the event that something is wrong and the electronics exceed our maximum specified temperature, 72°C (or approximately 162°F), the electronics will automatically shut off, and the pod will be brought back to the surface for maintenance.

Testing

Pressure Test

Unfortunately, when the previous senior project team pressure tested the pod, it leaked. They have since resealed the pod, but it still needed to be tested. The pod is now considered sealed and does not need to be leak tested any further. Before taking the pod a couple of miles out to sea in a boat to pressure test the pod at a depth of 100 feet (or approximately 45psi), we took advantage of the smaller bodies of water we had available to us.

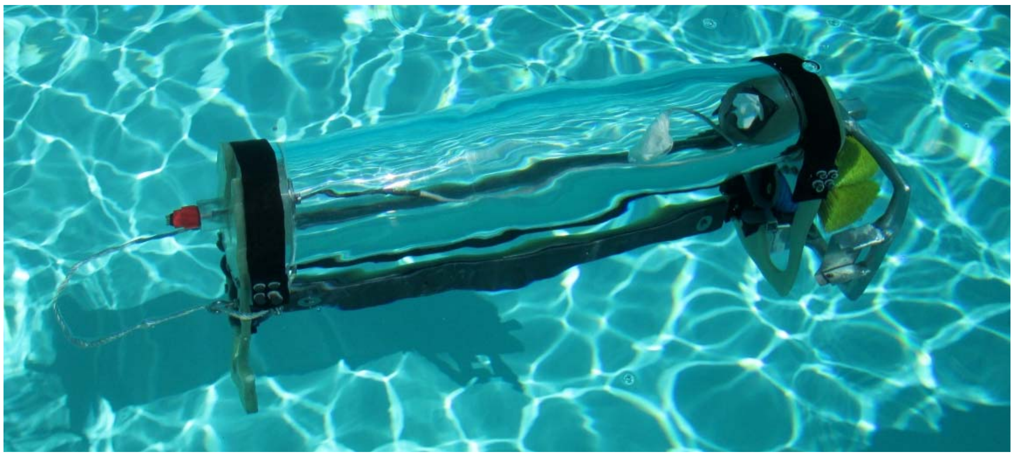


Figure 24. Preliminary leak test in a pool.

Over the break a preliminary leak test was conducted. The pod was sealed and submerged in a 7ft pool for 15minutes. No leaks occurred, however it was discovered that the pod is slightly buoyant, and more weight will need to be added after final assembly to achieve the desired 1ft/s sinking speed. This was a nice initial step because by using goggles, we would have been able to monitor the pod for leaks and tell where they were coming from.

After passing the preliminary test, the pod was taken out in a boat and depth tested to 70ft without leaking. The original intended depth was 100ft; however weather conditions prevented the team from venturing out further where the water was deeper. This success gives us a depth safety factor of 1.75, which is good enough for Tom to give the go-ahead.

Figure 25. A depth finder was used during the final leak test.

Track Cleaning

Since the pod cart couldn't move beneath the water line due to apparent growth, the GoPro was attached to the end of a rope and sent down to determine the state of the I-beam track. It was found that in the span of 5 months, sea life had completely overridden the track. According to Tom, the life seen in Figure 26 is easy to scrape off with a plastic scraper. However, while diving in an attempt to clean the track, it was found that the barnacle layer farther down the track is much more like a solid cement layer, which cannot be easily scraped off of the track surface. Some serious industrial strength cleaning will need to be done with the help of the Santa Barbara diving school in order to clean off the track. As soon as that takes place, the scrubber track system should be in place so that the sea life growth doesn't get out of hand again.

Figure 26. Growth on the I-beam track after six months.

The previous team had hoped to ward off sea stars by installing bird spikes along each beam bracket. However, this has proved ineffective, as the sea stars simply "float" past them. Future teams will need to find some way to prevent sea stars from obstructing the pod cart's path.

Drag/Wheel Test

This test is to see how easily the cart can move up and down the track. When in the water, the cart will feel a drag force when it moves. Although the wheels have been removed in our new design, the brushes still cause a lot of friction and may impede cart movements. These external forces will make the motor work harder to pull the cart upwards, or prevent it from sinking downwards. If there is a significant amount of resistance, we will change the brushes so that the bristles are longer and less rigid, or change the brush mount design so that there is more clearance between the I-beam and brush mounts. With the prototype cleaning system, this distance is easily modified. This

test will need to be repeated once the track is cleaned and the pod is allowed to move up and down the full track with different brushes.

Electronics & Code Testing

The pod electronics board will be tested system by system. By adding each subsystem of components one at a time and supplying power, we can quickly determine if there are any shorts or issues with power on the board. During this “smoke testing” it will be important to monitor how much current the board and each individual subsystem is drawing, as there are limitations to how much current various components of the board can handle. A table depicting the amperage limitations can be found in the Pod Electronics section in Table 8 and Table 9. In addition, higher power components such as the motor and motor driver, will be added first, so that if there are any issues, minimal collateral damage will be done. If we add all the smaller, low risk components first and then add a larger, high risk component that becomes damaged, the other low risk components may be damaged too. If we add the high risk components first the chances of collateral damage are reduced.

Code will be consistently tested during development once all the electronics are mounted to the board. Again, the code will be built up on a system by system basis. If multiple parts of the code are being edited and something “breaks”, it would be much more difficult to hunt down the issue.

Interference Testing

Upon lowering the pod on the I-beam track, it was found that some clearance issues had come into play. A track bracket was interfering with the pod cart, but it was difficult to discern where and why. In order to get a better look, the team affixed a GoPro to the top of the cart and sent it down while recording. It was found that the winch frame and I-beam track were misaligned (Figure 27). This misalignment caused the cart to be pulled up at a slight angle, which created the interference with the track bracket. Video was taken of the pod cart in the misaligned position, and again with the misalignment corrected by a Pawesome member. With the corrections, the cart was able to successfully move past the bracket. When the winch frame is permanently affixed to the pier deck, care must be taken to align the frame and the track, or further interferences and damage may occur.

Figure 27. Super scientific leak test setup.

Leak Detection Circuit Testing

Once hooked up on the pod board, the leak detection circuit functionality was tested. Water was distributed on a glass plate and the lead wires were placed a distance apart until a leak was no longer detected (Figure 28). It was found that for 16in lead wires, the circuit could detect leaks reliably up to 8.5in apart.

Figure 28. Leak detection test setup.

Sink Test

Pulling the cart up the track at different speeds presents no issues because the winch will neatly coil the cord in the winch drum. However, when the cart is lowered into the ocean, there are many more factors we must consider. Due to the buoyancy force of the pod (approximately 30 lbs, as calculated in Appendix C), it is possible that the cart could sink slower than the motor can safely de-spool. If the motor de-spools the cable faster than our cart sinks, the cable will become unseated from our sheave, and all operations will be forced to stop until the system is fixed. In addition, such a situation could damage our cable. Measures have been taken to prevent this from happening, such as the spring loaded switch, which detects slack in the cable, installed on the winch frame. However, testing still needs to be done to make sure that the cart is properly weighted and will sink faster than the maximum downward travel speed (1ft/s). Once the cart track is free of debris and encrusting life forms, we will perform a sink test to determine the maximum downward speed our pod will be able to travel.

In order to do this, we will lower the pod on the I-beam with a rope by hand. When the pod is submerged, a team member will hold the rope attached to the pod, and walk at a constant speed toward the pod and end of the deck so that the walking speed is the effective sinking speed of the pod. The approximate travel speed of the pod and team member will be measured by dividing the distance walked by the time it takes to walk it. The distance walked will be constant to make walking speed adjustment easier. When slack develops in the rope, we know the travel speed of the team member is exceeding the sinking speed of the pod. If this occurs before the 1 ft/s limit, we will add more weight to the pod until we have reached a sinking speed of 2 ft/s. This way, we will have a factor of

safety of 2. This safety factor will also help in the event of a wave trying to lift the pod up and unseat the cable. While adding weights it is important to remember not to exceed our 150lbf weight limit.

Final Design Development

There are five main components that are part of the current final design: a track cleaning system, a bracket to secure the track, the motor and motor driver, the pod/deck electronics, and the web interface. The final product will also be aided by a CPE student (Brian Markwart) and an EE student (Andy Lam). They will be in charge of the web interface and direct camera communication. For more specific information on their contributions to the project, view their individual senior project reports or contact Professor Benson.

Track Cleaning System

The purpose of the cleaning system is to keep the track free of algae and barnacles. The current track cleaning system is a prototype made out of aluminum that will be used to test different brushes for the final design. Aluminum was used for the prototype design because it is inexpensive and easy to fabricate. Unless there are any problems with this prototype, the final design will be the same except for small improvements based on which brushes work the best. It should be noted that the final design will most likely be made out stainless steel to provide better corrosion protection.

Figure 29. Track Cleaning Prototype.

The track cleaning system is designed to attach to the bottom of the cart with existing bolts so that no additional modification to the FRP cart is needed. The aluminum frame is TIG welded together except for the plates that hold the yellow brushes in place. These plates attach to the frame with stainless steel bolts which allows us to remove them when we need to switch the brushes. The track cleaning system holds seven brushes and will clean all sides of the I-beam, except for the side that attaches to the brackets holding the I-beam to the pier.

I-Beam Top Bracket

Currently, the top of the I-beam is secured to the pier with a rope and a temporary steel support made out of a metal clamping claw (Figure 30). A more permanent solution is needed to hold the I-beam in place while allowing the cart to move up and down. Our solution is to make a bracket that uses a setscrew design to clamp to the pier pylon cap. This type of design was chosen to eliminate the need to drill through the 1.5” thick pier pylon cap. This is beneficial because the location of the pier cap would make it difficult

Figure 30. Current I-Beam Support.

to drill through. Another benefit of this design is the pylon cap will be less susceptible to rust because we will not have to drill through the protective coating.

The clamping bolts will be heavy hex bolts and provide 4000 lbs. of clamping force when torqued to 60 ft.-lbs. These bolts will make direct contact with the steel in the pier pylon top plate which could cause the pier pylon to corrode faster. To illuminate an electrochemical potential between the bracket and the pier pylon cap we have decided to make the bracket out of the same material as the pier pylon; general low-carbon steel.

The nuts will be welded to the bottom of the clamp arm so that the welds do not take the load when the clamping bolts are tightened. Once the clamping bolts have been torqued down to 60 ft.-lbs., the locking nut will be tightened to lock the bolts in place ensuring they don't loosen over time.

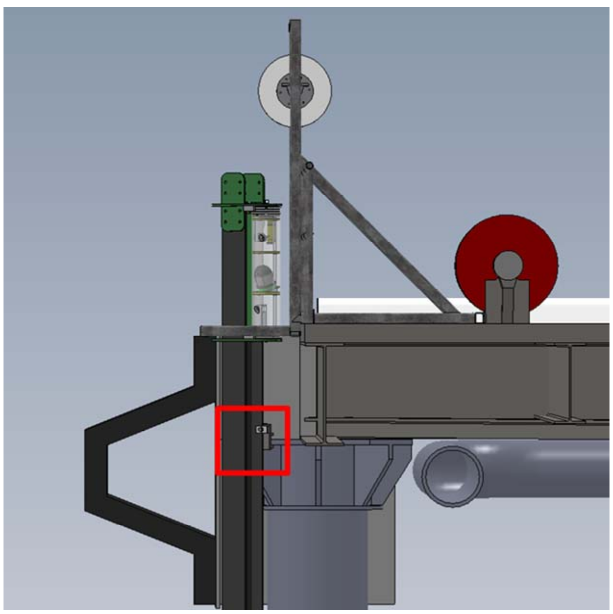


Figure 32. Model of Pier Corner with Bracket Design.

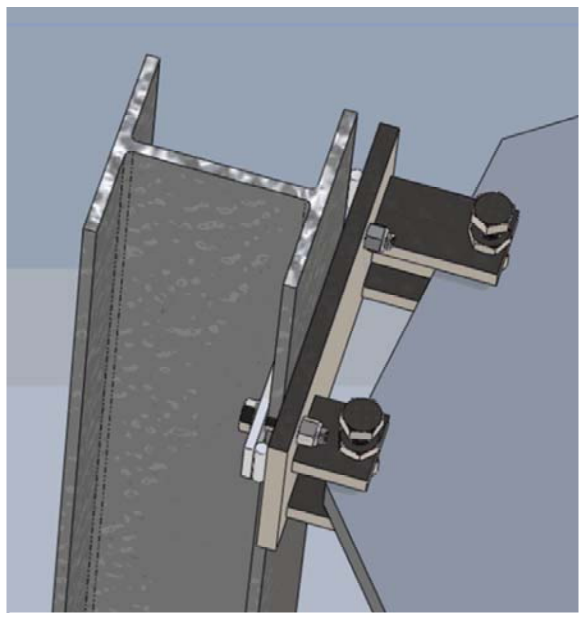


Figure 32. Close up of I-Beam Bracket.

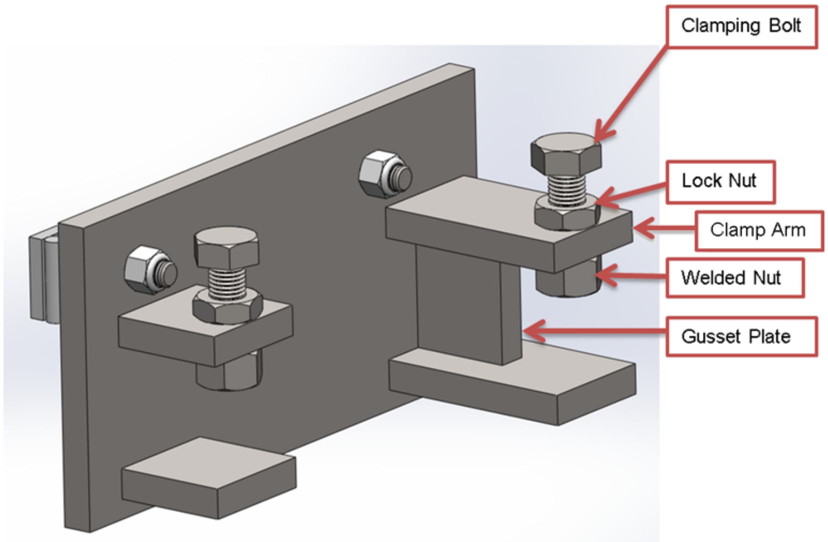


Figure 33. Labeling parts of the clamp for easier reference.

We are considering two different options for the type of coatings that will be used to protect the bracket from corrosion. Galvanizing the bracket would provide the best protection but is also more expensive and we may not have enough funds after we purchase other components for this project. The second option is to paint the bracket. First a zinc based primer would be used to help protect it from corrosion. Next epoxy based paint would be applied on top of the primer to seal it and provide extra durability.

As shown in the solid works studies (Figure 34) the largest deflection of 0.4 mm occurs at the longer top clamping arm. A gusset support was added between the top and bottom of the longer clamping arms to reduce the deflection and stress. As shown in the Von Mises Study the bracket has a yield factor of safety of about 2.

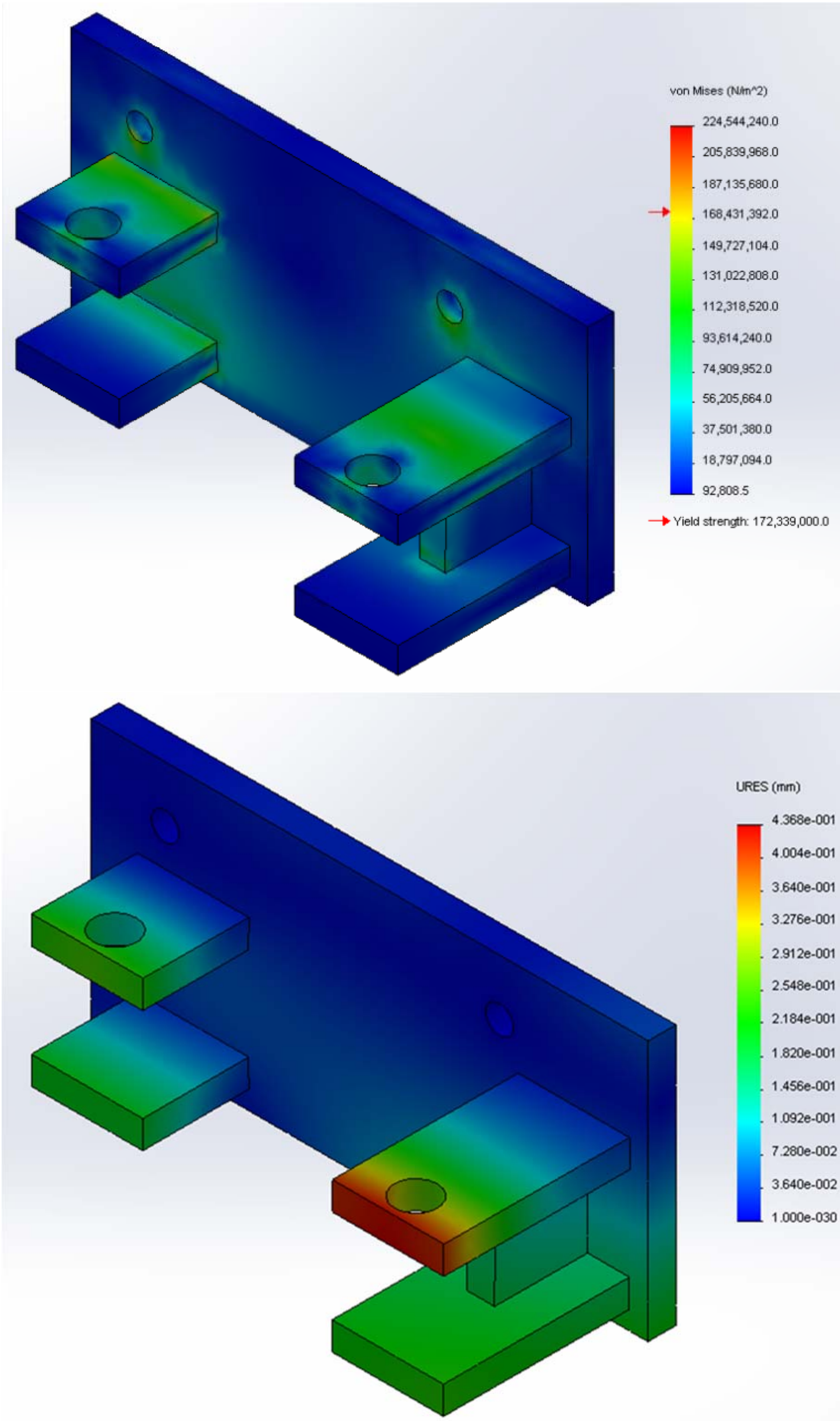


Figure 34. Stress and displacement analysis done on the bracket in SolidWorks. The top shows the Von Mises Study and the bottom shows the Displacement Study.

A prototype was made of the I-beam top bracket out of wood to test the fit of the design. This was necessary because the location of the pier pylon top is out of reach making it hard to take the necessary measurements. Additionaly, testing was required to verify that the I-beam would be able to bend away from the pier to make the necessary gap in order for the bracket to slip into place. A wood 2 x 4 was used to wedge the I-beam over and the bracket was lowered into place. The prototype fit well giving the green light for the final build.

Figure 35. Test fit of I-beam top bracket prototype.

Servo Motor

As mentioned previously, a motor donation from Yaskawa America Inc. would be ideal. This would allow us to save money from spending on a motor, variable frequency drive, and any other accessories. However, such funds will need to be used to buy a safety enclosure for the motor. It would also give us a high quality motor and motor driver that will allow us to control the cart with great accuracy.

After meeting with a few representatives, Eric Kelley, Joshua Crayton, and Minh Tran, from Yaskawa, the possibility for a motor donation is very likely. Their concerns of the motor not meeting the project conditions and outdoor environment were reduced when they found out that the cart weight is not too high and that the motor will be protected in a NEMA4X safety enclosure (see below).

They provided us with a program called SigmaSize that will determine which of their motors are suitable for our project. SigmaSize takes in many inputs including motion profiles, gear reductions, and any known loads, moments, and friction forces. It uses these inputs to size what kind of motor will do the job. Our motor must be able to lift at least 150 lbs. at a maximum rate of 1 ft/s. This specification takes into account our predictions for extra force due to large waves and debris such as kelp that may become snagged on the

cart. To find what size motor we need, the Yaskawa SigmaSize motor sizing software was used and the results were verified with hand calculations (see Appendix C). For the sizing calculations we chose a gear reduction efficiency of 68%. This was calculated using the planetary gear reduction drive efficiency of 85%, and a factor of safety of 1.25. With our specifications and the options available, we decided to ask Yaskawa for a SGMGV-05 motor. This motor is rated at 500 W with an application speed of 1479 rpm.

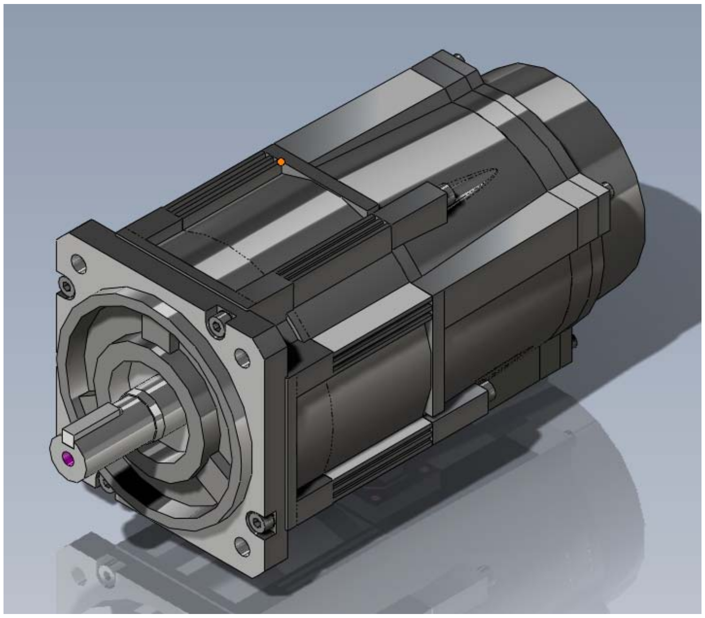


Figure 36. SolidWorks model of an SGMGV-05 motor with a brake and oil seal.

An SGMGV-05 motor was picked out because it is not too big of a motor and should be able to handle any unforeseen loads such as seaweed. See Appendix E for a table of the inputs and sizing results, motion profile, and speed/torque curves provided by SigmaSize for the SGMGV-05 motor.

A request for the SGMGV-05 motor, motor driver, and any required cables was sent a week after the meeting with the Yaskawa representatives. If the request goes through, the motor and driver should be delivered no later than the beginning of April.

Gear Reduction

We will use a Shimpo Able VRL-120-20-K5-19EC1600 planetary gear drive with a 20:1 gear reduction. Other reduction drives considered that were able to mount directly to our Yaskawa servo motor were harmonic gear drives and worm gear drives. The reasons a harmonic gear drive was not selected are higher cost and additional bearings would be needed to support the shafts. Worm gear drives and planetary gear drives have an outer frame with bearings on the input and output shafts that will be able to support the bending load. A planetary gear drive was chosen over a worm gear drive because it will provide better efficiency. This gear reducer came pre-assembled with a motor flange that allowed

it to be bolted directly to the servo motor. Modification to the existing sprocket/chain reduction was required because of the larger output shaft diameter of the gear reducer. An Ansi 40, 16-tooth sprocket was the smallest sprocket size that would fit on the output shaft. This larger sprocket caused the sprocket/chain reduction to drop from 12.9:1 to 7:1. In order to compensate for this, a 20:1 planetary drive was selected to bring the total reduction to 140:1.

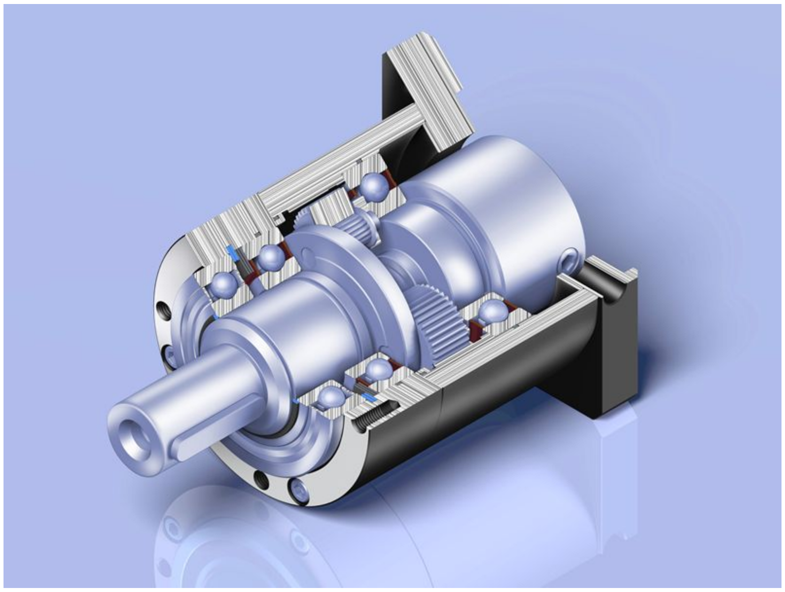


Figure 37. Planetary Gear Reducer Section View from www.shimpodrives.com/able.html.

The Shimpo reduction drive bolts onto the winch using a 3/8" thick aluminum bracket. This bracket was made to eliminate the need to machine the metal directly on the winch. Currently, the two sprockets do not line up perfectly and may need additional modification upon testing the system. One option is to remove the manual-cranking mechanism and use spacers to move the larger sprocket (attached directly to the winch drum) outwards so that it lines up with the smaller sprocket (attached to the gear reducer). This option would eliminate the option to self-crank the winch; however the self-cranking is currently ineffective anyways due to the brake that is attached to the servo motor.

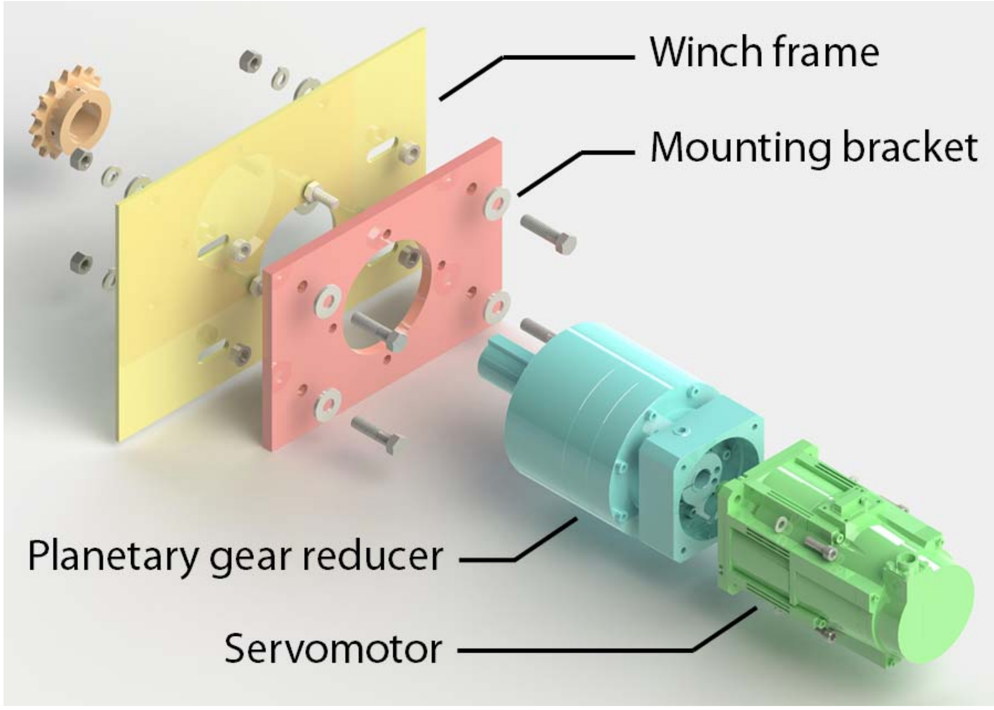


Figure 38. SolidWorks assembly of how the servmotor, gear reduction drive, mounting bracket, and winch will come together.

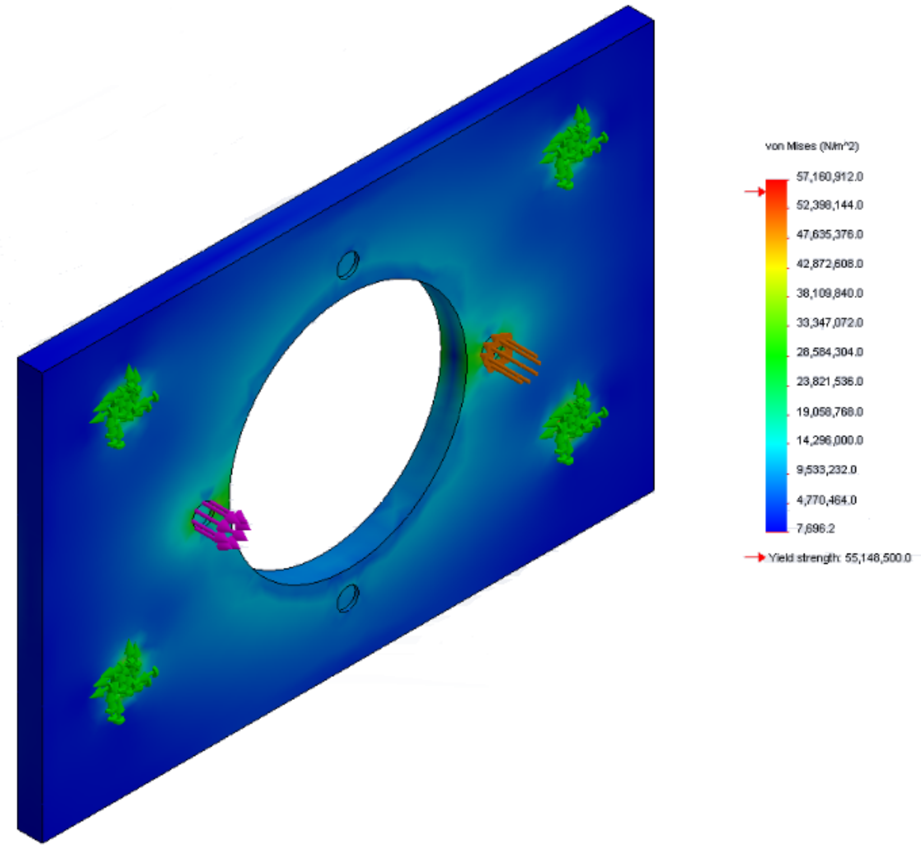


Figure 39. Von Mesis analysis done on the mounting bracket holding the gear reduction drive in SolidWorks.

Motor Driver

Yaskawa is also willing to donate a motor driver. They suggested an MP2600iec servopack because it is compatible with their Sigma V motors. An initial worry is that the driver will need to be reprogrammed in order to fully operate the Pier Portal. However, the driver has what Yaskawa calls "point-to-point" programming, meaning that the driver can tell the servo motor exactly how many degrees to rotate. This makes it really easy for the motor driver to operate the camera pod's position: rotary motion of the motor will need to be translated into vertical motion of the camera pod. In other words, a certain amount of revolutions of the motor shaft will correspond to a fixed amount of vertical distance the camera pod will move.

Figure 40. MP2600iec Servopack taken from Yaskawa's user manual.

When the motor driver was delivered, it was discovered that a molded-case circuit breaker, noise filter, and magnetic contactor are needed to power the driver. Using Yaskawa's servopack catalog, part numbers and specifications were found for the missing electronics. These catalog pages and the datasheets of the electronic components can be found in Appendix F.

The circuit breaker needs to have a current capacity of 3.0 A and an inrush current of 33 A. Using these specifications, an SA53RCUL-03 circuit breaker was selected from Fuji Electric.

The magnetic contactor model number is given in the catalog: SC-03. However, the number of auxiliary contacts and coil voltage is not specified. Based on the motor controller and 200 VAC power supply, the rest of the specifications were found. A 4NC0A0B10 magnetic contactor was selected from Fuji Electric. Both the circuit breaker and magnetic contactor were purchased from Online Electronics, a distributer for Fuji Electric. Two contactors were purchased just in case the system requires two of them.

The noise filter part number is given in the catalog: FN258L-7/07. This noise filter (manufactured by Schaffner) was purchased from Mouser Electronics.

Since no electrical cables are given with these components, a variety of twisted-pair cables were purchased from McMaster-Carr: AWG 10, 14, and 16. These cables were specified by Yaskawa's catalog pages and the components' datasheets.

All components and cables were received and given to Tom, who put in a work order for electricians to install these components at the pier. For further work on this project, these electrical components should be tested to see if they can power the servopack and servo motor. If everything goes properly, tests can be done to check if the motor is powerful enough to control the system.

The servo motor will be connected to the motor with long cables (provided by Yaskawa). These long cables will run from the service room to the pier corner, which is approximately 60 feet apart. In order to eliminate as much electrical noise as possible, conduits should be installed in the future. These conduits will surround each cable separately.

MotionWorks IEC 2 Express

Yaskawa's servopacks use their own program called MotionWorks IEC for communication. The express version of the program was given with the Yaskawa MP2600iec Servopack. Based on the tutorials and user guide videos, it seems that a command can be sent from a computer running MotionWorks to the servopack (via an Ethernet cable). The servopack will interpret the command and control the servo motor. Videos show that simple commands, such quarter rotations, can be sent to the servopack and then servo motor.

One great feature of this program is the ability to set minimum and maximum limits to various parameters, such as torque and angular velocity. This will help prevent the motor from applying too much torque and damaging the system.

For future work (assuming the servopack can be powered), MotionWorks IEC needs to be configured to communicate with the servopack. In terms of hardware, all of it is present and, hopefully, working properly. The rest of the work will be with the software to see if commands sent over the Internet can actually make the servo motor rotate.

Motor Testing

Even though this motor can be assumed to be accurate and reliable, a few tests to check its position and speed control cannot hurt. To test the position control, we will command the motor to rotate a specified amount and then check the accuracy of the movement. Another test for position control is to rotate the motor shaft a large amount at a high speed and then check if the movement is still accurate. To test the speed control of the motor, a tachometer will be used to see if the motor can speed at a specified constant speed.

These preliminary tests, however, do not test the motor under the project specifications and loads. The final test for the motor would be to see if it can actually operates as expected. This test will have to be at the pier with as much of the final system set up, including the gear reductions, the cart with weights, and brushes.

Unfortunately, this test can only happen after most of the project is completed, including the track being cleaned and clamped. If by the end of April and the project is not as near completion as expected, we will have to come up with a pseudo-test that will simulate the final project as close as possible.

Safety Enclosure

In order for Yaskawa to donate a Sigma V motor, the motor and driver needs to be completely secure. It was suggested that a NEMA4X enclosure be used to secure the system. With a NEMA4X rating, the motor and driver will be protected against corrosion. With a quick online search, a non-metallic enclosure with a size of 12 x 10 x 6 inches was found. Both components will fit inside this enclosure. However, a thermal analysis showed that a bigger enclosure will be needed to prevent the inside from heating up. In order to keep the system cool, the enclosure will need to be big enough for air to circulate within. And the enclosure should be made of aluminum due to its low thermal resistance. This will allow a majority of the heat to dissipate into the cool surroundings.

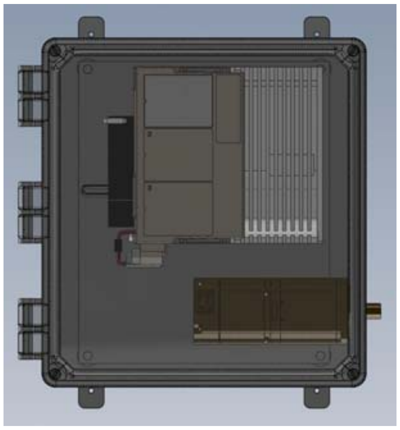


Figure 41. Top view of initial safety enclosure with motor and motor driver.

One issue of using a NEMA4X enclosure is the fact that the motor shaft will need to protrude out of the enclosure. A hole will need to be made in the enclosure to let the motor shaft stick out and connect to the gear reduction. Making a hole in the enclosure will defeat the purpose of the NEMA4X rating. In order to solve this problem, a sealed bearing will be used to surround the shaft as it protrudes out of the enclosure.

The first NEMA4X enclosure being considered is an aluminum enclosure with a size of 20 x 16 x 8 inches. This enclosure is made by NEMA Enclosures. An estimated cost for this specific enclosure is around $500. This is quite expensive with respect to the budget. However, it is still cheaper than buying a $1000 motor (without a driver). If buying a NEMA4X enclosure will ensure getting both a motor and driver donated, then it will be well worth it to buy a large enclosure.

Figure 42. Example of an aluminum NEMA4X safety enclosure. Taken from http://www.nemaenclosures.com.

However, after meeting with Yaskawa, they would prefer that the driver be separated from the motor and placed indoors. With the new system layout (where the motor and motor driver will be about 60 feet apart), the NEMA4X enclosure will only contain the motor and gear reducer. The motor driver will be indoors so it does not require extra protection. With only one electrical component inside the enclosure, there will be much less heat generated. That means that the enclosure can be sized down a bit from the previous design.

A basic heat calculation was done to see if the motor will generate too much heat for an aluminum enclosure with a size

of 16 x 12 x 8 inches. In this calculation, the system was simplified to a pure conduction problem with the motor operating at 50% efficiency. The highest outside temperature was assumed to be 100 °F (or 37.8 °C), and the maximum allowable inside temperature was assumed to be 72 °C. However, this initial calculation showed that approximately only 20 W of heat would transfer through the enclosure walls. This means the inside of the enclosure would heat up because the motor would be generating approximately 225 W, which is much more than the heat dissipating to the outside environment.

A second calculation was done with different numbers, including new temperatures and a bigger enclosure. According to the servo motor user manual, the maximum allowable temperature is actually 40 °C. In order to have significant heat transfer through the enclosure, the highest outside temperature was estimated to be 30 °C. The new dimensions for the enclosure were 36 x 30 x 16 inches. But these new numbers still gave a disappointing result: approximately only 40 W of the 225 W generated will dissipate through the walls.

However, these calculations (found in Appendix C) made a big assumption that the motor will be a simple heat source in the center of the enclosure and that no heat will dissipate through the top and bottom. Another assumption that may be incorrect is the efficiency of the motor. Yaskawa claims that their motors have very high efficiency, approximately 90%. With this high efficiency, the motor will only generate 45 W instead of 225 W.

Based on these calculations, an enclosure with the large dimensions of 36 x 30 x 16 inches will still likely heat up. This concludes that additional help, possibly in the form of small fans, will be needed to dissipate all the heat generated. With the intent of adding help, a 24 x 24 x 12 inches safety enclosure was purchased and received.

As mentioned in the final design development, the enclosure will still need to be modified to enclose the motor and gear reducer. A hole needs to be drilled out on the side of the enclosure for the motor shaft to come out. A sealed bearing will still be used to surround the shaft. The motor and gear reducer will be securely attached to the winch frame, which will be located right beside the enclosure. Because these two components are secured to the winch frame, fastening the motor to the bottom of the enclosure may not be necessary. However, if this additional security is desired, more holes will be made on the bottom of the enclosure. These holes will be used to securely mount the motor to the enclosure. Bolts will go through these holes and connect straight to the motor.

Pod Electronics Final Design (v2.6)

The pod board provides support for the electronics inside the pod. The contents of the pod have been outlined in the existing project section. In addition to those components, we have added a temperature and humidity sensor so that conditions inside the pod may be monitored. The main functions of the pod board are outlined below.

Pod Board Functions:

Yaw Motor Control (look left and right)
LED Motor Control (tilt lights up and down)
Fan Control (automatic or manual)
LED Brightness Control (auto or manual)
Leak Detection

In addition, the pod board routes the camera connections to the top of the pier, can switch between RS232 or RS485 communication[1], and utilizes a phototransistor for automatic brightness adjustment.

A complete schematic for the custom PCB, pin definitions for the ATmega1281, a bill of materials (BOM), and list of power requirements and ratings for various components inside the pod can be found in Appendix E. Specific part numbers and prices are listed in the BOM.

Controls

The pod is currently controllable via the internet. While controlling the pod online, the user only needs to click a button to achieve the desired effects. However, during development, the pod can be accessed by connecting a USB to serial cable to an RS232 breakout board (see BOM), opening up a serial communication with the ATmega 1281 microcontroller, and typing the keys stated in Table 6 and Table 7. The controls in Table 6 are also available to the internet user through the website. The user can also view a full menu of controls by typing '?' or 'w'. Many of these functions will need to be fine-tuned once the electronics are fully installed in the pod.

Table 6. List of direct pod controls.

DIRECT POD CONTROL	FUNCTION
n	pod rotate far right (jump 180 deg)
v	pod rotate far left (jump 180 deg)
h	motor rotate right (aka rotate pod CW)
g	motor rotate left (aka rotate pod CCW)
b	motor go back to 0 position
l	switch to auto lights
4	LED brightness decrease (instant manual mode)
6	LED brightness increase (instant manual mode)
8	rotate lights up
2	rotate lights down
5	bring lights back to home position

These controls outlined in Table 7 are for development purposes only, and are not available to the public online. The encoder ticks are used for yaw motor location feedback.

[1] More about the RS232 vs the RS485 in the connector pins section.

The “pod temp” variable is a theoretical pod temperature, which can be manipulated by the user to see that the fans are working correctly in “auto” mode. In the future, the pod temperature variable will be manipulated by the program to reflect the actual pod temperature read by the temperature and humidity sensor. There is no reason for public users to manipulate the fan speed, so direct manipulation is only available during development.

Table 7. Pod controls purely for developmental purposes.

DEVELOPMENT CONTROL	FUNCTION
i	read encoder ticks
x	increase "pod temp"
z	decrease "pod temp"
p	read from phototransistor
f	switch auto/manual fans
-	fan slower manual
+	fan faster manual

Currently, in order to control the pod online, a serial to USB cable needs to be plugged into the RS232 breakout board attached to the pod board. Then a python script connects the ATmega 1281 microcontroller to the internet. The pod can be manipulated from any browser. For more detail on this process, see senior project documentation published by Andy Lam. Functionality and control have not been tested through RS485 communication. The camera is also controllable over the internet; however this can only be done with an internet explorer web browser. For more information on this, see senior project documentation published by Brian Markwart.

Power

Diagrams showing the power distribution in the pod electronics can be seen below in Figure 43 and Figure 44. First, 24V will come from the pier down the cable to the pod and power the LEDs and yaw motor. Next, the voltage will be stepped down to 12V in order to power the fans and camera. Then the power will be stepped down once more to two different 5V sources. The LM2937IMP 5V regulator is an analog voltage regulator used for the analog to digital converter. The chip’s analog to digital conversion capabilities are used to read voltage outputs from various sensors in use (such as the phototransistor, which outputs a voltage proportional to the light it senses).

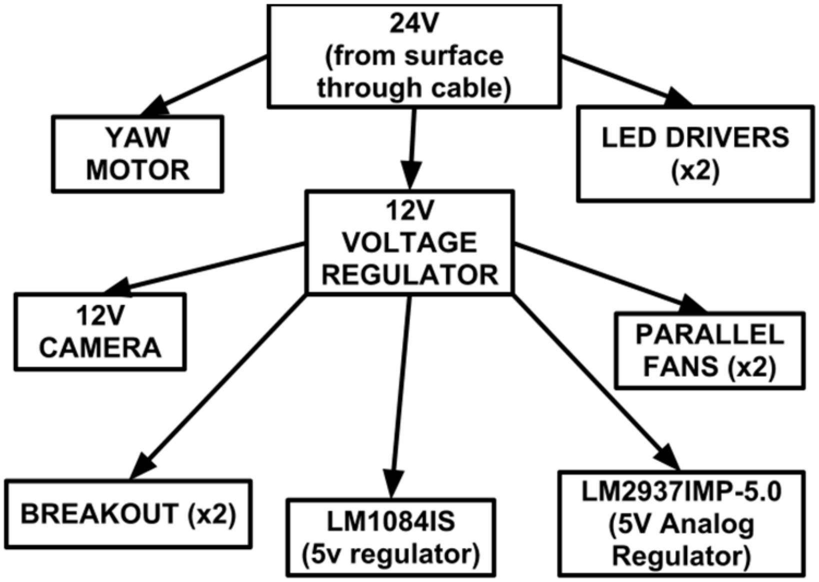


Figure 43. Diagram of power distribution within the pod.

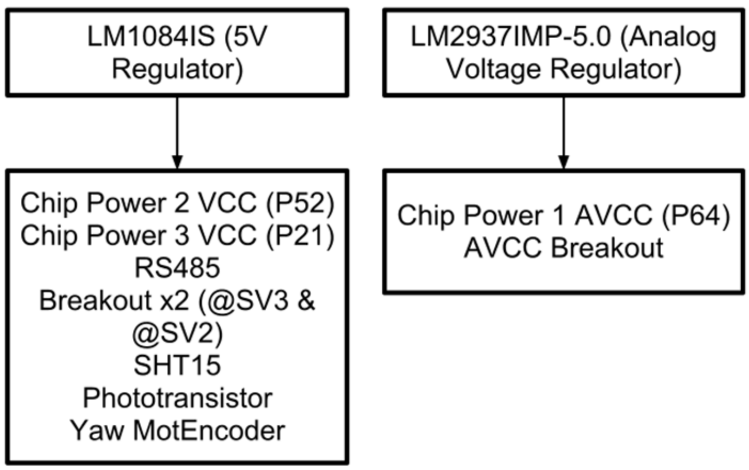


Figure 44. Components powered by the two 5V regulators.

When considering the power distribution in the pod, it is also important to note individual current limitations of the components. A complete list of pod electronic components and their power requirements and limitations can be found in Appendix E. However, important limitations are summarized below in Table 8. The standard power cable is a typical household extension cable that was already routed from the electronics closet to the winch area. The maximum of this cable was estimated as the maximum household load allowed before a breaker is tripped. The amperage limitation of the main winch cable is based on the fact that power for the cable is routed through four 16AWG lines (two for ground, two for +24V). According to an American Wire Gage table accessed through powerstream.com, the maximum power load amperage through a 16AWG wire is 3.7A. Doubling this number gives us the 7.4A limit seen below.

Table 8. Summary of amperage limitations of power components.

COMPONENT	MAXIMUM AMPERAGE	MAXIMUM AMPS DRAWN
Standard Power Cable	15A	3.08A
Winch Main Cable	7.4A	3.08A
Pod Board Connector	3A (250V)	3.08A
12V Switching FET Regulator	3A	1.38A
5V Regulator (LM1084IS)	5A	1.38A

To calculate the maximum amperage, various components were plugged in and measured directly by the power supply. However the current estimates for some components were overestimated by adding up the maximum possible amperage based on the rating listed in the datasheet or assuming a maximum. These values will need to be tested further and watched closely during development. These totals can be seen in Table 9. The estimation for the "5V Regulators (Combined)" includes the total current drawn by all 5V components attached to the pod board (see Figure 44 for a complete list).

Table 9. Summary of expected maximum current draws of various components.

COMPONENT	AMPERAGE	METHOD OF DETERMINATION
Yaw Motor	.5A	Estimation
LEDs	1.2A	Datasheet LED driver max output
Fans	.18A	Experimental
Camera	.1A	Experimental
5V Regulators (Combined)	.2A total	Estimation

In order to account for the large amperage that the pod board connector must pass, we have split the 24V power coming down the cable between two pins, so that all the current is not passing through one connector pin. These limits will leave more than enough room for our use. However, if further functionality is added to the pod, these limits should be kept in mind.

Board Layout

A schematic and board file were created using Eagle. Many part layouts were created by hand and saved in our own Pawesome Eagle library for the schematic and board based on datasheets available online. Then, gerber files were generated and sent to Oshpark (previously DorkbotPDX) for fabrication. The schematic can be found in Appendix E, and the board layout is discussed below.

The overall pod board layout can be seen in Figure 45. The components and traces on the top side of the board are red, while bottom side components, traces, and the ground plane are blue. Vias and connectors that go all the way through the board are green.

The components handling the largest amount of power are located in the lower left and right hand corners of the board (the LED drivers and yaw motor driver, respectively).

The 5V regulators are located in the upper left hand corner. The temperature and humidity sensor is located on the back side of the board in the upper right hand corner. It is important that this component is located away from the other high powered components because they will generate heat.

Unused pins on the microchip are broken out to screw terminals or vias on the board so that they can be easily accessed if needed. A majority of these breakouts are located in the upper right hand corner of the board and are labeled.

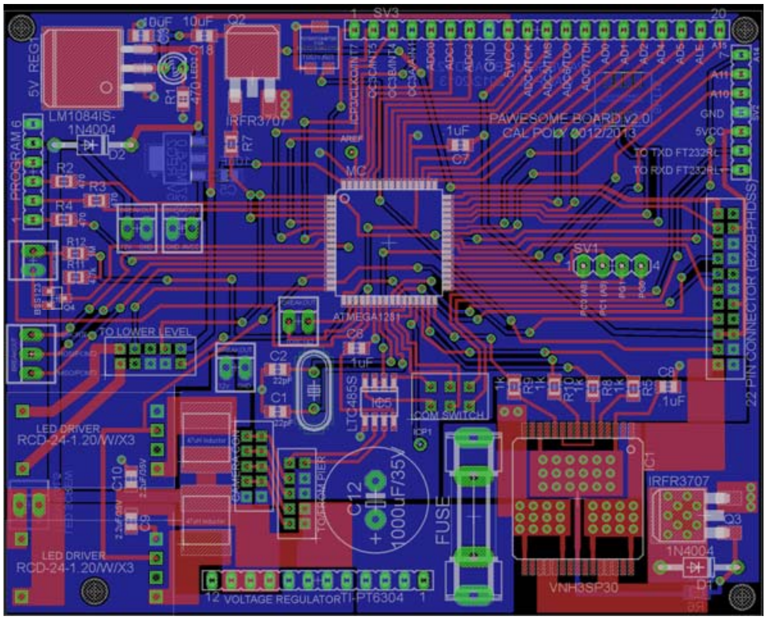


Figure 45. Overall pod board layout.

Figure 46 shows just the bottom layer of the board. There are very few components on this side of the board. For the most part, this layer contains the ground plane and large traces to handle the large amount of power leading to and away from the motor driver.

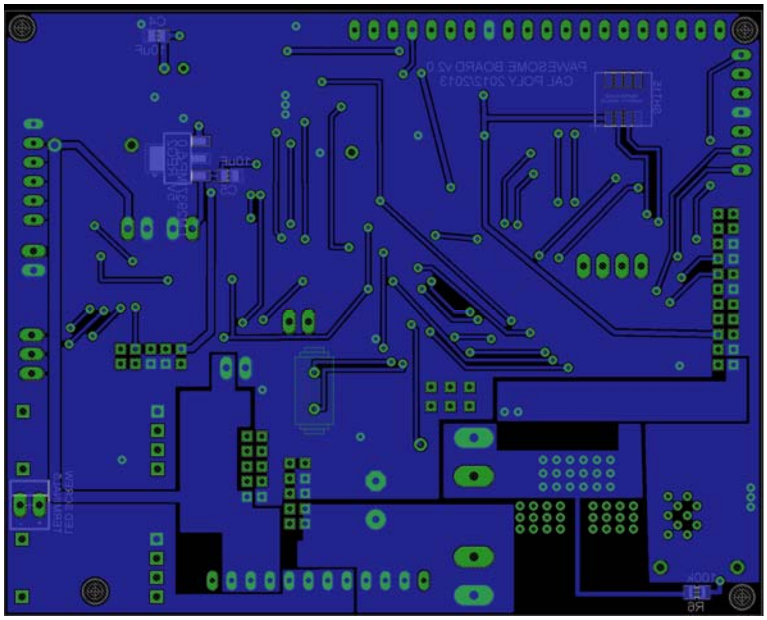


Figure 46. Bottom side of the P^{awesome} board.

Figure 47 shows just the top side (or "component side") of the board. In this view it is a lot easier to see the top side components and traces. Here, the larger traces can be seen leading to and from the motor driver and LED drivers.

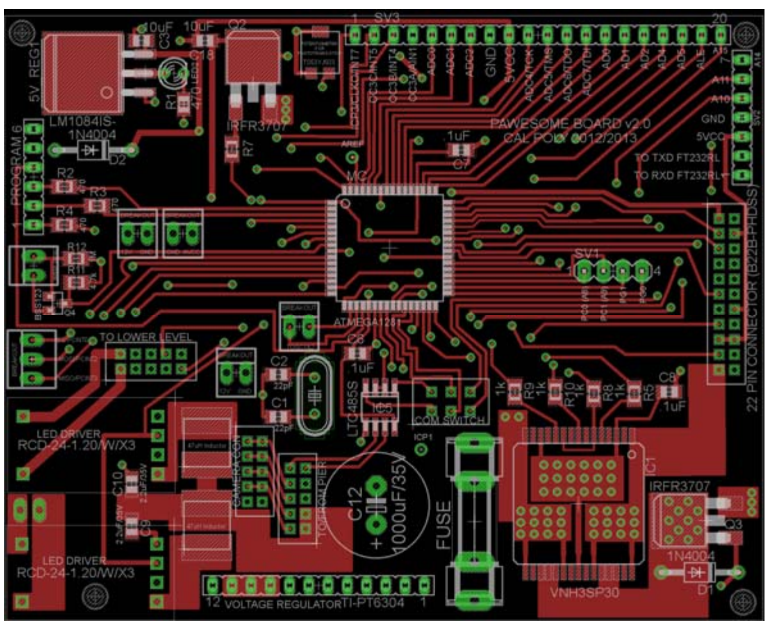


Figure 47. Top side components on the P^{awesome} Board.

Leak Detection Circuit

The previous leak detection circuit design has been replaced with another and moved to a different location in the pod. The previous leak detection circuit sat in a groove carved between two of the O-ring grooves. In the event that a leak occurs from somewhere

besides the bottom o-ring plug, this circuit will not be able to tell. There is a recess in the bottom plug of the pod that the previous team was going to use for a bottom sensor. However, when the sensor didn't work as well as hoped, the bottom sensor idea was abandoned and the recess was left behind. The leads to the new leak detection circuit will be placed in this recess, as water from any leak location will collect there.

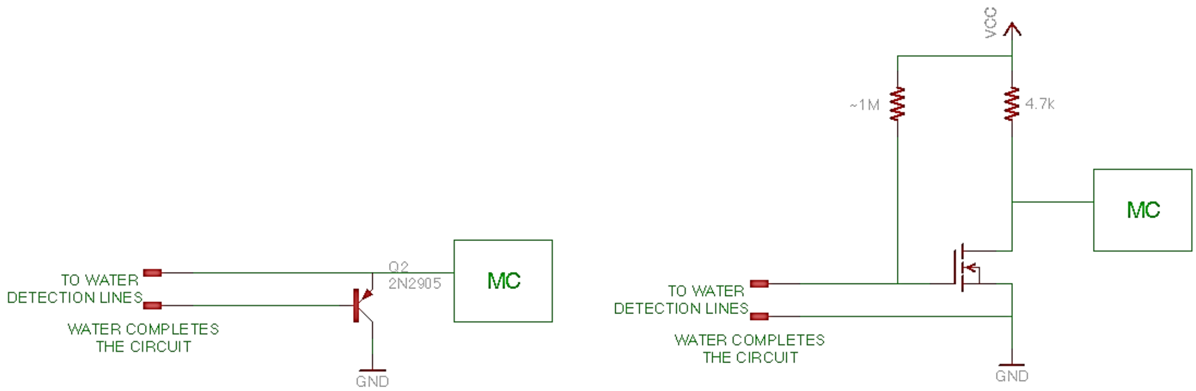


Figure 48. A comparison between the old (left) and new (right) leak detection circuit.

In the old design, the leak detection pin on the microcontroller (or MC) is set high (so the entire line sits at 5V) with its internal pull-up resistors turned on. Then, when water connects the base line of the transistor to the 5V line from the MC, the entire line is connected to ground, and the MC knows that a leak has been detected and will handle it accordingly. In the new design, the transistor is normally turned on so that the line connected to the MC is grounded. Now, if a leak occurs, water will tie the gate of the MOSFET to ground, and the MC line will be pulled high by the 5V source, signaling the pod to return to the surface. This circuit is debounced by our program so that a false positive doesn't cause the pod to erratically return to the surface. This circuit has been tested for functionality, and it has been found that with 16 inch lead wires, the circuit will reliably detect leaks when the wires are up to 8.5 inches apart.

Connector Pins

Here are the various signals leading to/from each connector. The first grey cell of each table tells you where the connector leads, and sums up how many connections it has. The actual signals are listed below in the white cells.

Table 10. Signals leading to the bottom level of the pod.

BOTTOM (9)	Pin Number
FANPWM (blue)	4
FANSPEED (yellow)	-
FAN-ONOFF/power 12V (red)	5
GND (fan) (black)	8
SERVO PWM	2
SERVO VCC (5V)	10
SERVO GND	9
LED2+	6
LED2-	1

The fan PWM (or pulse width modulation) signal leads from the Atmega1281 microcontroller to the fan, and controls its speed. The same goes for the servo PWM signal. The FANSPEED signal is sent from the fan to the microcontroller, and tells us how fast the fan is actually moving. The rest of the signals are related to power for various components on the lower level of the pod.

Table 11. Signals leading to the top of the pier.

TO/FROM SURFACE (10)	Pin Number
24V (x2)	6,7
CAM1	1
CAM2	2
CAM3	3
CAM4	4
RS485A	5
RS485B	10
GND (x2)	8,9

Table 11 shows the signals leading to the top of the pier. Included are ground, power, four camera signal lines, and two RS485 lines. The RS485 lines are used for

communication between the computer at the top of the pier and the pod board. An RS485 is used instead of an RS232 because of the maximum cable length of the RS232, which is 50ft. The RS485 more than meets our needs as its maximum cable length is 4000ft.

Table 12. Signals leading to the blue and black camera cables.

BLUE CAM CONN IN (10)	Pin Number
CAM1 (x2)	2,7
CAM2 (x2)	3,8
CAM3 (x2)	4,9
CAM4 (x2)	5,10
CAM 12V	1
GND	6

The blue Ethernet cable running from the camera to the board connector consists of eight camera lines, made up of only four different signals. The black Ethernet cable supplies power to the camera.

Table 13. Signals leading to the top level of the pod.

TOP (21)	Pin Number
MOTPOWER+	1
MOTPOWER-	12
LED1+	Screw Terminal
LED1-	Screw Terminal
FANPWM (blue)	9
FANSPEED (yellow)	10
FAN-ONOFF/power 12V (red)	11
GND (fan) (black)	20
HALL_EFFECT	6
ENCODER1	8
ENCODER2	7
VCC encoder (5V)	14
GND encoder	13
PHOTOTRANSISTOR PWR (5V)	3
F3 Phototransistor read	2
HALL EFFECT VCC (5V)	16
HALL EFFECT GND	17
SERVO PWM	4
SERVO VCC (5V)	21
SERVO GND	19
NC (wire tap to top)	-

There are quite a few connections running to the top level of the pod. In reality, not all of these components are actually at the top level of the pod (the phototransistor is located on the same level as the camera). Many of the top level connections are power lines for various components (the yaw motor, LEDs, fan, Hall Effect switch, yaw motor encoder, and phototransistor). There is one wire that is labeled blank. This was a preexisting, unconnected wire that has been left in place in case another wire is needed.

For the senior project expo, the exposed connections running to the board were loosely wrapped in black electrical tape to clean up the presentation (Figure 49). Since the pod board connectors may be replaced with different connectors on the next board version, the signal labels on the wires were left on, and the wrap was applied loosely so that it may be removed and the labels can be accessed. Care should be taken to not disturb the permanent cable wrap, as it is pretty and difficult to put in place.

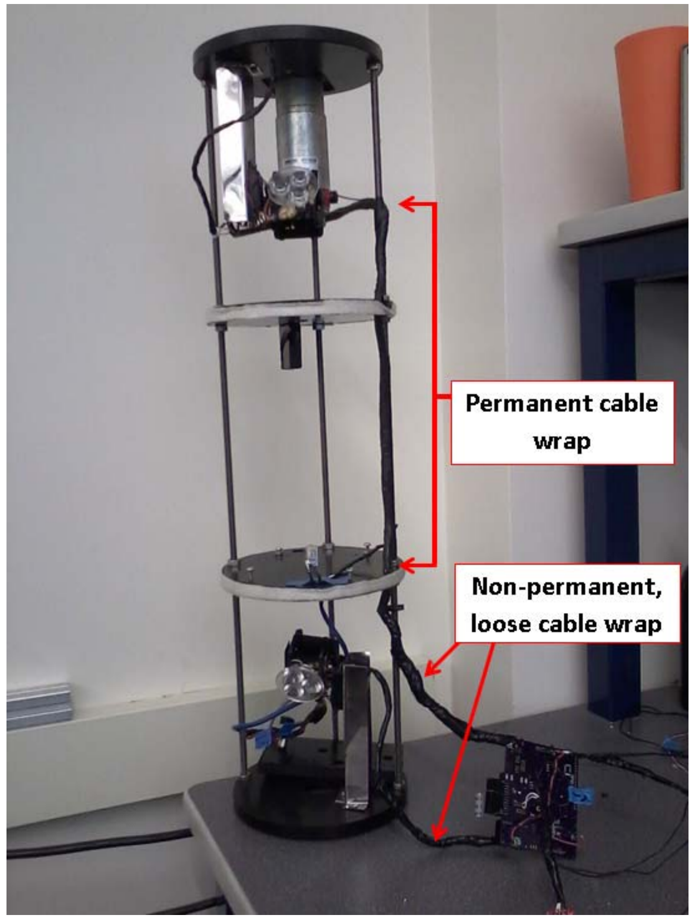


Figure 49. Permanent and non-permanent cable wraps installed on the internal pod frame.

Pod Board v2.6 Fabrication and Installation

Three copies of the custom PCB were printed using Oshpark (DorkbotPDX). One copy is completely unpopulated for trace testing, one copy has only the 12V regulator and a small resistor load installed, and the third is the main working pod board. All three copies are fully operational and can be used for this project.

Overall, the assembly process for the P^{awesome} board went fairly smoothly. Some phantom issues were caused due to ordering incorrect parts, such as a capacitor that was rated for 10V that was seeing 24V, or accidently ordering the adjustable voltage regulator instead of the fixed 5V regulator. The most difficult issue to troubleshoot was the motor driver short.

Once the motor driver and supporting components were soldered on, a short was immediately apparent. After a bit of hunting and desoldering and resoldering, it appeared that the problem had been narrowed down to a motor driver pin short. A strange situation arose because moving the location of the 24V source seemed to fix the problem when it shouldn't have. As can be seen in Figure 50, there shouldn't be a difference between feeding 24V to the motor driver side of the fuse or the pier power input location. However, when 24V was fed directly to the motor driver side of the fuse, no sparking would occur.

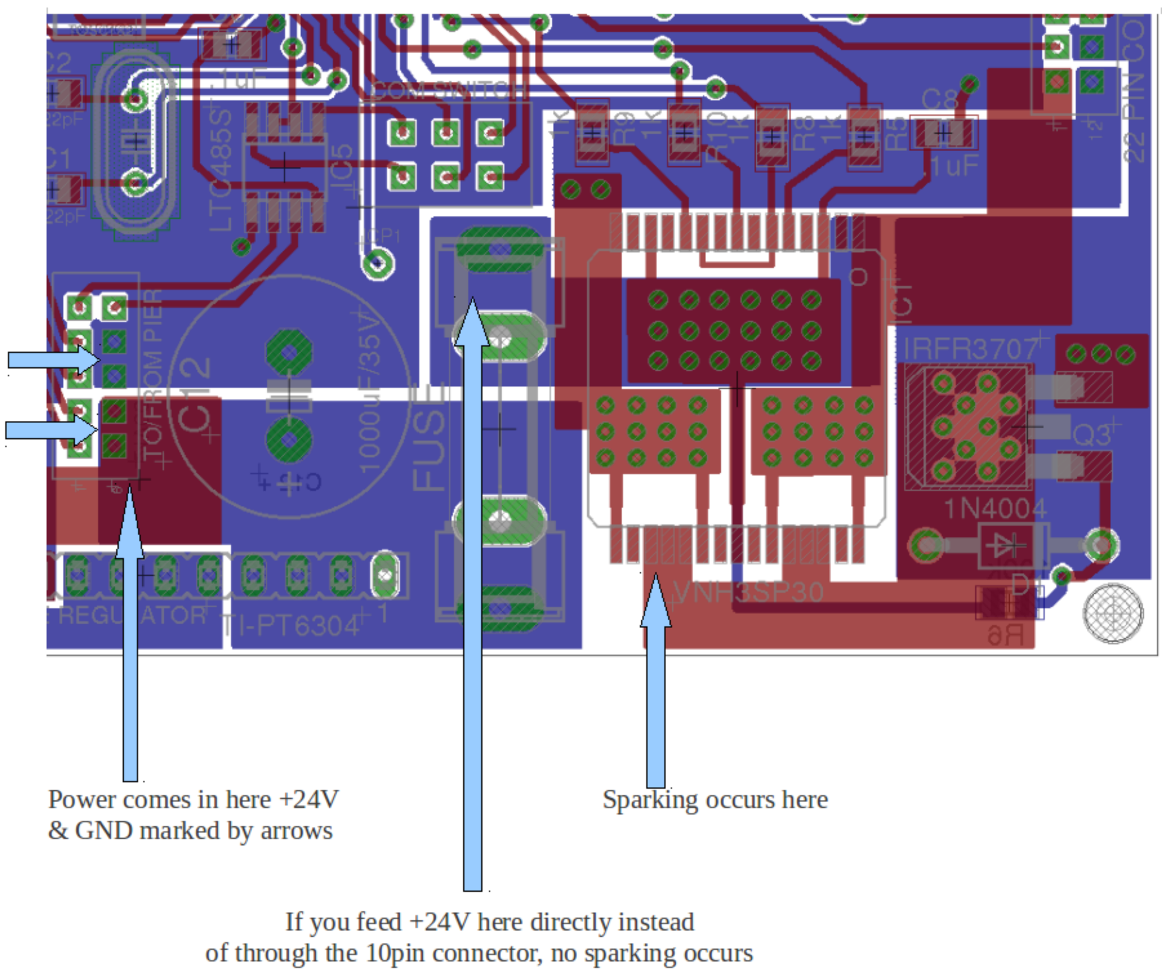


Figure 50. Picture of strange sparking issue.

The IRFR3707 was removed from the board and replaced with a short during this troubleshooting process. This seemed to fix the problem, and the motor driver was usable. However, once controlled by the microcontroller, the motor driver chip sparked while turning clockwise (Figure 51). After consulting the motor driver datasheet, the reason behind the location of the short became clear. The motor power pin and the motor ground pin are placed right next to each other, and the short was occurring between the two pins. Efforts were made to clean off the surface of the board, which had become gunked up after desoldering and resoldering the motor driver during the troubleshooting process. The pins

were bent farther away from each other and the driver was examined under a microscope to ensure that there was no small solder bridge between the two pins. After this did not fix the problem, the voltage was lowered so that the short was easier to see. It appeared that the traces on the board itself were shorting. One possible reason for this is a slight shift in position of the highlighted node in Figure 51. It appeared the node was shifted slightly to the right and may have been close enough to short. To fix this issue, the motor power trace leading up to the problem area was scraped up off the board and resoldered to the motor power pin, which was bent up and away from the motor ground pins. This was a surprisingly clean and effective solution.

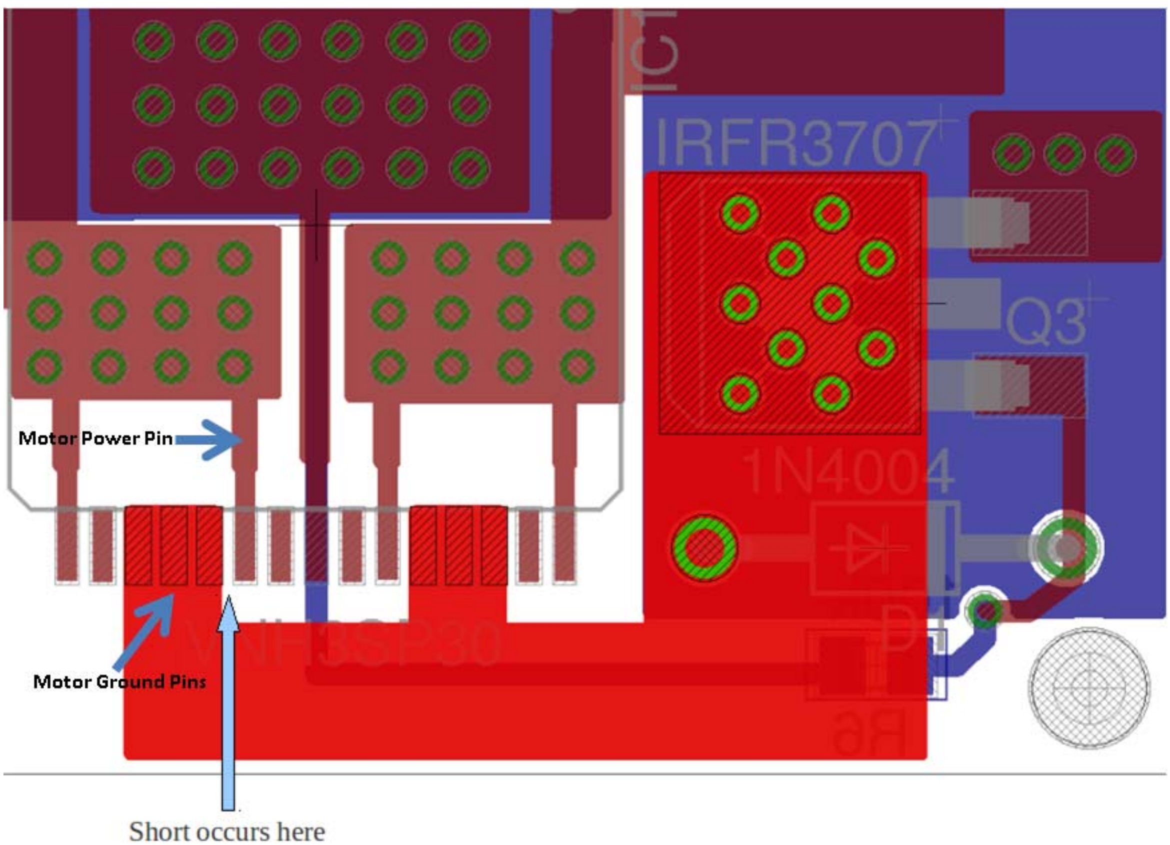


Figure 51. Secondary short location

A list of smaller board issues that should be fixed in the next Pawesome board can be found in the pod board future iterations section.

Pod Board Future Iterations

In terms of the pod internals, a new version of the Pawesome board should be designed and sent away for fabrication. However, it is highly recommended that the remaining components be tested on the current board v2.6 to ensure proper wiring and setup. Namely, the SHT15 temperature and humidity sensor should be soldered on and tested. The final pod board assembly is pictured in Figure 52.

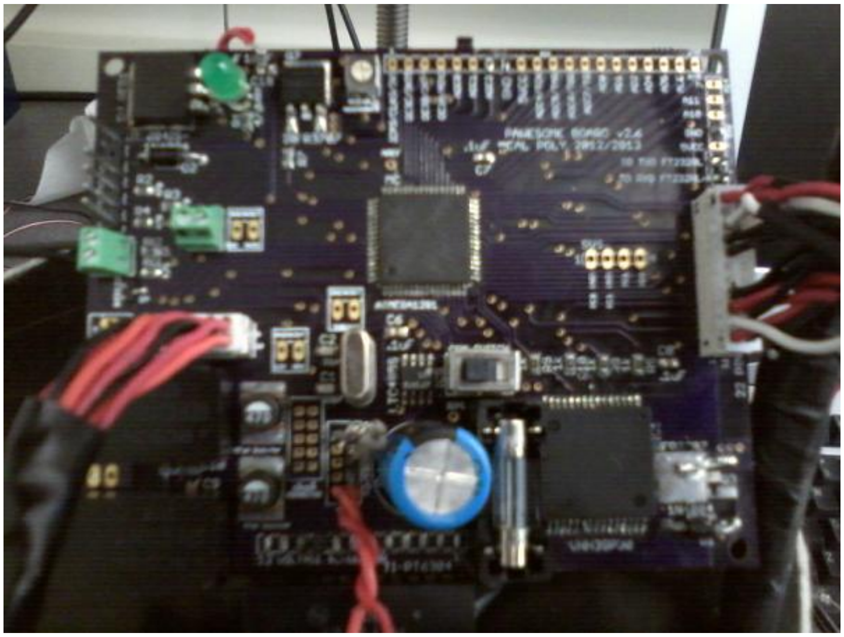


Figure 52. Final Pawesome v2.6 board assembly.

Tasks that are on the to-do-list include:

- The SHT15 temperature and humidity sensor should be soldered on and tested
- The lower servo needs to be replaced in the pod frame hardware.
- The board needs to be tested in conjunction with the winch cable via RS485 communication
- Hall Effect functionality still needs to be tested on the v2.6 pod board.
- Position control for the yaw motor needs to be re-tuned once installed in the pod

Here is a list of changes that need to be implemented on the next Pawesome Board version:

- Capacitors aren't placed correctly around LM1084IS-5V reg on eagle *board* file
- Make plug in connectors different. May get away with only changing the 10 pin connector leading to/from the pier deck. The current maximum amperage is 3A, but this needs to be higher for power coming down the main cable.
- Footprint may need to be adjusted for LED driver inductors. The original inductors were on backorder and had to be replaced by similar sized inductors.
- Oscillators ordered were surface mount but on second board footprint is through hole
- Need to use a larger font to label components (example: SHT15 chip labeling)

- Put protection diode & proper thru hole 100uF cap for 12V regulator on board (not included in v2.6). See 12V RECOM regulator datasheet in Appendix for more detail.
- Include better heat sinking on all regulators
- Be more conservative with large traces between MOT-PWR & MOT-GND on motor driver (see sparking issues pictures (Figure 50 & Figure 51) for more detail). May want to bring in traces a little more in case of shifting traces during manufacture.
- Ensure fan power is connected to 12V. In this board version, the fans were connected to 5V instead of 12V due to an Eagle copy error, despite the "12V" label (fans non-operational in v2.6). Other changes may need to be made to the fan schematic
- C18 should be a resistor. There is no such thing as a pull-up capacitor.
- Another Hall Effect switch should be added to the pod as another bottom detector. The plan was to install a permanent magnet near the bottom of the Pier Portal piling as another bottom detection backup.

Thermal Considerations

Calculations were done to ensure that the pod will not overheat due to the high heat output from the LEDs and other internal electronic components. It was estimated that the electronics inside the pod will produce no more than 60.9W of heat. This should be an overestimate so that a factor of safety is inherently included. It was then determined that the heat transfer out of the pod should total to approximately 1844W, which is far greater than our heat output, so no overheating should occur. Details from these calculations can be found in Appendix C.

Unfortunately, our concerns do not stop there. We can be sure that the pod will not overheat, but now we must make sure that the air inside the pod will not become too cool, and cause condensation to occur. If a lot of condensation occurs, it could become difficult to see outside of the pod walls due to fogging, or the electronic board could short out.

There are a few different factors involved in this sort of calculation. These factors include the maintenance ambient conditions such as air temperature and relative humidity. If the pod is opened up and serviced on a particularly humid morning, that humidity gets trapped in the pod, and will certainly condense once the internal pod temperatures drop.

Since there are so many possible humidity and temperature combinations, the plots in Figure 53 and Figure 54 were generated. In both plots, the blue line depicts the recommended service condition limits while the red line shows the critical service conditions where condensation will occur. Any combination of humidity and temperature that falls below the blue line is safe. Any combination of temperature and humidity above the red line will result in condensation in the pod, and is not recommended. Three data points were generated to ensure that a linear relationship exists. These data points are shown by small red and blue markers.

Figure 53 relates relative humidity to room temperature in degrees Fahrenheit, while Figure 54 relates the relative humidity to room temperature in degrees Celsius. The second plot is provided for convenience.

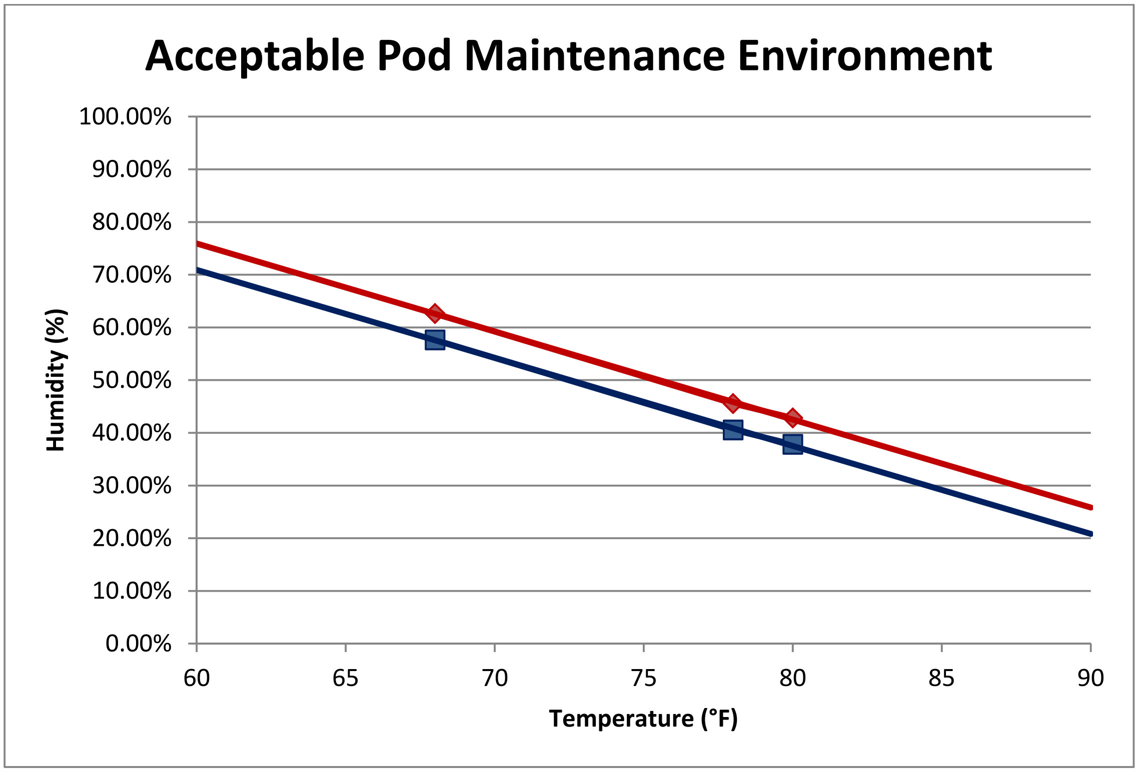


Figure 53. Visual representation of acceptable ambient pod maintenance conditions in °F. Recommended pod maintenance environments lie under the blue curve, which includes a 5% safety factor in relative humidity. The red line depicts the critical onset of condensation.

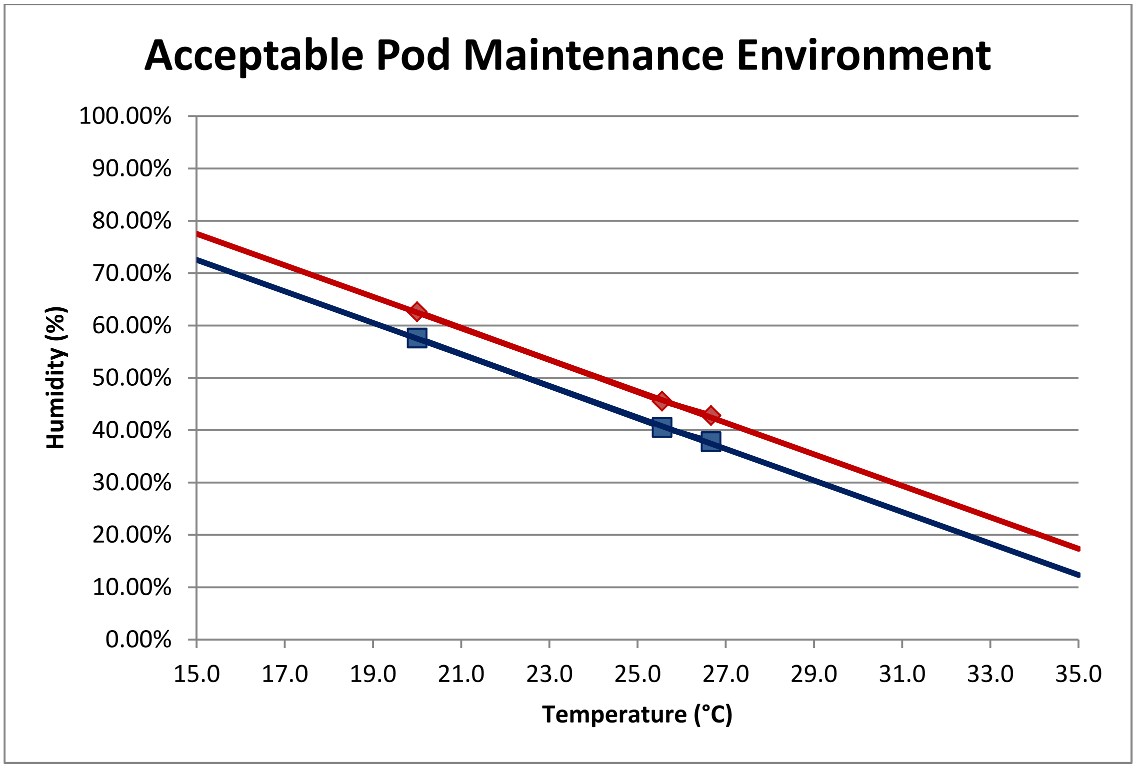


Figure 54. Visual representation of acceptable ambient pod maintenance conditions in °C for convenience. Recommended pod maintenance environments lie under the blue curve, which includes a 5% safety factor in relative humidity. The red line depicts the critical onset of condensation.

It was also determined in the calculations that in general, the pod should not be serviced outside in the morning, due to the higher humidity. Ideally, the pod will be serviced inside, where the ambient conditions are more easily controlled and monitored.

Details from all of these calculations can be found in Appendix C.

Hydrophone

A hydrophone is an underwater microphone which can be used to listen to sounds underwater. The CR2 hydrophone and preamp from Cetacean Research Technology (CRT) has been purchased for use with the Pier Portal. Many different animals such as seals, dolphins, whales and otters can be seen in the area, and a hydrophone will make it possible to hear them as well. According to the University of Rhode Island's Discovery of Sounds In the Sea website, most sea life can be heard between 10Hz-100kHz. The CR2 covers most of this range with its 4Hz-60kHz range and is advertised as being "virtually indestructible" and very low maintenance. The polyurethane jacketed coaxial cable comes with a beefy monophone connector attached. There are coaxial lines in the project's current winch cable which can accommodate the hydrophone. This way, the hydrophone can be attached to the pod and the users can listen to sounds directly around the pod. However, another slip ring contact must be installed in order for the hydrophone signals to reach the deck computer.

Figure 55. Hydrophone and cable picture from Cetacean Research Technology website.

GoPro

A GoPro (Hero3 White Edition) was purchased for all future Pier Portal testing. This sports camera is small, light, and has a casing which is sealed to 60m (197ft). This is especially helpful because the ocean depth at the pier is only 40ft. This device was very helpful during our project and will continue to be for future groups. Video and pictures captured by this device are archived on Google Drive.

Project Spending

This project had two grants approved for it, giving a total of $6,000. The following table, included for future reference, is a list of items purchased for this project:

Table 14. List of items purchased for Pier Portal II.

Item	Manufacturer	Part Number	Supplier	Qty.	Unit Cost
GoPro - HERO3 HD Camcorder	GoPro	6571752	Best Buy	1	$214.99
Gear Reducer	Motion Industries	VRL-1200-20-K5-19EC1600	Motion Industries	1	$1,108.24
NEMA4X Safety Enclosure	NEMA Enclosures	N24H2412ALWP	NEMA Enclosures	1	$484.19
AWG 10 Cable	-	7081K17	McMaster-Carr	10	$2.34
AWG 14 Cable	-	7422K62	McMaster-Carr	20	$0.99
AWG 16 Cable	-	8042K13	McMaster-Carr	20	$1.11
Magnetic Contactor	Fuji Electric	4NC0A0B10	Online Components	2	$47.23
Molded-Case Circuit Breaker	Fuji Electric	SA53RCUL/3	Online Components	1	$149.40
Noise Filter	Schaffner	FN-258L707	Mouser Electronics	1	$162.39
CR2 Hydrophone	Cetacean Research Technology	CR2/005	Cetacean Research Technology	1	$405.00
Preamplifier	Cetacean Research Technology	-	Cetacean Research Technology	1	$109.00
BNC to 1/4" Tip Sleeve Adapter	Cetacean Research Technology	-	Cetacean Research Technology	1	$36.00
Multipurpose Aluminum	-	8975K131	McMaster-Carr	1	$26.59
#40 ANSI Roller Chain	-	6261K173	McMaster-Carr	1	$3.53
Custom Pawsome Boards	-	-	OSHPark	1	$62.00
Humidity and Temperature Sensor	Sensirion	COM-08227	SparkFun	2	$28.95
Basic Green LED	China Young Sun LED Technology	COM-09592	SparkFun	3	$0.35
Break Away Headers	-	PRT-00116	SparkFun	2	$1.50

Item	Manufacturer	Part Number	Supplier	Qty.	Unit Cost
FT232RL Breakout Board	FTDI	BOB-00718	SparkFun	3	$14.95
USB to RS-485 Convertor	Sipex	BOB-09822	SparkFun	3	$19.95
Pocket AVR Programmer	-	PGM-09825	SparkFun	3	$14.95
2.2 UF Capacitor	TDK Corporation	445-8892-1-ND	Digikey	10	$0.46
10 UF Capacitor	TDK Corporation	445-1371-1-ND	Digikey	10	$0.11
22 PF Capacitor	TDK Corporation	709-1172-1-ND	Digikey	10	$0.10
0.1 UF Capacitor	TDK Corporation	445-7534-1-ND	Digikey	10	$0.07
1M Ohm Resistor	Panasonic Electronic	P1.00MCCT-ND	Digikey	50	$0.03
470 Ohm Resistor	Panasonic Electronic	P470ACT-ND	Digikey	50	$0.02
1K Ohm Resistor	Panasonic Electronic	P1.0KACT-ND	Digikey	50	$0.02
100K Ohm Resistor	Panasonic Electronic	P100KCCT-ND	Digikey	50	$0.03
4.7K Ohm Resistor	Panasonic Electronic	P4.7KACT-ND	Digikey	50	$0.02
47 UH Inductor	TDK Corporation	445-6537-1-ND	Digikey	10	$0.46
50K Ohm Trimmer	Vishay Sfernice	TS53YJ-50KCT-ND	Digikey	2	$1.62
32.514 MHz Oscillator	ECS Inc	XC649CT-ND	Digikey	1	$1.01
Slide Switch	C&K Components	CKN1830-ND	Digikey	1	$6.92
RS485 Transceiver	Linear Technology	LTC485CS8#PBF-ND	Digikey	2	$3.14
100V Mosfet	Fairchild Semiconductor	BSS123NCT-ND	Digikey	4	$0.29
Adjustable Voltage Regulator	Texas Instruments	LM1084IS-ADJ/NOPB-ND	Digikey	3	$2.79
5.0V Voltage Regulator	Texas Instruments	LM2937IMP-5.0/NOPBCT-ND	Digikey	3	$1.85
Motor Driver	STMicroelectronics	497-3565-1-ND	Digikey	2	$9.55
10 UF Capacitor	TDK Corporation	445-5984-1-ND	Digikey	10	$0.67

Item	Manufacturer	Part Number	Supplier	Qty.	Unit Cost
5.0V Voltage Regulator	Texas Instruments	LM1084IS-5.0/NOPB-ND	Digikey	3	$2.79
3-31V LED Driver	Recom Power	945-1132-ND	Digikey	4	$19.57
DC/DC Convertor	Recom Power	945-1729-5-ND	Digikey	4	$23.87
Electrical Tape	3M	3M33+A-ND	Digikey	1	$5.42

Certain costs from Digikey have three decimal places, but are rounded to two in the table. The costs for the hydrophone, preamplifier, and sleeve adapter are discounted because it is for a student project. The table does not include any shipping costs.

Management Plan

Meetings occur three times weekly for an hour at the very least:
Monday 6-8, Tuesday 4-6, Wednesday 6-8.
These hours have changed every quarter.

During the last quarter, progress meetings with Professor Ridgely have been scheduled to occur on Wednesday 2-3.

<u>Team Member Responsibilities</u>
Each member is responsible for research, documentation, testing, design, and fabrication. Sharing these responsibilities will help keep our members well informed of each other's progress. The following are general roles each team member will take on during our project.

Misha Balingit:

- Secondary coordinator- Coordinate all team meetings, send out reminders
- Mechatronics Specialist

Cory Spieler:

- Accountant- Keep track of spending
- Mechanical System Specialist

Aaron Jen:

- Main coordinator- Email companies, teachers, our sponsor, etc.

- Systems Integration Specialist

Table 15. List of Deliverables and their due dates.

Deliverable	Due By
Camera Pod Tests (leakage and drag force)	10/28/12
Sea Life Growth Test	11/04/12
Conceptual Model and Meeting with Sponsor	11/08/12
Conceptual Design Report	11/29/12
Conceptual Design Review with Sponsor	12/07/12
Meeting with Sponsor	01/11/13
Design Report	02/05/13
Critical Design Review with Sponsor	02/07/13
Prototype for Track Cleaning	03/01/13
Meeting with Sponsor	03/08/13
Send Current Design Report to Sponsor	03/22/13
Project Hardware/Assembly Demo	04/03/13
Senior Project Design Expo XII	05/30/13
Final Report Due	06/07/13

All meeting dates with the sponsor are shaded and are general ballparks. When the time comes, we will schedule meetings based on the sponsor's convenience.

Conclusion and Recommendations

The current solution for the track cleaning system is a prototype. However, to avoid spending too much time on trying to create the perfect cleaner, this current design will be used as the final design for now. If there is more time later, modifications will be made to improve the effectiveness of the track cleaning system.

The possibility that Yaskawa follows through with their donation is high. So it should be safe to say that the motor and motor driver donated by them will be used in the final design of the Pier Portal. The motor, motor driver, and safety enclosure is a reliable way to control the camera pod up and down the track.

As mentioned above, this final design only contains four main subsystems: track cleaning system, I-beam top clamp, motor system, and the pod electronics. There are still a few things that are left out for a later time due to their lower priority. However, once these four components are near completion, lower priority components will be designed such as the fresh water rinse system and the hydrophone attachment.

Appendix A: Quality Function Deployment

Appendix B: Gantt Chart

Appendix C: Calculations

Appendix D: Drawings

Appendix E: Electronics

Appendix F: Datasheets

Appendix G: Previous Pier Portal Datasheets

Appendix H: Procedures

Appendix A: Quality Function Deployment

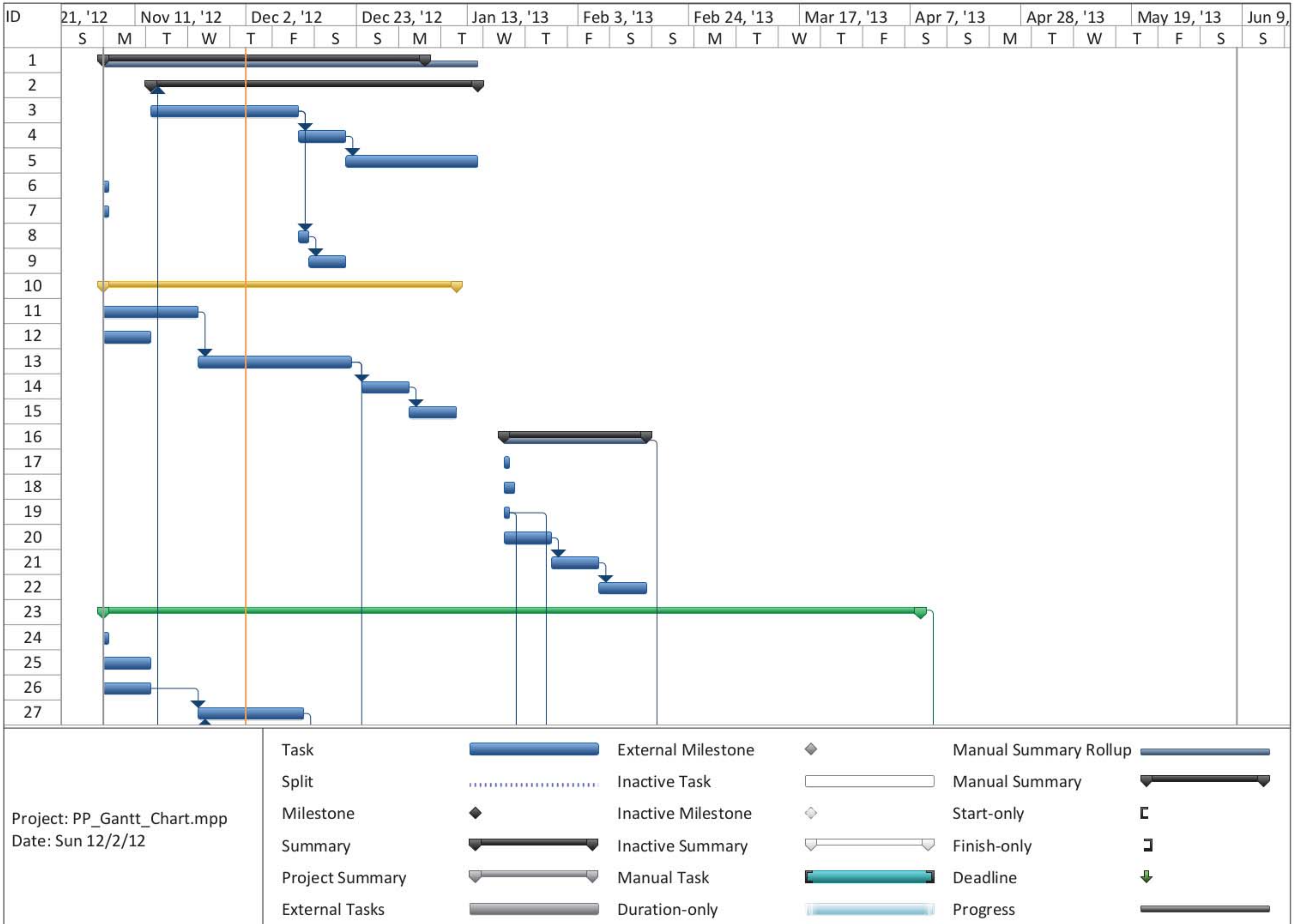
Engineering Requirements

Customer Requirements	Weighting (Total 100)	Brightness of the LEDs	External pressure the pod has to withstand	Shear force applied to track (to clean it)	Impact force the pod has to withstand	Max temperature of LEDs	Max temperature of electronics in pod	Minimum force applied by motor	Distance from floor for automatic stop	Distance from floor for automatic slow down	Range of the hydrophone	Resisting force triggering automatic stop of motor	Surface area of pod rinsed by fresh water	Maximum jerk of pod	Max current rating triggering automatic shutdown	Distance between manual override switch and dangerous mechanisms	Budget limit	Time paint-coated metal components must last w/o visible rust)	Max weight of pod assembly	Max temperature of electric components triggering automatic shutdown	Lifetime of gears	Lifetime of hydrophone	History recorded of sensor data	Number of contacts for the slip ring	Shortest time for the pod to surface from max depth	Benchmarks		
does not leak	*		●		○				-														-	-	○			
self cleans track	*			●													●											
able to sense bottom	4				-				●					-						-			-	○	○			
automatic & manual shutoff systs	5					○	○	-	●	●		●			●	●				●	○			○	●			
salt water resistant	5										●		●					●			●	●						
should be balanced	4													●					○									
safe electrical system	*					●	●			-					○	●				●		○		○	●			
winch control system	4					-	-		-	●		●		●	●	●	○		●		●			○	-			
safe from/can beat down kelp	6				-			●	-			●	○	-	○										○			
otter/seal resistant	6				●			●				●		-	○							●			○			
robust gear reduction	6													●	●		●		●		●				-			
leak detection	5		○					-	-							●				-				○	●			
pod temp monitor (ambient)	5					○	●									●				○			-	○	●			
hydrophone	5										●					○	●			-		●	●	-				
depth/time/temp info available	4		○			●	●	-	○	-												○	●	○				
capable of 24hr viewing	3	●	-	●	-	●	●	●														○	●	○				
adapt to changing sea floor levels	2		○					●	●	●													○		-			
camera pod must not discharge toxic substances	4			-														●							○			
will not interfere with pier	3											-			-	○												
minimal maintenance required	4		●	●	●	●	●	○	●	-			○		-	○				-	●	●		-				
Components moveable by small crane/fork lift	2																		-									
all moving parts easily accessible (for repair) (no divers)	2							-								○	-	○				○						
automatic freshwater rinse	*												●				●											
replaceable video cable	1																-							-				
data stream and sensor packages will be upgradable	1																-						○					
slip ring has spare contacts for upgrades	1																-							●				
track is fully installed	3																○											
cable must not de-spool	3							○						○	○	○			○									
must be able to see underwater	6	●		-		○	-																					
won't fog up	6					●	●													-								
pod will not detach from track when underwater	*				●				○	○		●		-														
Units		lm	psi	N	kN	°C	°C	lb	ft	ft	mi	lb	%	ft/s³	%	ft	$	yr	lb	°C	yr	yr	mo	#	sec			
Targets		900	45	6	3.6	150	85	40	3	7	1	?	85	0.1	90	2	2K	1	100	72	3	5	1	8	10			

"● = 9"	Strong Correlation
"○ = 3"	Medium Correlation
"- = 1"	Small Correlation
Blank	No Correlation

APPENDIX B: GANTT CHART

WBS	Task Name	Duration	Start	Finish	Predecessors
1	**Winch**	**45 days?**	**Mon 11/5/12**	**Fri 1/4/13**	
1.1	**Replace Motor**	**44 days**	**Wed 11/14/12**	**Mon 1/14/13**	**37**
1.1.1	Research	20 days	Wed 11/14/12	Tue 12/11/12	
1.1.2	Purchase	7 days	Wed 12/12/12	Thu 12/20/12	3
1.1.3	Install	17 days	Fri 12/21/12	Mon 1/14/13	4
1.2	Cable Guide	1 day?	Mon 11/5/12	Mon 11/5/12	
1.3	Slip ring add on/edit/replacement	1 day?	Mon 11/5/12	Mon 11/5/12	
1.4	Re-do the winch gear reduction	2 days	Wed 12/12/12	Thu 12/13/12	3
1.5	Purchase gears	5 days	Fri 12/14/12	Thu 12/20/12	8
2	**Scrubber System**	**49 days**	**Mon 11/5/12**	**Thu 1/10/13**	
2.1	Design	14 days	Mon 11/5/12	Thu 11/22/12	
2.2	Test Sponges	7 days	Mon 11/5/12	Tue 11/13/12	
2.3	Build Prototype	21 days	Fri 11/23/12	Fri 12/21/12	11
2.4	Test Prototype	7 days	Mon 12/24/12	Tue 1/1/13	13
2.5	Build Final Product	7 days	Wed 1/2/13	Thu 1/10/13	14
3	**Freshwater Rinse**	**21 days**	**Sun 1/20/13**	**Fri 2/15/13**	
3.1	Check hose connected at pier	1 day	Sun 1/20/13	Sun 1/20/13	
3.2	Install hose	2 days	Sun 1/20/13	Mon 1/21/13	
3.3	Check previous rinse progress	1 day	Sun 1/20/13	Sun 1/20/13	
3.4	Build (Doghouse) Prototype	7 days	Sun 1/20/13	Mon 1/28/13	
3.5	Test Prototype	7 days	Tue 1/29/13	Wed 2/6/13	20
3.6	Build Final Product	7 days	Thu 2/7/13	Fri 2/15/13	21
4	**Electronic Board**	**112 days**	**Mon 11/5/12**	**Mon 4/8/13**	
4.1	Order Pod Board (PB)	1 day	Mon 11/5/12	Mon 11/5/12	
4.2	Order Parts for PB	7 days	Mon 11/5/12	Tue 11/13/12	
4.3	Assemble PB	7 days	Mon 11/5/12	Tue 11/13/12	
4.4	Test/Install PB Code	14 days	Fri 11/23/12	Wed 12/12/12	26,32
4.5	Install Pod Board	1 day	Thu 12/13/12	Thu 12/13/12	27
4.6	Finish Deck Board	30 days	Mon 1/28/13	Fri 3/8/13	19,46
4.7	Test Deck Board	21 days	Mon 3/11/13	Mon 4/8/13	29
5	**Code**	**73 days**	**Mon 11/5/12**	**Tue 2/12/13**	
5.1	Convert pod code to RTOS	14 days	Mon 11/5/12	Thu 11/22/12	
5.2	Convert Swoop to RTOS	14 days	Mon 1/21/13	Thu 2/7/13	19
5.3	Document Code	3 days	Fri 2/8/13	Tue 2/12/13	32,33
6	**Research/Tests**	**56 days**	**Mon 11/5/12**	**Sun 1/20/13**	
6.1	Pod Pressure Test	1 day	Mon 11/5/12	Mon 11/5/12	
6.2	Drag Test	7 days	Mon 11/5/12	Tue 11/13/12	
6.3	Dunk Test/Sea Growth	21 days	Mon 12/24/12	Sun 1/20/13	13
7	**Bells & Whistles**	**31 days**	**Mon 2/18/13**	**Mon 4/1/13**	**16**
7.1	Switch bolts direction near wheels	1 day	Mon 2/18/13	Mon 2/18/13	
7.2	Replace galvanized hinge	4 days	Wed 2/20/13	Mon 2/25/13	43
7.3	Brackets for placement on the deck	2 days	Wed 2/20/13	Thu 2/21/13	43
7.4	Balancing	1 day	Tue 2/19/13	Tue 2/19/13	40
7.5	Wheel replacement/specialization?	5 days	Fri 2/22/13	Thu 2/28/13	42
7.6	Custom Deck Board	21 days	Mon 2/18/13	Mon 3/18/13	
8	**Hydrophone**	**28 days**	**Thu 12/20/12**	**Fri 1/25/13**	
8.1	Research	21 days	Thu 12/20/12	Thu 1/17/13	
8.2	Purchase	5 days	Fri 1/18/13	Wed 1/23/13	47
8.3	Install	2 days	Thu 1/24/13	Fri 1/25/13	48
9	Troubleshooting	19 days	Tue 4/9/13	Fri 5/3/13	23
10	Report Writing	25 days	Mon 5/6/13	Fri 6/7/13	50
11	Expo Presentation Preparation	19 days	Mon 5/6/13	Thu 5/30/13	50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21, '12
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Dec 2, '12
Dec 23, '12
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Apr 7, '13
Apr 28, '13
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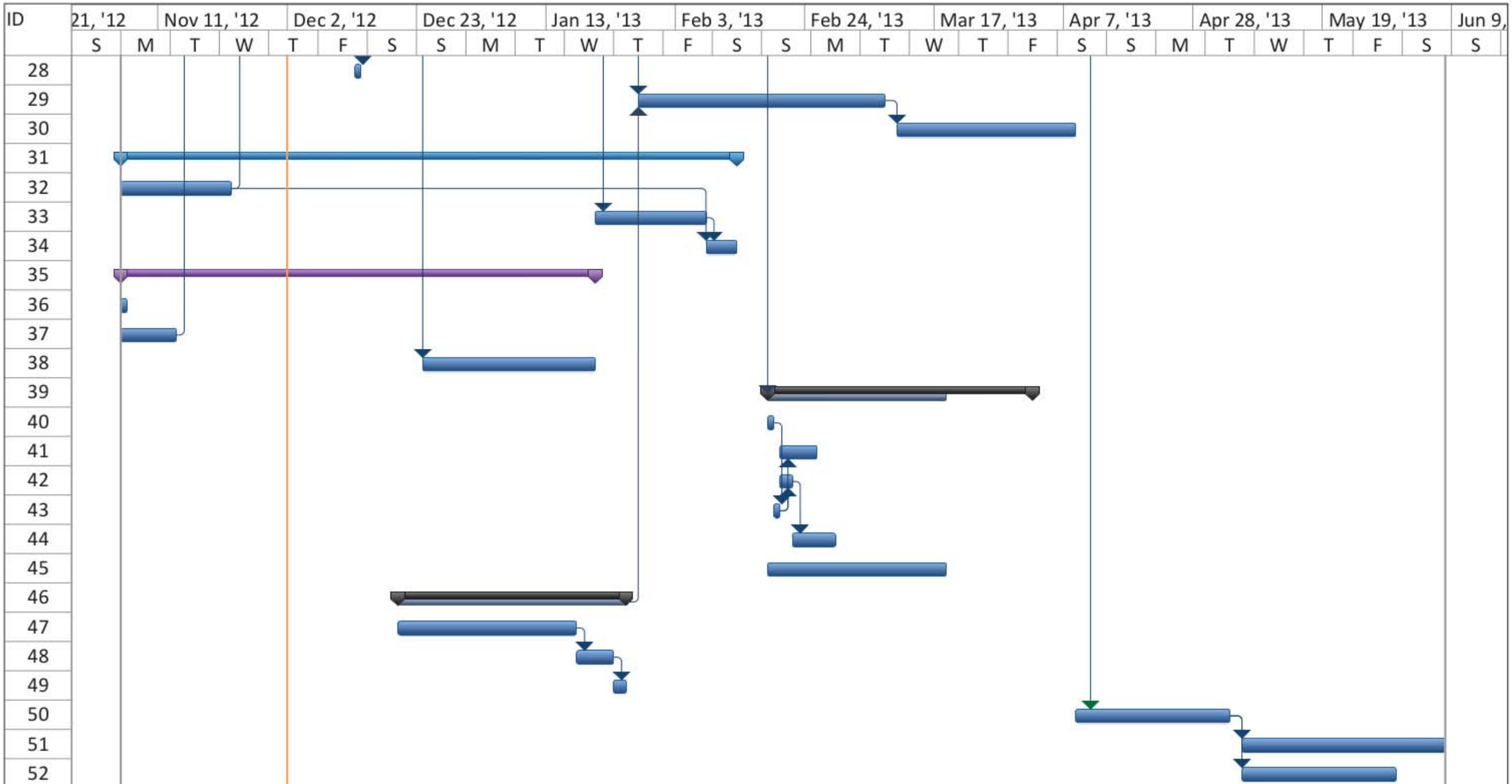
Project: PP_Gantt_Chart.mpp
Date: Sun 12/2/12
Task
Split
Milestone
Summary
Project Summary
External Tasks
External Milestone
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
Deadline
Progress



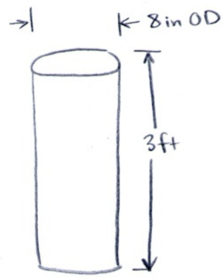
Project: PP_Gantt_Chart.mpp
Date: Sun 12/2/12

Task		External Milestone		Manual Summary Rollup	
Split		Inactive Task		Manual Summary	
Milestone		Inactive Milestone		Start-only	
Summary		Inactive Summary		Finish-only	
Project Summary		Manual Task		Deadline	
External Tasks		Duration-only		Progress	

APPENDIX C:

CALCULATIONS

Pod Buoyancy Calculations



ASSUME:

- Pod is completely submerged in seawater, so buoyancy force is based on volume

$$F_B = \rho_{H_2O} \forall_{pod}\, g$$

$$\forall_{pod} = \pi \left(8/2 \text{ in}\right)^2 (36 \text{ in})$$

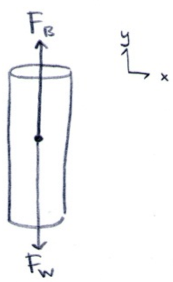
$$= 1809.6 \text{ in}^3 \left(\frac{ft^3}{1728 \text{ in}^3}\right)$$

$$\forall_{pod} = 1.05 \text{ ft}^3$$

$$\rho_{seawater} = 1.99 \text{ sl/ft}^3$$ (Fundamentals of Fluid Mechanics, Munson 6th ed.)

$$F_B = (1.99 \text{ sl/ft}^3)(1.05 \text{ ft}^3)(32.2 \text{ ft/s}^2)$$

$$F_B = 67.10 \text{ lbf}$$



$$\Sigma F = F_B - F_W$$

$$= 67.10 \text{ lbf} - 37.5 \text{ lbf}$$

$$\Sigma F = 29.6 \text{ lbf}$$

∴ The pod will have to be weighted down so that the pod will not float while submerged.

Pod Condensation Calculations

ASSUMPTIONS

- enclosed pod is a closed system (no exiting or entering air)
- pod is constant volume system
- air inside behaves as an ideal gas (Dalton model applies)
- when a liquid water phase is present, the water vapor exists as a saturated vapor at the system temperature. The liquid is a saturated liquid at the system temperature.
- due to the high heat transfer rate calculated previously, we will assume that the air inside the pod will cool to the ambient (ocean) water temperature
- the pressure inside the pod will be standard atmospheric pressure at sea level
- the inital air temperature will be a plausible pier air temperature

Myforecast.com reports that in August:

$\phi = 90\%$ relative humidity in the morning
T = 23°C (73.4°F) Average high temperature

Relative humidity is highest in the morning. We will assume the pod is serviced in the morning at the highest average temperature in order to assume a worst-case scenario. The relative humidity is highest in August.

The textbook referenced for this problem is:
Fundamentals of Engineering Thermodynamics (7th Edition), Moran, Shapiro...

Table A-2E, Properties of Saturated Water (Liquid-Vapor): Temperature Table
Table A-1E, Atomic or Molecular Weights & Critical Properties of Some Selected Elements and Compounds

Particularly, solutions to psychrometric problems like this are outlined in pages 732-735 in Chapter 12 were closely followed.

FOR INITIAL POD TEMP 74°F, SATURATION PRESSURE $P_g = .4158 \text{ lbf/in}^2$

$P_v = \phi P_g$ (P_v is partial vapor pressure)

$= (.90)(.4158 \text{ psi})$
$P_v = .37422 \text{ psi}$

$$v = \frac{\bar{R} T_1}{M_v P_v}$$

$\bar{R} = 1545 \frac{\text{ft}\cdot\text{lbf}}{\text{lbmol}\cdot°\text{R}}$ universal gas constant
$M_v = 18.02 \text{ lbm/lbmol}$ molecular weight H_2O vapor
v, specific volume

$$= \frac{(1545 \frac{\text{ft}\cdot\text{lbf}}{\text{lbmol}\cdot°\text{R}})(74 + 460.7°\text{R})}{(18.02 \text{ lbm/lbmol})(.37422 \text{ lbf/in}^2)}\left(\frac{\text{ft}^2}{144 \text{ in}^2}\right)$$

$v = 849 \text{ ft}^3/\text{lbm}$

Table A-2E ⇒ Find temperature where $v_g \approx 849\ ft^3/lbm$

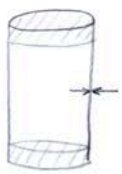
↳ Condensation will occur at approximately 71°F

Sea water temperature (worst case) ≈ 12°C (53.6°F)
∴ Condensation will occur, but how much?

H_2O vapor initially present:

$$m_{v_1} = \frac{V}{v_{v_1}}$$

need volume (V) of air inside pod:



$$V_{air} = \pi \left(\frac{8-.5\,in}{2}\right)^2 (36\,in - 2(2.5\,in))$$
$$= 1369.5\,in^3 \left(\frac{ft^3}{1728\,in^3}\right)$$
$$V_{air} = .79\,ft^3$$

$$m_{v_1} = \frac{.79\,ft^3}{849\,ft^3/lbm}$$

$m_{v_1} = 9.31 \times 10^{-4}\ lbm$ mass of water vapor initially present in the pod before cooling occurs

Need quality to determine mass of water vapor present at the final cooled temp

$$x_2 = \frac{v_{v_2} - v_{f_2}}{v_{g_2} - v_{f_2}}$$

v_{f_2} saturated liquid specific volume at final temp
v_{g_2} saturated vapor specific volume at final temp

$v_{v_2} = v_{v_1}$

$$= \frac{(849\,\frac{ft^3}{lbm}) - (0.01603\,ft^3/lbm)}{(1482\,ft^3/lbm) - (0.01603\,ft^3/lbm)}$$

$$x_2 = .573$$

Mass of water vapor present after cooling:

$$m_{v_2} = (.573)(9.31 \times 10^{-4}\,lbm) = 5.33 \times 10^{-4}\,lbm$$

Mass of the condensed water:

$$m_{w_2} = m_{v_1} - m_{v_2} = 3.98 \times 10^{-4}\,lbm$$

$$W = mg = (3.98 \times 10^{-4}\,lbm)(32.2\,ft/s^2) = 0.013\ lbf\ H_2O$$

$$\frac{96\ tsp}{1\ lb\ H_2O}(0.013\ lbf\ H_2O) = \underline{\underline{1.2\ \text{teaspoons of } H_2O \text{ will condense}}}$$

Will condensation occur if the pod is only serviced in the afternoon?
Worst case scenario occurs in September.

Myforecast.com reports that in September:

$\phi = 63\%$ relative humidity in the afternoon
$T = 24°C$ (75.2°F) Average high temperature

FOR INITIAL POD TEMP 76°F, SATURATION PRESSURE $P_g = .4446 \text{ lbf/in}^2$

$$P_v = \phi P_g$$

$$= (.63)(.4446 \text{ lbf/in}^2)$$

$$P_v = .2801 \text{ lbf/in}^2$$

$$v = \frac{\bar{R} T_1}{M_v P_v}$$

$$= \frac{\left(1545 \frac{\text{ft} \cdot \text{lbf}}{\text{lbmol} \, °\text{R}}\right)(76 + 460.7 °\text{R})}{(18.02 \text{ lbm/lbmol})(.2801 \text{ lbf/in}^2)}$$

$$v = 164283 \text{ ft}^3/\text{lbm}$$

Table A-2E ⇒ Find temperature where $v_g \approx 164283 \text{ ft}^3/\text{lbm}$

$T < 32°F$ ∴ Condensation will not occur

* Pod should only be serviced in the afternoon so that condensation will not occur.

How about a less humid month? (Still in the morning.)

Myforecast.com reports that in December:

$\phi = 79\%$ relative humidity in the morning
$T = 18\,°C\ (64.4\,°F)$ Average high temperature

For initial pod temp 64°F, saturation pressure $P_g = .2952\ lbf/in^2$

$$P_v = \phi P_g$$

$$= (0.79)(.2952\ lbf/in^2)$$

$$P_v = .2332\ lbf/in^2$$

$$v = \frac{\bar{R} T_1}{M_v P_v}$$

$$= \frac{(1545\ \frac{ft \cdot lbf}{lbmol\ °R})(64 + 460.7\,°R)}{(18.02\ lbm/lbmol)(.2332\ lbf/in^2)} \left(\frac{ft^2}{144\ in^2}\right)$$

$$v = 1339.6\ ft^3/lbm$$

Table A-2E ⇒ Find temperature where $v_g \approx 1339.6\ ft^3/lbm$

$T \approx 57\,°F\ (13.9\,°C)$ condensation will begin

∴ Condensation is likely to occur, but how much?

$$m_{v_1} = \frac{V}{v_{v_1}}$$

$$= \frac{.79\ ft^3}{1339\ ft^3/lbm}$$ using V of air in the pod and v that were previously calculated

$m_{v_1} = 5.90 \times 10^{-4}\ lbm$ mass of water vapor initially present in the pod before cooling

Need quality to determine mass of water vapor present at the final cooled temp

$$x_2 = \frac{v_{v_2} - v_{f_2}}{v_{g_2} - v_{f_2}}$$

v_{f_2} saturated liquid specific volume at final temp
v_{g_2} saturated vapor specific volume at final temp
$v_{v_2} = v_{v_1}$ specific volume constant b/c V constant

$$= \frac{1339.6\ \frac{ft^3}{lbm} - 0.01603\ ft^3/lbm}{1482\ ft^3/lbm - 0.01603\ ft^3/lbm}$$

$$x_2 = .9039$$

Mass of water vapor present after cooling:

$$m_{v_2} = (.9039)(5.90 \times 10^{-4}\ lbm) = 5.33 \times 10^{-4}\ lbm$$

Mass of condensed water:

$$m_{w_2} = m_{v_1} - m_{v_2} = 0.57 \times 10^{-4} \, lbm$$

$$W = mg = (0.57 \times 10^{-4} \, lbm)(32.2 \, ft/s^2) = 0.0018 \, lbf \; H_2O$$

$$\frac{96 \, tsp}{1 \, lb \; H_2O}(0.0018 \, lbf \; H_2O) = \underline{.176 \text{ teaspoons of } H_2O \text{ will condense}}$$

This time, we will use reverse engineering to figure out the acceptable pod maintenance conditions. All the same assumptions will be used.

We are interested in finding the maximum Temperature (T) and humidity (ϕ) the pod can be opened and serviced in without causing condensation to occur.

For an initial ambient temperature T=20°C (68°F), using Table A-2E:

$P_g = .3391\ lbf/in^2$ saturation pressure for T_1

$v_g = 1482\ ft^3/lbm$ specific volume of saturated vapor at T_2, the temperature of the ocean (54°F)

$$v_g = \frac{\bar{R}T_1}{M_v P_v}$$ solve for P_v

$$P_v = \frac{(1545\ \frac{ft \cdot lbf}{lbmol\ °R})(68 + 460.7°R)}{(18.02\ lbm/lbmol)(1482\ ft^3/lbm)}\left(\frac{ft^2}{144\ in^2}\right)$$

$$P_v = .2124\ psi$$

$$\phi_{CRITICAL} = \frac{P_v}{P_g}$$

$$= \frac{.2124\ psi}{.3391\ psi}$$

$$\phi_{CRITICAL} = 62.64\%$$

∴ One data point is T=68°F, ϕ = 62.64%
This is a temperature and humidity combination for which condensation will occur. The recommended limit is 5% below this to be safe.

Two more data points have been calculated to ensure a linear projection is appropriate.

Let's verify that 5% is a reasonable relative humidity percentage to subtract.

$$\phi_{CRITICAL} = \frac{P_v}{P_g}$$

$$(62.64 - 5)\% = \frac{P_v}{.3391\ psi}$$

$$P_v = .1955\ psi$$

$$v_g = \frac{\bar{R}T_1}{M_v P_v}$$

$$= \frac{(1545\ \frac{ft \cdot lbf}{lbmol\ °R})(68 + 460.7)}{(18.02\ \frac{lbmol}{lbm})(.1955\ lbf/in^2)}\left(\frac{ft^2}{144 in^2}\right)$$

$v_g = 1610.2\ ft^3/lbm$ ⟶ Actual dew temperature corresponding to this v_g in Table A-2E: 51°F (10.6°C)

This is reasonable. The ocean should never reach 10.6°C.

Excel Calculations for Critical Temperature & Humidity

Source:	Calculated	"Given"	Table A.2E	Calculated	Calculated	Calculated
	Ambient Temperature, T1 (*C)	Ambient Temperature, T1 (*F)	Saturation Pressure, Pg (psi)	Corresponding Pv (lbf/in^2)	Critical Humidity Limit	Recommended Limit
	20.0	68	0.3391	0.2124	62.64%	57.64%
	25.6	78	0.4750	0.2164	45.56%	40.56%
	26.7	80	0.5073	0.2172	42.82%	37.82%

Constant factors

Name	Value	Units
R	1545	ft*lbf/(lbmol*R)
Mv	18.02	lbm/lbmol
Vg (@ 12.4C)	1482	Ft^3/lbm

Deg F

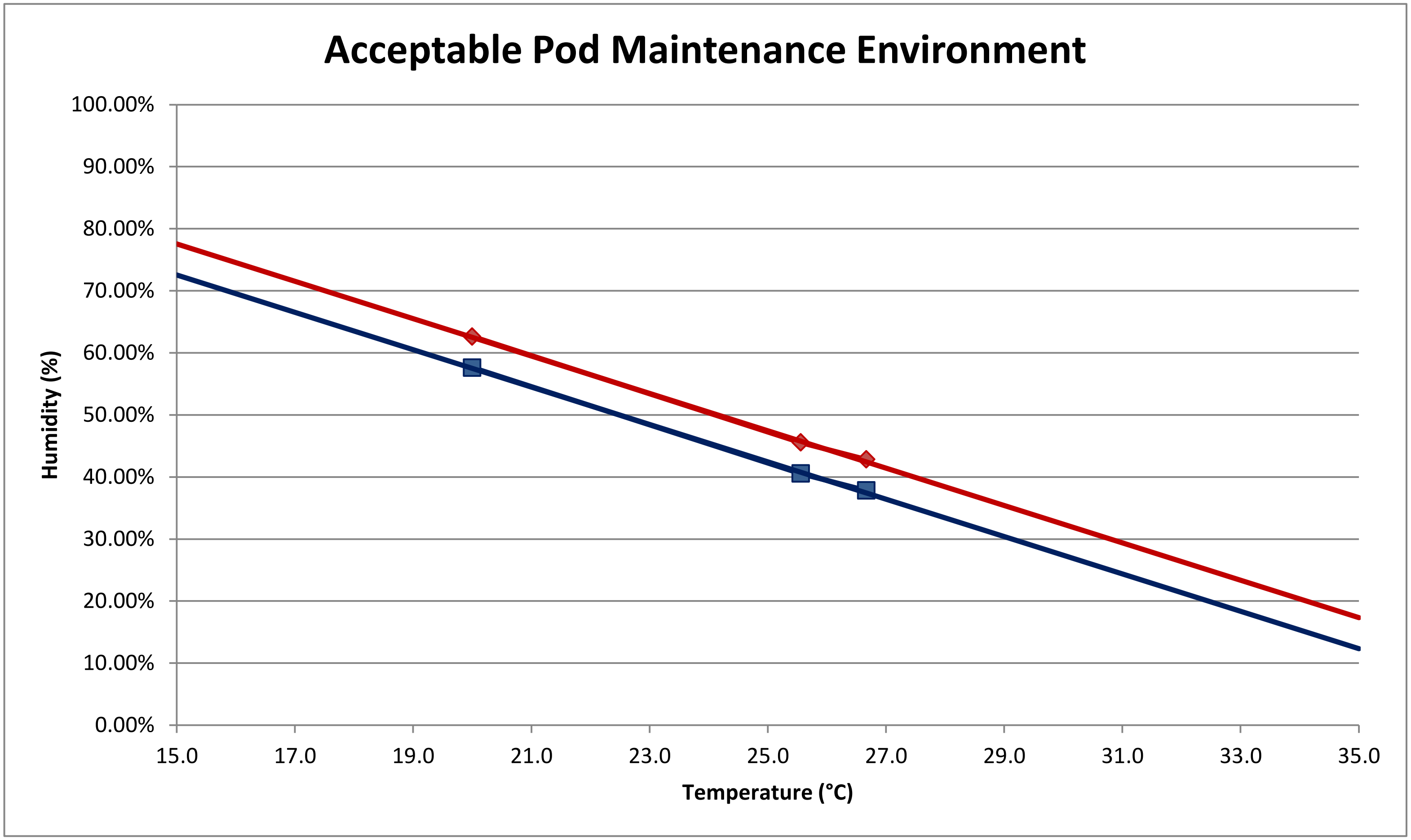
Points for Critical Limit Eqn		Recommended limit Eqn	
60	0.7592	60	0.7092
70	0.5922	70	0.5422
80	0.4252	80	0.3752
90	0.2582	90	0.2082

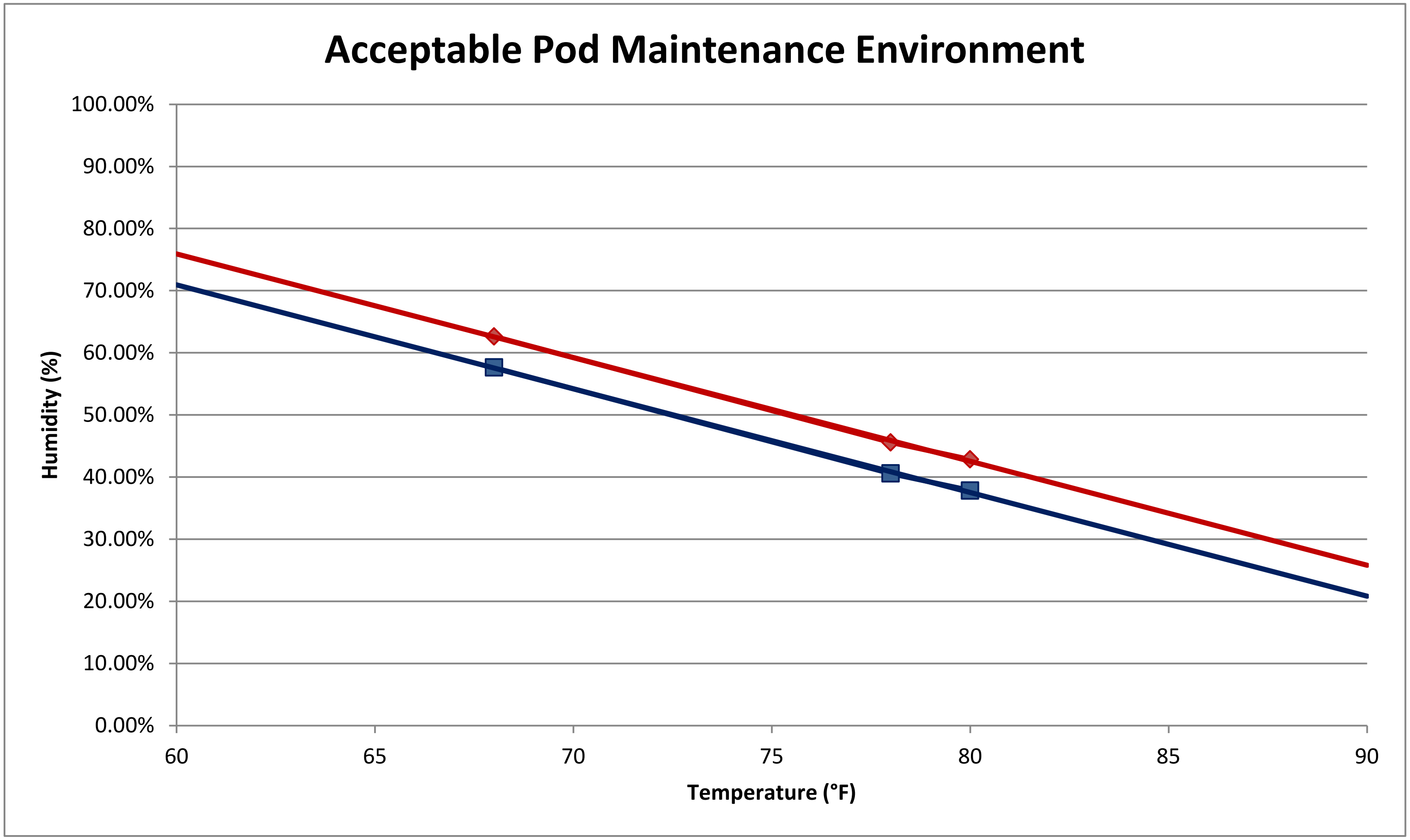
CRITICAL LIMIT EQN Y = -0.0167x + 1.7612
RECOMMENDED LIMIT EQN Y = -0.0167x + 1.7112

DegC

Points for Critical Limit Eqn		Recommended Limit Eqn	
15	0.7754	15	0.7254
20	0.6249	20	0.5749
35	0.1734	35	0.1234

CRITICAL LIMIT EQN Y = -.0301X + 1.2269
RECOMMENDED LIMIT EQN y = -.0301X + 1.1769


Acceptable Pod Maintenance Environment
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
Humidity (%)
15.0
17.0
19.0
21.0
23.0
25.0
27.0
29.0
31.0
33.0
35.0
Temperature (°C)


Acceptable Pod Maintenance Environment
Humidity (%)
100.00%
90.00%
80.00%
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
60
65
70
75
80
85
90
Temperature (°F)

MINIMUM WATER TEMPERATURE FOR CONDENSATION CALCULATIONS

Assumptions

- There is a linear variance in the temperature of the ocean water during the winter for the first ~100ft. This is a reasonable assumption based on thermocline plots online published by the Office of Naval Research (www.onr.navy.mil/focus/ocean/water/temp3.htm). This is especially true for ocean temperatures during the winter, which will be used here.
- Ocean temperatures are fairly constant during Winter

Based on online data from the Cal Poly Profiler on the pier in October:

DEPTH	MINIMUM TEMPERATURE
2 m (6.6ft)	~13.6°C
8 m (26ft)	~12.9°C

By plotting these points, the relation between depth and temperature can be represented by:

$$y = (-0.1167\ \tfrac{°C}{m})\,x + 13.833°C$$

where x = depth in meters
y = temperature in °C

By extrapolating, we can find the temperature of the water at the bottom of the pier:

$$y = (-0.1167\ \tfrac{°C}{m})(12.2m) + 13.833°C$$

$$y = 12.4°C$$

We will estimate the minimum temperature of the ocean water as 12°C in order to generate conservative numbers.

POD TEMPERATURE CALCULATIONS

ACRYLIC PROPERTIES

$K \approx .2 \frac{W}{m \cdot K}$ thermal conductivity

$\beta \approx 70\text{-}77 \times 10^{-6}\ K^{-1}$ thermal expansion coefficient

SEA WATER PROPERTIES

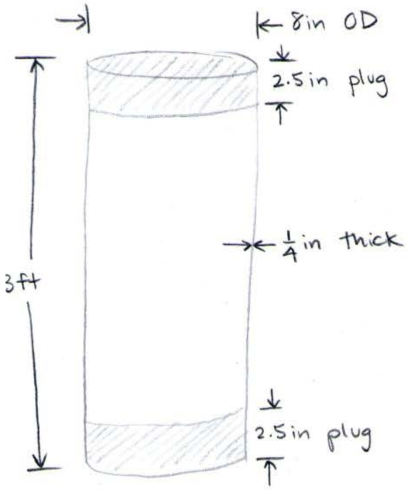
$K = .596 \frac{W}{m \cdot K}$ thermal conductivity

$\beta = 250 \times 10^{-6}\ 1/K$ thermal expansion coefficient

$\nu = 1.05 \times 10^{-6}\ m^2/s$ Kinematic viscosity

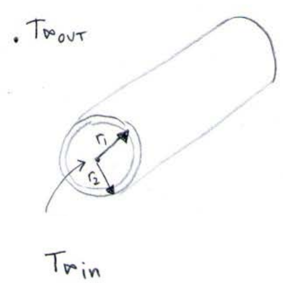
$\alpha = 1.46 \times 10^{-7}\ m^2/s$ thermal diffusivity

$Pr = 7.2$ Prandtl number



ASSUMPTIONS

- 2.5in thick solid acrylic plugs are perfect insulation and no heat transfer occurs out of the top or bottom of the pod
- the pod is isothermal due to the fans
- radiation is negligible
- free convection is the main form of heat transfer. (The water in the ocean will actually be flowing, so forced convection will occur most often. However, we will assume there is no water movement to be conservative. In reality, water movement would cause higher heat transfer rates.)



- The assumed water temperature is the high average temperature of the water at Avila Beach (via beachcalifornia.com). This temperature has been affirmed by Cal Poly Profiler data.

$T_{\infty_{OUT}} = 15.56°C$

$T_{\infty_{IN}} = 72°C$ (specified max internal pod temperature)

$r_1 = 3.875$ in

$r_2 = 4$ in

- The vertical cylinder can be treated as a flat vertical plate (to be verified after calculations)

APPROXIMATE Q BEING GENERATED WITHIN THE POD:

LED INFO:

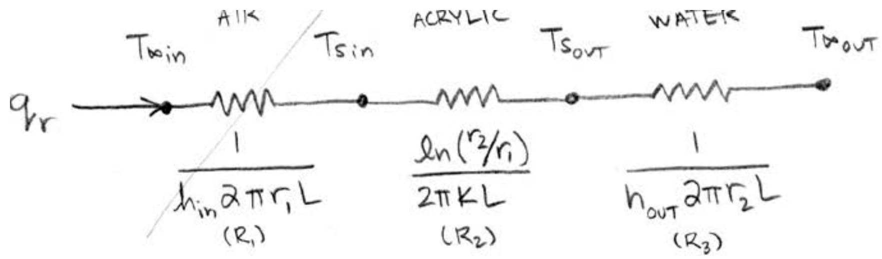
CURRENT MAX: 3A

FORWARD VOLTAGE: 2.9V

$P = IV = (3A)(2.9V) = 8.7$ Watts (for EACH LED)

☆ Assume the rest of the electronics have a heat output equal to 1 LED. This should be an overestimate.

$q_{in} = 8.7\,W(7) = \underline{\underline{60.9\,W}}$ max heat generated



Need to find h terms...

$$Ra_L = \frac{g\beta(T_s - T_\infty)L^3}{\nu\alpha}$$

for water on the outside of the acrylic pod...

$$Ra_L = \frac{(9.81\ m/s^2)(250\times10^{-6}\ 1/K)(72-15.56\ K)(.91m)^3}{(1.05\times10^{-6}\ m^2/s)(1.46\times10^{-7}\ m^2/s)}$$

$$Ra_L = 6.80\times10^{11} \longrightarrow \text{turbulent: } C = .10,\ n = \tfrac{1}{3} \quad (10^9 \lesssim Ra < 10^{13})$$

$$Nu_L = \frac{\bar{h}L}{K} = C Ra_L^n$$

$$\Rightarrow \frac{\bar{h}(.91m)}{(.596\ \frac{W}{m\cdot K})} = .1(6.80\times10^{11})^{1/3}$$

$$\bar{h}_{sea\ H_2O} = 576\ \frac{W}{m^2K}$$

for air inside the acrylic pod... assume an isothermic pod, & $T_s = T_{\infty in} = 72°C$

$$q_r = \frac{T_{\infty in} - T_{\infty OUT}}{R_1 + R_2 + R_3}$$

(R_1: $\emptyset$ isothermic)

$$q_r = \frac{(72-15.56)\ K}{\dfrac{\ln\left(\frac{4\ in}{3.875\ in}\right)}{2\pi(.2\ \frac{W}{m\cdot K})(.91m)} + \dfrac{1}{(576\ \frac{W}{m^2K})(2\pi)(.1016m)(.91m)}}$$

$q_r = 1844\ W \gg 60.9\ W$ maximum heat output of pod

Yay! No overheating!

Intro to Heat Transfer (Bergman) 6th Edition, states that vertical cylinders can be treated as vertical plates IF:

$$\frac{D}{L} \gtrapprox \frac{35}{Gr^{1/4}}$$

$Ra = Gr\,Pr$

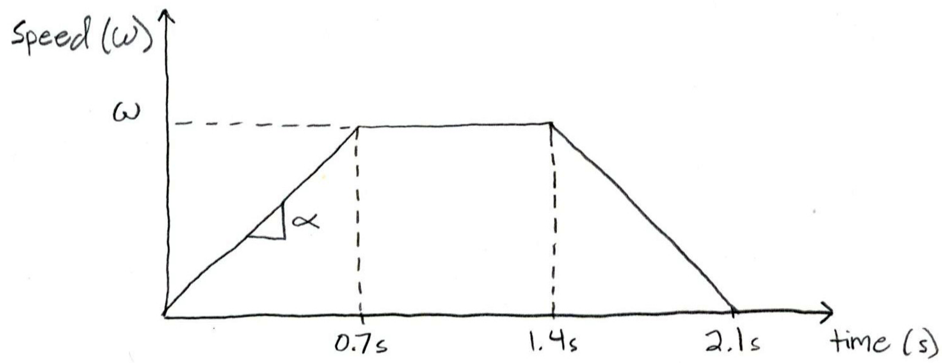
↳ Using Ra calculated on previous page & Pr for seawater, **7.2**:

$$Ra = 6.80 \times 10^{11} = Gr(7.2)$$
$$Gr = 9.44 \times 10^{10}$$

$$\frac{8\text{in}}{36\text{in}} \overset{?}{\gtrapprox} \frac{35}{(9.44 \times 10^{10})^{1/4}}$$

$.\overline{2} \gtrapprox .063$ It is safe to assume the pool behaves as a vertical plate

Motion Velocity Profile



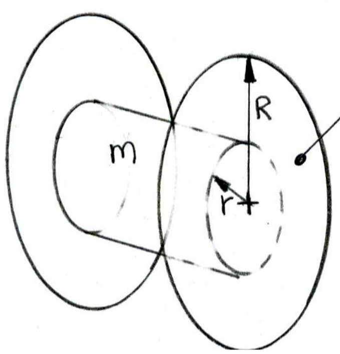
$$\omega = \frac{\text{max speed}}{\pi \cdot \phi}$$

$$\omega = 1\ ft/s \times \frac{1\ rev}{(20\ in \times \pi)} \times \left|\frac{12\ in.}{1\ ft.}\right| \times \left|\frac{2\pi\ rad}{1\ rev}\right|$$

$$\omega = 1.2\ rad/s$$

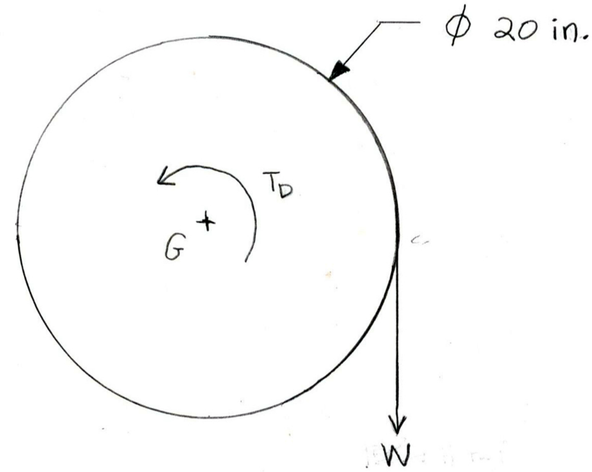
$$\alpha = \frac{\Delta \omega}{\Delta t}$$

$$\alpha = \frac{1.2\ rad/s}{0.7\ s}$$



R = 15 in.
M = 15 lbm.

r = 10 in.
m = 10 lbm.



$$\sum M_G : T_D - W \cdot r = I_D \alpha$$

$$I_D = 2\left(\frac{1}{2} M R^2\right) + m r^2$$

M = 15 lbm
R = 15 in.

m = 10 lbm
r = 10 in.

$$I_D = 2\left[\frac{15\ lbm}{2} \cdot \left(\frac{15\ in}{12\ in/ft}\right)^2\right] + 10\ lbm \times \left(\frac{10\ in.}{12\ in./ft}\right)^2$$

$$I_D = 30.38\ lbm \cdot ft^3 \times \frac{1\ slug}{32.17\ lbm}$$

$$I_D = 0.944\ slug\ ft^2$$

$$T = I_{tot}\, \alpha + W \cdot r$$

$$I_{tot} = I_D + I_W$$

I_W is the inertia of the cart weight as if it were a point mass on the drum

$$I_W = M_W \cdot r^2$$

$$I_w = 150 \text{ lbm} \times \left| \frac{1 \text{ slug}}{32.2 \text{ lbm}} \right| \times \left(\frac{10 \text{ in}}{12 \text{ in/ft}} \right)^2$$

$$I_w = 3.23 \text{ slug} \cdot \text{ft}^2$$

$$I_{tot} = 0.944 \text{ slug} \cdot \text{ft}^2 + 3.23 \text{ slug} \cdot \text{ft}^2$$

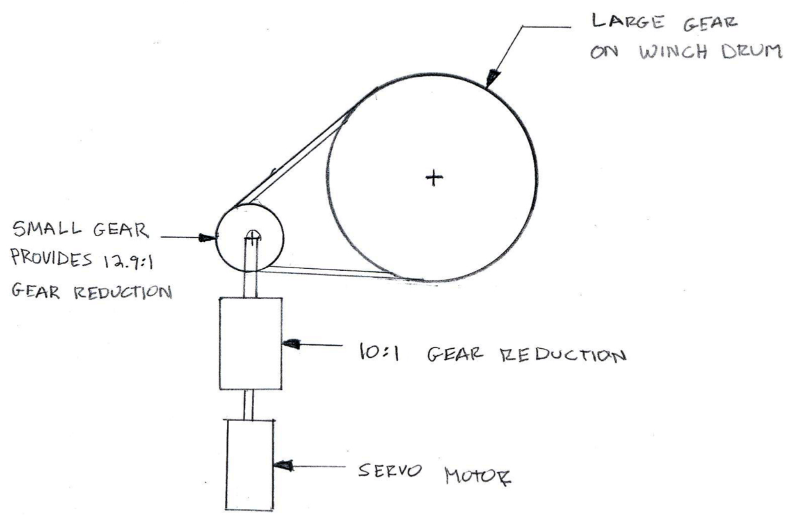
$$I_{tot} = 4.18 \text{ slug} \cdot \text{ft}^2$$

$$T = (4.18 \text{ slug} \cdot \text{ft}^2)(1.714 \text{ rad/s}^2) + 150 \text{ lbf} \times \left(\frac{10 \text{ in}}{12 \text{ in/ft}} \right)$$

$$T = 7.16 \frac{\text{slug} \cdot \text{ft}^2}{\text{s}^2} \times \left| \frac{\text{lbf} \cdot \text{s}^2}{1 \text{ slug ft}} \right| + 125 \text{ lbf} \cdot \text{ft}$$

$$T = 132.16 \text{ ft} \cdot \text{lbf}$$

$$\boxed{T_{max} = 132.16 \text{ ft-lbf}}$$



T_{MA}

$T_{max} = T_{D}$ ~~$_{rea}$~~

$T_{max} = T_D$ (torque on drum)

$$T_{motor} = \frac{T_D}{\text{gear reduction}} \times \frac{1}{(\text{reduction efficiency})}$$

Typical Planetary Efficiency = 85 %

F.S. = 1.25 (to account for chain efficiency)

$$\mathcal{E} = \frac{85\%}{1.25} = 68\%$$

$$T_{motor} = \frac{132.16 \text{ ft lbf}}{129 \cdot 0.68} = 1.51 \text{ ft. lbs.}$$

$$\boxed{T_{motor} = 18.1 \text{ lb-in.}}$$

ENCLOSURE HEAT TRANSFER CALCULATIONS

ALUMINUM PROPERTIES:

$k = 138$ W/m-K

$\beta = 2.38 \times 10^{-5}$ K^{-1}

AIR PROPERTIES:

$k = 0.0271$ W/mK (THERMAL CONDUCTIVITY)

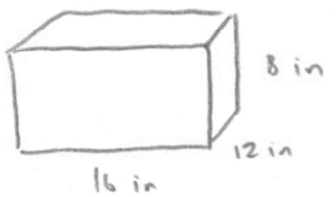
$\beta = 3.20 \times 10^{-3}$ K^{-1} (EXPANSION COEFFICIENT)

$\nu = 1.70 \times 10^{-5}$ m^2/s (KINEMATIC VISCOSITY)

$\alpha = 2.39 \times 10^{-5}$ m^2/s (THERMAL DIFFUSIVITY)

$Pr = 0.711$ (PRANDTL'S NUMBER)

ENCLOSURE SIZE:



16 in → 0.4064 m

12 in → 0.3048 m

8 in → 0.2032 m

WALL THICKNESS: 0.08 in → 0.002032 m

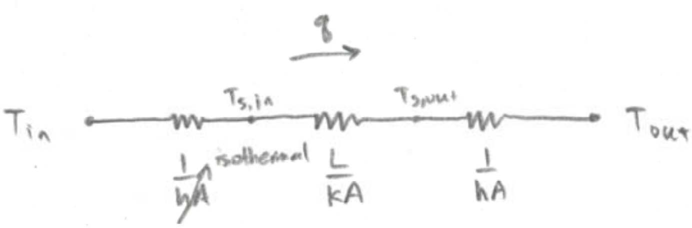
WALL AREA: $h(2W+2L)$ → 0.289 m^2

ASSUMPTIONS:

- HEAT IS EQUALLY DISSIPATED ON EACH WALL
- FREE CONVECTION ONLY.
- OUTSIDE AIR TEMP.: 100°F → 37.8°C
- INSIDE AIR TEMP.: 72°C (MAX ALLOWABLE TEMP.)
- TREAT AS VERTICAL WALL WITH SAME SURFACE AREA.

MOTOR HEAT GENERATED: POWER, W = 450 W

ASSUME 50% EFFICIENCY → $q = 225$ W.



$$Ra_L = \frac{g\beta(T_s - T_\infty)L^3}{\nu\alpha} = \frac{9.81\, m/s^2 \cdot 3.20\times10^{-3}\, 1/K\,(72^\circ C - 37.8^\circ C)(0.2032\, m)^3}{1.70\times10^{-5}\, m^2/s \cdot 2.39\times10^{-5}\, m^2/s}$$

$$= 2.22 \times 10^7 < 10^9 \checkmark$$

$$Nu_L = 0.68 + \frac{0.67 \cdot Ra_L^{\frac{1}{4}}}{\left[1 + \left(\frac{0.492}{Pr}\right)^{9/16}\right]^{4/9}} = 0.68 + \frac{0.67 \cdot (2.22 \times 10^7)^{\frac{1}{4}}}{\left[1 + \left(\frac{0.492}{0.711}\right)^{9/16}\right]^{4/9}}$$

$$= 35.97 = \frac{hL}{k}$$

$$h = \frac{Nu_L \cdot k}{L} = \frac{35.97 \cdot 0.0271 \ W/mK}{0.2032 \ m} = 4.80 \ W/m^2K$$

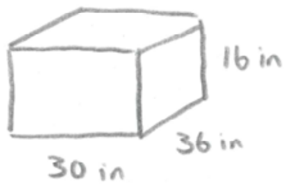
$$q = \frac{T_{in} - T_{out}}{\frac{L}{kA} + \frac{1}{hA}} = \frac{72°C - 37.8°C}{\frac{0.002032 \ m}{138 \ W/mK \cdot 0.284 \ m^2} + \frac{1}{4.80 \ W/m^2K \cdot 0.284 \ m^2}}$$

$$= \boxed{47.4 \ W} < 225 \ W$$ (NOT GOOD)

REDO OF HEAT CALCULATIONS

PROPERTIES ARE STILL THE SAME.

ENCLOSURE SIZE:

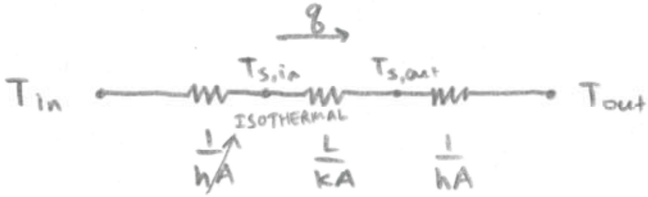


30 in → 0.762 m
36 in → 0.9144 m
16 in → 0.4064 m

WALL THICKNESS: 0.08 in → 0.002032 m
WALL AREA: $h(2W+2L) = 1.363\ m^2$

ASSUMPTIONS:

- OUTSIDE AIR TEMP: 30°C
- INSIDE AIR TEMP: 40°C (MAX ALLOWABLE TEMP.)



$$Ra_L = \frac{g\beta(T_s - T_\infty)L^3}{\nu\alpha} = \frac{9.81\ m/s^2 \cdot 3.20\times10^{-3}\ \frac{1}{K}\ (40°C - 30°C)(0.4064\ m)^3}{1.70\times10^{-5}\ m^2/s \cdot 2.39\times10^{-5}\ m^2/s}$$

$$= 5.19\times10^7 < 10^9 \ ✓$$

$$Nu_L = 0.68 + \frac{0.67 \cdot Ra_L^{\frac{1}{4}}}{\left[1 + \left(\frac{0.492}{Pr}\right)^{9/16}\right]^{4/9}} = 0.68 + \frac{0.67(5.19\times10^7)^{\frac{1}{4}}}{\left[1 + \left(\frac{0.492}{0.711}\right)^{9/16}\right]^{4/9}}$$

$$= 44.33 = \frac{hL}{k}$$

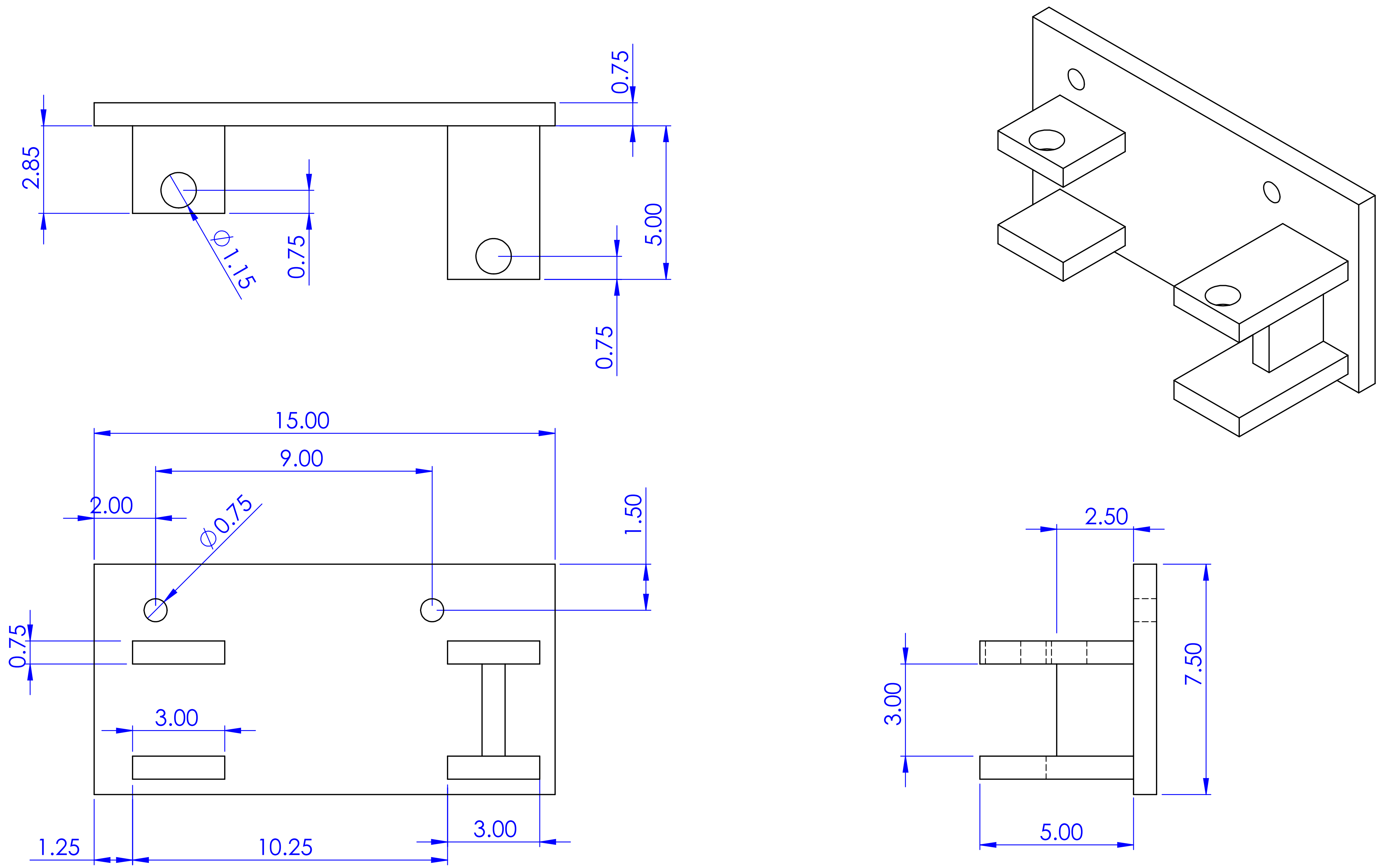
$$h = \frac{Nu_L \cdot k}{L} = \frac{44.33 \cdot 0.0271\ W/mK}{0.4064\ m} = 2.956\ W/m^2K$$

$$q = \frac{T_{in} - T_{out}}{\frac{L}{kA} + \frac{1}{hA}} = \frac{40°C - 30°C}{\frac{0.002032\ m}{138\ W/mK \cdot 1.36\ m^2} + \frac{1}{2.956\ W/m^2K \cdot 1.36\ m^2}}$$

$$= \boxed{40.28\ W} < 225\ W \quad \text{(NOT GOOD)}$$

APPENDIX D:

DRAWINGS



PROPRIETARY AND CONFIDENTIAL

NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

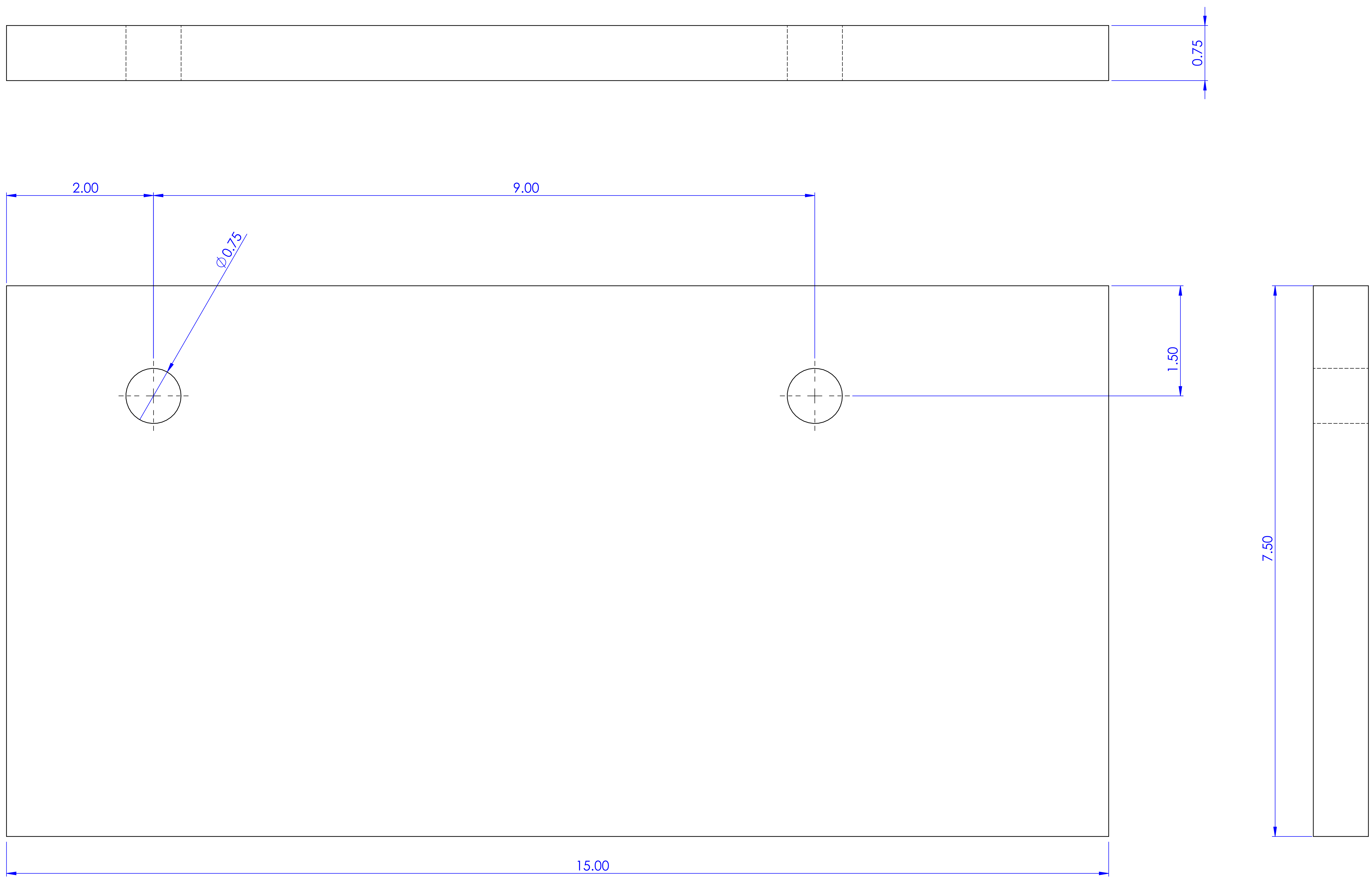
	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

SIZE	DWG. NO.	REV
B	JUSTBRACKET	

SCALE: 1:5 WEIGHT: SHEET 1 OF 1



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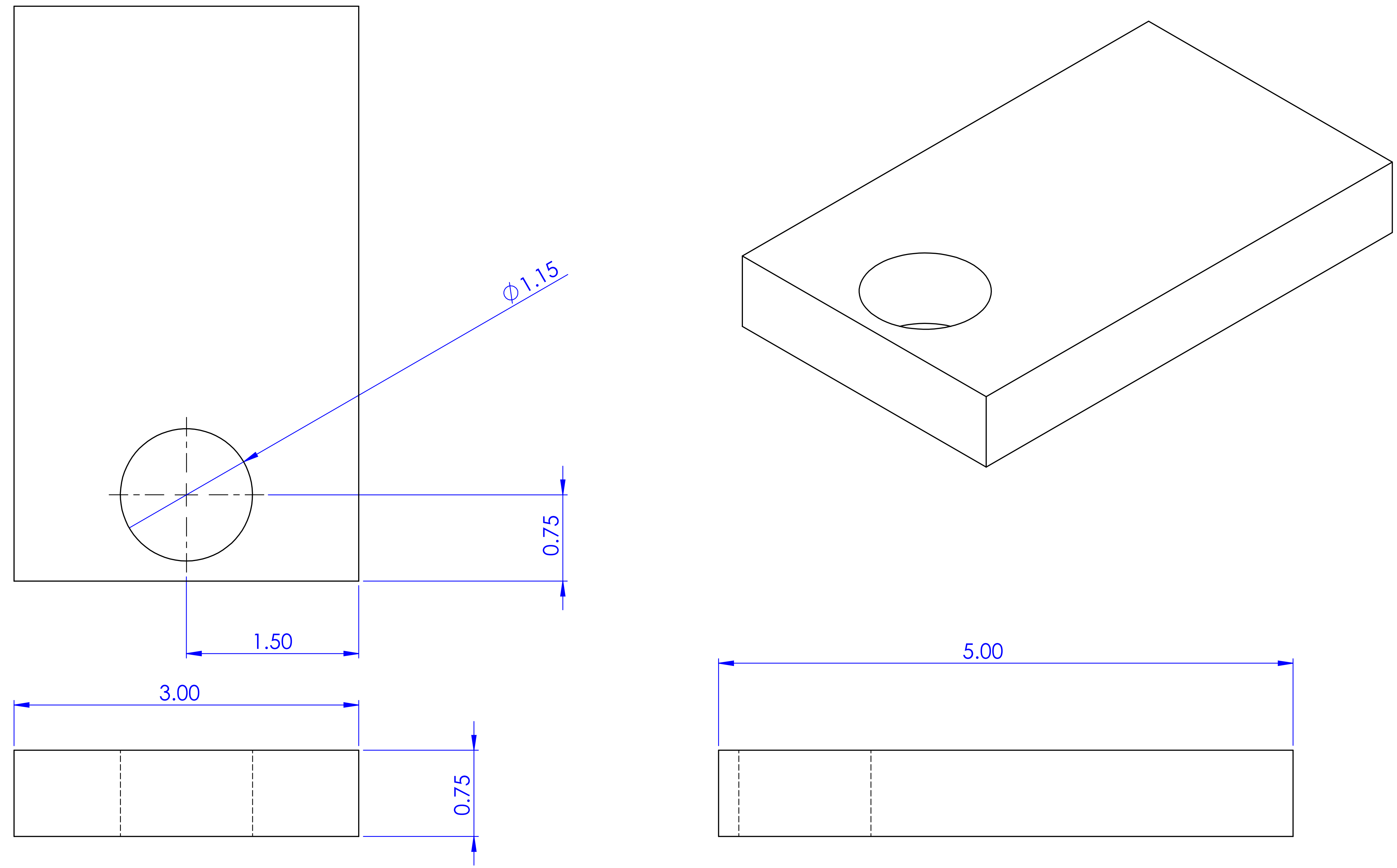
				NAME	DATE
		UNLESS OTHERWISE SPECIFIED:	DRAWN		
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

TITLE:

SIZE	DWG. NO.	REV
	topbracketplatea	
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1



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APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

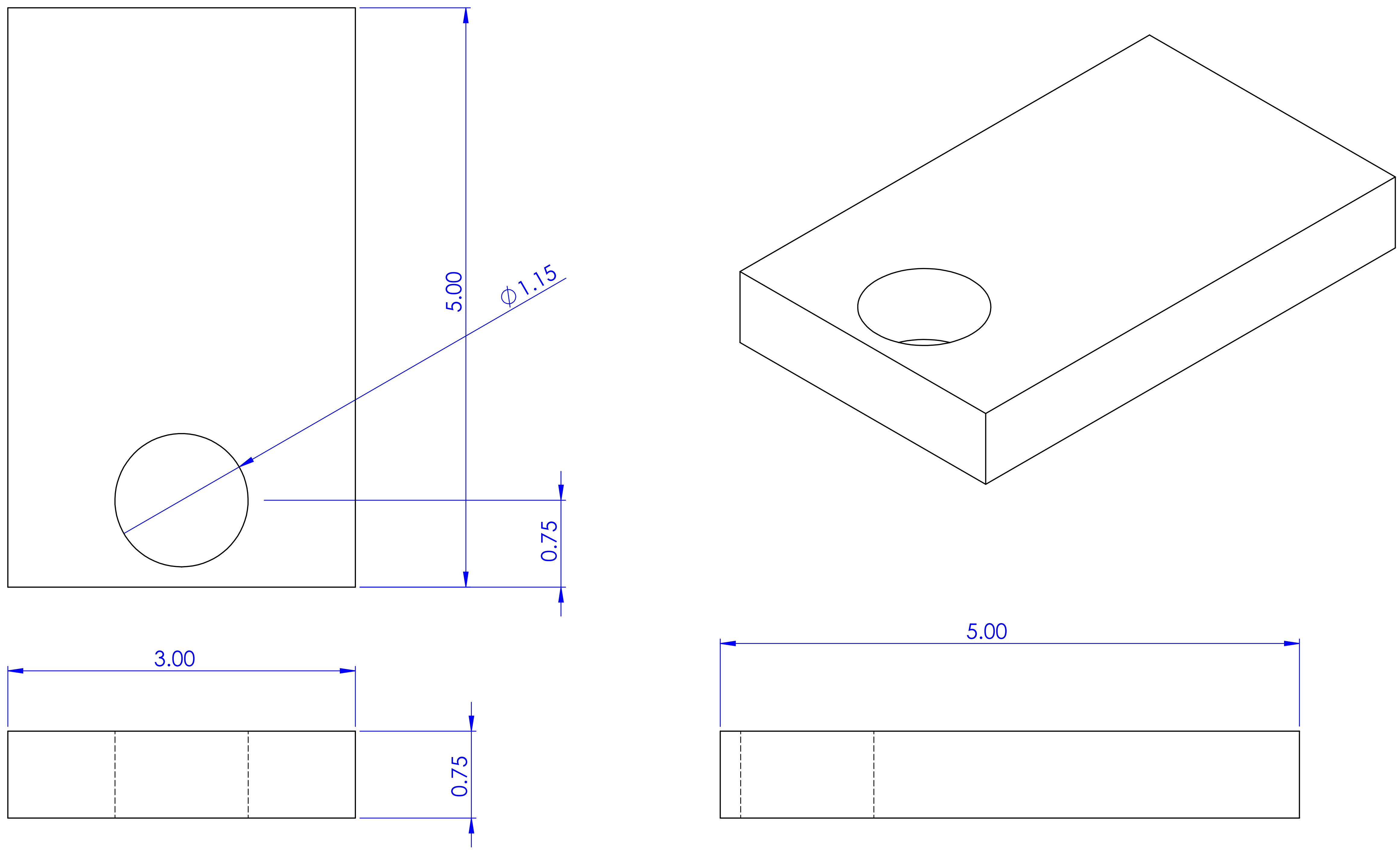
	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

SIZE	DWG. NO.	REV
B	clamparma	

SCALE: 1:1 WEIGHT: SHEET 1 OF 2



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APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

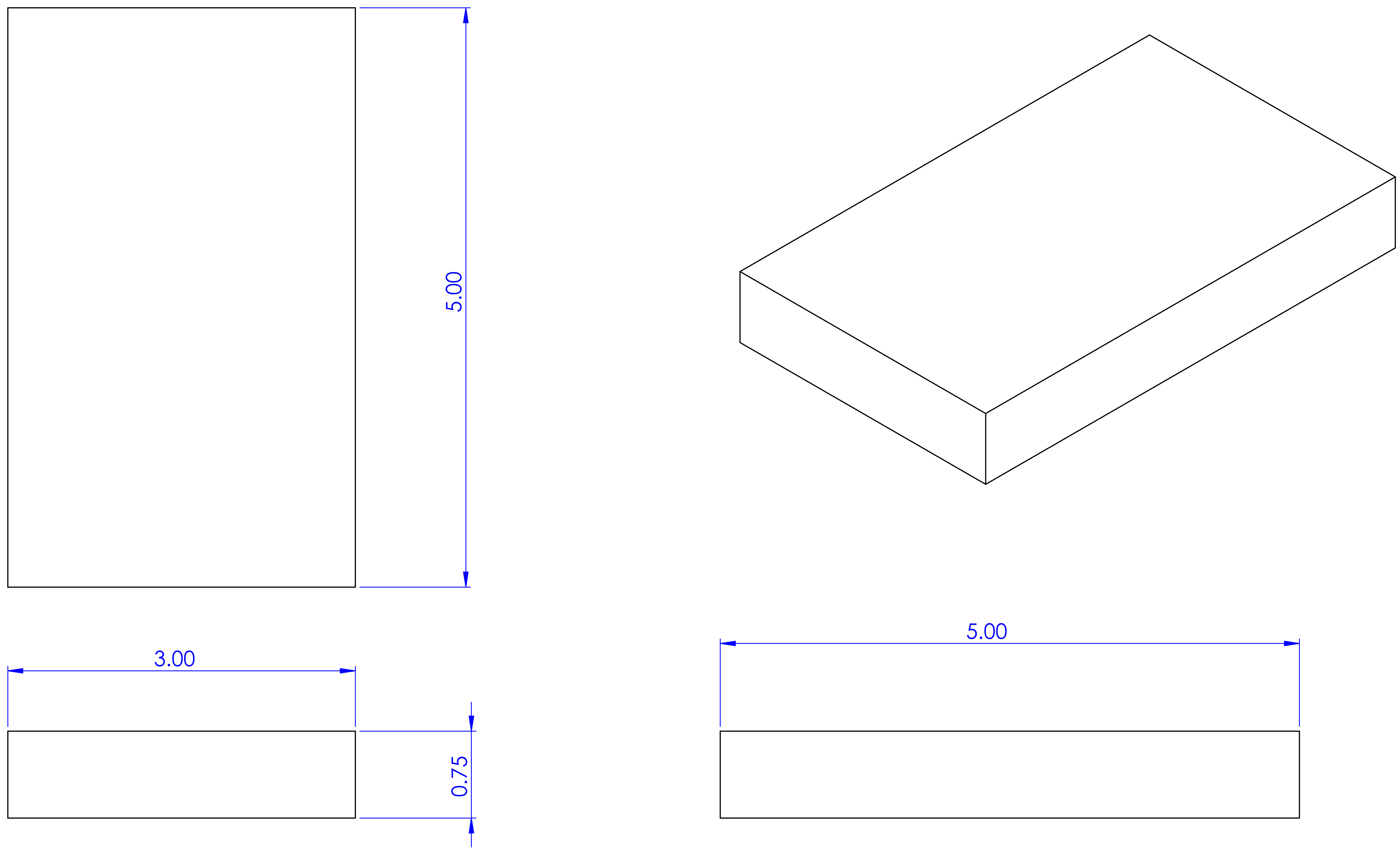
	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

SIZE	DWG. NO.	REV
B	clamparma	

SCALE: 1:1 WEIGHT: SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

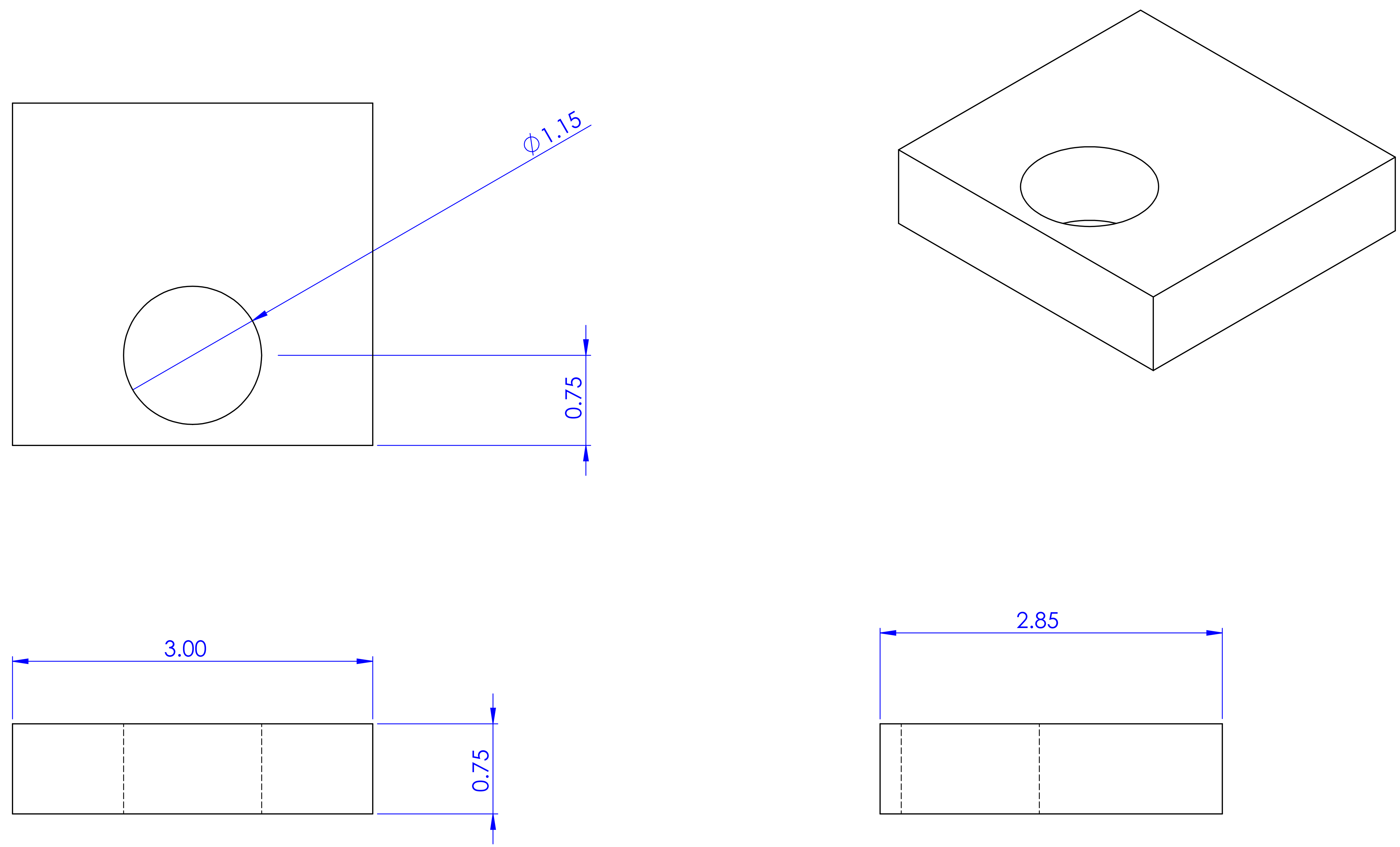
COMMENTS:

NEXT ASSY	USED ON
APPLICATION	

TITLE:

SIZE **B** DWG. NO. clamparma REV

SCALE: 1:1 WEIGHT: SHEET 1 OF 1



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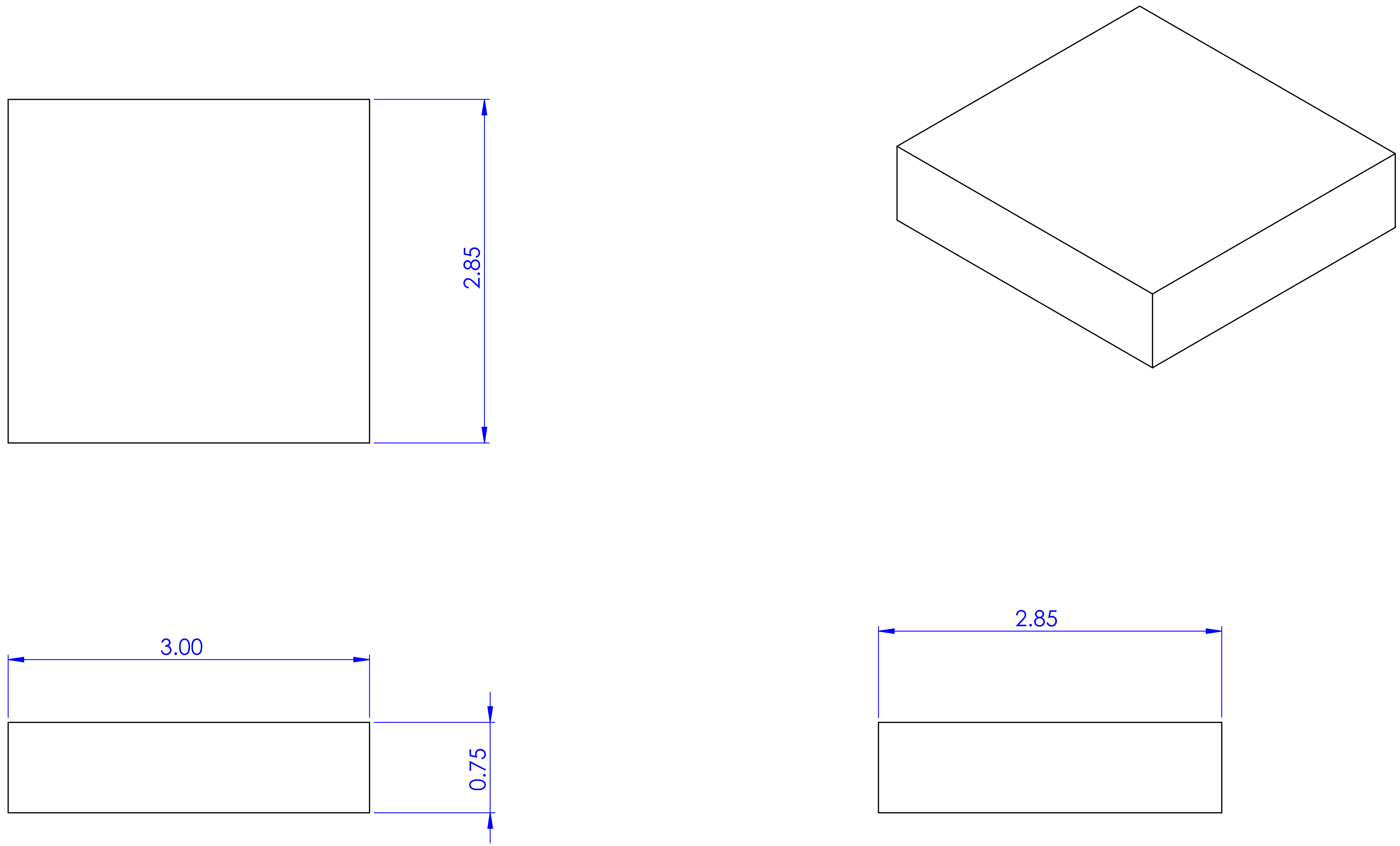
			CHECKED			
			ENG APPR.			
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
		MATERIAL	COMMENTS:			SIZE B DWG. NO. clamparma REV
NEXT ASSY	USED ON	FINISH				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:1 WEIGHT: SHEET 1 OF 1



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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

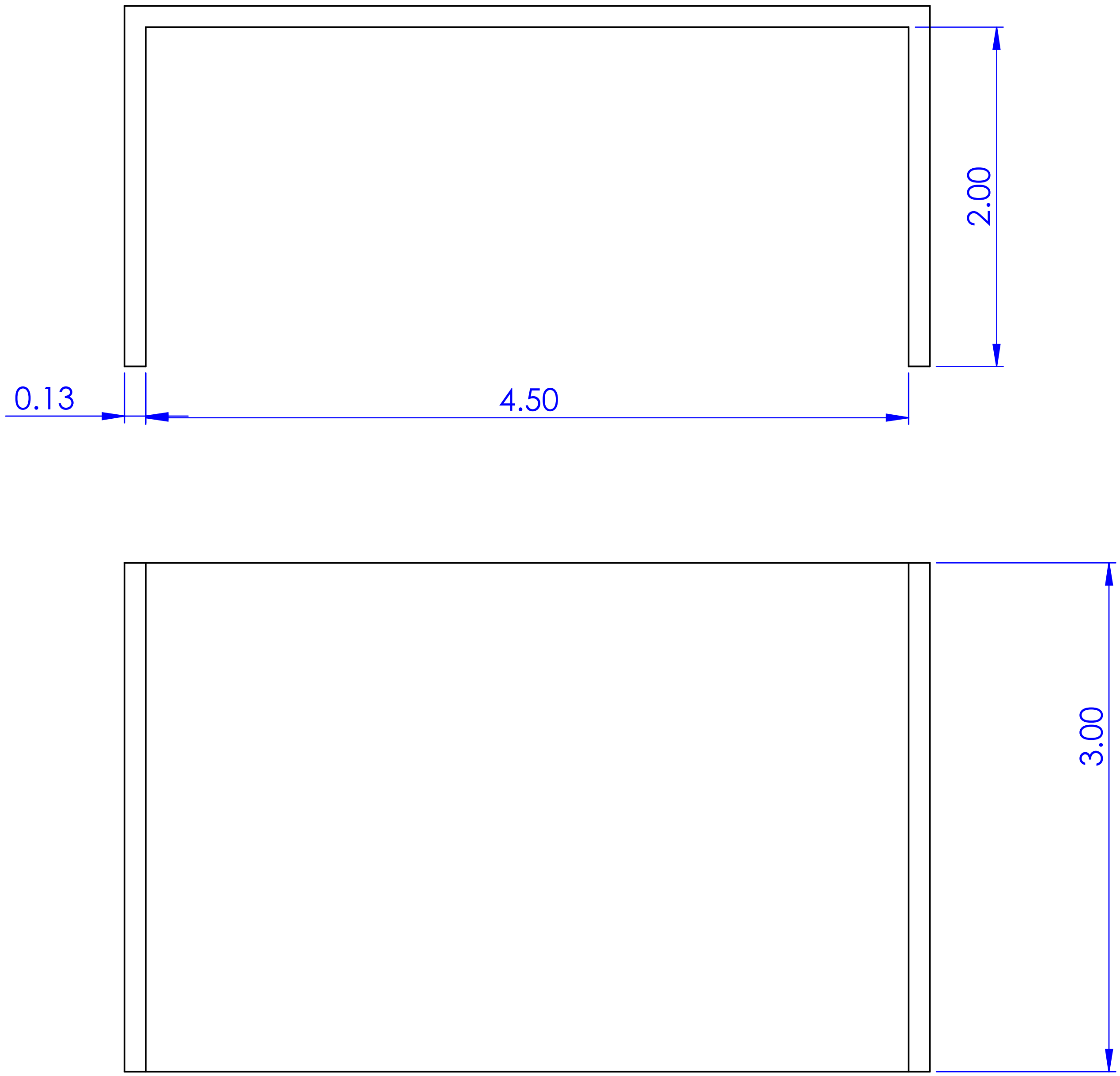
	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:

SIZE	DWG. NO.	REV
B	clamparma	

SCALE: 1:1 WEIGHT: SHEET 1 OF 1



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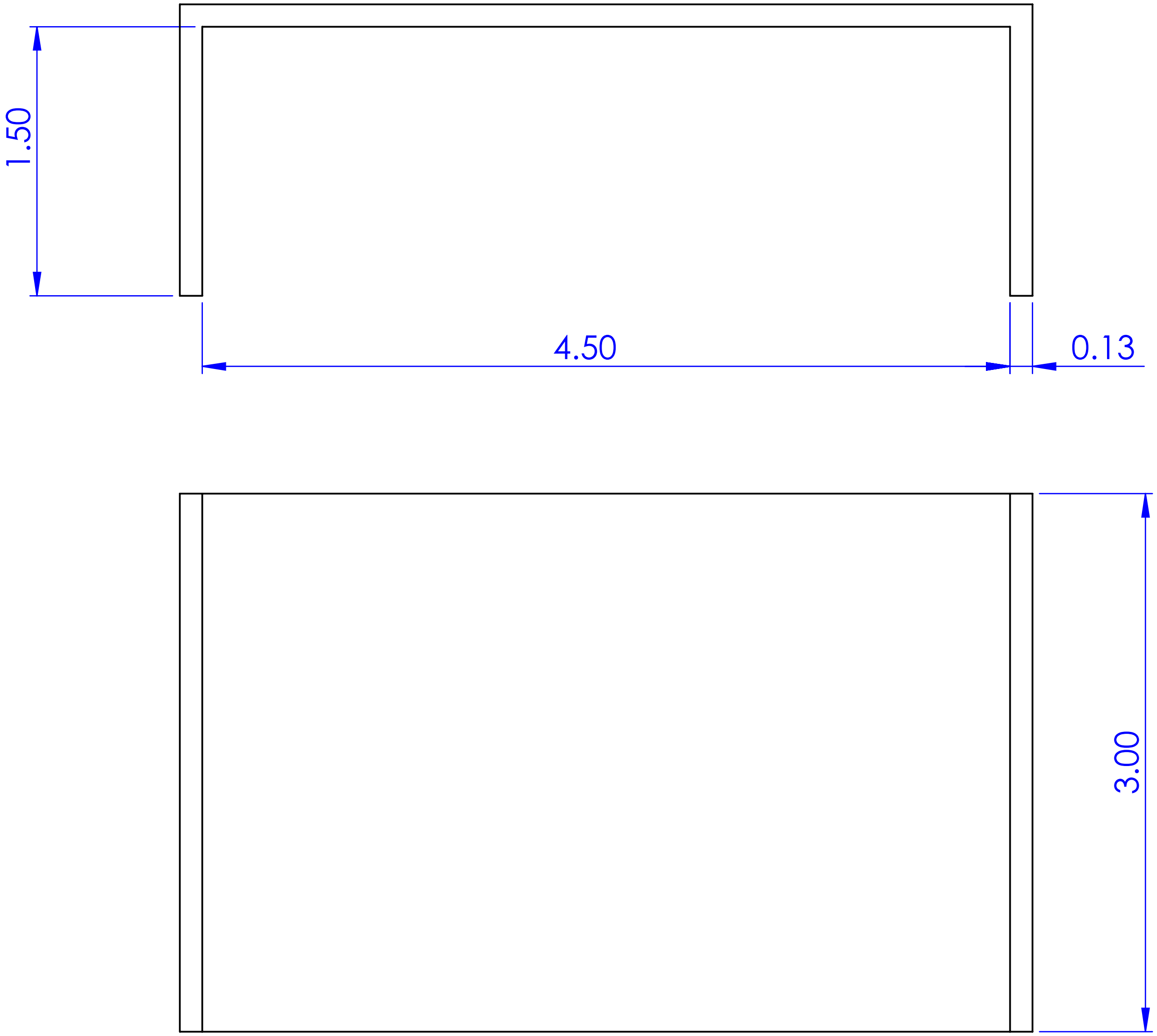
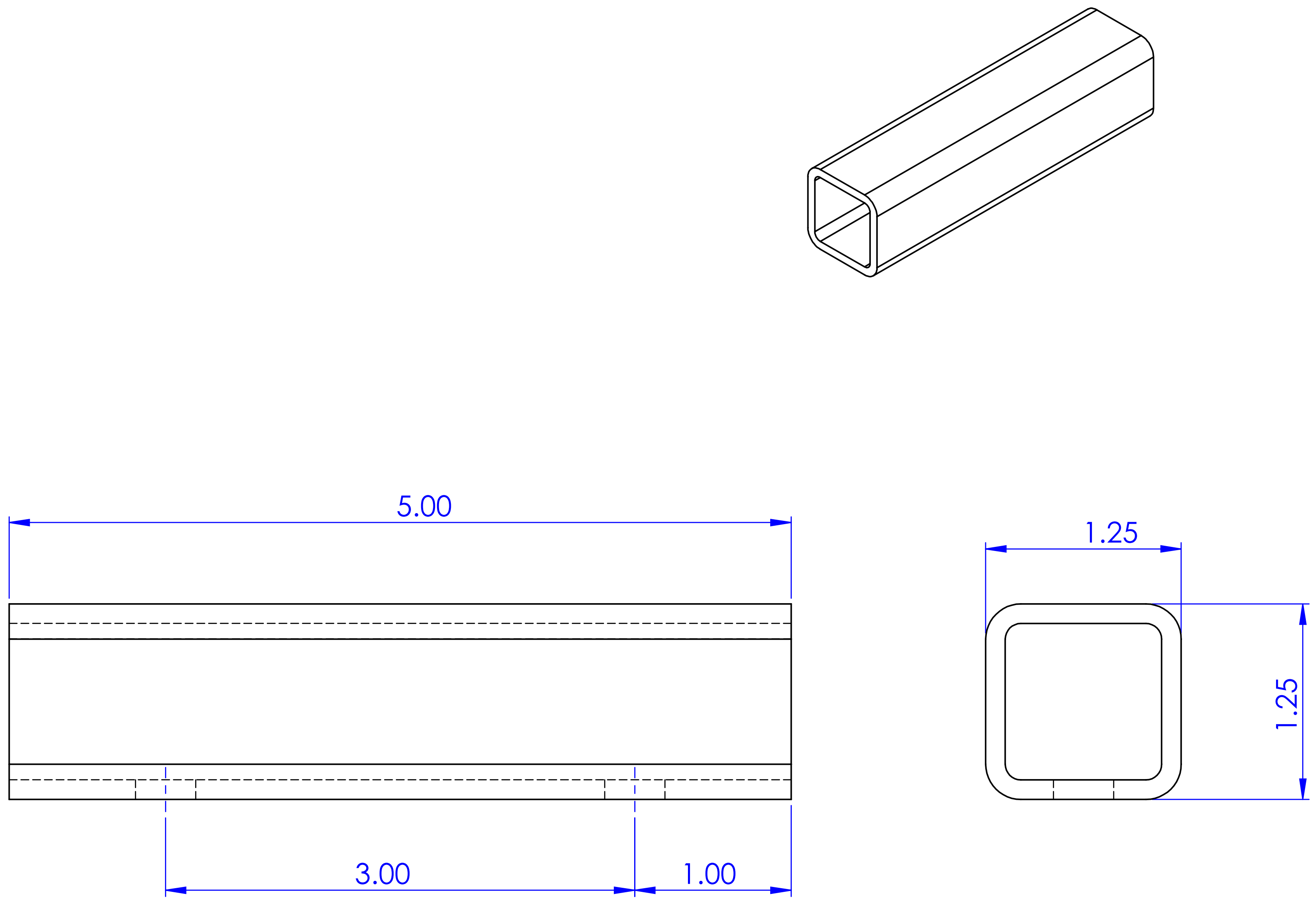
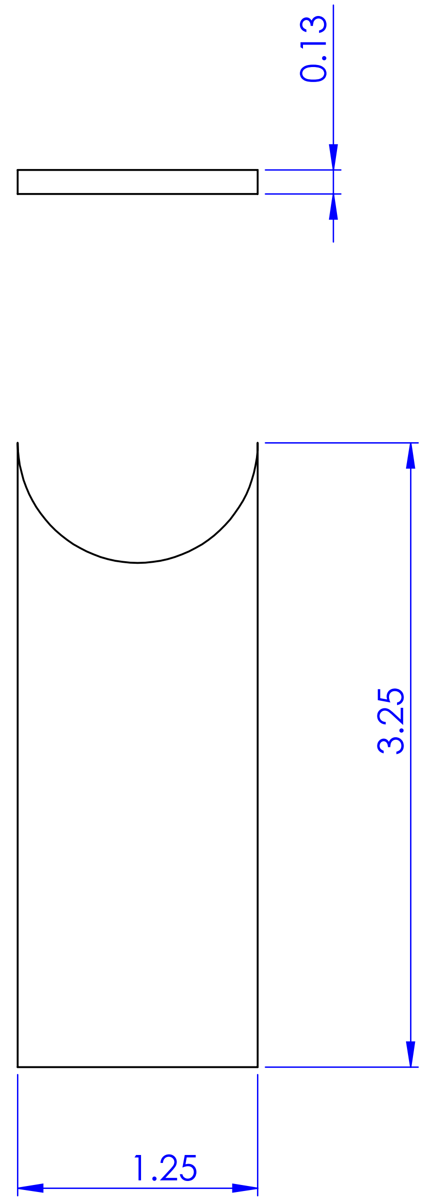
4.50
2.00
3.00



1.50
4.50
0.13
3.00


5.00
1.25
1.25
3.00
1.00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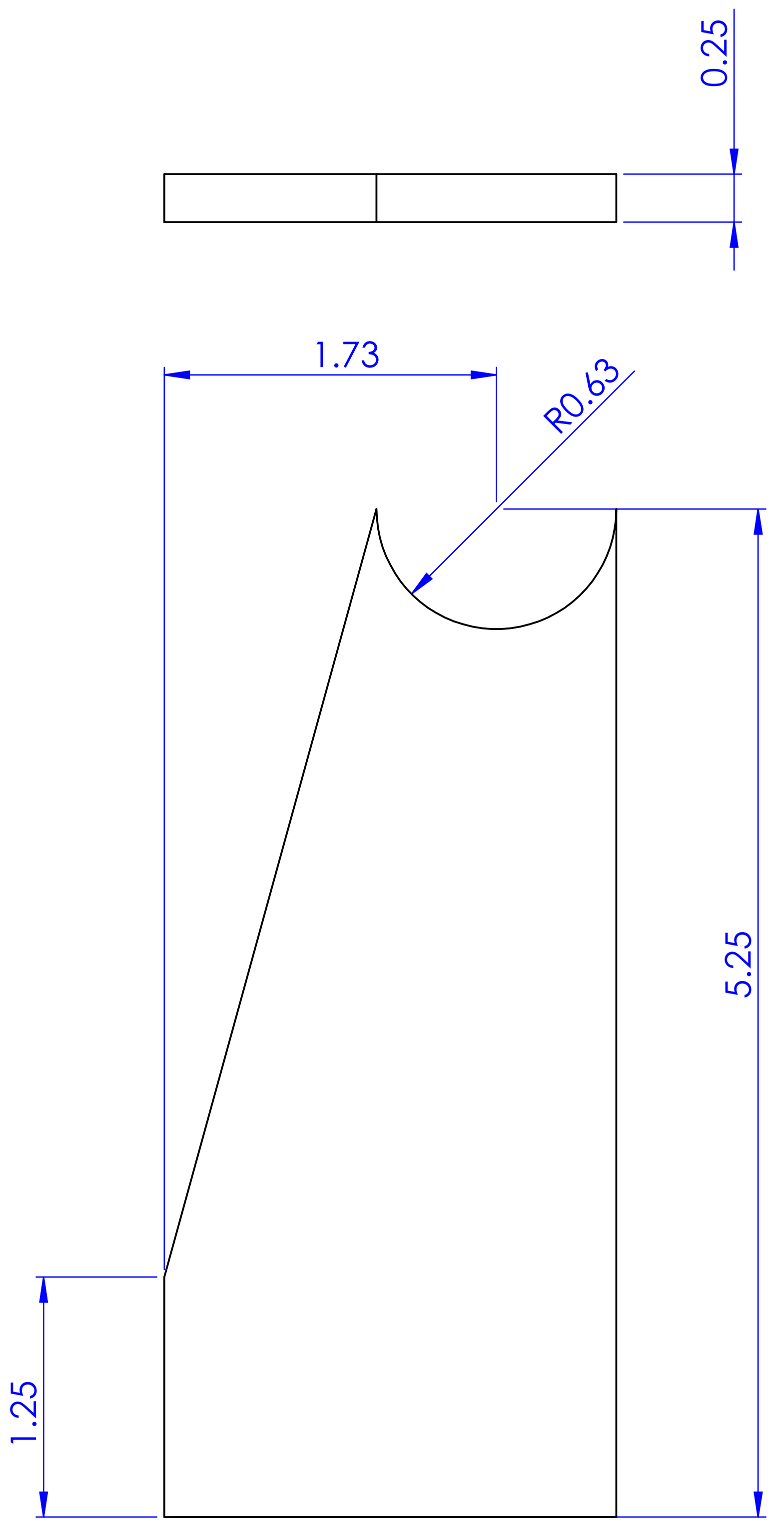
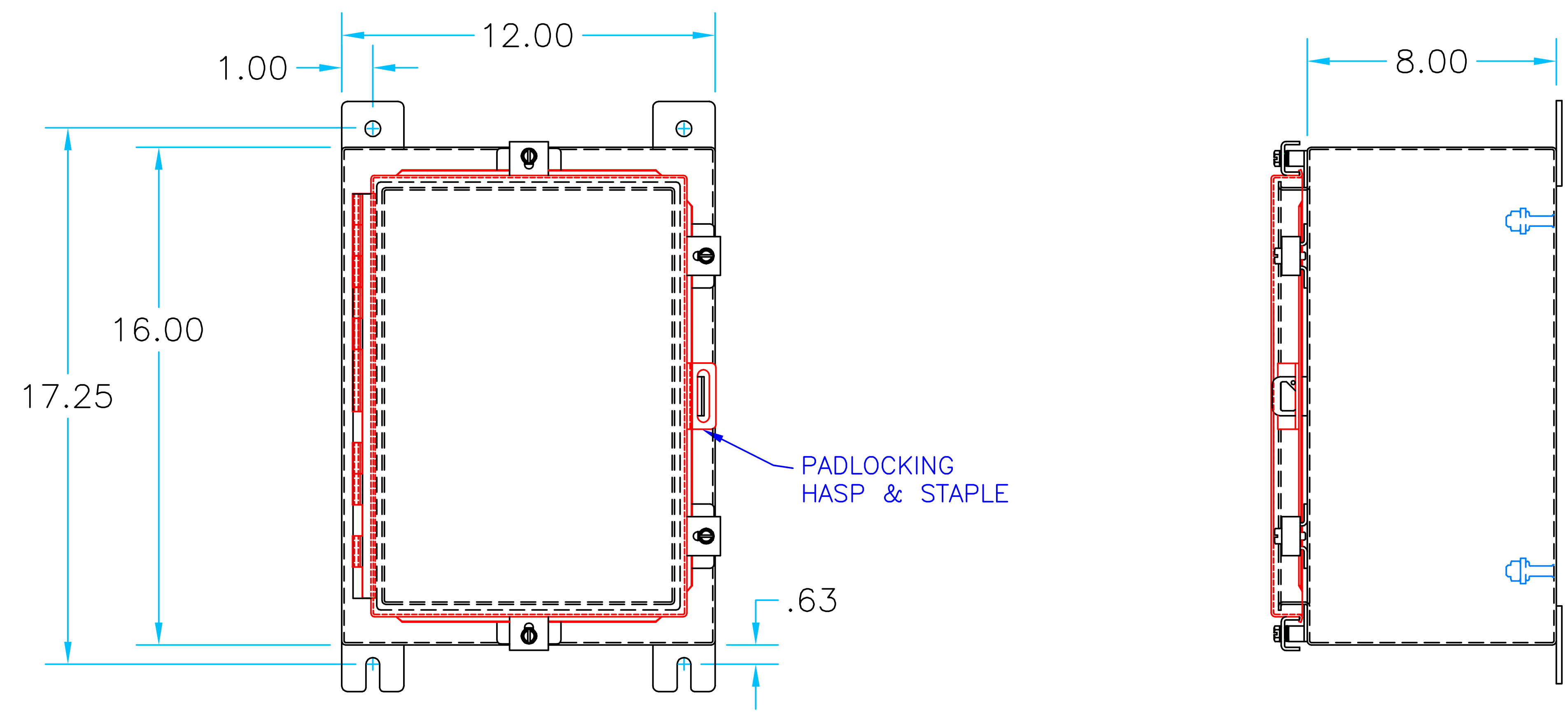
3.25
1.25



0.25
1.73
R0.63
5.25
1.25



FEATURES:

- UL LISTED
- NEMA 4X 5052 ALUMINUM
- BRUSHED OR POWDER COAT

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED

NEMA Enclosures Mfg. Corp.

NEMA ENCLOSURES
16" x 12" x 8"
NEMA TYPE 4X
WALL MOUNT ENCLOSURE

DRAWN	TDR	4/20/07
CHECKED	AS	4/20/07
MATERIAL	5052 ALUMINUM .080"	

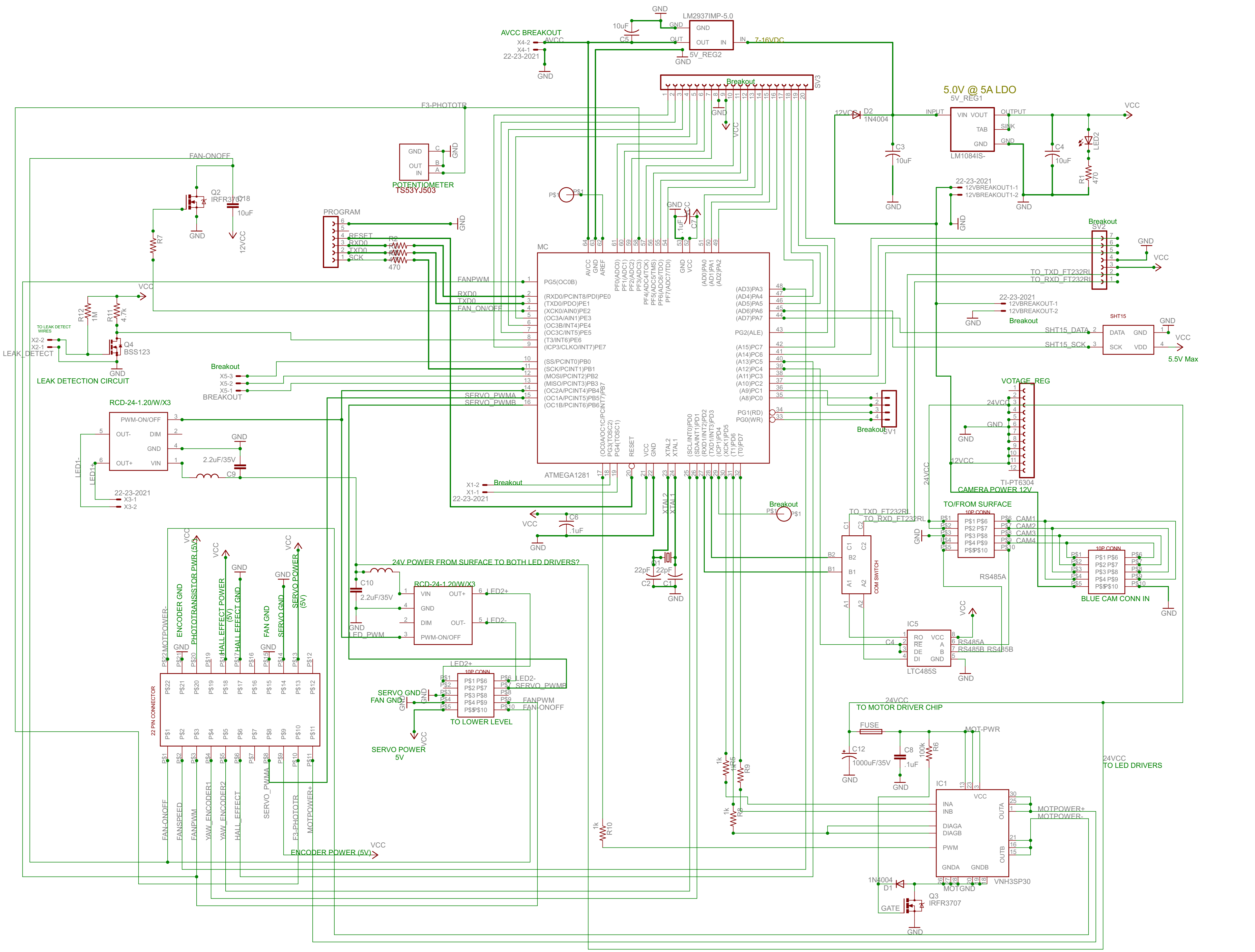
SIZE	FSCM NO.	DWG NO.	REV
D		N–WMT04X50501601208	
SCALE 1:1		SHEET 1 OF 1	

APPENDIX E:

ELECTRONICS

ATMEGA 1281 PIN CONNECTIONS				
PIN Number	**PORT**	**Function**	**Connections (New Board V2.6)**	**(old connection, pod board V1.0)**
1	PG5	OC0B	Fan PWM	Fan PWM
2	PE0	RXD0/PCINT8/PDI	Programmer RXD0	USB FT232RL & RS485 switch
3	PE1	TXD0/PD0	Programmer TXD0	USB FT232RL & RS485 switch
4	PE2	XCK0/AIN0	Fans On/Off	Fans On/Off
5	PE3	OC3A/AIN1	RTOS	RTOS
6	PE4	OC3B/INT4	RTOS	RTOS
7	PE5	OC3C/INT5	RTOS	RTOS
8	PE6	T3/INT6	Leak Detector Interrupt	Leak Detector Interrupt
9	PE7	ICP3/CLKO/INT7	**to Breakout Board / unused**	**to Breakout Board / unused**
10	PB0	notSS/PCINT0	**to Breakout Board / unused**	**to Breakout Board / unused**
11	PB1	SCK/PCINT1	Programming Header	Programming Header
12	PB2	MOSI/PCINT2	**to Breakout Board / unused**	Programming Header
13	PB3	MISO/PCINT3	**to Breakout Board / unused**	Programming Header
14	PB4	OC2A/PCINT4	LED Driver1&2 PWM in Parallel	LED Driver 1&2 in Parallel
15	PB5	OC1A/PCINT5	Servo PWMA	Gear Motor A Driver PWM
16	PB6	OC1B/PCINT6	Servo PWMB	Gear Motor B Driver PWM
17	PB7	OC0A/OC1C/PCINT	Yaw Motor Driver PWM	Yaw Motor Driver PWM
18	PG3	TOSC2	**to Breakout Board / unused**	**to Breakout Board / unused**
19	PG4	TOSC1	**to Breakout Board / unused**	**to Breakout Board / unused**
20	not RESET		Programming Header	Programming Header
21	VCC		VCC	VCC
22	GND		GND Plane	GND Plane
23	XTAL2		16 MHz Crystal	16 MHz Crystal
24	XTAL1		16 MHz Crystal	16 MHz Crystal
25	PD0	SCL/INT0	Encoder 1 for Yaw Motor	Encoder 1 for Yaw Motor
26	PD1	SDA/INT1	Encoder 2 for Yaw Motor	Encoder 2 for Yaw Motor
27	PD2	RXD1/INT2	USB FT232RL & RS485 switch	**to Breakout Board / unused**
28	PD3	TXD1/INT3	USB FT232RL & RS485 switch	**to Breakout Board / unused**
29	PD4	ICP1	**to Breakout Board / unused**	**to Breakout Board / unused**
30	PD5	XCK1	Motor Driver I/O	Motor Driver I/O
31	PD6	T1	Motor Driver I/O	Motor Driver I/O
32	PD7	T0	Motor Driver I/O	Motor Driver I/O
33	PG0	notWR	**to Breakout Board / unused**	**to Breakout Board / unused**
34	PG1	notRD	**to Breakout Board / unused**	**to Breakout Board / unused**
35	PC0	A8	**to Breakout Board / unused**	Motor A Driver DIR pin
36	PC1	A9	**to Breakout Board / unused**	Motor B Driver DIR pin
37	PC2	A10	**to Breakout Board / unused**	Motor B Status 2 pin
38	PC3	A11	**to Breakout Board / unused**	Motor A Status 2 pin
39	PC4	A12	RE/DE on RS485 chip	RE/DE on RS485 chip
40	PC5	A13	Hall Effect Interrupt	Hall Effect Interrupt
41	PC6	A14	**to Breakout Board / unused**	SHT15 SCK
42	PC7	A15	**to Breakout Board / unused**	SHT15 DATA
43	PG2	ALE	**to Breakout Board / unused**	**to Breakout Board / unused**
44	PA7	AD7	SHT15 SCK	**to Breakout Board / unused**
45	PA6	AD6	SHT15 DATA	**to Breakout Board / unused**
46	PA5	AD5	**to Breakout Board / unused**	**to Breakout Board / unused**
47	PA4	AD4	**to Breakout Board / unused**	**to Breakout Board / unused**
48	PA3	AD3	Yellow wire to fan (Fanspeed)	Yellow wire to fan
49	PA2	AD2	**to Breakout Board / unused**	**TO VIA**
50	PA1	AD1	**to Breakout Board / unused**	Servo Output Pin
51	PA0	AD0	**to Breakout Board / unused**	Servo Output Pin
52	VCC		VCC	VCC
53	GND		Ground Plane	Ground Plane

54	PF7	ADC7/TDI	**to Breakout Board / unused**	**to Breakout Board / unused**
55	PF6	ADC6/TDO	**to Breakout Board / unused**	**to Breakout Board / unused**
56	PF5	ADC5/TMS	**to Breakout Board / unused**	Analog Potentiometer for Servo1
57	PF4	ADC4/TCK	**to Breakout Board / unused**	Analog Potentiometer for Servo2
58	PF3	ADC3	Phototransistor	Phototransistor
59	PF2	ADC2	**to Breakout Board / unused**	**TO VIA**
60	PF1	ADC1	**to Breakout Board / unused**	**to Breakout Board / unused**
61	PF0	ADC0	**to Breakout Board / unused**	**to Breakout Board / unused**
62	AREF		AREF	AREF
63	AGND		AGND	AGND
64	AVCC		AVCC	AVCC



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Pawesome Pod Electronics BOM(B)

ORDER?	# Purchased	Components	Footprint	QTY	Vendor	$ Each	In Schematic?	Link	Notes
		Capacitors							
N		1000uF/35V	thru (12.5mm diam)	1	Digikey	$0.9	Y	http://www.digikey.com/product-detail/en/ECA-1VHG102/P5555-ND/245154	
Y	10	2.2uF/35V	smd (0805)	2	Digikey	$0.46	Y	http://www.digikey.com/product-detail/en/C2012X7R1V225K%2FSOFT/445-8892-1-ND/3283681	
Y	10	10uF	smd (0805)	2	Digikey	0.105	Y	http://www.digikey.com/product-detail/en/C2012Y5V1A106Z/445-1371-1-ND/567608	
Y	10	10uF	smd (0805)	2	Digikey	$0.67	Y	http://www.digikey.com/scripts/DKSearch/dksus.dll?Detail&itemSeq=127457309&uq=634984383741961157	C18, C3
Y	10	22pF	smd (0805)	2	Digikey	$0.1	Y	http://www.digikey.com/product-detail/en/500R15N220JV4T/709-1172-1-ND/1859504	
Y	10	.1uF	smd (0805)	3	Digikey	0.066	Y	http://www.digikey.com/product-detail/en/C2012X7R1H104K%2F0.85/445-7534-1-ND/2733606	
		Inductor							
~~N~~		~~47uH/35V/1.2A~~	~~smd~~	~~2~~	~~Digikey~~	~~$0.56~~	~~Y~~	~~http://www.digikey.com/product-detail/en/ASPI-6045S-470M-T/ASPI-6045S-470M-TCT-ND/3060390~~	Needed to replace! Unavailable from Digikey but this is inductor trace on board
Y	10	47uH	smd	2	Digikey	$0.46	Y	http://www.digikey.com/product-detail/en/VLC6045T-470M/445-6537-1-ND/2465843	Replacement inductor that should still fit trace
		Resistor							
Y	50	1M Ohm Res	smd (0805)	1	Digikey	$0.03	Y	http://www.digikey.com/product-detail/en/ERJ-6ENF1004V/P1.00MCCT-ND/119836	
Y	50	470 Ohm smd resistor	805	4	Digikey	$0.02	Y	http://www.digikey.com/product-detail/en/ERJ-6GEYJ471V/P470ACT-ND/90029	
Y	50	1k Resistor	805	4	Digikey	$0.02	Y	http://www.digikey.com/product-detail/en/ERJ-6GEYJ102V/P1.0KACT-ND/42833	
Y	50	100k Resistor	805	1	Digikey	$0.03	Y	http://www.digikey.com/product-detail/en/ERJ-6ENF1003V/P100KCCT-ND/119551	
Y	50	4.7k Ohm Resistor	805	1	Digikey	$0.02	Y	http://www.digikey.com/product-detail/en/ERJ-6GEYJ472V/P4.7KACT-ND/82468	
Y	2	TS53YJ503MR10 - Potentiometer	smd	1	Digikey	$1.62	Y	http://www.digikey.com/product-detail/en/TS53YJ503MR10/TS53YJ-50KCT-ND/1587989	
		Diode							
N		1N4004	thru	2	Digikey	$0.43	Y	http://www.digikey.com/product-detail/en/1N4004-E3%2F54/1N4004-E3%2F54GICT-ND/868987	
		Other Helpful Components							
N		Yaw Motor	-	1				GM14904SO16 Pittman Motor	
N		LEDs (Pod Light)	smd	6	Digikey	$7.44	N	http://www.digikey.com/product-detail/en/XMLAWT-00-0000-000LT50E3/XMLAWT-00-0000-000LT50E3CT-ND/2615397	3A max, 2.9V Vforward
N		standard 3mm LED	thru	1	Sparkfun	$0.35	Y	https://www.sparkfun.com/products/9650	
N		fuse	-	1			Y	ask Ridgely	
N		fuse holder	-	1			Y	ask Ridgely	
Y	2	RS 485 Transciever	smd	1	Digikey	$3.14	Y	http://www.digikey.com/scripts/DKSearch/dksus.dll?Detail&itemSeq=127022527&uq=634976724538238040	
N		Atmega 1281	smd	1	Digikey	$13.12	Y	http://www.digikey.com/product-detail/en/ATMEGA1281-16AU/ATMEGA1281-16AU-ND/1245829	
Y	1	External Oscillation Crystal	thru	1	Digikey	$1.01	Y	http://www.digikey.com/product-detail/en/ECS-160-20-5P-TR/XC694CT-ND/38747	
Y	1	ES23MCBE Switch	thru	1	Digikey	$6.92	Y	http://www.digikey.com/product-search/en?x=0&y=0&lang=en&site=us&KeyWords=es23mcbe	
Y	2	SHT15	smd	1	Sparkfun	$28.95	Y	https://www.sparkfun.com/products/8227	
N		Hall Effect Switch	thru	1	Sparkfun	$0.95	-	https://www.sparkfun.com/products/9312	Power, I/O pin, ground (this one is diff from original hall effect sensor, basically same)
N		Phototransistor visible light	thru	1	Digikey	$0.67		http://www.digikey.com/product-detail/en/BPW85/751-1023-ND/1681157	
N		Fan (AUC0512DB-AF00)	-	2	Digikey	9.2	N	http://www.digikey.com/product-search/en?x=0&y=0&lang=en&site=us&KeyWords=AUC0512DB-AF00	
N		Servo (parallax standard 900-00005)	-	2					
N		Canera (A1IPPTZ10X2MP)	-	1	Triton				
		Transistors							
N		IRFR3707	smd	2	Digikey	$1.17	Y	http://www.digikey.com/product-detail/en/IRFR3707ZTRPBF/IRFR3707ZTRPBFCT-ND/812523	
Y	4	BSS123	smd	1	Digikey	$0.29	Y	http://www.digikey.com/product-detail/en/BSS123/BSS123NCT-ND/244665	
		Regulators/Drivers							
~~Y~~	~~3~~	~~LM1084IS-ADJ (5V reg)~~	~~smd~~	~~1~~	~~Digikey~~	~~$2.79~~	-	~~http://www.digikey.com/product-detail/en/LM1084IS-ADJ%2FNOPB/LM1084IS-ADJ%2FNOPB-ND/363553~~	ACCIDENTAL ORDER! NEED 5.0 REG NOT ADJUSTABLE!
Y	4	LM1084IS-5.0 (5V reg)	smd	1	Digikey	$2.79	Y	http://www.digikey.com/product-detail/en/LM1084IS-5.0%2FNOPB/LM1084IS-5.0%2FNOPB-ND/363552	
Y	3	LM2937IMP-5.0 (5Vreg)	smd	1	Digikey	$1.85	Y	http://www.digikey.com/product-detail/en/LM2937IMP-5.0%2FNOPB/LM2937IMP-5.0%2FNOPBCT-ND/270743	
N		TI-PT6304 (12V regulator)	thru	1	-	$25	Y	http://www.digikey.com/product-detail/en/PT6304N/PT6304N-ND/278552	
Y	2	VNH3SP30 (motor driver)	smd	1	Digikey	$9.55	Y	http://www.digikey.com/product-detail/en/VNH3SP30TR-E/497-3565-1-ND/669421	
N		RCD-24-1.20 (Led Driver)	thru	2	Digikey	$19.57	Y	http://www.digikey.com/product-search/en/power-supplies-board-mount/led-supplies/4326590?k=RCD-24-1.20	
		Connectors/Headers							
N		CONN HEADER PHD SIDE 10POS 2MM	thru	3	Digikey	$0.45	Y	http://www.digikey.com/product-detail/en/S10B-PHDSS%20%20%28LF%29%28SN%29%28P%29/455-1775-ND/926681	hangs off board, up to 250 VAC/DC
N		CONN HOUSING PHD 10POS 2MM DUAL	-	3	Digikey	$0.32	-	http://www.digikey.com/product-detail/en/PHDR-10VS/455-1158-ND/608600	
N		CONN HEADER PHD TOP 22POS 2MM	-	1	Digikey	$0.54	-	http://www.digikey.com/product-detail/en/PHDR-22VS%28P%29/455-1175-ND/608617	connects to cable (22 pins), withstands 250V ACorDC, 3A
N		CONN HOUSING PHD 22POS 2MM DUAL	thru	1	Digikey	$0.81	Y	http://www.digikey.com/product-detail/en/B22B-PHDSS%28LF%29%28SN%29/455-1768-ND/926674	goes on PCB (22 pins), withstands 250V ACorDC, 3A
Y	2	0.1in Conn Header	thru	AR	Sparkfun	$1.5	Y	https://www.sparkfun.com/products/116	
Y	(ask JR)	0.1in Conn Header (2pin)	thru	6				ask ridgely	
N		Crimp Contacts	-	65	Digikey	$0.06	-	http://www.digikey.com/product-detail/en/SPHD-001T-P0.5/455-1325-1-ND/608808	
		Custom PCB							
		Pawesome Board V2.6	-	3	DorkBot	$62	-	oshpark.com	

PAWESOME POD POWER RATINGS AND REQUIREMENTS

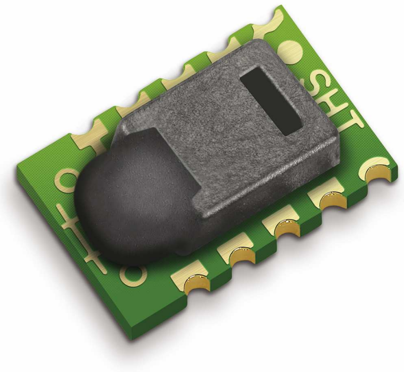
Components	QTY	POWER REQ	Rating Requirement	Voltage, Current/Power Rating of Ordered Part
Capacitors				
1000uF/35V	1	-	24V, 3A max	35V
2.2uF/35V	2	-	24V, 3A max	35V
10uF	2	-	5V x 2	10V
10uF	2	-	12V x2	25V
22pF	2	-	5V	50V
.1uF	3	-	5V x2, 24V x1	50V
Inductor				
47uH	2	-	1.2A	1.2A
Resistor				P = V^2/R or IV
1M Ohm Res	1	-	5V (.000025W)	.125W
470 Ohm smd resistor	4	-	5V (.053W)	.125W
1k Resistor	4	-	5V (.025W)	.125W
100k Resistor	1	-	24V (.0058W)	.125W
4.7k Ohm Resistor	1	-	5V (.0053W)	.125W
TS53YJ503MR10 - Potentiometer	1	-	5V	.25W (max 112V, 2.2mA)
Diode				
1N4004	2	-	12V, 3A MAX	400V, 1A (should be fine)
Other Helpful Components				
Yaw Motor	1	(24V motor)/23A peak current	-	-
LEDs (Pod Light)	6	24V/3A max	-	-
standard 3mm LED	1	-	-	20mA max
fuse	1	-	24V, .5A	?
fuse holder	1	-	?	?
RS 485 Transciever	1	3.3-5.0V	-	-
Atmega 1281	1	2.7-5.5V	-	-
External Oscillation Crystal	1	-	-	-
ES23MCBE Switch	1	-	-	.4W (20V max)
SHT15	1	5V	-	-
Hall Effect Switch	1	3.5-24V	-	-
Phototransistor visible light	1	5V	-	-
Fan (AUC0512DB-AF00)	2	12V, .18A	-	-
Servo (parallax standard 900-00005)	2	4-6V	-	-
Canera (A1IPPTZ10X2MP)	1	12V, 1A	-	-
Transistors				
IRFR3707	2	-	24V, 12V	30V, 56 A
BSS123	1	-	5V	.36W
Regulators/Drivers				
~~LM1084IS-ADJ (5V reg)~~	~~1~~	-		
LM1084IS-5.0 (5V reg)	1	-	24V	25V, 5A
LM2937IMP-5.0 (5Vreg)	1	-	24V	26V, .4A
TI-PT6304 (12V regulator)	1	-	-	16-38Vin, 3A max
VNH3SP30 (motor driver)	1	.3-40V max (use 5V)	-	40V, 30A max

RCD-24-1.20 (Led Driver)	2	24V/3A max	-	24V, 3A max
Connectors/Headers				
CONN HEADER PHD SIDE 10POS 2MM	3	-	24V, full A of POD components (3.08 A)	250V, 3A
CONN HOUSING PHD 10POS 2MM DUAL	3	-	24V, full A of POD components (3.08 A)	250V, 3A
CONN HEADER PHD TOP 22POS 2MM	1	-	24V, .5A max	250V, 3A
CONN HOUSING PHD 22POS 2MM DUAL	1	-	24V, .5A max	250V, 3A
0.1in Conn Header	AR	-	5V	
0.1in Conn Header (2pin)	6	-		
Crimp Contacts	65	-		
Custom PCB				
Pawesome Board V2.6	1	24V	-	-

Datasheet SHT1x (SHT10, SHT11, SHT15)

Humidity and Temperature Sensor

- Fully calibrated
- Digital output
- Low power consumption
- Excellent long term stability
- SMD type package – reflow solderable



Product Summary

SHT1x (including SHT10, SHT11 and SHT15) is Sensirion's family of surface mountable relative humidity and temperature sensors. The sensors integrate sensor elements plus signal processing on a tiny foot print and provide a fully calibrated digital output. A unique capacitive sensor element is used for measuring relative humidity while temperature is measured by a band-gap sensor. The applied CMOSens® technology guarantees excellent reliability and long term stability. Both sensors are seamlessly coupled to a 14bit analog to digital converter and a serial interface circuit. This results in superior signal quality, a fast response time and insensitivity to external disturbances (EMC).

Each SHT1x is individually calibrated in a precision humidity chamber. The calibration coefficients are programmed into an OTP memory on the chip. These coefficients are used to internally calibrate the signals from the sensors. The 2-wire serial interface and internal voltage regulation allows for easy and fast system integration. The tiny size and low power consumption makes SHT1x the ultimate choice for even the most demanding applications.

SHT1x is supplied in a surface-mountable LCC (Leadless Chip Carrier) which is approved for standard reflow soldering processes. The same sensor is also available with pins (SHT7x) or on flex print (SHTA1).

Dimensions

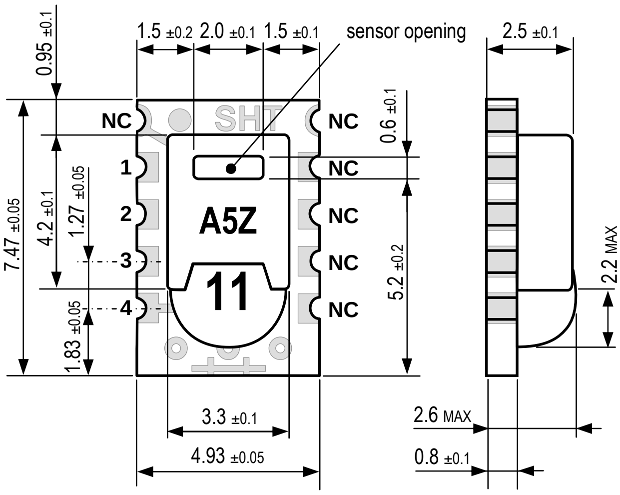


Figure 1: Drawing of SHT1x sensor packaging, dimensions in mm (1mm = 0.039inch). Sensor label gives "11" for SHT11 as an example. Contacts are assigned as follows: 1:GND, 2:DATA, 3:SCK, 4:VDD.

Sensor Chip

SHT1x V4 – for which this datasheet applies – features a version 4 Silicon sensor chip. Besides a humidity and a temperature sensor the chip contains an amplifier, A/D converter, OTP memory and a digital interface. V4 sensors can be identified by the alpha-numeric traceability code on the sensor cap – see example "A5Z" code on Figure 1.

Material Contents

While the sensor is made of a CMOS chip the sensor housing consists of an LCP cap with epoxy glob top on an FR4 substrate. The device is fully RoHS and WEEE compliant, thus it is free of Pb, Cd, Hg, Cr(6+), PBB and PBDE.

Evaluation Kits

For sensor trial measurements, for qualification of the sensor or even experimental application of the sensor there is an evaluation kit *EK-H2* available including sensor, hard and software to interface with a computer.

For more sophisticated and demanding measurements a multi port evaluation kit *EK-H3* is available which allows for parallel application of up to 20 sensors.

Sensor Performance

Relative Humidity

Parameter	Condition	min	typ	max	Units
Resolution [1]		0.4	0.05	0.05	%RH
		8	12	12	bit
Accuracy [2] SHT10	typical		±4.5		%RH
	maximal	see Figure 2			
Accuracy [2] SHT11	typical		±3.0		%RH
	maximal	see Figure 2			
Accuracy [2] SHT15	typical		±2.0		%RH
	maximal	see Figure 2			
Repeatability			±0.1		%RH
Replacement		fully interchangeable			
Hysteresis			±1		%RH
Nonlinearity	raw data		±3		%RH
	linearized		<<1		%RH
Response time [3]	τ (63%)		8		s
Operating Range		0		100	%RH
Long term drift [4]	normal		< 0.5		%RH/yr

Temperature

Parameter	Condition	min	typ	max	Units
Resolution [1]		0.04	0.01	0.01	°C
		12	14	14	bit
Accuracy [2] SHT10	typical		±0.5		°C
	maximal	see Figure 3			
Accuracy [2] SHT11	typical		±0.4		°C
	maximal	see Figure 3			
Accuracy [2] SHT15	typical		±0.3		°C
	maximal	see Figure 3			
Repeatability			±0.1		°C
Replacement		fully interchangeable			
Operating Range		-40		123.8	°C
		-40		254.9	°F
Response Time [6]	τ (63%)	5		30	s
Long term drift			< 0.04		°C/yr

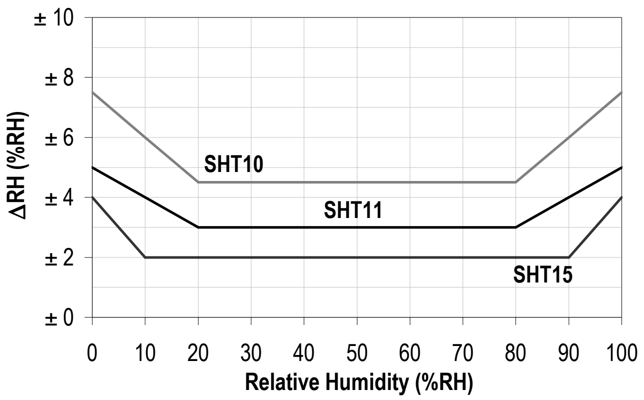


Figure 2: Maximal RH-accuracy at 25°C per sensor type.

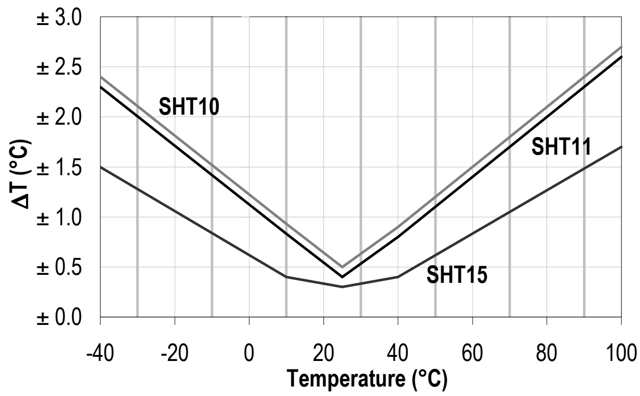


Figure 3: Maximal T-accuracy per sensor type.

Electrical and General Items

Parameter	Condition	min	typ	max	Units
Source Voltage		2.4	3.3	5.5	V
Power Consumption [5]	sleep		2	5	µW
	measuring		3		mW
	average		150		µW
Communication	digital 2-wire interface, see Communication				
Storage	10 – 50°C (0 – 125°C peak), 20 – 60%RH				

Packaging Information

Sensor Type	Packaging	Quantity	Order Number
SHT10	Tape & Reel	2000	1-100218-04
SHT11	Tape & Reel	100	1-100051-04
	Tape & Reel	400	1-100098-04
	Tape & Reel	2000	1-100524-04
SHT15	Tape & Reel	100	1-100085-04
	Tape & Reel	400	1-100093-04

1 The default measurement resolution of is 14bit for temperature and 12bit for humidity. It can be reduced to 12/8bit by command to status register.

2 Accuracies are tested at Outgoing Quality Control at 25°C (77°F) and 3.3V. Values exclude hysteresis and non-linearity.

3 Time for reaching 63% of a step function, valid at 25°C and 1 m/s airflow.

4 Value may be higher in environments with high contents of volatile organic compounds. See Section 1.3 of Users Guide.

5 Values for VDD=5.5V at 25°C, average value at one 12bit measurement per second.

6 Response time depends on heat capacity of and thermal resistance to sensor substrate.

1 Application Information

1.1 Operating Conditions

Sensor works stable within recommended normal range – see Figure 4. Long term exposures to conditions outside normal range may temporarily offset the RH signal (+3 %RH after 60h). After return to normal range it will slowly return towards calibration state by itself. See Section 1.4. "Reconditioning Procedure" to accelerate eliminating the offset. Prolonged exposure to extreme conditions may accelerate ageing.

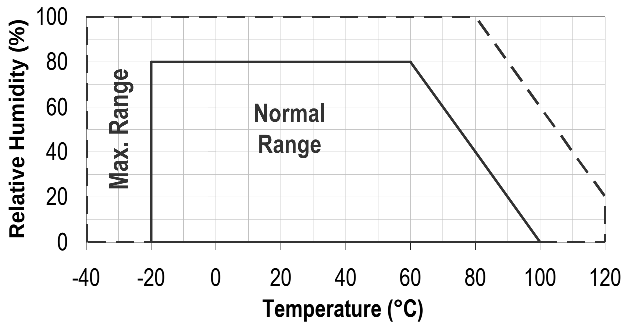


Figure 4: Operating Conditions

1.2 Soldering instructions

For soldering SHT1x standard reflow soldering ovens may be used. The sensor is qualified to withstand soldering profile according to IPC/JEDEC J-STD-020C with peak temperatures at 260°C during up to 40sec including Pb-free assembly in IR/Convection reflow ovens.

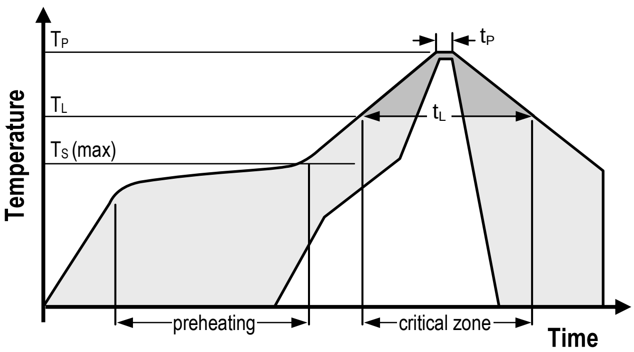


Figure 5: Soldering profile according to JEDEC standard. T_P <= 260°C and t_P < 40sec for Pb-free assembly. T_L < 220°C and t_L < 150sec. Ramp-up/down speeds shall be < 5°C/sec.

For soldering in Vapor Phase Reflow (VPR) ovens the peak conditions are limited to T_P < 233°C during t_P < 60sec and ramp-up/down speeds shall be limited to 10°C/sec. For manual soldering contact time must be limited to 5 seconds at up to 350°C[7].

IMPORTANT: After soldering the devices should be stored at >75%RH for at least 12h to allow the polymer to re-hydrate. Otherwise the sensor may read an offset that slowly disappears if exposed to ambient conditions.

In no case, neither after manual nor reflow soldering, a board wash shall be applied. Therefore it is strongly recommended to use "no-clean" solder paste. In case of application with exposure of the sensor to corrosive gases the soldering pads shall be sealed to prevent loose contacts or short cuts.

For the design of the SHT1x footprint it is recommended to use dimensions according to Figure 7. Sensor pads are coated with 35µm Cu, 5µm Ni and 0.1µm Au.

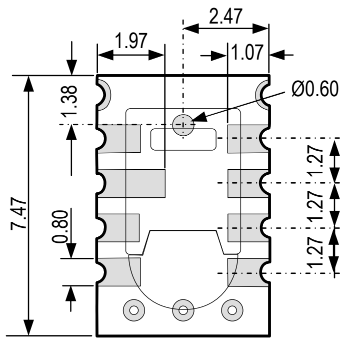


Figure 6: Rear side electrodes of sensor, view from top side.

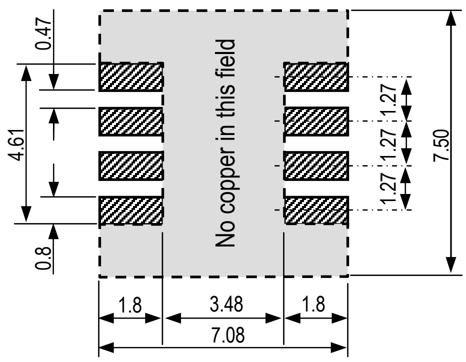


Figure 7: Recommended footprint for SHT1x. Values in mm.

1.3 Storage Conditions and Handling Instructions

It is of great importance to understand that a humidity sensor is not a normal electronic component and needs to be handled with care. Chemical vapors at high concentration in combination with long exposure times may offset the sensor reading.

For these reasons it is recommended to store the sensors in original packaging including the sealed ESD bag at following conditions: Temperature shall be in the range of 10°C – 50°C (0 – 125°C for limited time) and humidity at 20 – 60%RH (sensors that are not stored in ESD bags).

[7] 233°C = 451°F, 260°C = 500°F, 350°C = 662°F

For sensors that have been removed from the original packaging we recommend to stored them in ESD bags made of PE-HD[8].

In manufacturing and transport the sensors shall be prevented of high concentration of chemical solvents and long exposure times. Out-gassing of glues, adhesive tapes and stickers or out-gassing packaging material such as bubble foils, foams, etc. shall be avoided. Manufacturing area shall be well ventilated.

For more detailed information please consult the document *"Handling Instructions"* or contact Sensirion.

1.4 Reconditioning Procedure

As stated above extreme conditions or exposure to solvent vapors may offset the sensor. The following reconditioning procedure may bring the sensor back to calibration state:

Baking:	100 – 105°C at < 5%RH for 10h
Re-Hydration:	20 – 30°C at ~ 75%RH for 12h [9].

1.5 Temperature Effects

Relative humidity reading strongly depends on temperature. Therefore, it is essential to keep humidity sensors at the same temperature as the air of which the relative humidity is to be measured. In case of testing or qualification the reference sensor and test sensor must show equal temperature to allow for comparing humidity readings.

If the SHT1x shares a PCB with electronic components that produce heat it should be mounted in a way that prevents heat transfer or keeps it as low as possible. Measures to reduce heat transfer can be ventilation, reduction of copper layers between the SHT1x and the rest of the PCB or milling a slit into the PCB around the sensor (see Figure 8).

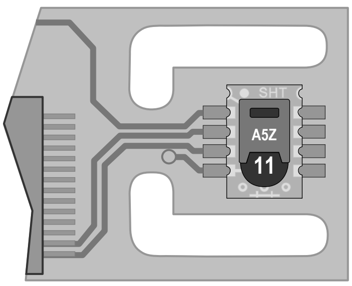


Figure 8: Top view of example of mounted SHT1x with slits milled into PCB to minimize heat transfer.

Furthermore, there are self-heating effects in case the measurement frequency is too high. Please refer to Section 3.3 for detailed information.

1.6 Light

The SHT1x is not light sensitive. Prolonged direct exposure to sunshine or strong UV radiation may age the housing.

1.7 Membranes

SHT1x does not contain a membrane at the sensor opening. However, a membrane may be added to prevent dirt and droplets from entering the housing and to protect the sensor. It will also reduce peak concentrations of chemical vapors. For optimal response times the air volume behind the membrane must be kept minimal. Sensirion recommends and supplies the SF1 filter cap for optimal IP54 protection (for higher protection – i.e. IP67 - SF1 must be sealed to the PCB with epoxy). Please compare Figure 9.

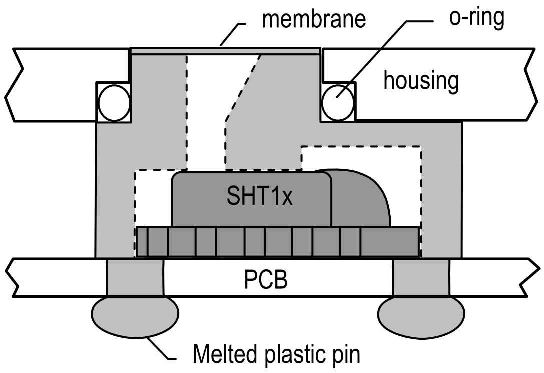


Figure 9: Side view of SF1 filter cap mounted between PCB and housing wall. Volume below membrane is kept minimal.

1.8 Materials Used for Sealing / Mounting

Many materials absorb humidity and will act as a buffer increasing response times and hysteresis. Materials in the vicinity of the sensor must therefore be carefully chosen. Recommended materials are: Any metals, LCP, POM (Delrin), PTFE (Teflon), PE, PEEK, PP, PB, PPS, PSU, PVDF, PVF.

For sealing and gluing (use sparingly): High filled epoxy for electronic packaging (e.g. glob top, underfill), and Silicone. Out-gassing of these materials may also contaminate the SHT1x (see Section 1.3). Therefore try to add the sensor as a last manufacturing step to the assembly, store the assembly well ventilated after manufacturing or bake at >50°C for 24h to outgas contaminants before packing.

1.9 Wiring Considerations and Signal Integrity

Carrying the SCK and DATA signal parallel and in close proximity (e.g. in wires) for more than 10cm may result in cross talk and loss of communication. This may be resolved by routing VDD and/or GND between the two data signals and/or using shielded cables. Furthermore, slowing down SCK frequency will possibly improve signal integrity. Power supply pins (VDD, GND) must be decoupled with a 100nF capacitor if wires are used.

[8] For example, please check www.sirel.ch

[9] 75%RH can conveniently be generated with saturated NaCl solution. 100 – 105°C correspond to 212 – 221°F, 20 – 30°C correspond to 68 – 86°F

Capacitor should be placed as close to the sensor as possible. Please see the Application Note "ESD, Latchup and EMC" for more information.

1.10 ESD (Electrostatic Discharge)

ESD immunity is qualified according to MIL STD 883E, method 3015 (Human Body Model at ±2 kV).

Latch-up immunity is provided at a force current of ±100mA with T_{amb} = 80°C according to JEDEC78A. See Application Note "ESD, Latchup and EMC" for more information.

2 Interface Specifications

Pin	Name	Comment
1	GND	Ground
2	DATA	Serial Data, bidirectional
3	SCK	Serial Clock, input only
4	VDD	Source Voltage
NC	NC	Must be left unconnected

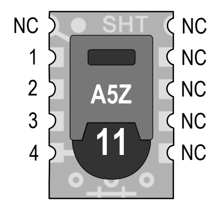


Table 1: SHT1x pin assignment, NC remain floating.

2.1 Power Pins (VDD, GND)

The supply voltage of SHT1x must be in the range of 2.4 – 5.5V, recommended supply voltage is 3.3V. Power supply pins Supply Voltage (VDD) and Ground (GND) must be decoupled with a 100 nF capacitor – see Figure 10.

The serial interface of the SHT1x is optimized for sensor readout and effective power consumption. The sensor cannot be addressed by I²C protocol, however, the sensor can be connected to an I²C bus without interference with other devices connected to the bus. The controller must switch between the protocols.

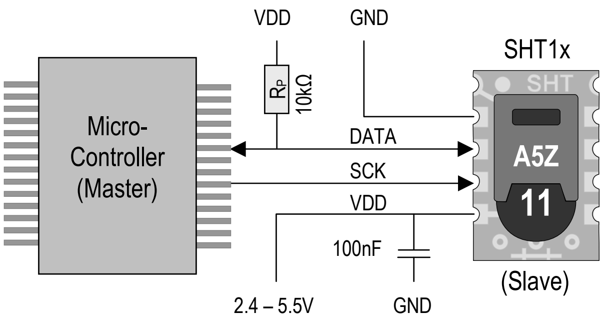


Figure 10: Typical application circuit, including pull up resistor R_P and decoupling of VDD and GND by a capacitor.

2.2 Serial clock input (SCK)

SCK is used to synchronize the communication between microcontroller and SHT1x. Since the interface consists of fully static logic there is no minimum SCK frequency.

2.3 Serial data (DATA)

The DATA tri-state pin is used to transfer data in and out of the sensor. For sending a command to the sensor, DATA is valid on the rising edge of the serial clock (SCK) and must remain stable while SCK is high. After the falling edge of SCK DATA may be changed. For safe communication DATA valid shall be extended T_{SU} and T_{HO} before the rising and after the falling edge of SCK, respectively – see Figure 11. For reading data from the sensor, DATA is valid T_V after SCK has gone low and remains valid until the next falling edge of SCK.

To avoid signal contention the microcontroller must only drive DATA low. An external pull-up resistor (e.g. 10kΩ) is required to pull the signal high – it should be noted that pull-up resistors may be included in I/O circuits of microcontrollers. See Table 2 for detailed I/O characteristic of the sensor.

2.4 Electrical Characteristics

The electrical characteristics such as power consumption, low and high level, input and output voltages depend on the supply voltage. Table 2 gives electrical characteristics of SHT1x with the assumption of 5V supply voltage if not stated otherwise. For proper communication with the sensor it is essential to make sure that signal design is strictly within the limits given in Table 3 and Figure 11.

Parameter	Conditions	min	typ	max	Units
Power supply DC[10]		2.4	3.3	5.5	V
Supply current	measuring		0.55	1	mA
	average[11]	2	28		µA
	sleep		0.3	1.5	µA
Low level output voltage	I_{OL} < 4 mA	0		250	mV
High level output voltage	R_P < 25 kΩ	90%		100%	VDD
Low level input voltage	Negative going	0%		20%	VDD
High level input voltage	Positive going	80%		100%	VDD
Input current on pads				1	µA
Output current	on			4	mA
	Tri-stated (off)		10	20	µA

Table 2: SHT1x DC characteristics. R_P stands for pull up resistor, while I_{OL} is low level output current.

[10] Recommended voltage supply for highest accuracy is 3.3V, due to sensor calibration.

[11] Minimum value with one measurement of 8 bit accuracy without OTP reload per second, typical value with one measurement of 12bit accuracy per second.

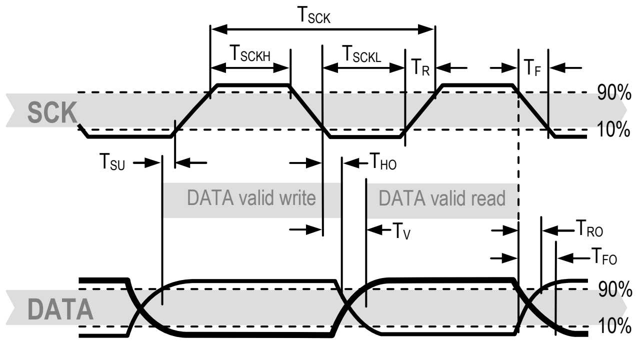


Figure 11: Timing Diagram, abbreviations are explained in Table 3. Bold DATA line is controlled by the sensor, plain DATA line is controlled by the micro-controller. Both valid times refer to the left SCK toggle.

	Parameter	Conditions	min	typ	max	Units
F_{SCK}	SCK Frequency	VDD > 4.5V	0	0.1	5	MHz
		VDD < 4.5V	0	0.1	1	MHz
T_{SCKx}	SCK hi/low time		100			ns
T_R/T_F	SCK rise/fall time		1	200	*	ns
T_{FO}	DATA fall time	OL = 5pF	3.5	10	20	ns
		OL = 100pF	30	40	200	ns
T_{RO}	DATA rise time		**	**	**	ns
T_V	DATA valid time		200	250	***	ns
T_{SU}	DATA setup time		100	150	***	ns
T_{HO}	DATA hold time		10	15	****	ns

* $T_{R\_max} + T_{F\_max} = (F_{SCK})^{-1} - T_{SCKH} - T_{SCKL}$

** T_{R0} is determined by the R_P*C_{bus} time-constant at DATA line

*** T_{V_max} and T_{SU_max} depend on external pull-up resistor (R_P) and total bus line capacitance (Cbus) at DATA line

**** $T_{H0\_max} < T_V - \max(T_{R0}, T_{F0})$

Table 3: SHT1x I/O signal characteristics, OL stands for Output Load, entities are displayed in Figure 11.

3 Communication with Sensor

3.1 Start up Sensor

As a first step the sensor is powered up to chosen supply voltage VDD. The slew rate during power up shall not fall below 1V/ms. After power-up the sensor needs 11ms to get to Sleep State. No commands must be sent before that time.

3.2 Sending a Command

To initiate a transmission, a Transmission Start sequence has to be issued. It consists of a lowering of the DATA line while SCK is high, followed by a low pulse on SCK and raising DATA again while SCK is still high – see Figure 12.

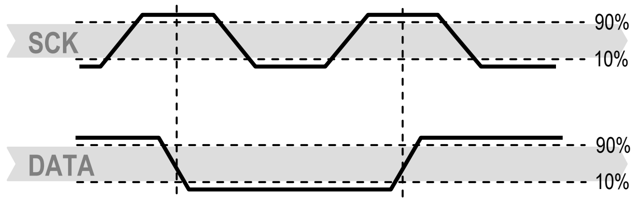


Figure 12: "Transmission Start" sequence

The subsequent command consists of three address bits (only '000' is supported) and five command bits. The SHT1x indicates the proper reception of a command by pulling the DATA pin low (ACK bit) after the falling edge of the 8th SCK clock. The DATA line is released (and goes high) after the falling edge of the 9th SCK clock.

Command	Code
Reserved	0000x
Measure Temperature	**00011**
Measure Relative Humidity	**00101**
Read Status Register	00111
Write Status Register	00110
Reserved	0101x-1110x
Soft reset, resets the interface, clears the status register to default values. Wait minimum 11 ms before next command	**11110**

Table 4: SHT1x list of commands

3.3 Measurement of RH and T

After issuing a measurement command ('00000101' for relative humidity, '00000011' for temperature) the controller has to wait for the measurement to complete. This takes a maximum of 20/80/320 ms for a 8/12/14bit measurement. The time varies with the speed of the internal oscillator and can be lower by up to 30%. To signal the completion of a measurement, the SHT1x pulls data line low and enters Idle Mode. The controller must wait for this Data Ready signal before restarting SCK to readout the data. Measurement data is stored until readout, therefore the controller can continue with other tasks and readout at its convenience.

Two bytes of measurement data and one byte of CRC checksum (optional) will then be transmitted. The micro controller must acknowledge each byte by pulling the DATA line low. All values are MSB first, right justified (e.g. the 5^{th} SCK is MSB for a 12bit value, for a 8bit result the first byte is not used).

Communication terminates after the acknowledge bit of the CRC data. If CRC-8 checksum is not used the controller may terminate the communication after the measurement data LSB by keeping ACK high. The device automatically returns to Sleep Mode after measurement and communication are completed.

Important: To keep self heating below 0.1°C, SHT1x should not be active for more than 10% of the time – e.g. maximum one measurement per second at 12bit accuracy shall be made.

3.4 Connection reset sequence

If communication with the device is lost the following signal sequence will reset the serial interface: While leaving DATA high, toggle SCK nine or more times – see Figure 13. This must be followed by a Transmission Start sequence preceding the next command. This sequence resets the interface only. The status register preserves its content.

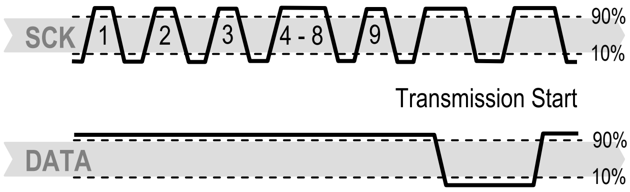


Figure 13: Connection Reset Sequence

3.5 CRC-8 Checksum calculation

The whole digital transmission is secured by an 8bit checksum. It ensures that any wrong data can be detected and eliminated. As described above this is an additional feature of which may be used or abandoned.

Please consult Application Note "CRC-8 Checksum Calculation" for information on how to calculate the CRC.

Status Register

Some of the advanced functions of the SHT1x such as selecting measurement resolution, end of battery notice or using the heater may be activated by sending a command to the status register. The following section gives a brief overview of these features. A more detailed description is available in the Application Note "Status Register".

After the command Status Register Read or Status Register Write – see Table 4 – the content of 8 bits of the status register may be read out or written. For the communication compare Figures 16 and 17 – the assignation of the bits is displayed in Table 5.

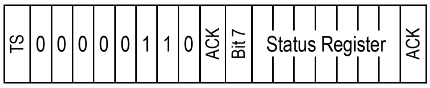


Figure 14: Status Register Write

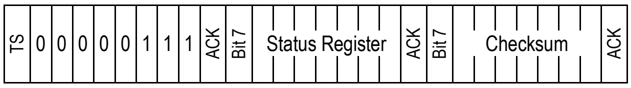


Figure 15: Status Register Read

Examples of full communication cycle are displayed in Figures 15 and 16.

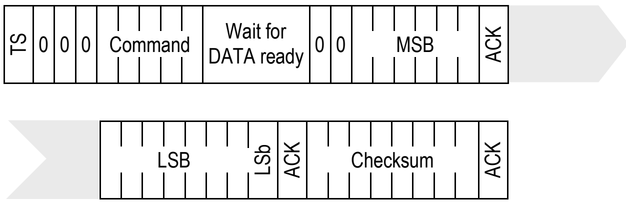


Figure 16: Overview of Measurement Sequence. TS = Transmission Start, MSB = Most Significant Byte, LSB = Last Significant Byte, LSb = Last Significant Bit.

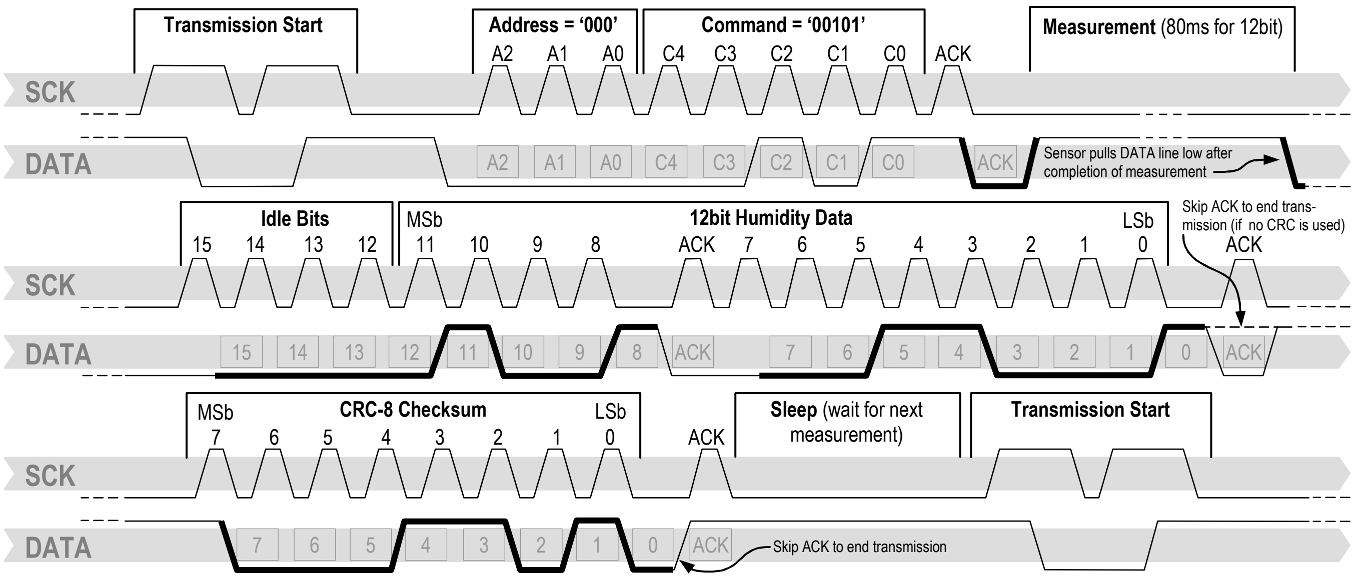


Figure 17: Example RH measurement sequence for value "0000'1001"0011'0001" = 2353 = 75.79 %RH (without temperature compensation). DATA valid times are given and referenced in boxes on DATA line. Bold DATA lines are controlled by sensor while plain lines are controlled by the micro-controller.

Bit	Type	Description	Default	
7		reserved	0	
6	R	End of Battery (low voltage detection) '0' for VDD > 2.47 '1' for VDD < 2.47	X	No default value, bit is only updated after a measurement
5		reserved	0	
4		reserved	0	
3		For Testing only, do not use	0	
2	R/W	Heater	0	off
1	R/W	no reload from OTP	0	reload
0	R/W	'1' = 8bit RH / 12bit Temp. resolution '0' = 12bit RH / 14bit Temp. resolution	0	12bit RH 14bit Temp.

Table 5: Status Register Bits

Measurement resolution: The default measurement resolution of 14bit (temperature) and 12bit (humidity) can be reduced to 12 and 8bit. This is especially useful in high speed or extreme low power applications.

End of Battery function detects and notifies VDD voltages below 2.47 V. Accuracy is ±0.05 V.

Heater: An on chip heating element can be addressed by writing a command into status register. The heater may increase the temperature of the sensor by 5 – 10°C[12] beyond ambient temperature. The heater draws roughly 8mA @ 5V supply voltage.

For example the heater can be helpful for functionality analysis: Humidity and temperature readings before and after applying the heater are compared. Temperature shall increase while relative humidity decreases at the same time. Dew point shall remain the same.

Please note: The temperature reading will display the temperature of the heated sensor element and not ambient temperature. Furthermore, the sensor is not qualified for continuous application of the heater.

4 Conversion of Signal Output

4.1 Relative Humidity

For compensating non-linearity of the humidity sensor – see Figure 18 – and for obtaining the full accuracy of the sensor it is recommended to convert the humidity readout (SO_{RH}) with the following formula with coefficients given in Table 6:

$$RH_{linear} = c_1 + c_2 \cdot SO_{RH} + c_3 \cdot SO_{RH}^2 \ (\%RH)$$

[12] Corresponds to 9 – 18°F

SO_{RH}	c_1	c_2	c_3
12 bit	-2.0468	0.0367	-1.5955E-6
8 bit	-2.0468	0.5872	-4.0845E-4

Table 6: Optimized V4 humidity conversion coefficients

The values given in Table 6 are newly introduced and provide optimized accuracy for V4 sensors along the full measurement range. The parameter set c_x^*, which has been proposed in earlier datasheets, which was optimized for V3 sensors, still applies to V4 sensors and is given in Table 7 for reference.

SO_{RH}	c_1^*	c_2^*	c_3^*
12 bit	-4.0000	0.0405	-2.8000E-6
8 bit	-4.0000	0.6480	-7.2000E-4

Table 7: V3 humidity conversion coefficients, which also apply to V4.

For simplified, less computation intense conversion formulas see Application Note "RH and Temperature Non-Linearity Compensation". Values higher than 99% RH indicate fully saturated air and must be processed and displayed as 100%RH[13]. Please note that the humidity sensor has no significant voltage dependency.

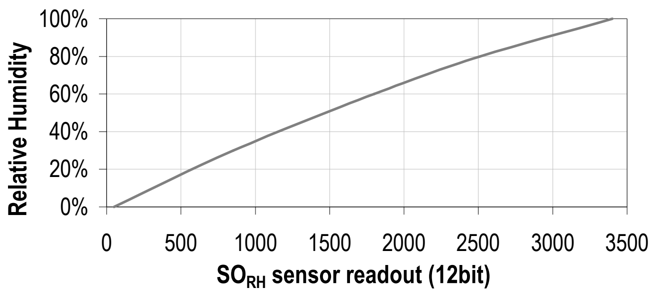


Figure 18: Conversion from SO_{RH} to relative humidity

4.2 Temperature compensation of Humidity Signal

For temperatures significantly different from 25°C (~77°F) the humidity signal requires a temperature compensation. The temperature correction corresponds roughly to 0.12%RH/°C @ 50%RH. Coefficients for the temperature compensation are given in Table 8.

$$RH_{true} = (T_{°C} - 25) \cdot (t_1 + t_2 \cdot SO_{RH}) + RH_{linear}$$

SO_{RH}	t_1	t_2
12 bit	0.01	0.00008
8 bit	0.01	0.00128

Table 8: Temperature compensation coefficients[14]

[13] If wetted excessively (strong condensation of water on sensor surface), sensor output signal can drop below 100%RH (even below 0%RH in some cases), but the sensor will recover completely when water droplets evaporate. The sensor is not damaged by water immersion or condensation.

[14] Coefficients apply both to V3 as well as to V4 sensors.

4.3 Temperature

The band-gap PTAT (Proportional To Absolute Temperature) temperature sensor is very linear by design. Use the following formula to convert digital readout (SO_T) to temperature value, with coefficients given in Table 9:

$$T = d_1 + d_2 \cdot SO_T$$

VDD	d_1 (°C)	d_1 (°F)
5V	-40.1	-40.2
4V	-39.8	-39.6
3.5V	-39.7	-39.5
3V	-39.6	-39.3
2.5V	-39.4	-38.9

SO_T	d_2 (°C)	d_2 (°F)
14bit	0.01	0.018
12bit	0.04	0.072

Table 9: Temperature conversion coefficients[15].

4.4 Dew Point

SHT1x is not measuring dew point directly, however dew point can be derived from humidity and temperature readings. Since humidity and temperature are both measured on the same monolithic chip, the SHT1x allows superb dew point measurements.

For dew point (T_d) calculations there are various formulas to be applied, most of them quite complicated. For the temperature range of -40 – 50°C the following approximation provides good accuracy with parameters given in Table 10:

$$T_d(RH, T) = T_n \cdot \frac{\ln\left(\frac{RH}{100\%}\right) + \frac{m \cdot T}{T_n + T}}{m - \ln\left(\frac{RH}{100\%}\right) - \frac{m \cdot T}{T_n + T}}$$

Temperature Range	Tn (°C)	m
Above water, 0 – 50°C	243.12	17.62
Above ice, -40 – 0°C	272.62	22.46

Table 10: Parameters for dew point (T_d) calculation.

Please note that "ln(…)" denotes the natural logarithm. For RH and T the linearized and compensated values for relative humidity and temperature shall be applied.

For more information on dew point calculation see Application Note "Dew point calculation".

[15] Temperature coefficients have slightly been adjusted compared to datasheet SHTxx version 3.01. Coefficients apply to V3 as well as V4 sensors.

5 Environmental Stability

If sensors are qualified for assemblies or devices, please make sure that they experience same conditions as the reference sensor. It should be taken into account that response times in assemblies may be longer, hence enough dwell time for the measurement shall be granted. For detailed information please consult Application Note "Qualification Guide".

The SHT1x sensor series were tested according to AEC-Q100 Rev. F qualification test method. Sensor specifications are tested to prevail under the AEC-Q100 temperature grade 2 test conditions listed in Table 11[16]. Sensor performance under other test conditions cannot be guaranteed and is not part of the sensor specifications. Especially, no guarantee can be given for sensor performance in the field or for customer's specific application.

Please contact Sensirion for detailed information.

Environment	Standard	Results[17]
HTSL	125°C, 1000 hours	Within specifications
TC	-50°C - 125°C, 1000 cycles Acc. JESD22-A104-C	Within specifications
UHST	130°C / 85%RH, 96h	Within specifications
THU	85°C / 85%RH, 1000h	Within specifications
ESD immunity	MIL STD 883E, method 3015 (Human Body Model at ±2kV)	Qualified
Latch-up	force current of ±100mA with T_{amb} = 80°C, acc. JEDEC 17	Qualified

Table 11: Qualification tests: HTSL = High Temperature Storage Lifetime, TC = Temperature Cycles, UHST = Unbiased Highly accelerated temperature and humidity Test, THU = Temperature humidity unbiased

6 Packaging

6.1 Packaging type

SHT1x are supplied in a surface mountable LCC (Leadless Chip Carrier) type package. The sensor housing consists of a Liquid Crystal Polymer (LCP) cap with epoxy glob top on a standard 0.8mm FR4 substrate. The device is fully RoHS and WEEE compliant – it is free of of Pb, Cd, Hg, Cr(6+), PBB and PBDE.

[16] Sensor operation temperature range is -40 to 105°C according to AEC-Q100 temperature grade 2.

[17] According to accuracy and long term drift specification given on Page 2.

Device size is 7.47 x 4.93 x 2.5 mm (0.29 x 0.19 x 0.1 inch), see Figure 1, weight is 100 mg.

6.2 Traceability Information

All SHT1x are marked with an alphanumeric, three digit code on the chip cap (for reference: V3 sensors were labeled with numeric codes) – see "A5Z" on Figure 1. The lot numbers allow full traceability through production, calibration and testing. No information can be derived from the code directly, respective data is stored at Sensirion and is provided upon request.

Labels on the reels are displayed in Figures 19 and 20, they both give traceability information.

```
Lot No.:     XX0-04-YRRRRTTTT
Quantity:    RRRR
RoHS:        Compliant

Lot No.
```

Figure 19: First label on reel: XX = Sensor Type (11 for SHT11), 04 = Chip Version (V4), Y = last digit of year, RRRR = number of sensors on reel, TTTT = Traceability Code.

SENSIRION
THE SENSOR COMPANY

Device Type:	1-100PPP-04
Description:	Humidity & Temperature Sensor SHTxx
Part Order No.	1-100PPP-04 or Customer Number
Date of Delivery:	DD.MM.YYYY
Order Code:	45CCCC / 0

Figure 20: Second label on reel: For Device Type and Part Order Number please refer to Table 12, Delivery Date (also Date Code) is date of packaging of sensors (DD = day, MM = month, YYYY = year), CCCC = Sensirion order number.

6.3 Shipping Package

SHT1x are shipped in 12mm tape at 100pcs, 400pcs and 2000pcs – for details see Figure 21 and Table 12. Reels are individually labeled with barcode and human readable labels.

Sensor Type	Packaging	Quantity	Order Number
SHT10	Tape & Reel	2000	1-100218-04
SHT11	Tape & Reel	100	1-100051-04
	Tape & Reel	400	1-100098-04
	Tape & Reel	2000	1-100524-04
SHT15	Tape & Reel	100	1-100085-04
	Tape & Reel	400	1-100093-04

Table 12: Packaging types per sensor type.

Dimensions of packaging tape is given in Figure 21. All tapes have a minimum of 480mm empty leader tape (first pockets of the tape) and a minimum of 300mm empty trailer tape (last pockets of the tape).

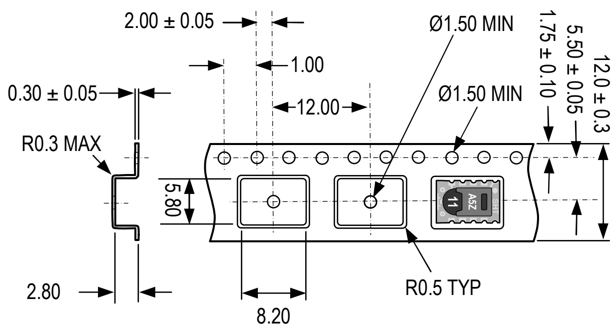


Figure 21: Tape configuration and unit orientation within tape, dimensions in mm (1mm = 0.039inch). The leader tape is at the right side of the figure while the trailer tape is to the left (direction of unreeling).

Revision History

Date	Version	Page(s)	Changes
March 2007	3.0	1 – 10	Data sheet valid for SHTxx-V4 and SHTxx-V3
August 2007	3.01	1 – 10	Electrical characteristics added, measurement time corrected
July 2008	4.0	1 – 10	New release, rework of datasheet

Important Notices

Warning, Personal Injury

Do not use this product as safety or emergency stop devices or in any other application where failure of the product could result in personal injury. Do not use this product for applications other than its intended and authorized use. Before installing, handling, using or servicing this product, please consult the data sheet and application notes. Failure to comply with these instructions could result in death or serious injury.

If the Buyer shall purchase or use SENSIRION products for any unintended or unauthorized application, Buyer shall defend, indemnify and hold harmless SENSIRION and its officers, employees, subsidiaries, affiliates and distributors against all claims, costs, damages and expenses, and reasonable attorney fees arising out of, directly or indirectly, any claim of personal injury or death associated with such unintended or unauthorized use, even if SENSIRION shall be allegedly negligent with respect to the design or the manufacture of the product.

ESD Precautions

The inherent design of this component causes it to be sensitive to electrostatic discharge (ESD). To prevent ESD-induced damage and/or degradation, take customary and statutory ESD precautions when handling this product.
See application note "ESD, Latchup and EMC" for more information.

Warranty

SENSIRION warrants solely to the original purchaser of this product for a period of 12 months (one year) from the date of delivery that this product shall be of the quality, material and workmanship defined in SENSIRION's published specifications of the product. Within such period, if proven to be defective, SENSIRION shall repair and/or replace this product, in SENSIRION's discretion, free of charge to the Buyer, provided that:

- notice in writing describing the defects shall be given to SENSIRION within fourteen (14) days after their appearance;
- such defects shall be found, to SENSIRION's reasonable satisfaction, to have arisen from SENSIRION's faulty design, material, or workmanship;
- the defective product shall be returned to SENSIRION's factory at the Buyer's expense; and
- the warranty period for any repaired or replaced product shall be limited to the unexpired portion of the original period.

This warranty does not apply to any equipment which has not been installed and used within the specifications recommended by SENSIRION for the intended and proper use of the equipment. EXCEPT FOR THE WARRANTIES EXPRESSLY SET FORTH HEREIN, SENSIRION MAKES NO WARRANTIES, EITHER EXPRESS OR IMPLIED, WITH RESPECT TO THE PRODUCT. ANY AND ALL WARRANTIES, INCLUDING WITHOUT LIMITATION, WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE, ARE EXPRESSLY EXCLUDED AND DECLINED.
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SENSIRION reserves the right, without further notice, (i) to change the product specifications and/or the information in this document and (ii) to improve reliability, functions and design of this product.

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Find your local representative at: http://www.sensirion.com/reps

Features

- Non-Isolated
- Synchronous rectification design
- Adjustable Output voltage
- 2, 3, 4AMP Adjustable Positive Step Down Integrated Switching Regulator
- Over load protection (125% full load typical)
- Remote ON/OFF Control(Ground Off)
- Wide Input Range
- UL94V-0 Package Material
- Continuous short circuit protection (Very low short current Iin sc<50mA)
- Input voltage range 4.5V~28V
- Efficiency to 97 %

INNOLINE
DC/DC-Converter
with 3 year Warranty

RECOM

2, 3, 4 AMP
SIP12
Vertical & Horizontal

RoHS 2002/95/EC 6/6

EN-60950-1 Certified

R-7xxx

Description

The R-7XXX series is a high performance 2.5V to 15V , 2Amp to 4Amp,12-Pin SIP (single in-line package), Integrated switching regulator (ISR). The Synchronuous - rectified design yields excellent efficiencies up to 97%. Short circuit protection with crowbar function reduces the short circuit current to under 50mA of input current.

Selection Guide

Part Number SIP12	Input Range (V)	Nominal Output Voltage (V)	Vout Adjust Range (V)	Output Current (A)	Efficiency (%) Min. Vin	12V	Max. Vin
R-723.3x	4.5 – 28	3.3	2.5 – 5.5	2	95	93	89
R-725.0x	6.5 – 28	5.0	3.0 – 5.5	2	96	95	91
R-726.5x	8.5 – 28	6.5	5.0 – 8.0	2	97	96	93
R-729.0x	12 – 28	9.0	7.0 – 11	2	96	-	93
R-7212x	15 – 28	12	10 – 14	2	97	-	95
R-7215x	19 – 28	15	13 – 17	2	97	-	96
R-733.3x	4.5 – 28	3.3	2.5 – 5.5	3	94	93	89
R-735.0x	6.5 – 28	5.0	3.0 – 5.5	3	95	95	92
R-736.5x	8.5 – 28	6.5	5.0 – 8.0	3	97	96	93
R-739.0x	12 – 28	9.0	7.0 – 11	3	96	-	94
R-7312x	15 – 28	12	10 – 14	3	97	-	96
R-7315x	19 – 28	15	13 – 17	3	97	-	96
R-743.3x	4.5 – 28	3.3	2.5 – 5.5	4	93	92	88
R-745.0x	6.5 – 28	5.0	3.0 – 5.5	4	95	94	91
R-746.5x	8.5 – 28	6.5	5.0 – 7.5	4	96	96	93

Note: Vin-Vout ≥ 1.5V~4.0V depending on Vout if adjust function is used!

Suffix x: (see mechanical drawing for details)
x = P pins vertical through hole
x = D pins bent for horizontal through hole mounting

Specifications (refer to the standard application circuit, Ta: 25°C)

Characteristics	Conditions	Min.	Typ.	Max.
Output Voltage Range	All Series	2.5		17V
Output Current	R-72xxP/D R-73xxP/D R-74xxP/D	0.2 0.3 0.4		2.0A 3.0A 4.0A
Output Current Limit	R-72xxP/D R-73xxP/D R-74xxP/D		2.5 3.75 5.0	3.0A 4.25A 5.5A
Short Circuit Input Current	All Series		50	100mA
Short Circuit Protection			Continuous, automatic recovery	
Output Voltage Accuracy (At 100% Load)	All Series		±1%	±2%
Line Voltage Regulation (Vin = min. to max. at full load)	All Series		0.5	1.0%
Load Regulation (10 to 100% full load)	All Series		0.5	1.0%
Ripple & Noise	All Series		40mVp-p	70mVp-p
Transient Response (see note 1)	50% Load Change – Vout Over / Undershoot		100µs	200µs 100mV
Remote ON / OFF (see note 2)	Open or High (Power ON) Low (Power OFF)	4.5		28V 0.8V
Max capacitance Load	with normal start-up time, no external diodes with <1 second start up time + diode protection circuit			200µF 6800µF
Switching Frequency		270	300	330kHz
Shutdown current	ON / OFF Pin pulled low			100µA
Quiescent Current	Vin = min. to max. at 0% load			30mA
Operating Temperature Range		-40°C		+85°C
Operating Case Temperature				+110°C
Storage Temperature Range		-40°C		+125°C
Case Material				Non-Conductive Black Plastic
Potting Material				Epoxy (UL94V-0)
Thermal Impedance	Natural Convection			25°C/W
Internal Power Dissipation	Ta < 60°C			1.4W
Package Weight				9g
Packing Quantity				15 pcs per Tube
MTBF (Nominal Vout, 100% load)	Tamb. = +25°C Tamb. = +85°C	*Detailed Information see Application Notes chapter "MTBF"*		749 x 10^3hours 150 x 10^3hours

Notes:

1. Requires a 100µF electrolytic or tantalum output capacitor for proper operation in all applications (the capacitor to be placed as close as possible to the output pins).
2. ON / OFF pin driven by TTL (logic gate), open-collector bipolar transistor or open-drain MOSFET.

Output Current vs Input Voltage

How to calculate the max output current

The internal power dissipation(P_D)follows the equation:

$P_D = Io \times Vo \times (1-\eta)$

$Io = P_D / Vo \times (1-\eta)$

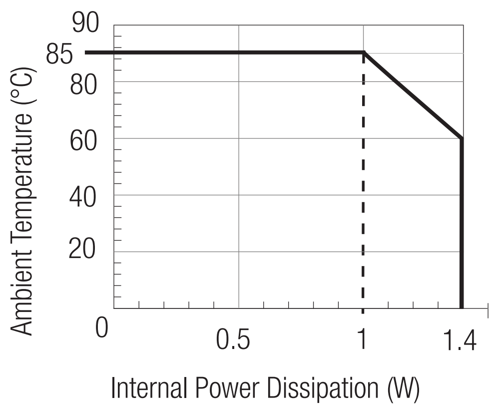
Where P_D = Internal power dissipation
Io = Output current
Vo = Output voltage
η = Efficiency

Example: R-745.0P , at Vin = 28Vdc , Vo = 5Vdc ,η=91% (see "Selection Guide" table)

(a) When Ta = 60°C , P_D = 1.4 Watt (see beside diagram)
Io = 1.4(W) / 5(V) × (1-0.91) = 3.11(A)

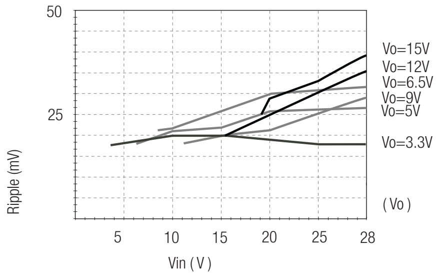
(b) When Ta = 85°C , P_D = 1 Watt (see beside diagram)
Io = 1(W) / 5(V) × (1-0.91) = 2.222(A)

(c) At Vin = 12Vdc efficiency = 94% (see "Selection Guide" table)
When Ta = 85°C , P_D = 1 Watt (see beside diagram)
Io = 1(W) / 5(V) × (1-0.94) =3.33(A)



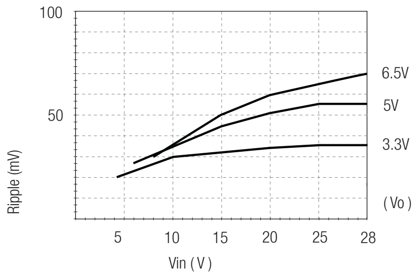
Characteristics

R-72xx / R-73xx
Ripple VS Vin



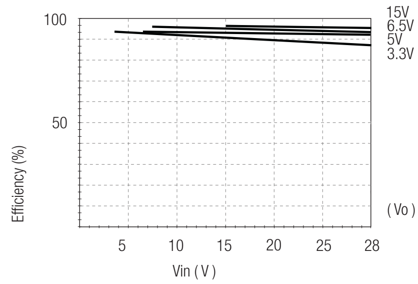
Ripple Vs Vin

R-74xx
Ripple VS Vin



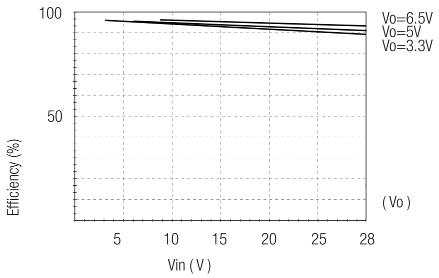
Ripple Vs Vin

R-72xx / R-73xx
Efficiency VS Vin



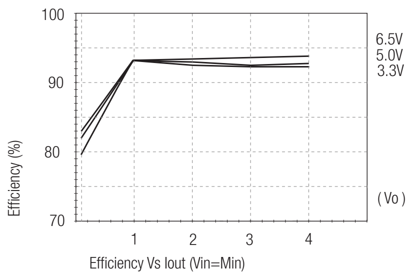
Efficiency Vs Vin

R-74xx
Efficiency VS Vin



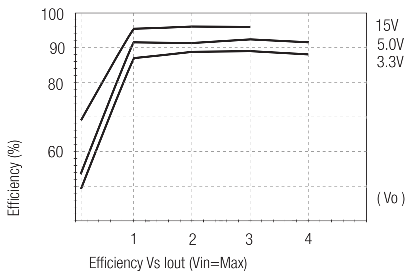
Efficiency Vs Vin

R-72xx / R-73xx / R-74xx
Efficiency / Load Vin=Min



Efficiency Vs Iout (Vin=Min)

R-72xx / R-73xx / R-74xx
Efficiency / Load Vin=Max

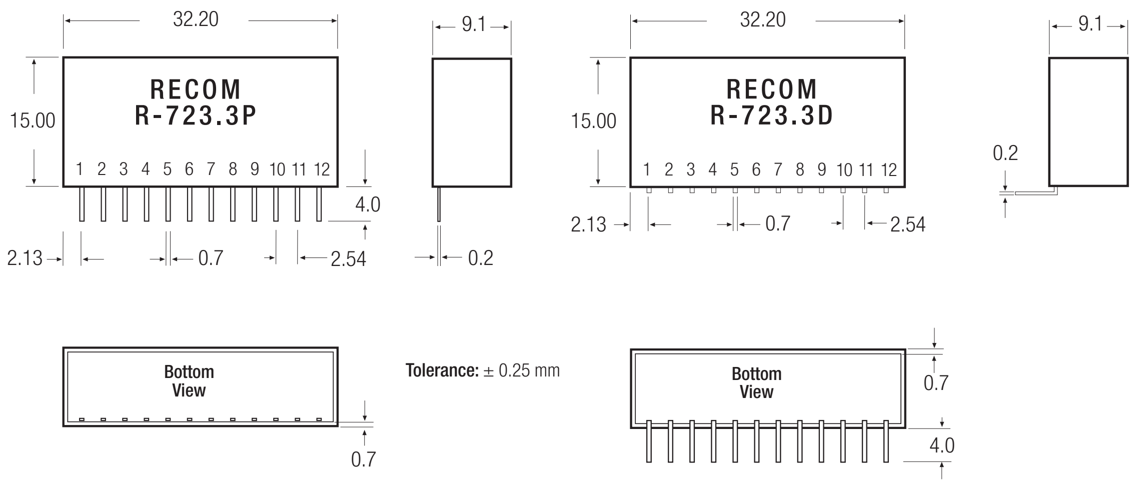


Efficiency Vs Iout (Vin=Max)

Package Style and Pinning (mm)

SIP12 PIN Package

3rd angle projection



Tolerance: ± 0.25 mm

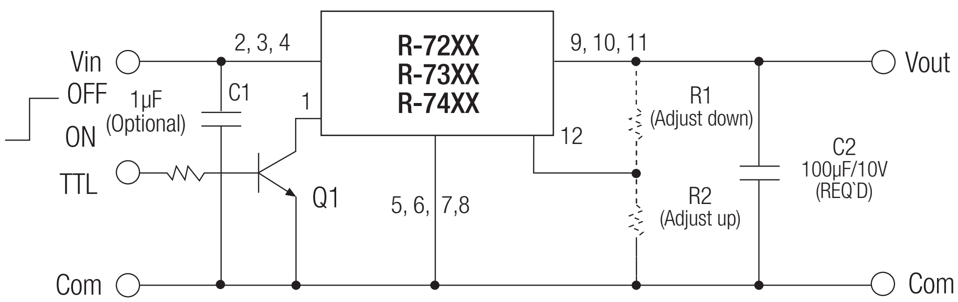
Pin Connections

Pin #	Name	Description
1	ON / OFF	Input pin : Active low (less than 0.8V) to disable the device
2, 3, 4	Vin	Power input
5, 6, 7, 8	GND	Input and output ground (common)
9 , 10, 11	Vout	Power output
12	Vout-Adj	With external resistors R1,R2 to selected output voltage

Table 1: Adjustment Resistor Values

2ADC	R-723.3P/D		R-725.0P/D		R-726.5P/D		R-729.0P/D		R-7212P/D		R-7215P/D	
3ADC	R-733.3P/D		R-735.0P/D		R-736.5P/D		R-739.0P/D		R-7312P/D		R-7315P/D	
4ADC	R-743.3P/D		R-745.0P/D		R-746.5P/D							
Vout (nominal)	3.3Vdc		5.0Vdc		6.5Vdc		9.0Vdc		12Vdc		15Vdc	
Vout (adj)	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2	R1	R2
2.5	8.5KΩ											
3.0	33KΩ		470Ω									
3.2	110KΩ		1.6KΩ									
3.3			2.2KΩ									
3.4		36KΩ	3.0KΩ									
3.6		11KΩ	4.7KΩ									
3.9		4.7KΩ	8.5KΩ									
4.5		1.6KΩ	30KΩ									
4.9		820Ω	220KΩ									
5.0		680Ω			11KΩ							
5.1		560Ω		28KΩ	12KΩ							
5.5		190Ω		2.6KΩ	20KΩ							
6.0					47KΩ							
6.5												
7.0						560Ω	13KΩ					
8.0						330Ω	31KΩ					
9.0												
10								2.2KΩ	20KΩ			
11								390Ω	47KΩ			
12												
13										2.4KΩ	36KΩ	
14										390Ω	76KΩ	
15												
16												2.6KΩ
17												860Ω
18												

Standard Application Circuit



Add a blocking diode to Vout if current can flow backwards into the output, as this can damage the converter.

Protection diodes are required for high capacitive loads.

Refer to R-5xxxA Datasheet (see Optional Diode Protection Circuit) for circuit suggestions.

R-7xxx

ORDER?	# Purchased	Components	Footprint	QTY	POWER REQ	Rating Requirement	Voltage, Current/Power Rating of Ordered Part	Vendor	$ Each	In Schematic?	Link	Notes
		Capacitors										
N		1000uF/35V	thru (12.5mm diam)	1	-	24V, 3A max	35V	Digikey	$0.90	Y	http://www.digikey.com/product-detail/en/ECA-1VHG102/P5555-ND/245154	
Y	10	2.2uF/35V	smd (0805)	2	-	24V, 3A max	35V	Digikey	$0.46	Y	http://www.digikey.com/product-detail/en/C2012X7R1V225K%2FSOFT/445-8892-1-ND/3283681	
Y	10	10uF	smd (0805)	2	-	5V x 2	10V	Digikey	0.105	Y	http://www.digikey.com/product-detail/en/C2012Y5V1A106Z/445-1371-1-ND/567608	
Y	10	10uF	smd (0805)	2	-	12V x2	25V	Digikey	$0.67	Y	http://www.digikey.com/scripts/DKSearch/dksus.dll?Detail&itemSeq=127457309&uq=634984383741961157	C18, C3
Y	10	22pF	smd (0805)	2	-	5V	50V	Digikey	$0.10	Y	http://www.digikey.com/product-detail/en/500R15N220JV4T/709-1172-1-ND/1859504	
Y	10	.1uF	smd (0805)	3	-	5V x2, 24V x1	50V	Digikey	0.066	Y	http://www.digikey.com/product-detail/en/C2012X7R1H104K%2F0.85/445-7534-1-ND/2733606	
		Inductor										
~~N~~		~~47uH/35V/1.2A~~	~~smd~~	~~2~~	-		~~35V, 1.2A~~	~~Digikey~~	~~$0.56~~	~~Y~~	~~http://www.digikey.com/product-detail/en/ASPI-6045S-470M-T/ASPI-6045S-470M-TCT-ND/3060390~~	Needed to replace! Unavailable from Digikey but this is inductor trace on board
Y	10	47uH	smd	2	-	1.2A	1.2A	Digikey	$0.46	Y	http://www.digikey.com/product-detail/en/VLC6045T-470M/445-6537-1-ND/2465843	Replacement inductor that should still fit trace
		Resistor					P = V^2/R or IV					
Y	50	1M Ohm Res	smd (0805)	1	-	5V (.000025W)	.125W	Digikey	$0.03	Y	http://www.digikey.com/product-detail/en/ERJ-6ENF1004V/P1.00MCCT-ND/119836	
Y	50	470 Ohm smd resistor	805	4	-	5V (.053W)	.125W	Digikey	$0.02	Y	http://www.digikey.com/product-detail/en/ERJ-6GEYJ471V/P470ACT-ND/90029	
Y	50	1k Resistor	805	4	-	5V (.025W)	.125W	Digikey	$0.02	Y	http://www.digikey.com/product-detail/en/ERJ-6GEYJ102V/P1.0KACT-ND/42833	
Y	50	100k Resistor	805	1	-	24V (.0058W)	.125W	Digikey	$0.03	Y	http://www.digikey.com/product-detail/en/ERJ-6ENF1003V/P100KCCT-ND/119551	
Y	50	4.7k Ohm Resistor	805	1	-	5V (.0053W)	.125W	Digikey	$0.02	Y	http://www.digikey.com/product-detail/en/ERJ-6GEYJ472V/P4.7KACT-ND/82468	
Y	2	TS53YJ503MR10 - Potentiometer	smd	1	-	5V	.25W (max 112V, 2.2 mA)	Digikey	$1.62	Y	http://www.digikey.com/product-detail/en/TS53YJ503MR10/TS53YJ-50KCT-ND/1587989	
		Diode										
N		1N4004	thru	2	-	12V, 3A MAX	400V, 1A (should be fine)	Digikey	$0.43	Y	http://www.digikey.com/product-detail/en/1N4004-E3%2F54/1N4004-E3%2F54GICT-ND/868987	
		Other Helpful Components										
N		Yaw Motor	-	1	(24V motor)/23A peak current	-	-				GM14904SO16 Pittman Motor	
N		LEDs (Pod Light)	smd	6	24V/3A max	-	-	Digikey	$7.44	N	http://www.digikey.com/product-detail/en/XMLAWT-00-0000-000LT50E3/XMLAWT-00-0000-000LT50E3CT-ND/2615397	3A max, 2.9V Vforward
N		standard 3mm LED	thru	1	-	-	20mA max	Sparkfun	$0.35	Y	https://www.sparkfun.com/products/9650	
N		fuse	-	1	-	24V, .5A	?			Y	ask Ridgely	
N		fuse holder	-	1	-	?	?			Y	ask Ridgely	
Y	2	RS 485 Transciever	smd	1	3.3-5.0V	-	-	Digikey	$3.14	Y	http://www.digikey.com/scripts/DKSearch/dksus.dll?Detail&itemSeq=127022527&uq=634976724538238040	
N		Atmega 1281	smd	1	2.7-5.5V	-	-	Digikey	$13.12	Y	http://www.digikey.com/product-detail/en/ATMEGA1281-16AU/ATMEGA1281-16AU-ND/1245829	
Y	1	External Oscillation Crystal	thru	1	-	-	-	Digikey	$1.01	Y	http://www.digikey.com/product-detail/en/ECS-160-20-5P-TR/XC694CT-ND/38747	
Y	1	ES23MCBE Switch	thru	1	-	-	.4W (20V max)	Digikey	$6.92	Y	http://www.digikey.com/product-search/en?x=0&y=0&lang=en&site=us&KeyWords=es23mcbe	
Y	2	SHT15	smd	1	5V	-	-	Sparkfun	$28.95	Y	https://www.sparkfun.com/products/8227	
N		Hall Effect Switch	thru	1	3.5-24V	-	-	Sparkfun	$0.95	-	https://www.sparkfun.com/products/9312	Power, I/O pin, ground (this one is diff from original hall effect sensor, basically same)
N		Phototransistor visible light	thru	1	5V	-	-	Digikey	$0.67		http://www.digikey.com/product-detail/en/BPW85/751-1023-ND/1681157	
N		Fan (AUC0512DB-AF00)	-	2	12V, .18A	-	-	Digikey	9.2	N	http://www.digikey.com/product-search/en?x=0&y=0&lang=en&site=us&KeyWords=AUC0512DB-AF00	
N		Servo (parallax standard 900-00005)	-	2	4-6V	-	-					
N		Canera (A1IPPTZ10X2MP)	-	1	12V, 1A	-	-	Triton				
Y	2	Humidity & Temp Sensor	smd	1	2.4-5.5V (3.3V typical)	-	-	Sparkfun	$28.95	Y	https://www.sparkfun.com/products/8227	Humidity and Temperature Sensor - SHT15, COM-08227
		Transistors										
N		IRFR3707	smd	2	-	24V, 12V	30V, 56 A	Digikey	$1.17	Y	http://www.digikey.com/product-detail/en/IRFR3707ZTRPBF/IRFR3707ZTRPBFCT-ND/812523	
Y	4	BSS123	smd	1	-	5V	.36W	Digikey	$0.29	Y	http://www.digikey.com/product-detail/en/BSS123/BSS123NCT-ND/244665	
		Regulators/Drivers										
~~Y~~	~~3~~	~~LM1084IS-ADJ (5V reg)~~	~~smd~~	~~1~~	-			~~Digikey~~	~~$2.79~~	-	~~http://www.digikey.com/product-detail/en/LM1084IS-ADJ%2FNOPB/LM1084IS-ADJ%2FNOPB-ND/363553~~	ACCIDENTAL ORDER! NEED 5.0 REG NOT ADJUSTABLE!
Y	4	LM1084IS-5.0 (5V reg)	smd	1	-	24V	25V, 5A	Digikey	$2.79	Y	http://www.digikey.com/product-detail/en/LM1084IS-5.0%2FNOPB/LM1084IS-5.0%2FNOPB-ND/363552	
Y	3	LM2937IMP-5.0 (5Vreg)	smd	1	-	24V	26V, .4A	Digikey	$1.85	Y	http://www.digikey.com/product-detail/en/LM2937IMP-5.0%2FNOPB/LM2937IMP-5.0%2FNOPBCT-ND/270743	
N		TI-PT6304 (12V regulator)	thru	1	-	-	16-38Vin, 3A max	-	$25.00	Y	http://www.digikey.com/product-detail/en/PT6304N/PT6304N-ND/278552	
Y	2	VNH3SP30 (motor driver)	smd	1	.3-40V max (use 5V)	-	40V, 30A max	Digikey	$9.55	Y	http://www.digikey.com/product-detail/en/VNH3SP30TR-E/497-3565-1-ND/669421	
N		RCD-24-1.20 (Led Driver)	thru	2	24V/3A max	-	24V, 3A max	Digikey	$19.57	Y	http://www.digikey.com/product-search/en/power-supplies-board-mount/led-supplies/4326590?k=RCD-24-1.20	
		Connectors/Headers										
N		CONN HEADER PHD SIDE 10POS 2MM	thru	3	-	24V, full A of POD components (3.08 A)	250V, 3A	Digikey	$0.45	Y	http://www.digikey.com/product-detail/en/S10B-PHDSS%20%20%28LF%29%28SN%29%28P%29/455-1775-ND/926681	hangs off board, up to 250 VAC/DC
N		CONN HOUSING PHD 10POS 2MM DUAL	-	3	-	24V, full A of POD components (3.08 A)	250V, 3A	Digikey	$0.32	-	http://www.digikey.com/product-detail/en/PHDR-10VS/455-1158-ND/608600	
N		CONN HEADER PHD TOP 22POS 2MM	-	1	-	24V, .5A max	250V, 3A	Digikey	$0.54	-	http://www.digikey.com/product-detail/en/PHDR-22VS%28P%29/455-1175-ND/608617	connects to cable (22 pins), withstands 250V ACorDC, 3A
N		CONN HOUSING PHD 22POS 2MM DUAL	thru	1	-	24V, .5A max	250V, 3A	Digikey	$0.81	Y	http://www.digikey.com/product-detail/en/B22B-PHDSS%28LF%29%28SN%29/455-1768-ND/926674	goes on PCB (22 pins), withstands 250V ACorDC, 3A
Y	2	0.1in Conn Header	thru	AR	-	5V		Sparkfun	$1.50	Y	https://www.sparkfun.com/products/116	
Y	(ask JR)	0.1in Conn Header (2pin)	thru	6	-						ask ridgely	
N		Crimp Contacts	-	65	-			Digikey	$0.06	-	http://www.digikey.com/product-detail/en/SPHD-001T-P0.5/455-1325-1-ND/608808	
		Custom PCB										
		Pawesome Board V2.6	-	3	24V	-	-	DorkBot	$62.00	-	oshpark.com	

Pier Portal II Project (P^{Awesome} Project)

Doxygen

Misha Balingit

Version 2.0

Class Index

Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

Class Index

Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

File Index

File List

Here is a list of all documented files with brief descriptions:

Class Documentation

ADC_result Union Reference

Public Attributes

uint8_t **bytes** [2]

The bytes in the number.

uint16_t **word**

The whole 16-bit number.

Detailed Description

This union holds the two bytes which are read from the A/D converter's result registers after a conversion has been completed. They're referenced also as one 16-bit integer which can be returned as the result of a conversion.

Definition at line 43 of file avr_adc.cpp.

The documentation for this union was generated from the following file:

1. **avr_adc.cpp**

avr_adc Class Reference

```
#include <avr_adc.h>
```

Public Member Functions

avr_adc (void)

unsigned int **read_once** (uint8_t)

uint16_t **read_once_in_ISR** (uint8_t)

uint16_t **read_oversampled** (uint8_t, uint8_t)

Protected Attributes

base_text_serial * **ptr_to_serial**

The ADC class uses this pointer to the serial port to say hello.

xSemaphoreHandle **a2d_mutex**

Detailed Description

This class should run the A/D converter on an AVR processor.

Definition at line 50 of file avr_adc.h.

Constructor & Destructor Documentation

avr_adc::avr_adc (void)

This constructor sets up an A/D converter.

Parameters:

p_serial_port	A pointer to the serial port which writes debugging info.

Member Function Documentation

uint16_t avr_adc::read_once (uint8_t *channel*)

This method takes one A/D reading from the given channel and returns it. WARNING: This method must not be called from within an Interrupt Service Routine because it uses the FreeRTOS mutex (semaphore) functions which aren't usable in an ISR.

Parameters:

Definition at line 55 of file avr_adc.cpp.

References a2d_mutex, and ADC_PRESCALE.

channel	The A/D channel which is being read must be from 0 to 7

The result of the A/D conversion, or 0xFFFF if there was a timeout

Definition at line 76 of file avr_adc.cpp.

References a2d_mutex, A2D_MUTEX_WAIT, ADC_RETRIES, ADC_result::bytes, and ADC_result::word.

Referenced by task_LED::run(), and task_user::run().

uint16_t avr_adc::read_once_in_ISR (uint8_t *channel*)

This method takes one A/D reading from the given channel and returns it. WARNING: This method must only be called from within an Interrupt Service Routine because it uses FreeRTOS mutex (semaphore) functions which are for ISR use only. If you're using the A/D within an ISR and within ordinary tasks, your program is designed in a fairly sketchy way and it will be difficult to ensure reliable operation; you would be well advised to reconsider your high level design.

Parameters:

Returns:

channel	The A/D channel which is being read must be from 0 to 7

The result of the A/D conversion, or 0xFFFF if there was a timeout

Definition at line 126 of file avr_adc.cpp.

References a2d_mutex, ADC_RETRIES, ADC_result::bytes, and ADC_result::word.

uint16_t avr_adc::read_oversampled (uint8_t *channel*, uint8_t *samples*)

This function sets the A/D multiplexer to read from the given channel, then reads that channel the given number of times (up to a maximum of 32) and computes the average of the readings. This can help reduce noise. Note that there are many ways to digitally filter a signal; this is just one very crude, simple way. WARNING: This method must never be called from an ISR. It takes a long time to run and doesn't belong in an ISR anyway. Also, since it does many reads of the A/D, it can block another task from using the A/D for a long time. Caveat lusor.

Parameters:

Returns:

channel	The A/D channel which is being read must be from 0 to 7
samples	The number of samples to be taken and averaged

The averaged result of the A/D conversions, or -1 if an error occurred

Definition at line 182 of file avr_adc.cpp.

References a2d_mutex, A2D_MUTEX_WAIT, ADC_RETRIES, ADC_result::bytes, and ADC_result::word.

Member Data Documentation

xSemaphoreHandle avr_adc::a2d_mutex `[protected]`

This mutex is used to prevent multiple tasks from trying to use the A/D converter at the same time. It is automatically taken and given back in methods of this class, so users don't usually have to worry about it, except to be careful that low priority tasks don't block higher priority tasks from running by selfishly taking over the A/D converter.

Definition at line 62 of file avr_adc.h.

Referenced by avr_adc(), read_once(), read_once_in_ISR(), and read_oversampled().

The documentation for this class was generated from the following files:

2 **avr_adc.h**

3 **avr_adc.cpp**

config_file Class Reference

`#include <config_file.h>`

Inheritance diagram for config_file:

IMAGE

Public Member Functions

config_file (sd_card *, base_text_serial *=NULL)

virtual void **read** (char const *)

uint16_t **skip_to_next_line** (void)

void **skip_to_EOL** (void)

uint8_t **read_bool** (uint16_t)

int32_t **read_int** (uint16_t)

Protected Attributes

sd_card * **sd_dev**

This pointer points to the SD card where the configuration file resides.

base_text_serial * **p_serial**

This pointer points to a serial debugging port if one is to be used.

Detailed Description

This class parses a configuration file which is kept on some type of serially accessed device such as an SD card. The configuration file is made up in sections, with sections being indicated by a text header in brackets; the file contains items which map to variables that will be kept in the configuration, generally numbers and flags (boolean values) and (in the future) text strings and comments. The items are distinguished as follows:

Comments are put in the file line by line; they begin with a number sign (#). When a number sign is found, the rest of the line is ignored. A comment may be on a line after a data item.

Numbers are expected to be integers (floats may be supported in the future). They are to be given one per line. It's OK to have comments after the numbers.

Boolean values can be given as text which begins with Y, y, T, t, or On for values which are true; N, n, F, f, or Off represent false values.

An example file looks like the following: `# Sample configuration file`

```
# This comment explains something really important.
157 # Numerator
100 # Denominator
-13 # Offset

# The following lines contain switches that turn A/D channels on or off.
# There are eight A/D channels in most AVR microcontrollers. On
Off
On
Off
On
On
Off
Off

# End of file
```

CAUTION: Make sure that there aren't any mostly-blank lines which only contain spaces. Such lines may confuse this program by appearing as if they're data when they're not.

Definition at line 87 of file config_file.h.

Constructor & Destructor Documentation

config_file::config_file (sd_card * *p_sd_device*, base_text_serial * *p_ser_dev* = `NULL`)

This constructor creates a configuration file parser attached to the given SD card.

Parameters:

Returns:

p_sd_device	The device, such as an SD card, on which the file is kept
p_ser_dev	Pointer to a serial port used for debugging output

Member Function Documentation

void config_file::read (char const * *file_name*) `[virtual]`

This is a base class method to read a configuration file. It only reads and prints out the file, if debugging is properly enabled. Descendent classes need to implement their own versions of read() which are appropriate for configurations of specific systems.

Parameters:

Definition at line 38 of file config_file.cpp.

References p_serial, and sd_dev.

file_name	Pointer to a string containing the name of the file to be read

uint8_t config_file::read_bool (uint16_t *a_char*)

This method reads a Boolean value from the configuration file. The value may be represented by various symbols; anything beginning with [YyTt] is taken as meaning true; anything beginning with [NnFf] is taken as false; if the first letter is [Oo] then the second letter is checked, as we've probably got 'On' or 'Off.'

Parameters:

Reimplemented in **logger_config** (*p.*Error! Bookmark not defined.).

Definition at line 54 of file config_file.cpp.

a_char	The first character of the item, often found by **skip_to_next_line()**

0 for false, 1 for true, and 0xFF for undetermined (not a valid Boolean)

Definition at line 155 of file config_file.cpp.

References sd_dev.

Referenced by logger_config::read().

int32_t config_file::read_int (uint16_t *a_char*)

This method reads an integer from the configuration file. It goes through the digits until it finds something that isn't in the range [0..9], at which time the result is assumed to be known. Floating point numbers are not handled by this method; a decimal point just means the end of the integer, and anything after it will be paid no attention.

Parameters:

Returns:

a_char	The first character of the item, often found by **skip_to_next_line()**

The integer which was found, given in a signed long for generality. If you need a smaller integer, just typecast this return value into something with fewer bits.

Definition at line 221 of file config_file.cpp.

References sd_dev.

Referenced by logger_config::read().

void config_file::skip_to_EOL (void)

This method is called when a comment character has been found. It reads and ignores all characters up to the end of the current line. The file pointer is moved forward in the file, but nothing else is changed.

Definition at line 136 of file config_file.cpp.

References CFG_END_OF_LINE, and sd_dev.

Referenced by skip_to_next_line().

uint16_t config_file::skip_to_next_line (void)

This method reads characters, skipping whitespace (spaces and returns) and ignoring lines which are comments, until it has found the first character on the next active (non-comment) line. That first character is returned, and the file pointer is left pointing to the character after that first character.

Returns:

The first non-comment character found, or (-1) if error or end of file

Definition at line 88 of file config_file.cpp.

References CFG_COMMENT_CHAR, CFG_END_OF_LINE, sd_dev, and skip_to_EOL().

Referenced by logger_config::read().

The documentation for this class was generated from the following files:

4 **config_file.h**

5 **config_file.cpp**

da_encoder Class Reference

This define prevents this .h file from being included more than once in a .cpp file.

#include <da_encoder.h>

Public Member Functions

da_encoder (void)

uint16_t **get_error** (void)

int32_t **get_ticks** (void)

Detailed Description

This define prevents this .h file from being included more than once in a .cpp file.

Following are the headers of the constructor and methods contained in **da_encoder.cpp**.

Definition at line 27 of file da_encoder.h.

Constructor & Destructor Documentation

da_encoder::da_encoder (void)

The constructor says hello using the serial port which is specified in the pointer given to it. It is also given pointers to two variables in main which count encoder ticks and two which count the number of encoder errors.

This constructor sets up an encoder driver. Pin Change Interrupts are enabled on port E and utilize INT6 and 7. These mentioned ports are also verified to be outputs in the DDR and pull-up resitors are enabled.

Definition at line 39 of file da_encoder.cpp.

Member Function Documentation

uint16_t da_encoder::get_error (void)

This method returns the number of missed encoder ticks.

Definition at line 91 of file da_encoder.cpp.

References error.

int32_t da_encoder::get_ticks (void)

This method returns the current tick count of the encoder.

Definition at line 96 of file da_encoder.cpp.

References encoder.

Referenced by task_yaw_motor::run(), and task_user::run().

The documentation for this class was generated from the following files:

6 **da_encoder.h**

7 **da_encoder.cpp**

da_motor Class Reference

This define prevents this .h file from being included more than once in a .cpp file.

```
#include <da_motor.h>
```

Public Member Functions

da_motor (void)

Include header for serial port class.

void **set_mode** (uint8_t mode)

void **update_duty_cycle** (uint8_t duty_cycle)

Detailed Description

This define prevents this .h file from being included more than once in a .cpp file.

Definition at line 23 of file da_motor.h.

Constructor & Destructor Documentation

da_motor::da_motor (void)

Include header for serial port class.

Include standard library header files You'll need this for SFR and bit names This constructor sets up a motor driver. It configures the correct bits in the correct registers to run motor #2 on an ME405 board.

Definition at line 36 of file da_motor.cpp.

Member Function Documentation

void da_motor::set_mode (uint8_t *mode*)

This method allows a user to choose a motor's rotational direction or apply unmodulated braking. These tasks are performed by passing mode 1,2,or 3. mode 1 = spin CW mode 2 = spin CCW mode 3 = unmodulated braking

Parameters:

Returns:

mode,:	selects mode as detailed above.

void da_motor::update_duty_cycle (uint8_t *duty_cycle*)

This method sets the duty cycle of the motor to the value passed to the function.

Definition at line 181 of file da_motor.cpp.

Referenced by task_yaw_motor::run().

The documentation for this class was generated from the following files:

8 **da_motor.h**

9 **da_motor.cpp**

fan_driver Class Reference

This define prevents this .h file from being included more than once in a .cpp file.

`#include <fan_driver.h>`

Public Member Functions

fan_driver (void)

void **fan_on** (void)

void **fan_off** (void)

void **set_speed** (uint8_t speed)

Detailed Description

This define prevents this .h file from being included more than once in a .cpp file.

Definition at line 27 of file fan_driver.h.

Constructor & Destructor Documentation

fan_driver::fan_driver (void)

Constructor sets the correct bits in the correct registers for PWM output to the fan.

Definition at line 37 of file fan_driver.cpp.

Member Function Documentation

void fan_driver::fan_off (void)

This method disables the fans by clearing pin E2.

Definition at line 101 of file fan_driver.cpp.

Referenced by task_fans::run(), and task_user::run().

void fan_driver::fan_on (void)

This method enables the fans by setting pin E2.

Definition at line 93 of file fan_driver.cpp.

Referenced by task_fans::run(), and task_user::run().

void fan_driver::set_speed (uint8_t *speed*)

This method sets the speed of the fans by updating the frequency of the PWM output.

Parameters:

Definition at line 144 of file da_motor.cpp.

Referenced by task_yaw_motor::run().

speed	Sets the fan speed.

The documentation for this class was generated from the following files:

10 **fan_driver.h**

11 **fan_driver.cpp**

Leaky_driver Class Reference

This define prevents this .h file from being included more than once in a .cpp file.

`#include <Leaky_driver.h>`

Public Member Functions

Leaky_driver (void)

Include header for serial port class.

bool **check_leaks** (void)

Protected Attributes

uint8_t **LED_PWM_out**

This variable is used to set the duty cycle for the PWM.

Detailed Description

This define prevents this .h file from being included more than once in a .cpp file.

Definition at line 19 of file Leaky_driver.h.

Constructor & Destructor Documentation

Leaky_driver::Leaky_driver (void)

Include header for serial port class.

Include standard library header files You'll need this for SFR and bit names Include A2D This constructor sets up the leak detection circuit driver.

Definition at line 26 of file Leaky_driver.cpp.

Member Function Documentation

bool Leaky_driver::check_leaks (void)

This function checks if there are leaks in the pod! It's so simple! =o

Definition at line 39 of file Leaky_driver.cpp.

Referenced by task_leak::run().

The documentation for this class was generated from the following files:

12 **Leaky_driver.h**

13 **Leaky_driver.cpp**

LED_driver Class Reference

This define prevents this .h file from being included more than once in a .cpp file.

`#include <LED_driver.h>`

Public Member Functions

LED_driver (void)

Include header for serial port class.

void **set_light** (uint8_t percent)

Protected Attributes

uint8_t **LED_PWM_out**

This variable is used to set the duty cycle for the PWM.

Detailed Description

This define prevents this .h file from being included more than once in a .cpp file.

Definition at line 24 of file LED_driver.h.

Constructor & Destructor Documentation

LED_driver::LED_driver (void)

Include header for serial port class.

Include standard library header files You'll need this for SFR and bit names Include A2D This constructor sets up an LED driver. The output pins are enabled here. The LED driver uses a non-inverting fast PWM and clk/64 which is set up here

Definition at line 32 of file LED_driver.cpp.

References LED_PWM_out.

Member Function Documentation

void LED_driver::set_light (uint8_t *percent*)

Set light changes the duty cycle of the lights to change their brightness

Parameters:

Definition at line 111 of file fan_driver.cpp.

Referenced by task_fans::run(), and task_user::run().

percent,:	The percentage of light desired from 0 to 100%

The documentation for this class was generated from the following files:

14 **LED_driver.h**

15 **LED_driver.cpp**

logger_config Class Reference

```
#include <logger_config.h>
```

Inheritance diagram for logger_config:

IMAGE

Public Member Functions

logger_config (sd_card *, base_text_serial *=NULL)

void **read** (const char *const file_name)

bool **read_channel** (void)

uint16_t **get_ms_per_sample** (void)

bool **is_valid** (void)

bool **channel_on** (uint8_t)

Protected Attributes

uint16_t **ms_per_reading**

bool **channels_on_off** [**N_A2D_CHANNELS**]

bool **config_valid**

This boolean is true only if a valid configuration has been read.

Detailed Description

This class parses simple configuration files, kept on SD cards, for Swoop data loggers. This version of the logger is very simple. Data is recorded by taking measurements from the specified A/D channels, at the given rate in milliseconds per sample. The data is written as raw A/D readings onto the SD card. That's it.

The configuration file must contain the following:

Comments which describe what's in the file. A comment begins with a "#".

An integer which specifies the number of RTOS ticks per sample. This number should be in the range [80..40000]; faster and the SD card won't be able to record the data quickly enough.

A set of eight channel on/off specifications; for each A/D channel, there must be a boolean value of "On" or "Off."

Definition at line 68 of file logger_config.h.

Constructor & Destructor Documentation

logger_config::logger_config (sd_card * *p_card*, base_text_serial * *p_ser_dev* = `NULL`)

This constructor creates a logger configuration file reader but does not yet read the configuration file.

Parameters:

Definition at line 113 of file LED_driver.cpp.

References LED_PWM_out.

Referenced by task_LED::run().

p_card	A pointer to the SD card on which the configuration is stored
p_ser_dev	A pointer to a base_text_serial descendent object to be used for diagnostic and debugging output

---

Member Function Documentation

bool logger_config::channel_on (uint8_t *channel*)

This method returns a Boolean that indicates if a given A/D channel is on or off. If there is no valid configuration, all channels will be considered on by default.

Parameters:

Definition at line 37 of file logger_config.cpp.

References channels_on_off, config_valid, ms_per_reading, and N_A2D_CHANNELS.

channel	The number of the A/D channel to be checked

True if the channel is on and false if it is off

Definition at line 116 of file logger_config.cpp.

References channels_on_off, config_valid, and N_A2D_CHANNELS.

Referenced by task_sender::run().

uint16_t logger_config::get_ms_per_sample (void) `[inline]`

This method returns the milliseconds per data point specified in the configuration file, or (-1) if no valid rate has been given.

Returns:

The number of readings per second to take

Definition at line 96 of file logger_config.h.

References ms_per_reading.

Referenced by task_sender::run().

bool logger_config::is_valid (void) `[inline]`

This method returns a Boolean that indicates if a valid configuration has been successfully read from a configuration file.

Returns:

True if the configuration is valid and usable, false if not

Definition at line 105 of file logger_config.h.

References config_valid.

Referenced by task_sender::run().

void logger_config::read (const char *const *file_name*) `[virtual]`

This method reads configuration data from a file of the given name and stores the configuration data in member variables belonging to this class, except for the list of A/D channels to read, which is stored in an array whose pointer is given to the constructor of this class.

Parameters:

Returns:

file_name	The name of the file in which the configuration is stored

Member Data Documentation

bool logger_config::channels_on_off[N_A2D_CHANNELS] `[protected]`

This array holds channel settings: which A/D channels are to be measured and which are to be ignored.

Definition at line 80 of file logger_config.h.

Referenced by channel_on(), logger_config(), and read().

uint16_t logger_config::ms_per_reading `[protected]`

The timer interrupt service routine which controls data recording goes off much faster than we actually save data; data is only saved once in every this-many-times runs of the interrupt service routine.

Definition at line 75 of file logger_config.h.

Referenced by get_ms_per_sample(), logger_config(), and read().

The documentation for this class was generated from the following files:

16 **logger_config.h**

17 **logger_config.cpp**

servo_driver::separate Union Reference

This union contains the high and low byte of the duty cycle.

`#include <servo_driver.h>`

Public Attributes

uint16_t **temp_duty**

uint8_t **parts** [2]

Detailed Description

This union contains the high and low byte of the duty cycle.

Definition at line 33 of file servo_driver.h.

The documentation for this union was generated from the following file:

18 **servo_driver.h**

task_user::servo_data Union Reference

Union for writing to the servo queue.

`#include <task_user.h>`

Public Attributes

uint16_t **both**

uint8_t **servo** [2]

Detailed Description

Union for writing to the servo queue.

Definition at line 92 of file task_user.h.

The documentation for this union was generated from the following file:

19 **task_user.h**

servo_driver Class Reference

This define prevents this .h file from being included more than once in a .cpp file.

`#include <servo_driver.h>`

Classes

union **separate**

This union contains the high and low byte of the duty cycle. **Public Member Functions**

servo_driver (void)

void **Set_Angle** (uint16_t angle)

Protected Attributes

uint16_t **ServoSet**

This is a buffer for converting angle to PWM duty cycle.

union **servo_driver::separate duty_parts**

Detailed Description

This define prevents this .h file from being included more than once in a .cpp file.

Definition at line 25 of file servo_driver.h.

Constructor & Destructor Documentation

servo_driver::servo_driver (void)

Constructor sets the correct pins for PWM output to the servos.

Definition at line 38 of file servo_driver.cpp.

Member Function Documentation

void servo_driver::Set_Angle (uint16_t *angle*)

Set_Angle sets the angle of the servos

Parameters:

Reimplemented from **config_file** (*p.*Error! Bookmark not defined.).

Definition at line 58 of file logger_config.cpp.

References channels_on_off, config_valid, MAX_MS_PER_READING, MIN_MS_PER_READING, ms_per_reading, config_file::p_serial, config_file::read_bool(), config_file::read_int(), config_file::sd_dev, and config_file::skip_to_next_line().

Referenced by task_sender::run().

angle	sets the servo angle between 0 and 360 degrees

The documentation for this class was generated from the following files:

20 **servo_driver.h**

21 **servo_driver.cpp**

task_fans Class Reference

`#include <task_fans.h>`

Public Member Functions

task_fans (const char *, unsigned portBASE_TYPE, size_t, base_text_serial *)

This constructor creates a task object.

void **run** (void)

This run method is called by the RTOS and contains a loop which operates the fans.

Detailed Description

This task class controls the operation of the fans. The two fans will run in parallel. The on/off functionality of the fans will be dependent on the temperature and humidity readings from the SHT15 sensor.

Definition at line 55 of file task_fans.h.

Constructor & Destructor Documentation

task_fans::task_fans (const char * *a_name*, unsigned portBASE_TYPE *a_priority*, size_t *a_stack_size*, base_text_serial * *p_ser_dev*)

This constructor creates a task object.

Header for this task.

This constructor creates a new fan control task. Its main job is to call the parent class's constructor which does most of the work.

Parameters:

Definition at line 128 of file servo_driver.cpp.

Referenced by task_servo::run().

a_name	A character string which will be the name of this task
a_priority	The priority at which this task will initially run (default: 0)
a_stack_size	The size of this task's stack in bytes (default: configMINIMAL_STACK_SIZE)
p_ser_dev	Pointer to a serial device (port, radio, SD card, etc.) which can be used by this

	task to communicate (default: NULL)

Member Function Documentation

void task_fans::run (void)

This run method is called by the RTOS and contains a loop which operates the fans.

This run method controls the operation of the fans. The two fans will run in parallel. The on/off functionality of the fans will be dependent on the temperature and humidity readings from the SHT15 sensor.

Definition at line 51 of file task_fans.cpp.

References fan_driver::fan_off(), fan_driver::fan_on(), FAN_TICKS_PER_RUN, my_fans, p_fan_queue, fan_driver::set_speed(), and temperature.

The documentation for this class was generated from the following files:

22 **task_fans.h**

23 **task_fans.cpp**

task_leak Class Reference

```
#include <task_leak.h>
```

Public Member Functions

task_leak (const char *, unsigned portBASE_TYPE, size_t, base_text_serial *)

This constructor creates a task object.

void **run** (void)

This run method is called by the RTOS and contains a loop which monitors the leak detector.

Protected Attributes

bool **leaky**

This tells us if the pod is leaking (True = leaks! false = sealed up good n proper!)

Detailed Description

This task class controls the operation of the leak detector.

Definition at line 50 of file task_leak.h.

Constructor & Destructor Documentation

task_leak::task_leak (const char * *a_name*, unsigned portBASE_TYPE *a_priority*, size_t *a_stack_size*, base_text_serial * *p_ser_dev*)

This constructor creates a task object.

Header for leak detection driver.

Header for this task This constructor creates a new leak detector task. Its main job is to call the parent class's constructor which does most of the work.

Parameters:

Definition at line 32 of file task_fans.cpp.

a_name	A character string which will be the name of this task
a_priority	The priority at which this task will initially run (default: 0)
a_stack_size	The size of this task's stack in bytes (default: configMINIMAL_STACK_SIZE)

p_ser_dev	Pointer to a serial device (port, radio, SD card, etc.) which can be used by this task to communicate (default: NULL)

Member Function Documentation

void task_leak::run (void)

This run method is called by the RTOS and contains a loop which monitors the leak detector.

This run method monitors the leak detection circuit. If a leak is detected, the serial port is to be spammed with warnings.

Definition at line 47 of file task_leak.cpp.

References Leaky_driver::check_leaks(), LEAK_TICKS_PER_RUN, leaky, and my_leaky_task.

The documentation for this class was generated from the following files:

24 **task_leak.h**

25 **task_leak.cpp**

task_LED Class Reference

```
#include <task_LED.h>
```

Public Member Functions

task_LED (const char *, unsigned portBASE_TYPE, size_t, base_text_serial *)

This constructor creates a the LED task object.

void **run** (void)

This run method is called by the RTOS and contains a loop in which the LED brightness is controlled.

Protected Attributes

uint16_t **photo_reading**

This holds the value of the most recent reading from the phototransistor.

uint8_t **brightness**

This holds the latest brightness setting value (ranges 0-100)

bool **auto_mode**

This holds the last LED mode- auto is true.

Detailed Description

This task class controls the brightness of the LEDs.

Definition at line 52 of file task_LED.h.

Constructor & Destructor Documentation

task_LED::task_LED (const char * *a_name*, unsigned portBASE_TYPE *a_priority*, size_t *a_stack_size*, base_text_serial * *p_ser_dev*)

This constructor creates a the LED task object.

Header for this task.

This constructor creates a new LED task. Its main job is to call the parent class's constructor which does most of the work.

Parameters:

Definition at line 28 of file task_leak.cpp.

References leaky.

a_name	A character string which will be the name of this task
a_priority	The priority at which this task will initially run (default: 0)
a_stack_size	The size of this task's stack in bytes (default: configMINIMAL_STACK_SIZE)
p_ser_dev	Pointer to a serial device (port, radio, SD card, etc.) which can be used by this task to communicate (default: NULL)

Member Function Documentation

void task_LED::run (void)

This run method is called by the RTOS and contains a loop in which the LED brightness is controlled.

This run method controls the LED brightness. The final version of this task will increase and decrease the brightness of the LEDs based on the readings from the phototransistors. This task will continually check to see how bright the environment is and adjust the LED array brightness accordingly.

WARNING: this auto mode will need to be calibrated in the pod!!

it is currently calibrated for the mecha room!

Definition at line 50 of file task_LED.cpp.

References auto_mode, brightness, LED_TICKS_PER_RUN, my_LED_driver, p_LED_PWM_queue, PHOTO_CHAN, photo_reading, avr_adc::read_once(), LED_driver::set_light(), and the_a2d.

The documentation for this class was generated from the following files:

26 **task_LED.h**

27 **task_LED.cpp**

task_sender Class Reference

This define prevents this .H file from being included multiple times in a .CPP file.

`#include <task_sender.h>`

Public Member Functions

task_sender (const char *, unsigned portBASE_TYPE, size_t, base_text_serial *, sd_card *)

void **run** (void)

Protected Attributes

sd_card * **p_the_card**

base_text_serial * **p_serial**

Detailed Description

This define prevents this .H file from being included multiple times in a .CPP file.

This task reads measurements that were taken by the data acquisition task in task_daq.* and puts those measurements into a queue.

Definition at line 50 of file task_sender.h.

Constructor & Destructor Documentation

task_sender::task_sender (const char * *a_name*, unsigned portBASE_TYPE *a_priority*, size_t *a_stack_size*, base_text_serial * *p_ser_dev*, sd_card * *p_sd_card*)

This constructor creates a new data acquisition task. Its main job is to call the parent class's constructor which does most of the work.

Parameters:

Definition at line 29 of file task_LED.cpp.

References auto_mode, and brightness.

a_name	A character string which will be the name of this task
a_priority	The priority at which this task will initially run (default: 0)
a_stack_size	The size of this task's stack in bytes (default: configMINIMAL_STACK_SIZE)

p_ser_dev	Pointer to a serial device (port, radio, SD card, etc.) which can be used by this task to communicate (default: NULL)
p_sd_card	Pointer to an SD card on which data will be written

Member Function Documentation

void task_sender::run (void)

This run method is called by the RTOS and contains a loop in which the task checks for data and sends it if appropriate.

This method receives data from the data acquisition task in a queue and sends the information or saves it, depending on what its serial device pointer points to.

Definition at line 96 of file task_sender.cpp.

References logger_config::channel_on(), DEF_MS_PER_SAMPLE, logger_config::get_ms_per_sample(), logger_config::is_valid(), N_A2D_CHANNELS, p_serial, p_the_card, logger_config::read(), SD_EXT, SD_FILENAME, and ticks_to_delay.

Member Data Documentation

base_text_serial* task_sender::p_serial `[protected]`

This pointer allows debugging messages to be sent out as this task sets itself up, unless it's left as NULL in the constructor, in which case it does nothing.

Definition at line 62 of file task_sender.h.

Referenced by run(), and task_sender().

sd_card* task_sender::p_the_card `[protected]`

This is a pointer to the SD card on which data will hopefully be saved.

Definition at line 57 of file task_sender.h.

Referenced by run(), and task_sender().

The documentation for this class was generated from the following files:

28 **task_sender.h**

29 **task_sender.cpp**

task_servo Class Reference

`#include <task_servo.h>`

Public Member Functions

task_servo (const char *, unsigned portBASE_TYPE, size_t, base_text_serial *)

This constructor creates a servo task object.

void **run** (void)

This run method is called by the RTOS and contains a loop in which the servos are independent controlled.

Protected Attributes

int8_t **servo1_pos**

servo1_pos and servo2_pos will hold the position values for independent servo control.

int8_t **servo2_pos**

uint16_t **test_var**

this is a test variable

Detailed Description

This run method controls the servos and LED angular position. This task will eventually run a control loop for a desired position. The two servos will be able to operate independently using seperated position variables and control loops.

Definition at line 47 of file task_servo.h.

Constructor & Destructor Documentation

task_servo::task_servo (const char * *a_name*, unsigned portBASE_TYPE *a_priority*, size_t *a_stack_size*, base_text_serial * *p_ser_dev*)

This constructor creates a servo task object.

Header for this task.

This constructor creates a new servo task. Its main job is to call the parent class's constructor which does most of the work.

Parameters:

Definition at line 75 of file task_sender.cpp.

References p_serial, and p_the_card.

a_name	A character string which will be the name of this task
a_priority	The priority at which this task will initially run (default: 0)
a_stack_size	The size of this task's stack in bytes (default: configMINIMAL_STACK_SIZE)
p_ser_dev	Pointer to a serial device (port, radio, SD card, etc.) which can be used by this task to communicate (default: NULL)

Member Function Documentation

void task_servo::run (void)

This run method is called by the RTOS and contains a loop in which the servos are independent controlled.

This task function controls the servos and LED angular position. This task will eventually run a control loop for a desired position. The two servos will be able to operate independently using seperated position variables and control loops.

Definition at line 51 of file task_servo.cpp.

References my_servos, p_servo_queue, servo1_pos, SERVO_TICKS_PER_RUN, servo_driver::Set_Angle(), and test_var.

The documentation for this class was generated from the following files:

30 **task_servo.h**

31 **task_servo.cpp**

task_user Class Reference

`#include <task_user.h>`

Classes

union **servo_data**

Union for writing to the servo queue.

Public Member Functions

task_user (const char *, unsigned portBASE_TYPE, size_t, base_text_serial *)

This constructor creates a user interface task object.

void **run** (void)

Protected Member Functions

void **print_help_message** (void)

void **show_status** (void)

Protected Attributes

base_text_serial * **p_serial**

union **task_user::servo_data position**

Detailed Description

This user task allows the Pawesome team to code and debug functionality including operation of the fans, LEDs, main yaw motor, readings from the phototransistors, and the use of queues to pass information/commands between tasks.

Definition at line 54 of file task_user.h.

Constructor & Destructor Documentation

task_user::task_user (const char * *a_name*, unsigned portBASE_TYPE *a_priority*, size_t *a_stack_size*, base_text_serial * *p_ser_dev*)

This constructor creates a user interface task object.

This constructor creates a new data acquisition task. Its main job is to call the parent class's constructor which does most of the work.

Parameters:

Definition at line 30 of file task_servo.cpp.

References servo1_pos.

a_name	A character string which will be the name of this task
a_priority	The priority at which this task will initially run (default: 0)
a_stack_size	The size of this task's stack in bytes (default: configMINIMAL_STACK_SIZE)
p_ser_dev	Pointer to a serial device (port, radio, SD card, etc.) which can be used by this task to communicate (default: NULL)

Member Function Documentation

void task_user::print_help_message (void) `[protected]`

This method displays a simple help message telling the user what to do. It's protected so that only methods of this class or possibly descendents can use it

This method prints a simple help message.

Definition at line 354 of file task_user.cpp.

References p_serial.

Referenced by run().

void task_user::run (void)

This run method is called by the RTOS and contains a loop in which the task checks for user input and characters in the print queue, dealing with each in the appropriate manner.

This task interacts with the user. This user task allows the Pawesome team to code and debug functionality including operation of the fans, LEDs, main yaw motor, readings from the phototransistors, and the use of queues to pass information/commands between tasks.

for demo/testing purposes, increase & decrease pod temp will be taken out in final product

Definition at line 82 of file task_user.cpp.

References fan_driver::fan_off(), fan_driver::fan_on(), da_encoder::get_ticks(), my_encoder, my_fans, p_LED_PWM_queue, p_serial, p_servo_queue, p_yaw_queue, print_help_message(), print_ser_queue, avr_adc::read_once(), fan_driver::set_speed(), show_status(), temperature, the_a2d, and ticks_to_delay.

void task_user::show_status (void) `[protected]`

This method displays information about the status of the system

This method displays information about the status of the system, including

32 The name and version of the program

33 The name, status, priority, and free stack space of each task

34 Processor cycles used by each task

35 Amount of heap space free and setting of RTOS tick timer

Definition at line 420 of file task_user.cpp.

References p_serial, and PROGRAM_VERSION.

Referenced by run().

Member Data Documentation

base_text_serial* task_user::p_serial `[protected]`

This pointer allows all the methods in this task to use the serial port, or whatever serial device is being used to communicate with the user.

Definition at line 78 of file task_user.h.

Referenced by print_help_message(), run(), show_status(), and task_user().

The documentation for this class was generated from the following files:

36 **task_user.h**

37 **task_user.cpp**

task_yaw_motor Class Reference

`#include <task_yaw_motor.h>`

Public Member Functions

task_yaw_motor (const char *, unsigned portBASE_TYPE, size_t, base_text_serial *)

Delay counter to turn off motor current at destination.

void **run** (void)

void **set_kp** (uint16_t kp_val)

set K_p

void **set_ki** (uint16_t ki_val)

set K_i

void **set_kd** (uint16_t kd_val)

set K_d

uint16_t **GET_Kp** (void)

returns K_p

uint16_t **GET_Ki** (void)

returns K_i

uint16_t **GET_Kd** (void)

returns K_d

Protected Attributes

uint8_t **dummy**

stupid counting variable

uint8_t **duty_cycle**

name pretty well says it

uint16_t **K_p**

proportional gain

uint16_t **K_i**

integral gain

uint16_t **K_d**

differential gain

int32_t **prev_error**

used for differential feedback

int32_t **E_sum_old**

used for integral feedback

int32_t **encoder**

encoder reading

int32_t **Set_Point**

the set point

Detailed Description

This task class controls the position of the yaw motor.

Definition at line 52 of file task_yaw_motor.h.

Constructor & Destructor Documentation

task_yaw_motor::task_yaw_motor (const char * *a_name*, unsigned portBASE_TYPE *a_priority*, size_t *a_stack_size*, base_text_serial * *p_ser_dev*)

Delay counter to turn off motor current at destination.

This constructor creates a new yaw motor task. Its main job is to call the parent class's constructor which does most of the work.

Parameters:

Definition at line 59 of file task_user.cpp.

References p_serial, and temperature.

a_name	A character string which will be the name of this task
a_priority	The priority at which this task will initially run (default: 0)
a_stack_size	The size of this task's stack in bytes (default: configMINIMAL_STACK_SIZE)
p_ser_dev	Pointer to a serial device (port, radio, SD card, etc.) which can be used by this task to communicate (default: NULL)

Member Function Documentation

void task_yaw_motor::run (void)

This run method is called by the RTOS and contains a loop in which the data acquisition takes place.

This run method runs a position PID control loop that controls the position of the yaw motor inside the pod.

Definition at line 62 of file task_yaw_motor.cpp.

References duty_cycle, E_sum_old, encoder, da_encoder::get_ticks(), K_d, K_i, K_p, K_P_DIVISOR, my_encoder, my_motor, p_yaw_queue, prev_error, da_motor::set_mode(), Set_Point, stop_count, da_motor::update_duty_cycle(), and YAW_TICKS_PER_RUN.

void task_yaw_motor::set_kd (uint16_t *kd_val*) `[inline]`

set K_d

Parameters:

Definition at line 44 of file task_yaw_motor.cpp.

kd_val,:	the value you wish to set the gain to

void task_yaw_motor::set_ki (uint16_t *ki_val*) `[inline]`

set K_i

Parameters:

Definition at line 91 of file task_yaw_motor.h.

References K_d.

ki_val,:	the value you wish to set the gain to

void task_yaw_motor::set_kp (uint16_t *kp_val*) `[inline]`

set K_p

Parameters:

Definition at line 89 of file task_yaw_motor.h.

References K_i.

kp_val,:	the value you wish to set the gain to

The documentation for this class was generated from the following files:

38 **task_yaw_motor.h**

39 **task_yaw_motor.cpp**

File Documentation

avr_adc.cpp File Reference

```
#include <stdlib.h>

#include <avr/io.h>

#include "rs232int.h"

#include "avr_adc.h"
```

Classes

union **ADC_result**

Defines

#define **ADC_PRESCALE** (1 << ADPS1)

Default prescaler setting (F_cpu / 4)

#define **ADC_RETRIES** 10000

Retries before giving up on conversion.

Detailed Description

This file contains a very simple A/D converter driver. The driver is hopefully thread safe in FreeRTOS due to the use of a mutex to prevent its use by multiple tasks at the same time. There is no protection from priority inversion, however.

Revisions:

01-15-2008 JRR Original (somewhat useful) file

10-11-2012 JRR Less original, more useful file with FreeRTOS mutex added

10-12-2012 JRR There was a bug in the mutex code, and it has been fixed

Definition in file **avr_adc.cpp**.

avr_adc.h File Reference

```
#include "base_text_serial.h"
#include "FreeRTOS.h"
#include "task.h"
#include "queue.h"
#include "semphr.h"
```

Classes

class **avr_adc**

Variables

const portTickType **A2D_MUTEX_WAIT** = 100

This define prevents this .H file from being included multiple times in a .CPP file.

Detailed Description

This file contains a very simple A/D converter driver. The driver is hopefully thread safe in FreeRTOS due to the use of a mutex to prevent its use by multiple tasks at the same time. There is no protection from priority inversion, however.

Revisions:

01-15-2008 JRR Original (somewhat useful) file

10-11-2012 JRR Less original, more useful file with FreeRTOS mutex added

10-12-2012 JRR There was a bug in the mutex code, and it has been fixed

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Definition in file **avr_adc.h**.

Variable Documentation

const portTickType A2D_MUTEX_WAIT = 100

This define prevents this .H file from being included multiple times in a .CPP file.

This constant defines how long the A/D functions are willing to wait for the mutex which prevents tasks from stepping on each other's A/D use. It's in RTOS ticks. A typical value is 100, which is 0.1 second (eternity) for a 1 ms RTOS tick period.

Definition at line 43 of file avr_adc.h.

Referenced by avr_adc::read_once(), and avr_adc::read_oversampled().

config_file.cpp File Reference

```
#include "config_file.h"
```

Detailed Description

This file contains a base class used to create a parser for really simple configuration files which are to be kept on an SD cards or similar devices. The SD card (or other device) is expected to be used in a small AVR based data logger of some sort. This base class provides generic configuration file reading functions; it is expected that descendents will be designed to read specific files in specific projects.

Revisions:

01-15-2008 JRR Original (somewhat useful) file

12-27-2009 JRR Added tools for reading booleans and integers

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Definition in file **config_file.cpp**.

config_file.h File Reference

`#include "sd_card.h"`

Classes

class **config_file**

Variables

const char **CFG_COMMENT_CHAR** = '#'

const char **CFG_END_OF_LINE** = '\n'

Detailed Description

This file contains a base class used to create a parser for really simple configuration files which are to be kept on an SD cards or similar devices. The SD card (or other device) is expected to be used in a small AVR based data logger of some sort. This base class provides generic configuration file reading functions; it is expected that descendents will be designed to read specific files in specific projects.

Revisions:

01-15-2008 JRR Original (somewhat useful) file

12-27-2009 JRR Added tools for reading booleans and integers

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Definition in file **config_file.h**.

Variable Documentation

const char CFG_COMMENT_CHAR = '#'

This definition specifies which character will be seen as beginning a comment. The most common choice is usually the pound sign (or number sign, or hash).

Definition at line 36 of file config_file.h.

Referenced by config_file::skip_to_next_line().

const char CFG_END_OF_LINE = '\n'

This constant specifies the character which is the last character on a line. It is usually a newline '

'.

Definition at line 43 of file config_file.h.

Referenced by config_file::skip_to_EOL(), and config_file::skip_to_next_line().

da_encoder.cpp File Reference

```
#include <stdlib.h>

#include <avr/io.h>

#include "rs232int.h"

#include "da_encoder.h"
```

Functions

ISR (INT0_vect)

ISR (INT1_vect)

Variables

bool **skip** = false

Creates a boolean to be toggled in order to check for missed ticks.

uint16_t **error** = 0

Counts number of missed ticks encountered on encoder.

int32_t **encoder** = 0

Counts encoder ticks.

Detailed Description

da_encoder.cpp is an object class that contains a constructor which initializes interrupts and configures necessary i/o ports. It also is passed a serial pointer which allows encoder objects to print to the terminal window. All other operations handled by **da_encoder** are contained in the ISR. The constructor is passed pointers to two variables in main which keep count of encoder ticks, where those values are inc/decremented here in the ISR.

Revisions:

04-18-11 Began tearing and hacking at our lab_3 code.

04-25-11 Final iteration. (for now)

05-05-11 Gutted version of encoder to be paired with slave_driver

04-23-12 Refinishing driver to use on senior project

11-10-12 CMG Copied and revised driver for use on ME405 board License: This file released under the Lesser GNU Public License. The program is intended for educational use only, but its use is not restricted thereto.

Definition in file **da_encoder.cpp**.

Function Documentation

ISR (INT0_vect)

This is the interrupt service routine which is called everytime there is a logic shift (0 to 1 or 1 to 0) on the "A" input channel of the encoder This is the interrupt service routine which is called everytime there is a logic shift (0 to 1 or 1 to 0) on the "B" input channel of the encoder This is the interrupt service routine which is called everytime there is a logic shift (0 to 1 or 1 to 0) on the "A" input channel of the encoder

Definition at line 181 of file da_encoder.cpp.

References encoder, error, and skip.

ISR (INT1_vect)

This is the interrupt service routine which is called everytime there is a logic shift (0 to 1 or 1 to 0) on the "B" input channel of the encoder

Definition at line 207 of file da_encoder.cpp.

References encoder, error, and skip.

Variable Documentation

bool skip = false

Creates a boolean to be toggled in order to check for missed ticks.

< Include standard library header files You'll need this for SFR and bit names Include header for serial port class This object utilizes 3 file scope variables for each encoder. This allows motor movement to be determined using interrupts. Also, errors are counted.

Definition at line 30 of file da_encoder.cpp.

Referenced by ISR().

da_encoder.h File Reference

Classes

class **da_encoder**

This define prevents this .h file from being included more than once in a .cpp file.

Detailed Description

da_encoder.h contains specifications necessary for the methods within **da_encoder.cpp** to be called from within any main program as long as this header file is included.

Revisions:

04-18-11 Began tearing and hacking at our lab_3 code.

04-21-11 Final iteration. Sweet.

04-25-11 I lied. Doxygen comments added today.

05-04-11 began integrating into slave draver

05-05-11 this gutted version of encoder does all lab5 requires and nothing more

04/23/12 Revising for use in senior project License: This file released under the Lesser GNU Public License. The program is intended for educational use only, but its use is not restricted thereto.

Definition in file **da_encoder.h**.

da_motor.cpp File Reference

```
#include <stdlib.h>

#include <avr/io.h>

#include "rs232int.h"

#include "da_motor.h"
```

Detailed Description

da_motor.cpp is an object class that contains a constructor and two methods which control a motor(s). The constructor initializes timers, prescalars and configures necessary i/o ports. The first method sets the duty cycle of the motor to a specified value. The second method sets the H bridge to achieve proper rotational direction and braking.

Revisions:

04-12-11 Began tearing and hacking at our lab_2 code.

04-18-11 Final iteration. This code is the bestest.

11-11-12 CMG Modified the code to work with RTOS on an ME405 board

02-21-13 MGB modified code to work on an ME405 board with an Atmega1281 instead of 128

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Definition in file **da_motor.cpp**.

da_motor.h File Reference

Classes

class **da_motor**

This define prevents this .h file from being included more than once in a .cpp file.

Detailed Description

da_motor.h contains specifications necessary for the methods within **da_motor.cpp** to be called from within any main program as long as this header file is included.

Revisions:

11-04-11 Included specification for the method "read_a_few" within **avr_adc.cpp**

04-12-11 Began tearing and hacking at our lab_2 code.

04-18-11 Final iteration. This code is the bestest.

11-11-12 CMG Modified the code to work with RTOS on an ME405 board.

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Definition in file **da_motor.h**.

fan_driver.cpp File Reference

```
#include <stdlib.h>

#include <avr/io.h>

#include <avr/interrupt.h>

#include "rs232int.h"

#include "fan_driver.h"
```

Defines

#define **MIN** 0

Include header for serial port class.

#define **MAX** 255

Detailed Description

fan_driver.cpp is a class that is used to create an object to drive the fans. It contains two methods that turn the fans on and off by setting or clearing a bit that is wired to a transistor. There is a third method used to set the duty cycle of the PWM output to the fans to change their speed.

Revisions:

11-04-11 Included specification for the method "read_a_few" within **avr_adc.cpp**

04-12-11 Began tearing and hacking at our lab_2 code.

04-18-11 Final iteration. This code is the bestest.

04-10-12 Turns out bestest gets better. Using for senior project now

11-20-12 CMG Copied file from old senior project team and modified to work with RTOS on ME405 board with an Atmega128

02-14-13 MGB makes it so this file works w/ ME405 board w/ Atmega 1281! We're getting closer and closer to the actual Possum board...

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Definition in file **fan_driver.cpp**.

Define Documentation

#define MIN 0

Include header for serial port class.

Standard C library Input-output ports, special registers Interrupt handling function

Definition at line 31 of file fan_driver.cpp.

fan_driver.h File Reference

Classes

class **fan_driver**

This define prevents this .h file from being included more than once in a .cpp file.

Detailed Description

This is the header file for **fan_driver.cpp**. Servo 1 is the upper one and has it's pin on the left of the temp boardservo contains specifications necessary for the methods within servo.cpp to be called from within any main program as long as this header file is included.

Revisions:

11-04-11 Included specification for the method "read_a_few" within **avr_adc.cpp**

04-12-11 Began tearing and hacking at our lab_2 code.

04-18-11 Final iteration. This code is the bestest.

04-10-12 Turns out bestest gets better. Using for senior project now

11-20-12 CMG Copied file from old senior project team and modified to work with RTOS on ME405 board

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Definition in file **fan_driver.h**.

Leaky_driver.cpp File Reference

```
#include <stdlib.h>

#include <avr/io.h>

#include "rs232int.h"

#include "avr_adc.h"

#include "Leaky_driver.h"
```

Detailed Description

This file is used as a driver for the leak detection circuit.

Revisions:

11-20-12 MGB Modified LED driver for use with RTOS on ME405 board

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Definition in file **Leaky_driver.cpp**.

Leaky_driver.h File Reference

Classes

class **Leaky_driver**

This define prevents this .h file from being included more than once in a .cpp file.

Detailed Description

This is a header file for the leak detection driver.

Revisions:

05-20-13 MGB Modified LED driver for use with RTOS on ME405 board

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Definition in file **Leaky_driver.h**.

LED_driver.cpp File Reference

```
#include <stdlib.h>

#include <avr/io.h>

#include "rs232int.h"

#include "avr_adc.h"

#include "LED_driver.h"
```

Detailed Description

This file is used as a driver for the LED arrays. The two LEDs operate in parallel. This driver allows the user to increase or decrease the brightness of the LEDs by changing the duty cycle so as to achieve any desied brightness between 0-100%.

Revisions:

04-12-11 Began tearing and hacking at our lab_2 code.

04-18-11 Final iteration. This code is the bestest.

04-10-12 Turns out bestest gets better. Using for senior project now

11-20-12 CMG Modified for use with RTOS on ME405 board

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Definition in file **LED_driver.cpp**.

LED_driver.h File Reference

Classes

class **LED_driver**

This define prevents this .h file from being included more than once in a .cpp file.

Detailed Description

This is a header file for the LED driver. The two LEDs operate in parallel. This driver allows the user to increase or decrease the brightness of the LEDs by changing the duty cycle so as to achieve any desied brightness between 0-100%.

Revisions:

04-12-11 Began tearing and hacking at our lab_2 code.

04-18-11 Final iteration. This code is the bestest.

04-10-12 Turns out bestest gets better. Using for senior project now

11-20-12 CMG Modified for use with RTOS on ME405 board

License: This file released under the Lesser GNU Public License. The program is intended for educational use only, but its use is not restricted thereto.

Definition in file **LED_driver.h**.

logger_config.cpp File Reference

```
#include "logger_config.h"
```

Detailed Description

This file contains a parser for simple configuration files that set up channels on a simple AVR based datalogger using a Swoop data acquisition board.

Revisions:

12-30-2009 JRR Original file

05-23-2011 JRR Modified for use with interrupt timed data acquisition

10-27-2012 JRR Modified again for use in a FreeRTOS based project

License: This file released under the Lesser GNU Public License. The program is intended for educational use only, but its use is not restricted thereto.

Definition in file **logger_config.cpp**.

logger_config.h File Reference

```
#include "FreeRTOS.h"
#include "config_file.h"
```

Classes

class **logger_config**

Variables

const uint16_t **MAX_MS_PER_READING** = 60000

This define prevents this .h file from being included more than once in a .cpp file.

const uint16_t **MIN_MS_PER_READING** = 10

const uint8_t **N_A2D_CHANNELS** = 8

Detailed Description

This file contains a parser for simple configuration files that set up channels on a simple AVR based datalogger using a Swoop data acquisition board.

Revisions:

12-30-2009 JRR Original file

05-23-2011 JRR Modified for use with interrupt timed data acquisition

10-27-2012 JRR Modified again to work in FreeRTOS based projects, using milliseconds per reading in the data file (other parts of the program are responsible for converting those to timer ticks).

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Definition in file **logger_config.h**.

Variable Documentation

const uint16_t MAX_MS_PER_READING = 60000

This define prevents this .h file from being included more than once in a .cpp file.

This is the maximum number of milliseconds per data point, giving the slowest acceptable sample rate.

Definition at line 39 of file logger_config.h.

Referenced by logger_config::read().

const uint16_t MIN_MS_PER_READING = 10

This is the minimum number of milliseconds per data point, giving the fastest acceptable sample rate.

Definition at line 44 of file logger_config.h.

Referenced by logger_config::read().

const uint8_t N_A2D_CHANNELS = 8

This is the number of A/D channels in the on/off list; for ATmegaXX processors this should almost always be 8. Some of those big fancy ones that are really hard to solder have 16, though.

Definition at line 50 of file logger_config.h.

Referenced by logger_config::channel_on(), logger_config::logger_config(), and task_sender::run().

possum_main.cpp File Reference

```
#include <stdlib.h>

#include <avr/io.h>

#include <avr/wdt.h>

#include "FreeRTOS.h"

#include "task.h"

#include "queue.h"

#include "croutine.h"

#include "rs232int.h"

#include "avr_adc.h"

#include "da_encoder.h"

#include "da_motor.h"

#include "fan_driver.h"

#include "LED_driver.h"

#include "servo_driver.h"

#include "Leaky_driver.h"

#include "time_stamp.h"

#include "sd_card.h"

#include "frt_task.h"

#include "frt_text_queue.h"

#include "frt_queue.h"

#include "frt_shared_data.h"

#include "task_shares.h"

#include "task_user.h"

#include "task_LED.h"

#include "task_yaw_motor.h"
```

```
#include "task_fans.h"

#include "task_servo.h"

#include "task_leak.h"
```

Functions

int **main** (void)

Variables

frt_text_queue * **print_ser_queue**

This queue allows tasks to send characters to the user interface task for display.

frt_queue< int32_t > * **p_yaw_queue**

frt_queue< bool > * **p_fan_queue**

This queue sends commands from the user interface to the fans.

frt_queue< uint16_t > * **p_servo_queue**

This queue sends 2 position bytes from the user interface to the fans.

frt_queue< uint16_t > * **p_LED_PWM_queue**

This queue sends commands from the user interface to the LEDs.

frt_queue< bool > * **p_leak_queue**

This queue sends commands from the user interface to the leak task.

da_encoder my_encoder

This is the driver for the encoder.

da_motor my_motor

This is the driver for the yaw motor.

fan_driver my_fans

This is the driver for the fans.

LED_driver my_LED_driver

This is the driver for the LEDs.

servo_driver my_servos

This is the driver for the servos.

Leaky_driver my_leaky_task

This is the driver for the Leak Detector.

avr_adc the_a2d

This is the driver for the ADC.

uint8_t **temperature**

This is the temperature inside the pod.

Detailed Description

This file contains the **main()** code for the board inside the Pier Portal Pod. This program will run a task scheduler driven by FreeRTOS which will control the functionality of the pod. The capabilities of this program include the control of a main yaw motor, LED servo motors, LED brightness, temperature and humidity sensing, and phototransistor operation.

Revisions:

09-30-2012 JRR Original file was a one-file demonstration with two tasks

10-05-2012 JRR Split into multiple files, one for each task plus a main one

10-30-2012 JRR A hopefully somewhat stable version with global queue pointers and the new operator used for most memory allocation

11-2012 PAW Convert file to possum_main and begin implementation of Pier Portal tasks.

12-02-2012 NTJ Finals revisions of the file for ME507 project

Definition in file **possum_main.cpp**.

Function Documentation

int main (void)

The main function sets up the RTOS. Tasks are created. Then the scheduler is started up; the scheduler runs until power is turned off or there's a reset.

Returns:

This is a real-time microcontroller program which doesn't return. Ever.

Definition at line 129 of file possum_main.cpp.

References p_fan_queue, p_leak_queue, p_LED_PWM_queue, p_servo_queue, p_yaw_queue, and print_ser_queue.

Variable Documentation

da_encoder my_encoder

This is the driver for the encoder.

This driver is used to read an encoder

Definition at line 103 of file possum_main.cpp.

Referenced by task_yaw_motor::run(), and task_user::run().

fan_driver my_fans

This is the driver for the fans.

This driver is used to control the fans

Definition at line 107 of file possum_main.cpp.

Referenced by task_fans::run(), and task_user::run().

Leaky_driver my_leaky_task

This is the driver for the Leak Detector.

This driver is used to monitor the leak detection circuit

Definition at line 113 of file possum_main.cpp.

Referenced by task_leak::run().

LED_driver my_LED_driver

This is the driver for the LEDs.

This driver is used to control the LED brightness

Definition at line 109 of file possum_main.cpp.

Referenced by task_LED::run().

da_motor my_motor

This is the driver for the yaw motor.

This driver is used to control the main yaw motor

Definition at line 105 of file possum_main.cpp.

Referenced by task_yaw_motor::run().

servo_driver my_servos

This is the driver for the servos.

This driver is used to control the LED servos

Definition at line 111 of file possum_main.cpp.

Referenced by task_servo::run().

frt_queue<bool>* p_fan_queue

This queue sends commands from the user interface to the fans.

This queue carries a flag from the UI that tells the fan control task whether the user or the control task is in charge of the fans.

Definition at line 87 of file possum_main.cpp.

Referenced by main(), and task_fans::run().

frt_queue<bool>* p_leak_queue

This queue sends commands from the user interface to the leak task.

This queue carries commands from the user interface to the leak detection task

Definition at line 98 of file possum_main.cpp.

Referenced by main().

frt_queue<uint16_t>* p_LED_PWM_queue

This queue sends commands from the user interface to the LEDs.

This queue carries commands from the user interface to the LED task.

Definition at line 95 of file possum_main.cpp.

Referenced by main(), task_LED::run(), and task_user::run().

frt_queue<uint16_t>* p_servo_queue

This queue sends 2 position bytes from the user interface to the fans.

This queue is used to send the position of each servo, each as a uint8_t taken together as a union, to the servo control task.

Definition at line 92 of file possum_main.cpp.

Referenced by main(), task_servo::run(), and task_user::run().

frt_queue<int32_t>* p_yaw_queue

This queue sends the desired motor position from the UI to the yaw motor task.

Definition at line 82 of file possum_main.cpp.

Referenced by main(), task_yaw_motor::run(), and task_user::run().

frt_text_queue* print_ser_queue

This queue allows tasks to send characters to the user interface task for display.

This is a print queue, descended from base_text_serial so that things can be printed into the queue using the "<<" operator and they'll come out the other end as a stream of characters. It's used by tasks that send things to the user interface task to be printed.

Definition at line 79 of file possum_main.cpp.

Referenced by main(), and task_user::run().

uint8_t temperature

This is the temperature inside the pod.

Temperature of the pod. Any task can see and edit this variable.

Definition at line 121 of file possum_main.cpp.

Referenced by task_fans::run(), task_user::run(), and task_user::task_user().

avr_adc the_a2d

This is the driver for the ADC.

This driver is used to operate the ADC. A mutex will be used to ensure tasks don't access the A/D simultaneously.

Definition at line 118 of file possum_main.cpp.

Referenced by task_LED::run(), and task_user::run().

servo_driver.cpp File Reference

```
#include <stdlib.h>

#include <avr/io.h>

#include <avr/interrupt.h>

#include "servo_driver.h"
```

Defines

#define **SERVOLIMIT** 2000

#define **UPPERADJ** 9000

#define **LOWERADJ** 1875

#define **ANGLEMAX** 110

#define **TMAX** 9000

#define **BMAX** 5300

#define **TMIN** 5550

#define **BMIN** 1750

Detailed Description

Servo_driver.cpp allows a user to run a pair of hobby servos based on PWM output.

Revisions:

11-04-11 Included specification for the method "read_a_few" within **avr_adc.cpp**

04-12-11 Began tearing and hacking at our lab_2 code.

04-18-11 Final iteration. This code is the bestest.

04-10-12 Turns out bestest gets better. Using for senior project now

11-20-12 CMG Modified for use with RTOS on ME405 board

05-20-13 Mishaaargh!! Modified for use on Pawesome Board V2.6

Definition in file **servo_driver.cpp**.

Define Documentation

#define SERVOLIMIT 2000

Standard C library Input-output ports, special registers Interrupt handling functions include own header file

Definition at line 25 of file servo_driver.cpp.

servo_driver.h File Reference

Classes

class **servo_driver**

> *This define prevents this .h file from being included more than once in a .cpp file.* union **servo_driver::separate**
>
> *This union contains the high and low byte of the duty cycle.*

Detailed Description

This header file for **servo_driver** contains specifications necessary for the methods within servo.cpp to be called from within any main program as long as this header file is included.

Revisions:

11-04-11 Included specification for the method "read_a_few" within **avr_adc.cpp**

04-12-11 Began tearing and hacking at our lab_2 code.

04-18-11 Final iteration. This code is the bestest.

04-10-12 Turns out bestest gets better. Using for senior project now

11-20-12 CMG Modified for use with RTOS on ME405 board

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Definition in file **servo_driver.h**.

task_fans.cpp File Reference

```
#include "task_fans.h"
```

Detailed Description

This file contains the task that runs the fans. Both fans are run in parallel and controlled by a single on/off transistor, and a PWM signal for speed. We can also measure the speed of the fans by reading some sort of signal coming from the fan's yellow wire. Should the yellow wire be connected to an adc instead? - This still needs to be tested.

Revisions:

11-11-12 MGB File created by copying and modifying task_daq.cpp

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Definition in file **task_fans.cpp**.

task_fans.h File Reference

```
#include <stdlib.h>
#include "FreeRTOS.h"
#include "task.h"
#include "queue.h"
#include "avr_adc.h"
#include "rs232int.h"
#include "time_stamp.h"
#include "frt_task.h"
#include "frt_queue.h"
#include "frt_text_queue.h"
#include "task_shares.h"
```

Classes

class **task_fans**

Variables

const portTickType **FAN_TICKS_PER_RUN** = configTICK_RATE_HZ

This define prevents this .H file from being included multiple times in a .CPP file.

Detailed Description

This file contains the header for a task that runs the fans. Both fans are run in parallel and controlled by a single on/off transistor, and a PWM signal for speed. We can also measure the speed of the fans by reading some sort of signal coming from the fan's yellow wire.

Revisions:

11-11-12 MGB File created by copying and modifying task_daq.h

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Definition in file **task_fans.h**.

Variable Documentation

const portTickType FAN_TICKS_PER_RUN = configTICK_RATE_HZ

This define prevents this .H file from being included multiple times in a .CPP file.

Prototype declarations for I/O functions Primary header for FreeRTOS Header for FreeRTOS task functions FreeRTOS inter-task communication queues Header for A/D converter driver class ME405/507 library for serial comm. Class to implement a microsecond timer Header of wrapper for FreeRTOS tasks Header for generic RTOS queue class Header for RTOS text queue class Header for queue declarations This is the default number of RTOS ticks per run of the fan task. It runs approximately once per second (for now).

Definition at line 37 of file task_fans.h.

Referenced by task_fans::run().

task_leak.cpp File Reference

```
#include "task_leak.h"
#include "Leaky_driver.h"
```

Detailed Description

This file contains the task that runs the leak detector.

Revisions:

11-11-12 MGB File created by copying and modifying task_daq.cpp

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Definition in file **task_leak.cpp**.

task_leak.h File Reference

```
#include <stdlib.h>
#include "FreeRTOS.h"
#include "task.h"
#include "queue.h"
#include "avr_adc.h"
#include "rs232int.h"
#include "time_stamp.h"
#include "frt_task.h"
#include "frt_queue.h"
#include "frt_text_queue.h"
#include "task_shares.h"
```

Classes

class **task_leak**

Variables

const portTickType **LEAK_TICKS_PER_RUN** = configTICK_RATE_HZ

This define prevents this .H file from being included multiple times in a .CPP file.

Detailed Description

This file contains the header for a task that runs the leak detector.

Revisions:

11-11-12 MGB File created by copying and modifying task_daq.h

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Definition in file **task_leak.h**.

Variable Documentation

const portTickType LEAK_TICKS_PER_RUN = configTICK_RATE_HZ

This define prevents this .H file from being included multiple times in a .CPP file.

Prototype declarations for I/O functions Primary header for FreeRTOS Header for FreeRTOS task functions FreeRTOS inter-task communication queues Header for A/D converter driver class ME405/507 library for serial comm. Class to implement a microsecond timer Header of wrapper for FreeRTOS tasks Header for generic RTOS queue class Header for RTOS text queue class Header for queue declarations This is the default number of RTOS ticks per run of the fan task. It runs approximately once per second (for now).

Definition at line 34 of file task_leak.h.

Referenced by task_leak::run().

task_LED.cpp File Reference

```
#include "task_LED.h"
```

Detailed Description

This file contains the LED brightness task that currently does nothing. Eventually, it will control the brightness of the LEDs base on the measured brightness from the phototransistor.

Revisions:

11-01-12 CMG File created by copying and modifying task_daq.cpp

Definition in file **task_LED.cpp**.

task_LED.h File Reference

```
#include <stdlib.h>
#include "FreeRTOS.h"
#include "task.h"
#include "queue.h"
#include "avr_adc.h"
#include "da_encoder.h"
#include "da_motor.h"
#include "fan_driver.h"
#include "LED_driver.h"
#include "rs232int.h"
#include "time_stamp.h"
#include "frt_task.h"
#include "frt_queue.h"
#include "frt_text_queue.h"
#include "task_shares.h"
```

Classes

class **task_LED**

Variables

const portTickType **LED_TICKS_PER_RUN** = configTICK_RATE_HZ/10

This define prevents this .H file from being included multiple times in a .CPP file.

const uint8_t **PHOTO_CHAN** = 3

This is the A/D channel number connected to the phototransistor.

Detailed Description

This file contains the header for a task that controls the brightness of the LEDs, either based on user input or the measured brightness from the phototransistor.

Revisions:

11-01-12 CMG File created by copying and modifying task_daq.h

Definition in file **task_LED.h**.

Variable Documentation

const portTickType LED_TICKS_PER_RUN = configTICK_RATE_HZ/10

This define prevents this .H file from being included multiple times in a .CPP file.

Prototype declarations for I/O functions Primary header for FreeRTOS Header for FreeRTOS task functions FreeRTOS inter-task communication queues Header for A/D converter driver class Header for encoder driver Header for motor driver Header for fan driver Header for LED driver ME405/507 library for serial comm. Class to implement a microsecond timer Header of wrapper for FreeRTOS tasks Header for generic RTOS queue class Header for RTOS text queue class Header for queue creation This is the default number of RTOS ticks per run of the LED brightness task. It runs approximately once per second.

Definition at line 41 of file task_LED.h.

Referenced by task_LED::run().

task_sender.cpp File Reference

```
#include "frt_text_queue.h"
#include "sd_card.h"
#include "task_sender.h"
```

Defines

#define **SD_FILENAME** "/DATA_"

#define **SD_EXT** "TXT"

#define **SEPARATOR** ","

Variables

const uint16_t **DEF_MS_PER_SAMPLE** = 100

const portTickType **ticks_to_delay** = 50

Detailed Description

This file contains the code for a task which sends data over a serial and/or radio link and/or to an SD card. The data has been supplied by a data acquisition task.

Revisions:

09-30-2012 JRR Original file was a one-file demonstration with two tasks

10-05-2012 JRR Split into multiple files, one for each task

10-25-2012 JRR Changed to a more fully C++ version with class **task_sender**

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Definition in file **task_sender.cpp**.

Define Documentation

#define SD_EXT "TXT"

This is the default file extension, combined with SD_FILENAME to make a complete DOS style file name.

Definition at line 55 of file task_sender.cpp.

Referenced by task_sender::run().

#define SD_FILENAME "/DATA_"

This is the default name used for data files stored on the card. It must be a maximum of 5 characters long; an example would be `data_`. The name will be followed by an extension such as `txt`. The name and extension will be put together with an automatically generated number to create a data file name such as `data_012.txt<tt>.`

Definition at line 50 of file task_sender.cpp.

Referenced by task_sender::run().

#define SEPARATOR ","

This separator character appears between readings on a line of data. Common choices for the separator include spaces, commas for CSV files, or tab characters.

Definition at line 60 of file task_sender.cpp.

Variable Documentation

const uint16_t DEF_MS_PER_SAMPLE = 100

This is the default rate for sampling, in milliseconds per sample. A typical default rate is 100 ms per sample, for 10 samples per second.

Definition at line 37 of file task_sender.cpp.

Referenced by task_sender::run().

const portTickType ticks_to_delay = 50

After running through its loop once, this task will delay for the given number of RTOS ticks so as not to take up too much processor time.

Definition at line 42 of file task_sender.cpp.

Referenced by task_sender::run(), and task_user::run().

task_sender.h File Reference

```
#include <stdlib.h>
#include "FreeRTOS.h"
#include "task.h"
#include "queue.h"
#include "rs232int.h"
#include "time_stamp.h"
#include "sd_card.h"
#include "logger_config.h"
#include "frt_queue.h"
#include "task_shares.h"
```

Classes

class **task_sender**

This define prevents this .H file from being included multiple times in a .CPP file.

Detailed Description

This file contains the header for a task which sends data over a serial and/or radio link and/or to an SD card.

Revisions:

09-30-2012 JRR Original file was a one-file demonstration with two tasks

10-05-2012 JRR Split into multiple files, one for each task

10-25-2012 JRR Changed to a more fully C++ version with class **task_sender**

Definition in file **task_sender.h**.

task_servo.cpp File Reference

```
#include "task_servo.h"
```

Detailed Description

This file contains the servo control task. The servos are used to control the angular position of the LEDs. Servo functionality will be implemented initially because that is the system that is currently in place. The 2012-13 Pier Portal senior project team may choose to utilize a motor/encoder system in place of servos.

Revisions:

11-01-12 MGB File created by copying and modifying task_daq.cpp

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Definition in file **task_servo.cpp**.

task_servo.h File Reference

```
#include <stdlib.h>

#include "FreeRTOS.h"

#include "task.h"

#include "queue.h"

#include "rs232int.h"

#include "time_stamp.h"

#include "frt_task.h"

#include "frt_queue.h"

#include "frt_text_queue.h"

#include "task_shares.h"

#include "servo_driver.h"
```

Classes

class **task_servo**

Variables

const portTickType **SERVO_TICKS_PER_RUN** = (configTICK_RATE_HZ/100)

This define prevents this .H file from being included multiple times in a .CPP file.

Detailed Description

This file contains the header file for the servo control task. The servos are used to control the angular position of the LEDs. Servo functionality will be implemented initially because that is the system that is currently in place. The 12-13 Pier Portal senior project team may choose to utilize a motor/encoder system.

Revisions:

11-01-12 NTJ File created by copying and modifying task_daq.h

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Definition in file **task_servo.h**.

Variable Documentation

const portTickType SERVO_TICKS_PER_RUN = (configTICK_RATE_HZ/100)

This define prevents this .H file from being included multiple times in a .CPP file.

Prototype declarations for I/O functions Primary header for FreeRTOS Header for FreeRTOS task functions FreeRTOS inter-task communication queues ME405/507 library for serial comm. Class to implement a microsecond timer Header of wrapper for FreeRTOS tasks Header for generic RTOS queue class Header for RTOS text queue class Header for queue creation Header for servo driver This is the default number of RTOS ticks per run of the LED brightness task. It runs approximately 100 times per second.

Definition at line 38 of file task_servo.h.

Referenced by task_servo::run().

task_shares.h File Reference

```
#include "avr_adc.h"

#include "da_encoder.h"

#include "da_motor.h"

#include "fan_driver.h"

#include "LED_driver.h"

#include "servo_driver.h"

#include "Leaky_driver.h"
```

Variables

frt_text_queue * **print_ser_queue**

This queue allows tasks to send characters to the user interface task for display.

frt_queue< int32_t > * **p_yaw_queue**

This queue sends the desired motor position from the UI to the yaw motor task.

frt_queue< bool > * **p_fan_queue**

This queue sends commands from the user interface to the fans.

frt_queue< uint16_t > * **p_servo_queue**

This queue sends 2 position bytes from the user interface to the fans.

frt_queue< uint16_t > * **p_LED_PWM_queue**

This queue sends commands from the user interface to the LEDs.

frt_queue< bool > * **p_leak_queue**

This queue sends commands from the user interface to the leak task.

avr_adc the_a2d

This is the driver for the ADC.

da_encoder my_encoder

This is the driver for the encoder.

da_motor my_motor

This is the driver for the yaw motor.

fan_driver my_fans

This is the driver for the fans.

LED_driver my_LED_driver

This is the driver for the LEDs.

servo_driver my_servos

This is the driver for the servos.

Leaky_driver my_leaky_task

This is the driver for the Leak Detector.

uint8_t **temperature**

This is the temperature inside the pod.

Detailed Description

This file contains extern declarations for queues and other inter-task data communication objects used in an ME405/507/FreeRTOS project.

Revisions:

09-30-2012 JRR Original file was a one-file demonstration with two tasks

10-05-2012 JRR Split into multiple files, one for each task plus a main one

10-29-2012 JRR Reorganized with global queue and shared data references

12-02-2012 NTJ Final modifications for Pawesome ME507 project

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Definition in file **task_shares.h**.

Variable Documentation

da_encoder my_encoder

This is the driver for the encoder.

This driver is used to read an encoder

Definition at line 103 of file possum_main.cpp.

Referenced by task_yaw_motor::run(), and task_user::run().

fan_driver my_fans

This is the driver for the fans.

This driver is used to control the fans

Definition at line 107 of file possum_main.cpp.

Referenced by task_fans::run(), and task_user::run().

Leaky_driver my_leaky_task

This is the driver for the Leak Detector.

This driver is used to monitor the leak detection circuit

Definition at line 113 of file possum_main.cpp.

Referenced by task_leak::run().

LED_driver my_LED_driver

This is the driver for the LEDs.

This driver is used to control the LED brightness

Definition at line 109 of file possum_main.cpp.

Referenced by task_LED::run().

da_motor my_motor

This is the driver for the yaw motor.

This driver is used to control the main yaw motor

Definition at line 105 of file possum_main.cpp.

Referenced by task_yaw_motor::run().

servo_driver my_servos

This is the driver for the servos.

This driver is used to control the LED servos

Definition at line 111 of file possum_main.cpp.

Referenced by task_servo::run().

frt_queue<bool>* p_fan_queue

This queue sends commands from the user interface to the fans.

This queue carries a flag from the UI that tells the fan control task whether the user or the control task is in charge of the fans.

Definition at line 87 of file possum_main.cpp.

Referenced by main(), and task_fans::run().

frt_queue<bool>* p_leak_queue

This queue sends commands from the user interface to the leak task.

This queue carries commands from the user interface to the leak detection task

Definition at line 98 of file possum_main.cpp.

Referenced by main().

frt_queue<uint16_t>* p_LED_PWM_queue

This queue sends commands from the user interface to the LEDs.

This queue carries commands from the user interface to the LED task.

Definition at line 95 of file possum_main.cpp.

Referenced by main(), task_LED::run(), and task_user::run().

frt_queue<uint16_t>* p_servo_queue

This queue sends 2 position bytes from the user interface to the fans.

This queue is used to send the position of each servo, each as a uint8_t taken together as a union, to the servo control task.

Definition at line 92 of file possum_main.cpp.

Referenced by main(), task_servo::run(), and task_user::run().

frt_text_queue* print_ser_queue

This queue allows tasks to send characters to the user interface task for display.

Header for the ADC driver Header for encoder driver Header for motor driver Header for fan driver Header for LED driver Header for servo driver Header for leak detection driver

This is a print queue, descended from base_text_serial so that things can be printed into the queue using the "<<" operator and they'll come out the other end as a stream of characters. It's used by tasks that send things to the user interface task to be printed.

Definition at line 79 of file possum_main.cpp.

Referenced by main(), and task_user::run().

uint8_t temperature

This is the temperature inside the pod.

Temperature of the pod. Any task can see and edit this variable.

Definition at line 121 of file possum_main.cpp.

Referenced by task_fans::run(), task_user::run(), and task_user::task_user().

avr_adc the_a2d

This is the driver for the ADC.

This driver is used to operate the ADC. A mutex will be used to ensure tasks don't access the A/D simultaneously.

Definition at line 118 of file possum_main.cpp.

Referenced by task_LED::run(), and task_user::run().

task_user.cpp File Reference

```
#include <avr/io.h>
#include <avr/wdt.h>
#include "task_user.h"
#include "task_shares.h"
#include "task_LED.h"
#include "da_encoder.h"
#include "da_motor.h"
#include "fan_driver.h"
#include "LED_driver.h"
#include "Leaky_driver.h"
```

Variables

const portTickType **ticks_to_delay** = (configTICK_RATE_HZ / 1000)

Header for Leak detection driver.

Detailed Description

This file contains source code for the user task of the Pier Portal (P^Awesome) Project. This user task allows the Pawesome team to code and debug functionality including operation of the fans, LEDs, main yaw motor, readings from the phototransistors, and the use of queues to pass information/commands between tasks.

Revisions:

09-30-2012 JRR Original file was a one-file demonstration with two tasks

10-05-2012 JRR Split into multiple files, one for each task

10-25-2012 JRR Changed to a more fully C++ version with class **task_user**

12-02-2012 NTJ Final modifications for the ME507 project

05-30-2013 MGB More mods for Pawesome project

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Definition in file **task_user.cpp**.

Variable Documentation

const portTickType ticks_to_delay = (configTICK_RATE_HZ / 1000)

Header for Leak detection driver.

Port I/O for SFR's Watchdog timer header Header for this file Global ('extern') queue declarations Header for LED brightness task Header for encoder driver Header for motor driver Header for fan driver Header for LED driver This constant sets how many RTOS ticks the task delays if the user's not talking. The duration is calculated to be about 1 ms.

Definition at line 46 of file task_user.cpp.

task_user.h File Reference

```
#include <stdlib.h>
#include "FreeRTOS.h"
#include "task.h"
#include "queue.h"
#include "rs232int.h"
#include "time_stamp.h"
#include "avr_adc.h"
#include "frt_queue.h"
#include "frt_task.h"
#include "frt_text_queue.h"
```

Classes

class **task_user**

union **task_user::servo_data**

Union for writing to the servo queue.

Defines

#define **PROGRAM_VERSION** PMS ("Pawesome Pier Portal Project V2.6 ")

This define prevents this .H file from being included multiple times in a .CPP file.

Detailed Description

This file contains header stuff (common declarations) for the user task.

Revisions:

09-30-2012 JRR Original file was a one-file demonstration with two tasks

10-05-2012 JRR Split into multiple files, one for each task

10-25-2012 JRR Changed to a more fully C++ version with class **task_user**

12-02-2012 NTJ Final modifications for the ME 507 project

Definition in file **task_user.h**.

Define Documentation

#define PROGRAM_VERSION PMS ("Pawesome Pier Portal Project V2.6 ")

This define prevents this .H file from being included multiple times in a .CPP file.

Prototype declarations for I/O functions Primary header for FreeRTOS Header for FreeRTOS task functions FreeRTOS inter-task communication queues ME405/507 library for serial comm. Class to implement a microsecond timer Class with A/D converter driver Header of wrapper for FreeRTOS queues Header of wrapper for FreeRTOS tasks Header for RTOS text queue class This macro defines a string that identifies the name and version of this program.

Definition at line 45 of file task_user.h.

Referenced by task_user::show_status().

task_yaw_motor.cpp File Reference

```
#include "task_yaw_motor.h"
#include "da_encoder.h"
#include "task_user.h"
#include "task_LED.h"
```

Defines

#define **K_P_DIVISOR** 5

#define **K_I_DIVISOR** 10000

#define **K_D_DIVISOR** 10000

#define **INTEGRAL_SATURATE** 3000

#define **DUTY_CYCLE_SATURATE** 80

#define **STOPDELAY** 200

Variables

uint16_t **stop_count** = 0

Number of ticks seen by the motor.

Detailed Description

This file contains the position control task for the yaw motor inside the pod. The yaw motor will allow the camera system to pan left/right to provide a wider angle of view for the end user.

Revisions:

11-07-12 CMG File created by copying and modifying **task_LED.cpp**

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Definition in file **task_yaw_motor.cpp**.

Define Documentation

#define K_P_DIVISOR 5

Header for this task Header for encoder Header for motor Header for user task Header for LED task

Definition at line 24 of file task_yaw_motor.cpp.

Referenced by task_yaw_motor::run().

task_yaw_motor.h File Reference

```
#include <stdlib.h>
#include "FreeRTOS.h"
#include "task.h"
#include "queue.h"
#include "avr_adc.h"
#include "rs232int.h"
#include "time_stamp.h"
#include "frt_task.h"
#include "frt_queue.h"
#include "frt_text_queue.h"
#include "task_shares.h"
```

Classes

class **task_yaw_motor**

Variables

const portTickType **YAW_TICKS_PER_RUN** = configTICK_RATE_HZ/100

This define prevents this .H file from being included multiple times in a .CPP file.

Detailed Description

This file contains the header for a task that runs a position control loop for the yaw motor in the pod.

Revisions:

11-07-12 CMG File created by copying and modifying **task_LED.h**

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Definition in file **task_yaw_motor.h**.

Variable Documentation

const portTickType YAW_TICKS_PER_RUN = configTICK_RATE_HZ/100

This define prevents this .H file from being included multiple times in a .CPP file.

This is the default number of RTOS ticks per run of the LED brightness task. It runs approximately 100 times per second.

Definition at line 36 of file task_yaw_motor.h.

Referenced by task_yaw_motor::run().

APPENDIX F:

DATASHEETS

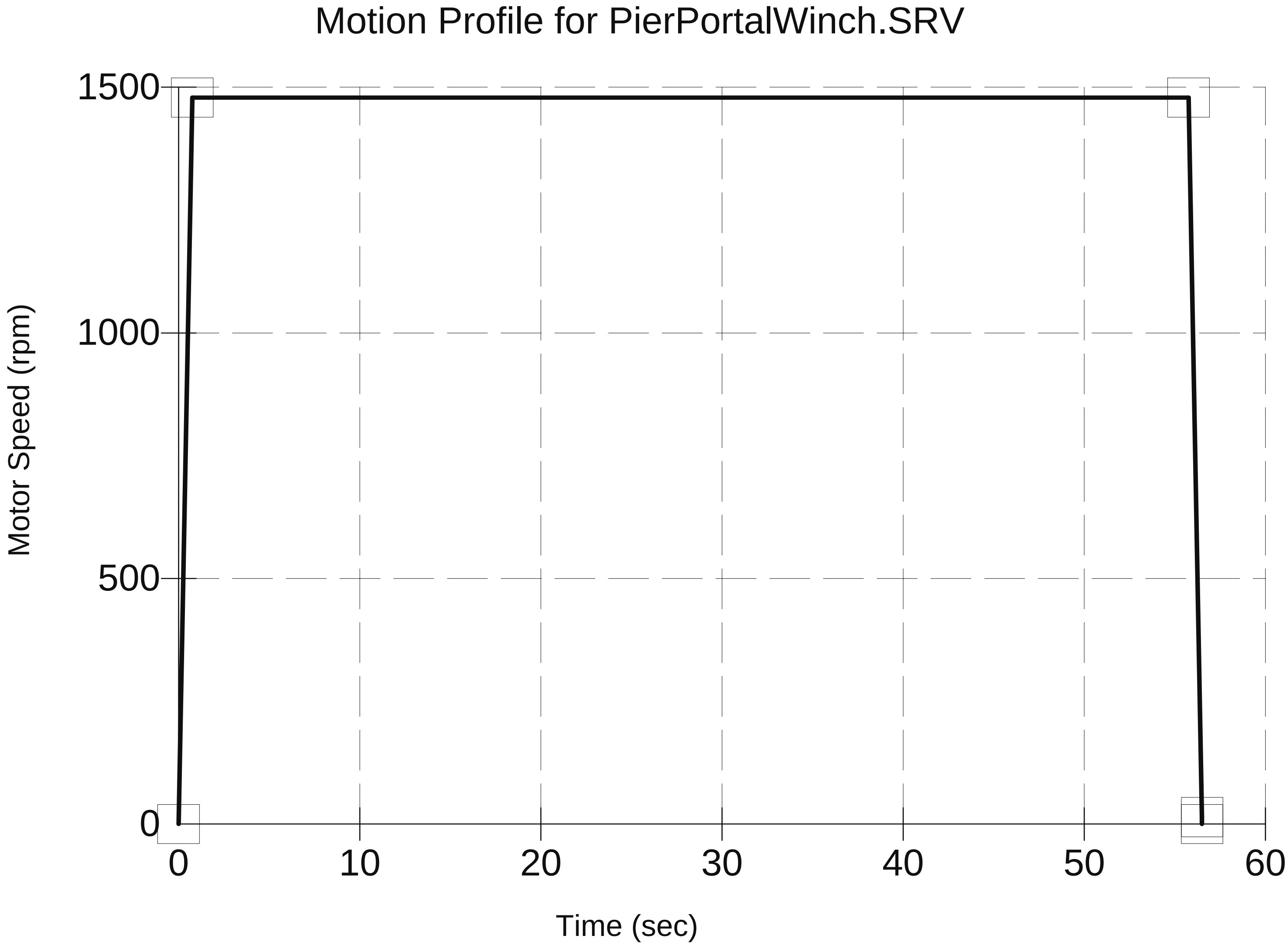
Sigma Size
Version: 2.2
Copyright 1998-1999
Yaskawa Electric America, Inc.

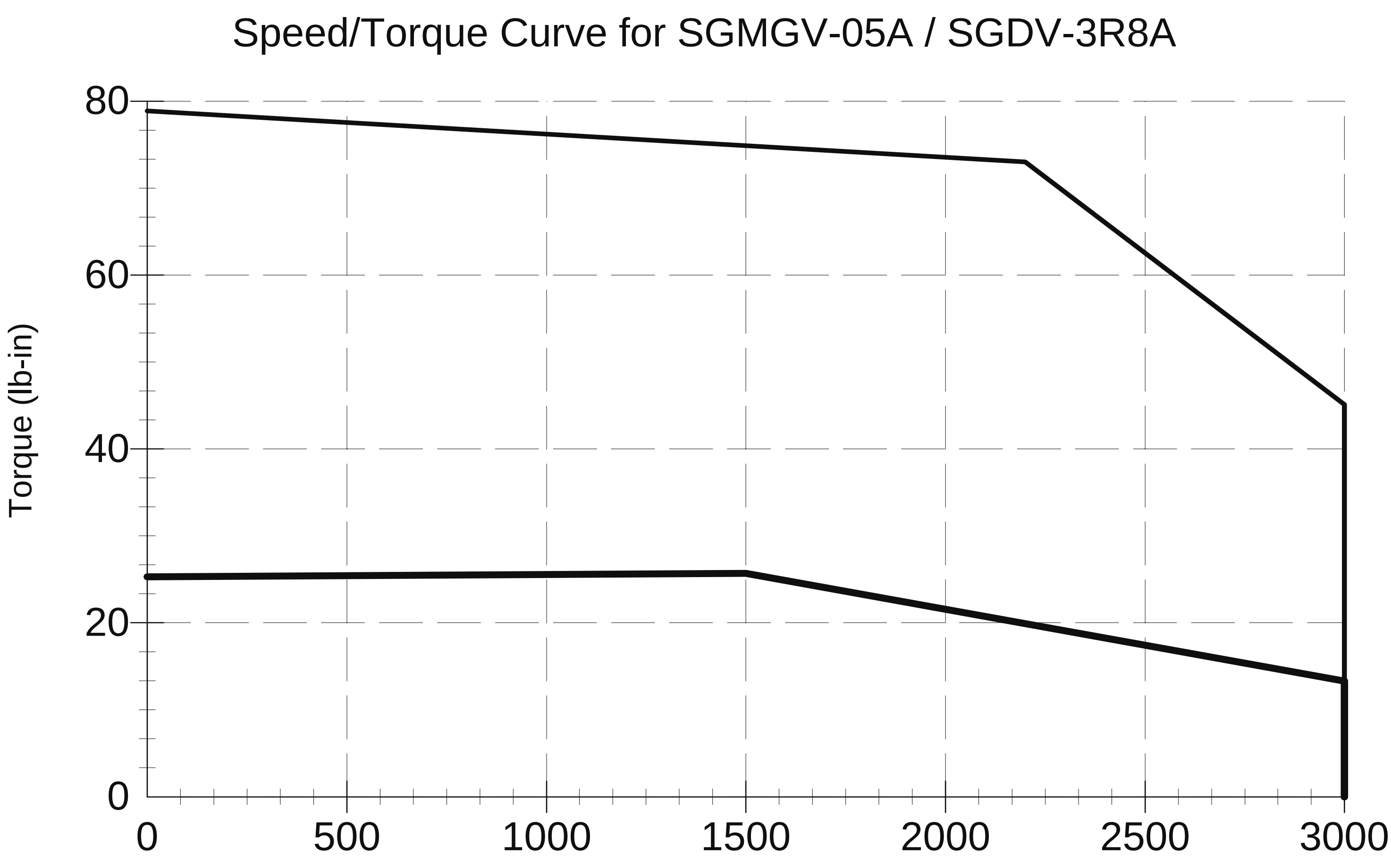
Yaskawa Electric America, Inc.
2121 Norman Drive South
Waukegan, IL, 60085
847 / 887-7000 (fax = 7090)

Servo Sizing Results - PierPortalWinch.SRV	
Company:	Date: February 27, 2013
Application:	Prepared by:

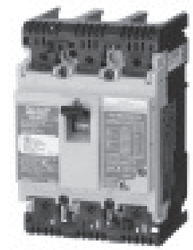
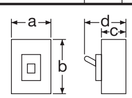
	Value	Unit
Drive package selection		
Motor / amplifier type	SGMGV-05A / SGDV-3R8A	
Speed overhead selected	0	%
Torque overhead selected	0	%
Regen capacity of drive w/o external resistor	8 W	(load = 0.0 W)
Regen capacity of drive with JUSP-RA04(rewired)	88 W	(load = 0.0 W)
Linear Inputs (Linear Application)		
Weight in Linear motion	150	lb
Coefficient of friction	0.0	n/a
Linear distance per rev of input shaft	62.8	in
Persistent force	0.0	lb
Occasional force	0.0	lb
Machine efficiency	90	
Total Linear J @ motor shaft	0.000263	kgm^2
Shaft Inputs		
Total Shaft J @ motor shaft	0.0	lb-in-s^2
Transmission Inputs		
Total ratio	129.0	to 1
Total efficiency	68	%
Total Transmission J @ motor shaft	0.000000	lb-in-s^2
Special Inputs		
Inclination angle	90	deg
Counterbalance	0.0	lb
Total Special J @ motor shaft	0.00000	lb-in-s^2
Sizing Results		
Application Speed		
Max speed @ motor shaft	1479	rpm
RMS speed @ motor shaft	1466	rpm
Application Torque		
Peak torque @ motor shaft	20.4	lb-in
RMS torque @ motor shaft	18.99	lb-in
Machine accel torque @ motor shaft	.79	lb-in
Transmission accel torque @ motor shaft	.0	lb-in
Motor accel torque @ motor shaft	.61	lb-in
Friction torque @ motor shaft	.0	lb-in
Persistent torque @ motor shaft	.0	lb-in
Occasional torque @ motor shaft	.0	lb-in
Gravity torque @ motor shaft	19.0	lb-in
Application Max acceleration @ machine input shaft	16.0	in/s^2
Application Max acceleration @ motor shaft	206.5	rad / s^2
Total J @ motor shaft	0.00528	lb-in-s^2
Ratio of application J to motor J	0.79	to 1

Application Notes


Motion Profile for PierPortalWinch.SRV
Motor Speed (rpm)
1500
1000
500
0
0
10
20
30
40
50
60
Time (sec)


Speed/Torque Curve for SGMGV-05A / SGDV-3R8A
Torque (lb-in)
80
60
40
20
0
0
500
1000
1500
2000
2500
3000

■ Specifications

Frame size (A)				50		100	
Type				SA52RCUL	SA53RCUL	EA102CUL	EA103CUL
Appearance (with Screw Terminals, 3 pole)							
Rated insulation voltage (V) (IEC60947-2)			AC	690		690	
Rated voltage (V) (UL489)			AC	240		240	
Rated current (A)				3,5,10,15,20,30,40,50		60,70,75,80,90,100	
Poles				2	3	2	3
Rated frequency (Hz)				50/60		50/60	
Rated interrupting capacity sym (kA)	UL489 CSA22-2	AC	480Y	–		–	
			480Y/277V	–		–	
			240V	14		14	
	IEC60947-2 [Icu/Ics] JIS C 8201-2	AC	690V	–		–	
			600V	5/3		5/3	
			500V	7.5/4		7.5/4	
			440V	10/5		10/5	
			400V	10/5		10/5	
			230V	25/13		25/13	
		DC	250V	5/3		5/3	
Dimensions (mm)			a	50	75	50	75
			b	120		120	
			c	60		60	
			d	84		84	
Terminal construction	Screw Terminals		NONE	●		●	
	Flat Terminals		L1	●		●	
	Lug Terminals		L	–		–	
Internal accessories *4	Auxiliary switch		W	BZ6WR10CU	BZ6W□10CU	BZ6WR10CU	BZ6W□10CU
	Auxiliary switch for low current		WD	BZ6WDR10CU	BZ6WD□10CU	BZ6WDR10CU	BZ6WD□10CU
	Alarm switch		K	BZ6KR10CU	BZ6K□10CU	BZ6KR10CU	BZ6K□10CU
	Alarm switch for low current		KD	BZ6KDR10CU	BZ6KD□10CU	BZ6KDR10CU	BZ6KD□10CU
	Auxiliary & Alarm switch		WK	BZ6WKR10CU	BZ6WK□10CU	BZ6WKR10CU	BZ6WK□10CU
	Auxiliary & Alarm switch		WDKD	BZ6WDKDR10CU	BZ6WDKD□10CU	BZ6WDKDR10CU	BZ6WDKD□10CU
	Shunt trip		F	BZ6F□10CU	BZ6F□10CU	BZ6F□10CU	BZ6F□10CU
	Under voltage trip		R	BZ6R□10CAU	BZ6R□10CAU	BZ6R□10CAU	BZ6R□10CAU
	Accessories with terminal block		A	*1	*1	*1	*1
External accessories	Handle locking key, Cap type		Q1	BZ6L10C	BZ6L10C	BZ6L10C	BZ6L10C
	External Operating Handle		V	BZ6V10C	BZ6V10C	BZ6V10C	BZ6V10C
			N	BZ6N10CP	BZ6N10CP	BZ6N10CP	BZ6N10CP
	Field Installable Terminal Kit	Flat Terminal Kit		BZ-SU20B	BZ-SU20B	BZ-SU25B	BZ-SU25B
		Lug Terminal Kit		–	–	–	–
	Terminal Covers *3	for screw, short type		Provided	Provided	Provided	Provided
		for screw, long type		BZ6TB10C2U	BZ6TB10C3U	BZ6TB10C2U	BZ6TB10C3U
		for Flat terminal		–	–	–	–
		for Lug terminal		–	–	–	–
	Insulation Barrier *2			BZ6B10C	BZ6B10C	BZ6B10C	BZ6B10C
Mass (kg) (Screw Terminals)				0.4	0.5	0.4	0.5

Notes: *1 For internal accessories with terminal block, specify "A" in the accessory P/N. When 50A Frame & 100A Frame are ordered w/UVT, the UVT is supplied with terminal block as standard. (see page 18, 19)
*2 Insulation barriers are only required with flat terminal.
*3 Short terminal covers are supplied as standard. If long terminal covers are required, please order BZ6TB10C2U or BZ6TB10C3U.
*4 These internal accessories can be installed in the field. (see page 18, 19 for part number)
●: Available. –: Not available.

■ Part Number

SA-UL; MCCB

SA103CUL / 100 L1 Q1

- Product category — SA103CUL
- Rated current (A) — 100
- Terminal structure — L1
- Handle locking cover for lockout (Cap type) — Q1

Cap type (Q1) is applicable for 400-800A Frame. For 225A Frame or smaller, order the Handle Lock cover separately

Terminal construction for SA-UL series

Code	Line side	Load side	SA52RCUL, SA53RCUL EA102CUL, EA103CUL	SA102CUL, SA103CUL SA102RCUL, SA103RCUL	SA202CUL, SA203CUL SA203RCUL, SA203RCUL	SA402CUL, SA403CUL SA402RCUL, SA403RCUL	SA603RUL SA803RUL/700	SA803RUL/800
None	–	–	●	●	–	–	–	–
L	Lug	Lug	–	●	●	●	●	●
L1	Flat	Flat	●	●	●	●	●	–

SA-UL; ELCB

SG103CUL / 100 – 30MA L1 Q1

- Product category — SG103CUL
- Rated current (A) — 100
- Rated sensitive current (mA) — 30MA
- Terminal structure — L1
- Handle locking cover for lockout (Cap type) — Q1

Cap type (Q1) is applicable for 400-800A Frame. For 225A Frame or smaller, order the Handle Lock cover separately

Rated sensitive current (mA)

Code	Line side	2 poles	3 poles
30MA	30mA	●	●
CO	100/200mA changeable	●	–
CO	100/200/500mA changeable	–	●

Terminal structure

Code	Line side	Load side	SG53RCUL, EG103CUL	SG103CUL	SG203CUL	SG403CUL
None	–	–	●	●	●	–
L1	Flat	Flat	●	●	●	●

ACCESSORIES

For up to 225AF

- Auxiliary switches & Alarm switches

BZ6 WK L 30C A U

- Product category — BZ6
- Type of accessory — WK
  - **W**; Auxiliary switch
  - **WD**; Auxiliary switch (for Small current)
  - **K**; Alarm switch
  - **KD**; Alarm switch (for Small current)
- Installation, — L
  - **L**; Left side of the breaker
  - **R**; Right side of the breaker
- Applicable frame size — 30C
  - **10C**; 50AF, 100AF(EA&EG10_CUL)
  - **30C**; 100AF
  - **40C**; 225AF
- Method of connection. — A
  - **None**; Lead wire
  - **A**; with terminal block
- UL listed — U

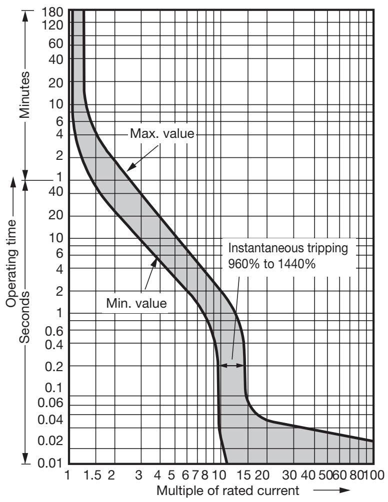
- Shunt trip & Undervoltage trip devices

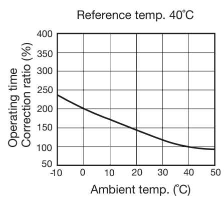
BZ6 F S 30C A U

- Product category — BZ6
- Type of accessory — F
  - **F**; Shunt trip device
  - **R**; Undervoltage trip device
- Operating voltage, — S
  For details, see page 18, 19.
- Applied frame size — 30C
  - **10C**; 50AF, 100AF(EA&EG10_CUL)
  - **30C**; 100AF
  - **40C**; 225AF
- Method of connection. — A
  - **None**; Lead wire
  - **A**; with terminal block
- UL listed — U

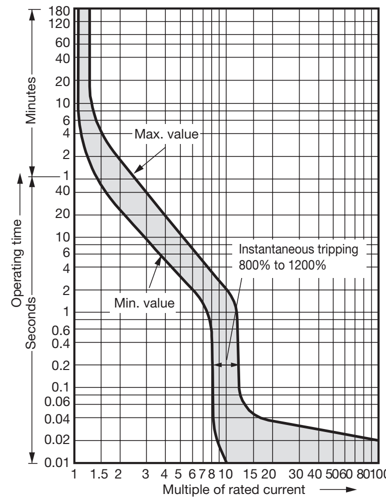
■ Characteristic Curves

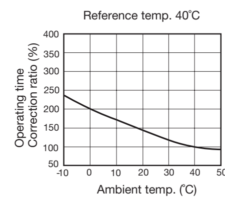
● SA52RCUL, SA53RCUL, SG53RCUL (Rated current: 5A, 10A, 40A)



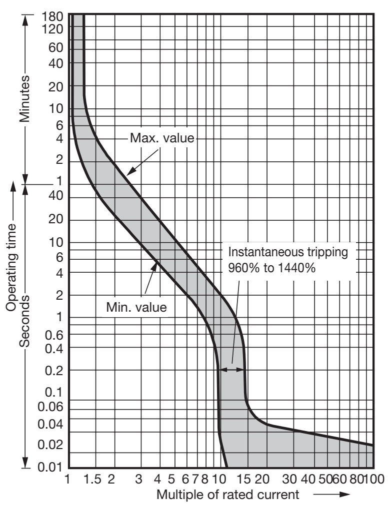


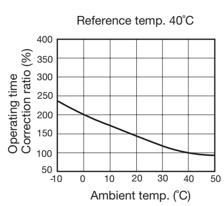
● SA52RCUL, SA53RCUL, SG53RCUL (Rated current: 3A, 15A, 20A, 30A, 50A)



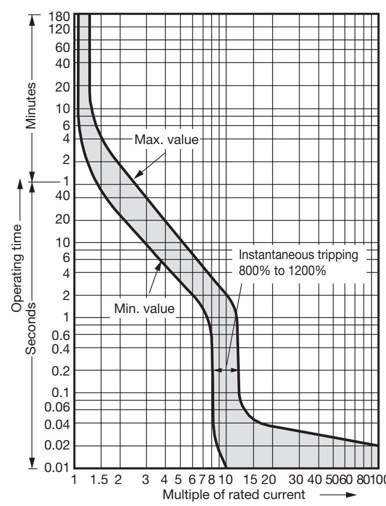


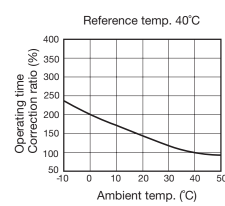
● EA102CUL, EA103CUL, EG102CUL, EG103CUL (Rated current: 60A, 75A)



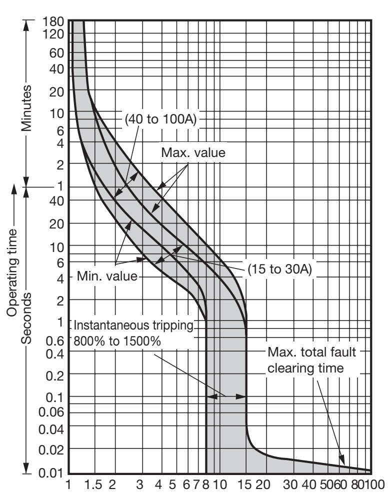


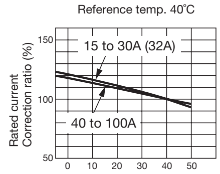
● EA102CUL, EA103CUL, EG102CUL, EG103CUL (Rated current: 100A) (Rated current: 80A, 90A, 100A)



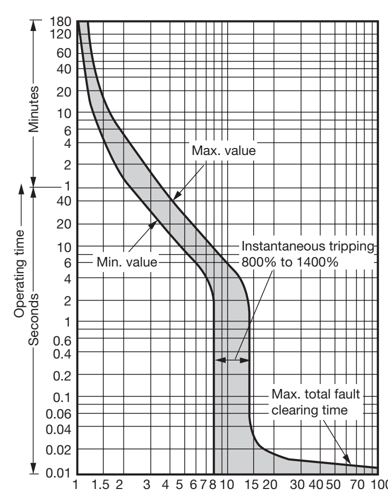


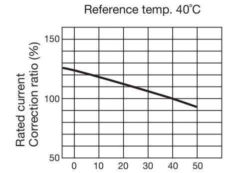
● SA102CUL, SA103CUL, SA102RCUL, SA103RCUL





● SA202CUL, SA203CUL, SA202RCUL, SA203RCUL



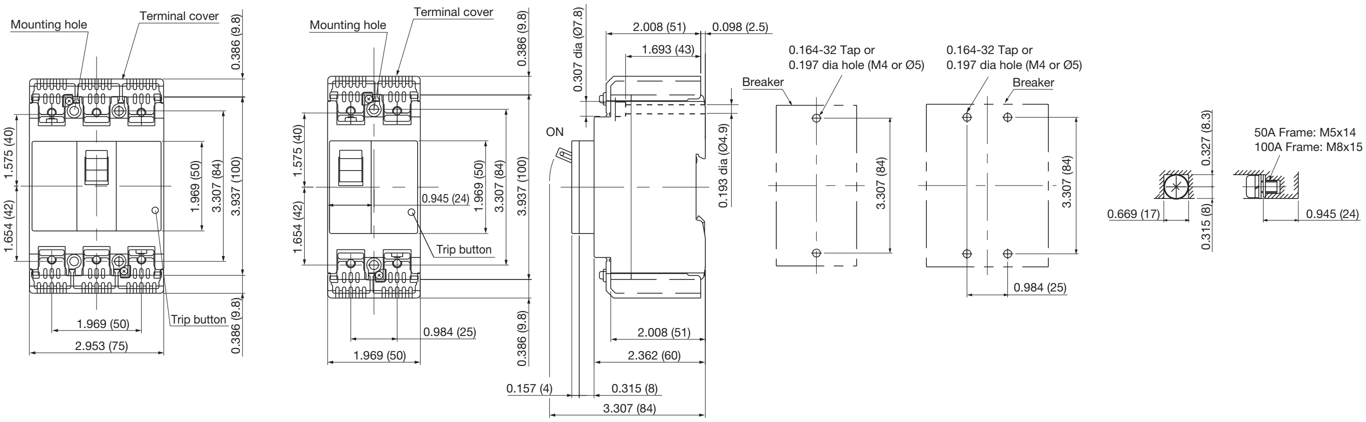


■ Dimensions unit: inch (mm)

● SA52RCUL/□, SA53RCUL/□, SG53RCUL/□, EA102CUL/□, EA103CUL/□, EG102CUL/□, EG103CUL/□

3 pole
2 pole (EG102CUL)

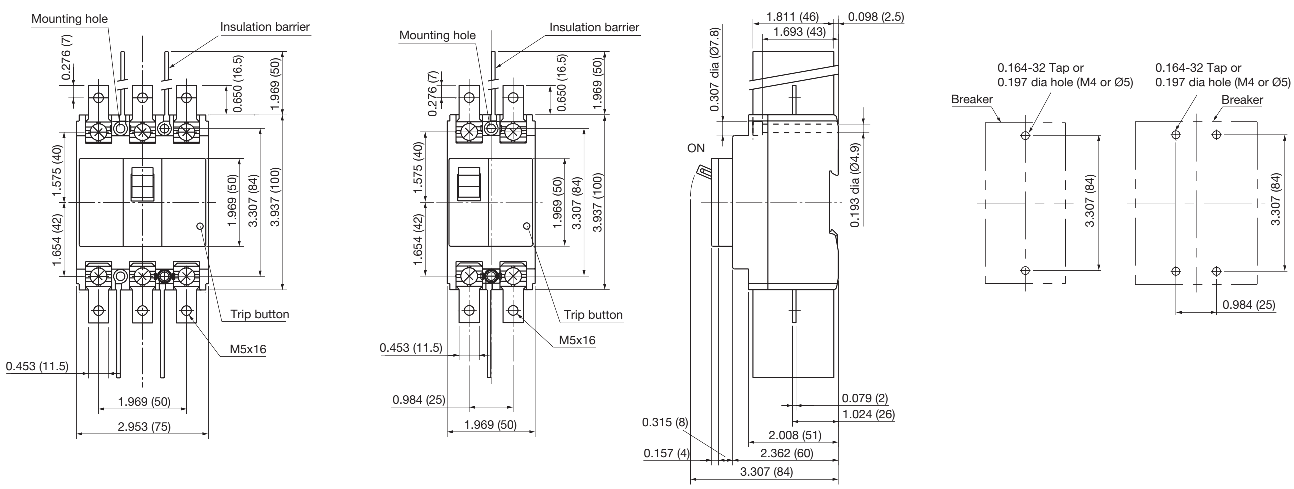
2 pole



● SA52RCUL/□L1, SA53RCUL/□L1, SG53RCUL/□L1

3 pole

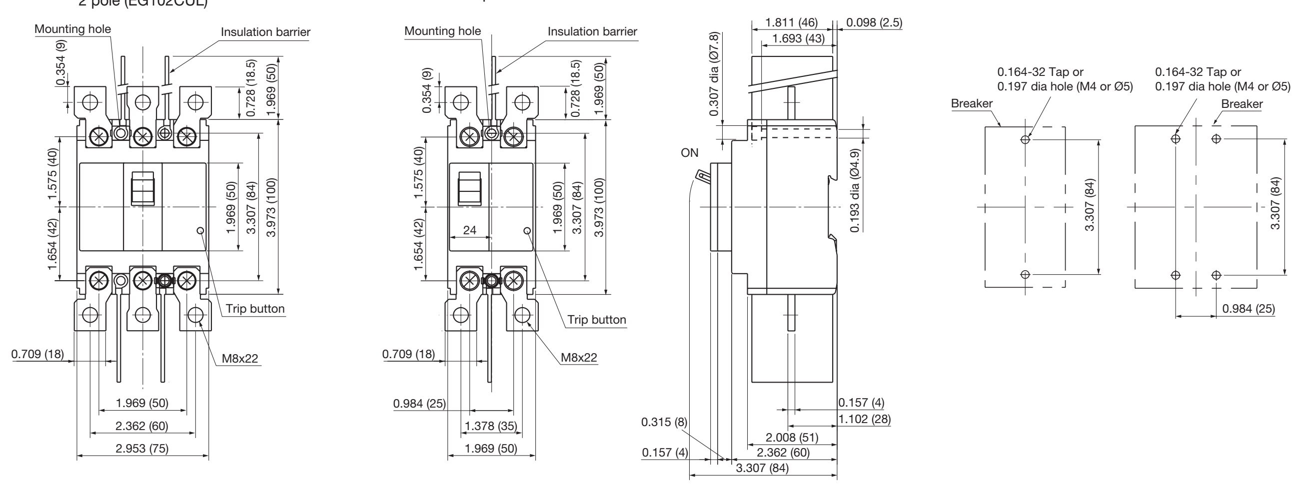
2 pole



● EA102CUL/□L1, EA103CUL/□L1, EG102CUL/□L1, EG103CUL/□L1

3 pole
2 pole (EG102CUL)

2 pole



■ Wiring

① Connecting Precautions

- When connecting the wires, follow the instruction of NEC (National Electric Code, USA) or CEC (Canadian Electrical code Part 1, Canada).
- For connecting, use copper wire rated for 75°C. It is recommended to use UL or CSA approved wires.
- Keep the connection of the wire sufficiently tight, because a very large electromagnetic force will be generated, when the short circuit current is applied.
- Perform additional tightening of the terminal screws periodically.

② Terminal Construction

	Screw Terminals	Flat Terminals	Lug Terminals
50A, EA/EG 100A Frame	○	○	—
SA100~225A Frame	○	○	○
SG100~225A Frame	○	—	—
400~800A Frame	—	○	○

○ : Available — : Not available

③ Allowable wire spec for Lug Terminals

Number of strands connecting wires

Wire size AWG or MCM (mm^2)	Number of strands
14 – 2 (2.1 – 33.6)	7
1 – 4/0 (42.4 – 107.2)	19
250 – 500 (127 – 250)	37

(mm^2) Values are those converted from AWG or MCM size

⚠ Caution

- Two wires can not be connected to the lug terminal at once.
- Follow the number of strands of wire indicated in the table.
- Multiconductor wire can not be connected.
- Do not solder the end of the wire.

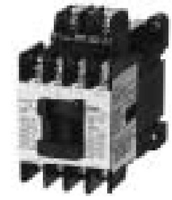
■ Max Wire Sizes and Tightening Torque

Type	Rated Current (A)	Wire size AWG or MCM (mm^2)	Tightening torque		Applicable ring (crimp) terminal			
			Screw / Flat terminal	Lug terminal	JST (UL file No.E42024)	NICHIFU (UL file No.E44245)	AIKOKU (UL file No.E74103)	DST (UL file No.E74917)
SA53RCUL SG53RCUL	3	14 AWG (2.1mm^2)	Screw / Flat terminal Screw; 20-25 lb.-In (2.3-2.8N-m) Flat; 30-40 lb.-in. (3.5-4.5N-m)	50 lb. - In. (5.8N-m)	R2-5		R2-5	
	5	14 AWG (2.1mm^2)						
	10	14 AWG (2.1mm^2)						
	15	14 AWG (2.1mm^2)						
	20	12 AWG (3.3mm^2)			R5.5-5		R5.5-5	
	30	10 AWG (5.3mm^2)						
	40	8 AWG (8.4mm^2)			R8-5		R8-5	
	50	6 AWG (13.3mm^2)						
EA102CUL, EA103CUL EG102CUL, EG103CUL	60	6 AWG (13.3mm^2)			R14-8		R14-8	
	75	4 AWG (21.1mm^2)			22-S8		22-S8	
	100	3 AWG (26.7mm^2)			38-S8		38-S8	
SA102CUL SA102RCUL SA103CUL SA103RCUL SG103CUL	15	14 AWG (2.1mm^2)	50 lb. - In. (5.8N-m)	50 lb. - In. (5.8N-m)	R2-8	R2-8	2-8	2-8, 2-B8
	20	12 AWG (3.3mm^2)			R5.5-8, 5.5-S8	R3.5-8, R5.5-8	5.5-8	3.5-8, 5.5-8
	30	10 AWG (5.3mm^2)			R5.5-8, 5.5-S8	R5.5-8		5.5-8
	32	8 AWG (8.4mm^2)			R8-8, 8-8NS	R8-8	8-8	8-8
	40	8 AWG (8.4mm^2)						
	50	8 AWG (8.4mm^2)						
	60	6 AWG (13.3mm^2)			R14-8, 14-8NS, 14-S8	R14-8, R14-8S	14-8	14-S8, 14-8
	70	4 AWG (21.1mm^2)			R22-8, 22-S8, CB22-S8	R22-8, R22-8S, CB22-8S	22-8	22-S8, 22-8, CB22-8
	75	4 AWG (21.1mm^2)						
	80	4 AWG (21.1mm^2)						
	90	3 AWG (26.7mm^2)			38-S8	R38-8S, CB22-8S	38-8S	38-S8
	100	3 AWG (26.7mm^2)						
SA202CUL SA202RCUL SA203CUL SA203RCUL SG203CUL	125	1 AWG (42.4mm^2)	93 lb. - In. (10.5N-m)	200 lb. - In. (23N-m)	R38-8, 38-S8	R38-8S, R38-8	38-8S	38-S8
	150	1/0 AWG (53.5mm^2)			R60-8, 60S8	R60-8, CB60-8, CB60-8S	60-8	60-8, CB60-8
	175	2/0 AWG (67.4mm^2)			70-8	R70-8	-	70-8
	200	3/0 AWG (85.0mm^2)			CB80-S8	-	-	CB80-8
	225	4/0 AWG (107.2mm^2)			CB100-S8	-	-	CB100-8
SA402CUL SA402RCUL SA403CUL SA403RCUL SG403CUL	250	250 MCM (127mm^2)	375 lb. - In. (43.5N-m)	375 lb. - In. (43.5N-m)	150-12	R150-12	-	-
	300	350 MCM (177mm^2)			180-12	R180-12		
	350	500 MCM (253mm^2)			325-12	R325-12S		
	400	3/0 AWG x 2 (85.0mm^2 x 2)		275 lb. - In. (31.9N-m)	R80-12	R80-12		
SA603RCUL	500	250 MCM x 2 (126.7mm^2 x 2)	416 lb. - In. (47N-m)		150-12	R150-12		
	600	350 MCM x 2 (177.4mm^2 x 2)			180-12	R180-12		
SA803RCUL	700	500 MCM x 2 (253.4mm^2 x 2)			325-12	R325-12S		
	800	300 MCM x 3 (152mm^2 x 3)			-	-		

Notes: *1 Ring (Crimp) Terminal Manufacturer : JST=Japan Solderless Terminal MFG Co., Ltd.
DST=Daido Solderless Terminal MFG Co., Ltd.
AIKOKU=Aikoku Kogyou KK.
NICHIFU=Nichifu Terminal Co., Ltd.

*2 167°F (75°C) Copper wire

"ORANGE LINE" AC Contactors, AC Operated



■ *NON-REVERSING CONTACTORS* UL File No. E42419, E44592 CSA File No. LR20479

1 Phase Ratings 120	240	3 Phase Ratings 200 208	220 240	440 480	550 600	AC1	Qty. of Auxiliary Contacts	Part Number	Fuji Type	Frame Size
1/3	1	2	2	5	5	11	1	4NC0A0#10	SC-03	0A
1/3	1	3	3	5	5	13	1	4NC0F0#10	SC-0	0F
1/3	1	3	3	5	5	13	2	4NC0G0#11	SC-05	0G
1	2	5	5	71/2	71/2	20	1	4NC0Q0#10	SC-4-0	0Q
1	2	5	5	10	10	20	1	4NC0R0#10	SC-4-1	0R
1	2	5	5	10	10	20	2	4NC0H0#11	SC-5-1	0H

■ *REVERSING CONTACTORS* UL File No. E42419, E44592 CSA File No. LR20479

1 Phase Ratings 120	240	3 Phase Ratings 200 208	220 240	440 480	550 600	AC1	Qty. of Auxiliary Contacts	Part Number	Fuji Type	Frame Size
1/3	1	2	2	5	5	11	1	4ND0A0#10	SC-03RM	0A
1/3	1	3	3	5	5	13	1	4ND0F0#10	SC-0RM	0F
1/3	1	3	3	5	5	13	2	4ND0G0#11	SC-05RM	0G
1	2	5	5	71/2	71/2	20	1	4ND0Q0#10	SC-4-0RM	0Q
1	2	5	5	10	10	20	1	4ND0R0#10	SC-4-1RM	0R
1	2	5	5	10	10	20	2	4ND0H0#11	SC-5-1RM	0H

Note: The list above indicates the No. of auxiliary contacts provided per contactor.

EXPLANATION OF PART NUMBER SYSTEM

4 N C 0 A 0 # 1 0

- ***PRODUCT LINE*** (4)
  4=Orange Line
- ***OPERATION*** (N)
  N=AC Coil
  G=DC Coil
- ***DESCRIPTION*** (C)
  C=Non-Reversing Contactor
  D=Reversing Contactor
- ***FRAME SIZE*** (0A)
- ***FRAME ENCLOSURE*** (0)
  0=Open Frame, No Enclosure
- ***COIL VOLTAGE*** (#)
  Select code from chart on next page
- ***QUANTITY OF N.O. AUX. CONTACTS*** (1)
- ***QUANTITY OF N.C. AUX. CONTACTS*** (0)

"ORANGE LINE" AC Contactors, AC Operated

AVAILABLE COILS

Code Letter	AC Coil 60Hz	AC Coil 50Hz
E	24–26V	24V
F	48–52V	48V
A	100–110V	100V
1	110–120V	100–110V
G	120–130V	110–120V
B	200–220V	200V
2	220–240V	200–220V
C	400–440V	380–400V
4	440–480V	415–440V
5	550–600V	500–550V

■ COIL CHARACTERISTICS

Frame Size	Power Consumption (VA) Inrush	Power Consumption (VA) Sealed	Pick-up Voltage (V)	Drop-out Voltage (V)	Operating Time (ms) Coil ON → Contact ON	Operating Time (ms) Coil OFF → Contact OFF
0A	95	9	58–68	40–55	9–20	5–16
0F	95	9	58–68	40–55	9–20	5–16
0G	95	9	58–68	40–55	9–20	5–16
0Q	95	9	65–73	44–60	9–20	5–16
0R	95	9	65–73	44–60	9–20	5–16
0H	95	9	65–73	44–60	9–20	5–16

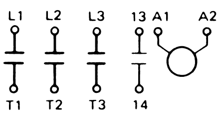
This data is based on 110-120Vac, 50/60Hz coil, tested at 120Vac, 60Hz.

WIRING DIAGRAMS / AUXILIARY CONTACT INFORMATION

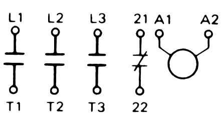
■ NON-REVERSING CONTACTORS

(4NC0A0, 0F0, 0Q0 and 0R0)

1NO* (Standard)*

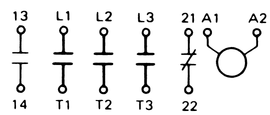


1NC* (Option)

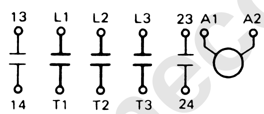


(4NC0G0 and 4NC0H0)

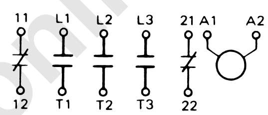
1NO+1NC (Standard)**



2NO (Option)**

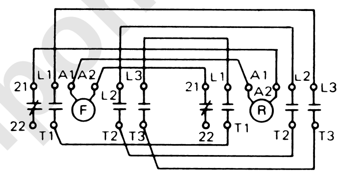


2NC (Option)**

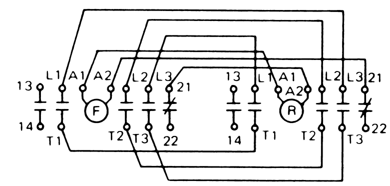


■ REVERSING CONTACTORS

(4ND0A0, 0F0, 0Q0, 0R0) ***



(4ND0G0 and 4ND0H0) ***



■ AUXILIARY CONTACT RATINGS

Operating	Contact rating Code Designation	Continuous Ampere Rating	Current–Make/Break (A) 110 to 120V	220 to 240V	440 to 480V	550 to 600V
AC	A600	10	60/6	30/3	15/1.5	12/1.2
DC	Q300	10	120V		240V	
			0.55/0.55		0.27/0.27	

* The 0A, 0F, 0Q & 0R frames offer 1 Aux. contact, NO standard. However, NC is available as an option.
** The 0G & 0H frames offer 2 Aux. contacts, 1NO + 1NC standard. However, 2NO or 2NC is available as an option.
*** Reversing contactors are NOT pre-wired with an electrical interlock unless requested when ordered.
Reversing contactors without at least 1NC Aux. contact can not be electrically interlocked.

ORDERING INFORMATION

1. **Select the basic part number from the previous page.**
2. **Replace the # mark with the appropriate coil code from the chart above.**
3. **Verify the desired auxiliary contact arrangement.**

APPENDIX G:

PREVIOUS PIER PORTAL DATASHEETS

RoHS COMPLIANT

Description

The **MA3** is a miniature rotary absolute shaft encoder that reports the shaft position over 360 ° with no stops or gaps. The **MA3** is available with an analog or a pulse width modulated (PWM) digital output.

Analog output provides an analog voltage that is proportional to the absolute shaft position. Analog output is only available in 10-bit resolution.

PWM output provides a pulse width duty cycle that is proportional to the absolute shaft position. PWM output is available in 10-bit and 12-bit resolutions. While the accuracy is the same for both encoders, the 12-bit version provides higher resolution.

Three shaft torque versions are available. The standard torque version has a sleeve bushing lubricated with a viscous motion control gel to provide torque and feel that is ideal for front panel human interface applications.

The no torque added option has a sleeve bushing and a low viscosity lubricant (that does not intentionally add torque) for low RPM applications where a small amount of torque is acceptable.

The ball bearing version uses miniature precision ball bearings that are suitable for high speed and ultra low torque applications. The shaft diameter for ball bearing version option is 1/8" rather than 1/4".

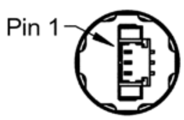
Connecting to the **MA3** is simple. The 3-pin high retention snap-in 1.25mm pitch polarized connector provides for +5V, output, and ground.

Features

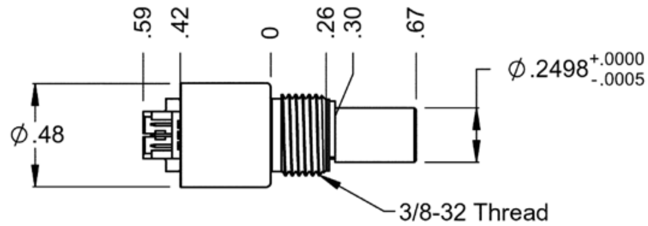
- Patent pending
- Miniature size (0.48" diameter)
- Non-contacting magnetic single chip sensing technology
- -40C to 125C. operating temperature range
- 10-bit Analog output - 2.6 kHz sampling rate
- 10-bit PWM output - 1024 positions per revolution, 1 kHz
- 12-bit PWM output - 4096 positions per revolution, 250 Hz

Mechanical Drawing

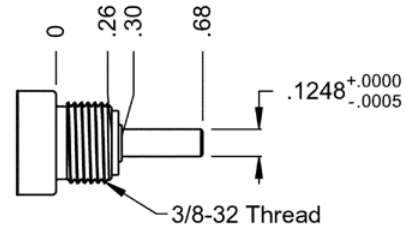
RoHS COMPLIANT



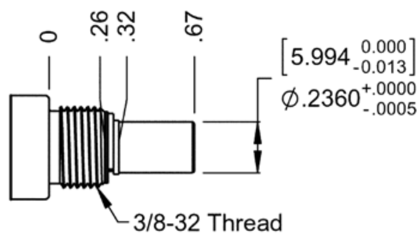
1/4" Sleeve Bushing (Default)



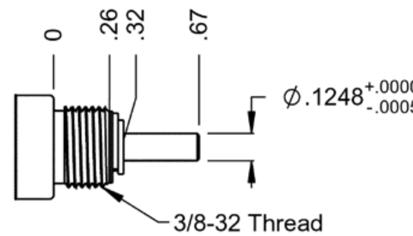
1/8" Ball Bearing (B8-option)



6mm Sleeve Bushing (M6-option)



1/8" Sleeve Bushing (8-option)



Environmental

Parameter	Value
Operating Temperature	-40C to +125C
Storage Temperature	-55C to +125C
Humidity, Non-condensing	5% to 85%
Vibration (5Hz to 2kHz)	20 G.
Electrostatic Discharge, Human Body Model	± 2 kV

Mechanical

Specification	Sleeve Bushing	Ball Bearing
Moment of Inertia	4.1 x 10^-6 oz-in-s²	4.1 x 10^-6 oz-in-s²
Angular Accuracy	<0.5 deg. @ 25C	<0.5 deg. @ 25C
Angular Accuracy Over Temperature	<0.9 deg. @ -40C to 125C	<0.9 deg. @ -40C to 125C
Max. Shaft Speed (1)	100 rpm	15000 rpm
Max. Acceleration	10000 rad/sec²	250000 rad/sec²
Max. Shaft Torque	0.5 ± 0.2 in-oz (**D** - torque option) 0.3 in-oz (**N** - torque option)	0.05 in-oz
Max. Shaft Loading	2 lb. dynamic 20 lb. static	1 lb.

Specification	Sleeve Bushing	Ball Bearing
Bearing Life (2)	> 1,000,000 revolutions	$L_{10} = (18.3/F_r)^3$? Where L_{10} = bearing life in millions of revs, and F_r = radial shaft loading in pounds
Weight	0.46 oz.	0.37 oz.
Max. Shaft Total Indicated Runout	0.0015 in.	0.0015 in.

(1) When a pulley, gear, or friction wheel drives the shaft, the Ball Bearing option is recommended instead of the Sleeve Bushing. The ch ip that decodes position uses sampled data. There will be fewer readings per revolution as the speed increases. The formula for n umber of readings per revolution is given by:

n = (60 / (rpm * 96 usec))

(2) only valid with negligible axial shaft loading

Mounting

Parameter	Value
Hole Diameter	0.375" +0.005 / -0.0
Panel Thickness	0.125" max.
Panel Nut Max. Torque	20 in.-lbs.

Materials

Parameter	Dimension
Shaft	Stainless
Bushing	Brass

Magnetic Field Crosstalk

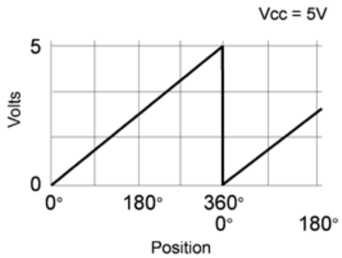
The **MA3** absolute encoder contains a small internal magnet, mounted on the end of the shaft that generates a weak magnetic field extending outside the housing of each encoder. If two **MA3** units are to be installed closer than 1 inch apart (measured between the center of both shafts), a magnetic shield, such as a small steel plate should be installed in between to prevent one encoder from causing small changes in reported position through magnetic field cross-talk.

Electrical

Parameter	Min.	Typ.	Max.	Units
Power Supply	4.5	5.0	5.5	Volts
Supply Current	-	16	20	mA

Parameter	Min.	Typ.	Max.	Units
Power-up Time	-	-	50	mS

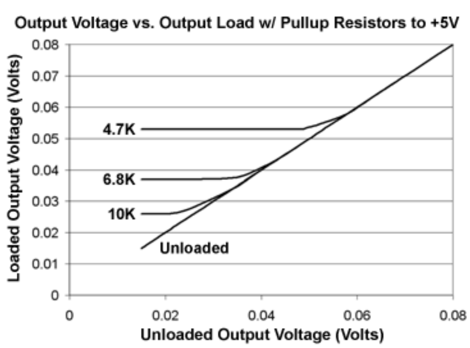
Analog Output Operation

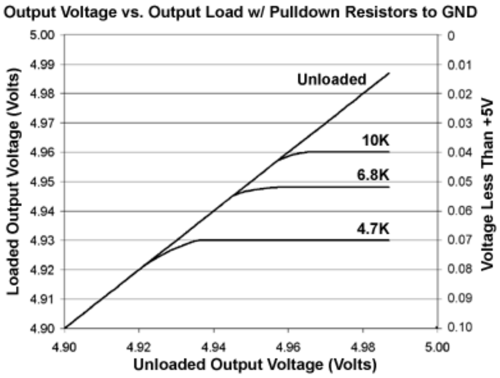


Analog output is only available in 10-bit resolution. The analog output voltage is ratiometric to the power supply voltage and will typically swing within 15 millivolts of the power supply rails with no output load. This non-linearity near the rails increases with increasing output loads. For this reason, the output load impedance should be ≥ 4.7kΩ and less than 100pF. The graphs below show the typical output levels for various output loads when powered by a 5V supply.

Parameter	Min.	Typ.	Max.	Units
Position Sampling Rate	2.35	2.61	2.87	kHz
Propagation Delay	-	-	384	?S
Analog Output Voltage Maximum (1)	-	4.987	-	Volts
Analog Output Voltage Minimum (1)	-	0.015	-	Volts
Output Short Circuit Sink Current (2)	-	32	50	mA
Output Short Circuit Source Current (2)	-	36	66	mA
Output Noise (2)	160	220	490	μ Vrms
Output Transition Noise (3)	-	0.03	-	Deg. RMS

(1) With no output load. See graphs below.
(2) Continuous short to +5V or ground will not damage the**MA3**.
(3) Transition noise is the jitter in the transition between two adjacent position steps.





PWM Output Operation

The magnetic sensor chip in the **MA3** has an on-chip RC oscillator which is factory trimmed to 5% accuracy at room temperature (10% over full temperature range). This tolerance influences the sampling rate and pulse period of the PWM output. If only the PWM pulse w idth ton and the nominal pulse period is used to measure the angle, the resulting value also has this timing tolerance. However, this to lerance can be cancelled by measuring both ton and toff and calculating the angle from the duty cycle. Angular accuracy including non-linearity is within 0.5 deg. at 25C, but may increase to 0.9 deg. at high temperatures.

Parameter	Min.	Typ.	Max.	Units
PWM Frequency (-40C to 125C)				
10-bit	0.877	0.975	1.072	kHz
12-bit	220	244	268	Hz
Minimum Pulse Width				
10-bit	0.95	1.00	1.05	?S
12-bit	0.95	1.00	1.05	?S
Maximum Pulse Width				
10-bit	974	1025	1076	?S
12-bit	3892	4097	4302	?S
Internal Sampling Rate				
10-bit	9.38	10.42	11.46	kHz
12-bit	2.35	2.61	2.87	kHz
Propagation				
10-bit	-	-	48	?S
12-bit	-	-	384	?S
Output Transition Noise, 12-bit version (1)		0.03		Deg. RMS
Output Transition Noise, 10-bit version (1)		0.12		Deg. RMS
Output High Voltage (V OH: @4mA Source) (2)	Vcc -0.5	-	-	V
Output Low Voltage (V OL: @4mA Sink) (2)	-	-	0.4	V

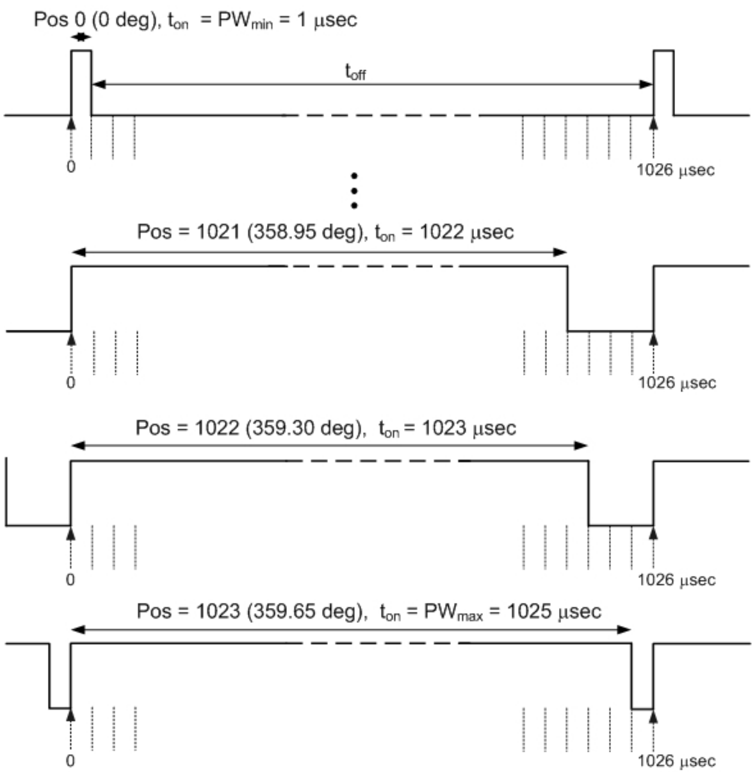
(1) Transition noise is the jitter in the transition between two adjacent position steps.
(2) Continuous short to +5V or ground will not damage the**MA3**.

10-bit PWM:

x = ((ton * 1026) / (t on+ t off)) -1

If x <= 1022, then Position = x

If x = 1024, then Position = 1023

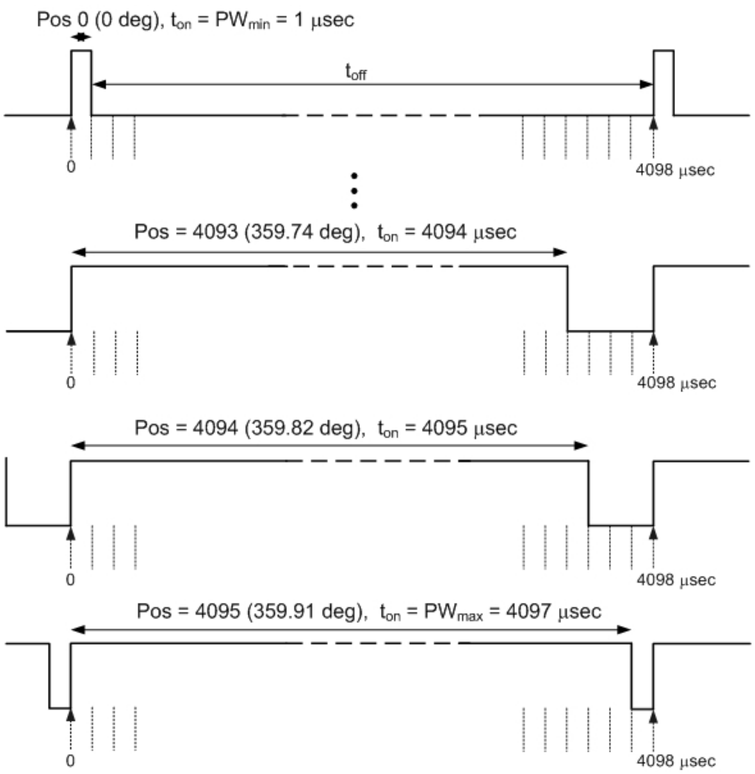


12-bit PWM:

x = ((ton * 4098) / (t on+ t off)) -1

If x <= 4094, then Position = x

If x = 4096, then Position = 4095



Pin-outs

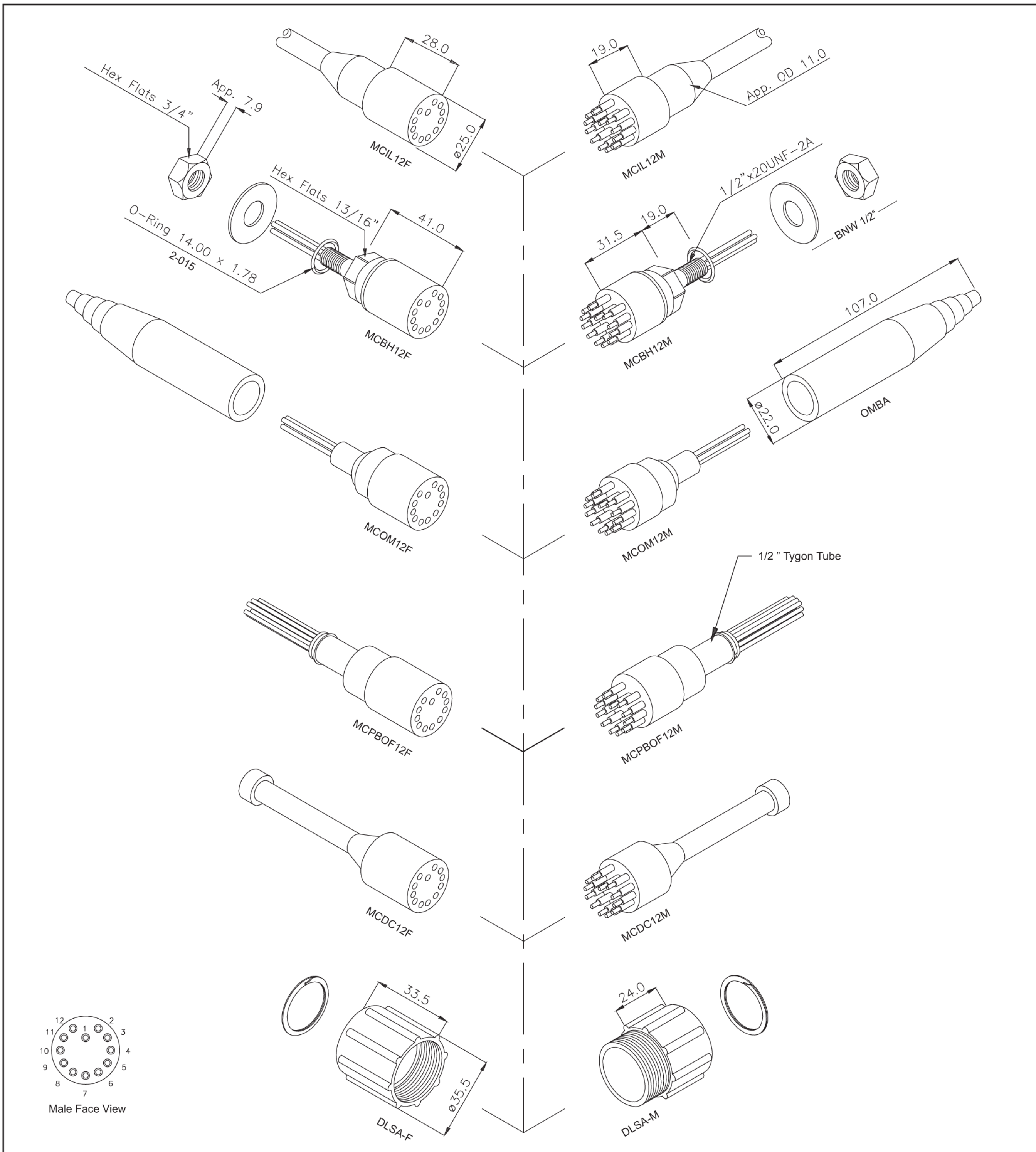
Analog Output (MA3-A):

Pin	Name	Description
1	5	+5VDC power
2	A	Analog output
3	G	Ground

PWM Output (MA3-P10, MA3-P12):

Pin	Name	Description
1	5	+5VDC power
2	A	PWM output
3	G	Ground

SubConn® Micro Series 12 Contacts



Inline Cable Colour Code

1 Black	9 Green/Black
2 White	10 Orange/Black
3 Red	11 Blue/black
4 Green	12 Black/White
5 Orange	
6 Blue	
7 White/Black	
8 Red/Black	

(Bulkhead Leads Number Tagged)

Connector Specifications

Single Contact Rating	: 300 V @ 5 Amp
Connector Rating 2 pins	: 300 V @ 5 Amp
Connector Rating 3-4 pins	: 300 V @ 4 Amp
Connector Rating 5-8 pins	: 300 V @ 3 Amp
Connector Rating 9-12 pins	: 300 V @ 2 Amp
Insulation Resistance	: >200 megaohm
Contact Resistance	: <0,01 ohm
Wet Matings	: >500
Temp. Rating	: -4° to +60° C 25° to 140° F
Depth Rating	: 700 bar - 10.000 psi

Material Specifications

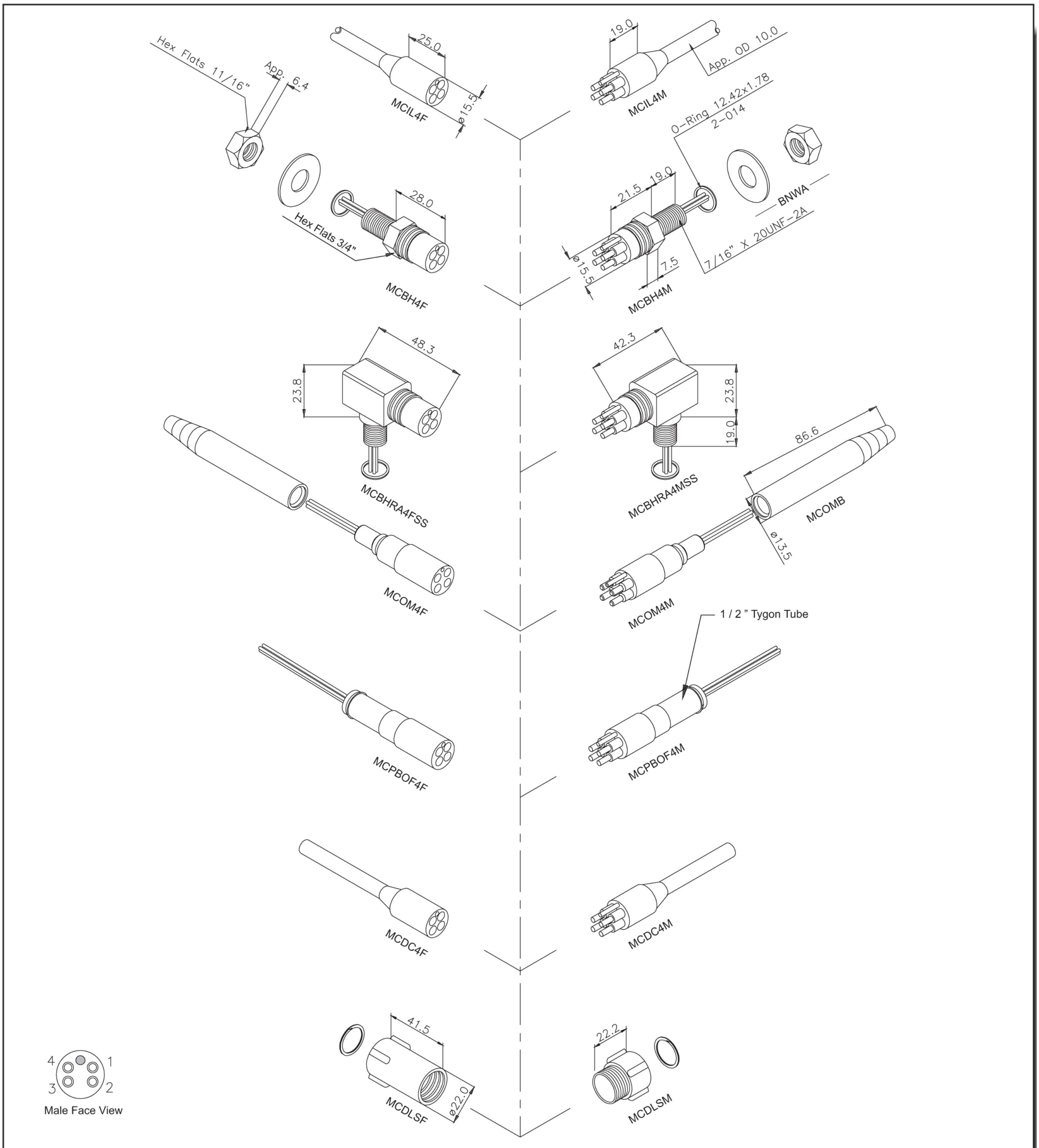
Connector Body	: Neoprene (CR)
Bulkhead Body	: Brass UNS-C36000
Pin mat	: Gold Plated Beryllium Copper UNS-C17300
Socket mat	: Gold Plated UNS-C36000 F.H.
Nuts & Washers	: Brass UNS-C36000
Locking Sleeve	: Delrin
Snap Ring	: AISI 302
Inline Cable (60 cm)	: 20 AWG 0,5 mm² Rubber
BH Leads (30 cm)	: 20 AWG 0,5 mm² Teflon
Options	: See index pages

Dimensions in mm.
Threads in inches.
1 inch = 25,4 mm.
1 mm = 0,03937 inch.

Drawing No.
SE 300-70

11-08

SubConn® Micro Series 4 Contacts



Inline Cable Colour Code

1 Black
2 White
3 Red
4 Green

(Bulkhead Leads Number Tagged)

Connector Specifications

Single Contact Rating	: 300 V @ 10 Amp
Connector Rating 2 pins	: 300 V @ 10 Amp
Connector Rating 3-4 pins	: 300 V @ 6 Amp
Insulation Resistance	: >200 megaohm
Contact Resistance	: <0,01 ohm
Wet Matings	: >500
Temp. Rating	: -4° to +60° C 25° to 140° F
Depth Rating	: 700 bar - 10.000 psi

Material Specifications

Connector Body	: Neoprene (CR)
Bulkhead Body	: Brass UNS-C36000
Contacts	: Brass UNS-C36000
Nuts & Washers	: Brass UNS-C36000
Location pin	: AISI 303
'O' Rings	: Nitrile
Locking Sleeve	: Delrin
Snap Ring	: AISI 302
Inline Cable (60 cm)	: 18 AWG 1,0 mm² Rubber
BH Leads (30 cm)	: 20 AWG 0,5 mm² Teflon
Options	: See index pages

Dimensions in mm.
Threads in inches.
1 inch = 25,4 mm.
1 mm = 0,03937 inch.

Drawing No.
SE 300-53

11-08

To provide accurate dead-time control for shoot-through avoidance and duty-cycle maximization, two resistors tied to pins HDEL and LDEL provide precise delay matching of upper and lower propagation delays, which are typically only 55ns. The HIP4081A H-Bridge driver has enough voltage margin to meet all SELV (UL classification for operation at $\leq$ 42.0V) applications and most Automotive applications where “load dump” capability over 65V is required. This capability makes the HIP408X family a more cost-effective solution for driving N-Channel power MOSFETs than either discrete solutions or other solutions relying on transformer- or opto-coupling gate-drive techniques.

The biggest difference between the HIP4080A and the HIP4081A is that the HIP4081A allows separate and individual control of the 4 MOSFET gates, whereas the HIP4080A does not. Also the HIP4081A does not include an internal comparator which can create a PWM signal directly within the HIP4080A.

Description of the HIP4081A

The block diagram of the HIP4081A relating to driving the A-side of the H-Bridge is shown in Figure 4. The blocks associated with each half of the H-Bridge are identical, so the B-side is not shown for simplicity.

The V_{CC} and V_{DD} terminals on the HIP4081A should be tied together. They were separated within the HIP4081A IC to avoid possible ground loops internal to the IC. Tying them together and providing a decoupling capacitor from the common tie-point to V_{SS} greatly improves noise immunity.

Input Logic

The HIP4081A has 4 inputs, ALI, BLI, AHI and BHI, which control the gate outputs of the H-Bridge. The DIS, “Disable,” pin disables gate drive to all H-Bridge MOSFETs regardless of the command states of the input pins above. The state of the bias voltage, V_{DD}, also can disable all gate drive as discussed in the introduction. The HIP4081A has pullups on the high input terminals, AHI and BHI, so that the bridge can be totally controlled using only the lower input control pins, ALI and BLI, which can greatly simplify the external control circuitry needed to control the HIP4081A. As Table 1 suggests, the lower inputs ALI and BLI dominate the upper inputs. That is, when one of the lower inputs is high, it doesn’t matter what the level of the upper input is, because the lower will turn on and the upper will remain off.

TABLE 1. INPUT LOGIC TRUTH TABLE

INPUT				OUTPUT	
ALI, BLI	AHI, BHI	U/V	DIS	ALO, BLO	AHO, BHO
X	X	X	1	0	0
1	X	0	0	1	0
0	1	0	0	0	1
0	0	0	0	0	0
X	X	1	X	0	0

NOTE: X signifies that input can be either a “1” or “0”.

The input sensitivity of the DIS input pin is best described as “enhanced TTL” levels. Inputs which fall below 1.0V or rise above 2.5V are recognized, respectively, as low level or high level inputs.

Propagation Delay Control

Propagation delay control is a major feature of the HIP4081A. Two identical sub-circuits within the IC delay the commutation of the power MOSFET gate turn-on signals for both A and B sides of the H-Bridge. The gate turn-off signals are not delayed. Propagation delays related to the level-translation function (see section on Level-Translation) cause both upper on/off propagation delays to naturally be longer than the lower on/off propagation delays. Four delay trim sub-circuits are incorporated to better match the H-bridge delays, two for upper delay control and two for lower gate control.

Users can tailor the low side to high side commutation delay times by placing a resistor from the HDEL pin to the V_{SS} pin. Similarly, a resistor connected from LDEL to V_{SS} controls the high side to low side commutation delay times of the lower power switches. The HDEL resistor controls both upper commutation delays and the LDEL resistor controls the lower commutation delays. Each of the resistors sets a current which is inversely proportional to the created delay. The delay is added to the falling edge of the “off” pulse associated with the MOSFET which is being commutated off. When the delay is complete, the “on” pulse is initiated. This has the effect of “delaying” the commanded on pulse by the amount set by the delay, thereby creating dead-time.

Proper choice of resistor values connected from HDEL and LDEL to V_{SS} provides a means for matching the commutation dead times whether commutating high to low or low to high. Values for the resistors ranging from 10kΩ to 200kΩ are recommended. Figure 3 shows the dead-time delays obtainable as a function of the resistor values used.

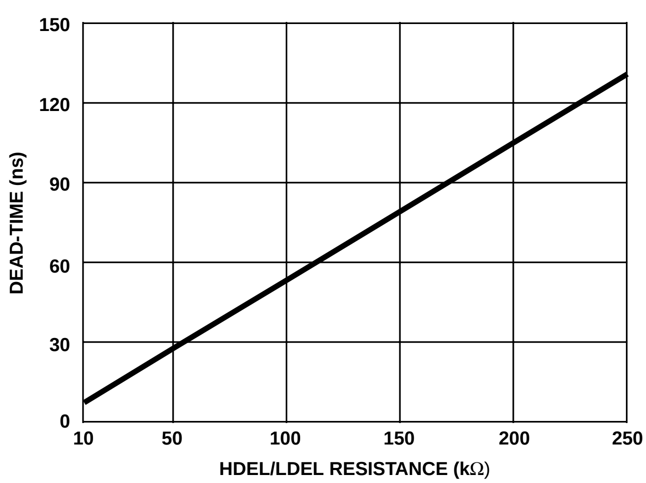


FIGURE 3. MINIMUM DEAD-TIME vs DEL RESISTANCE

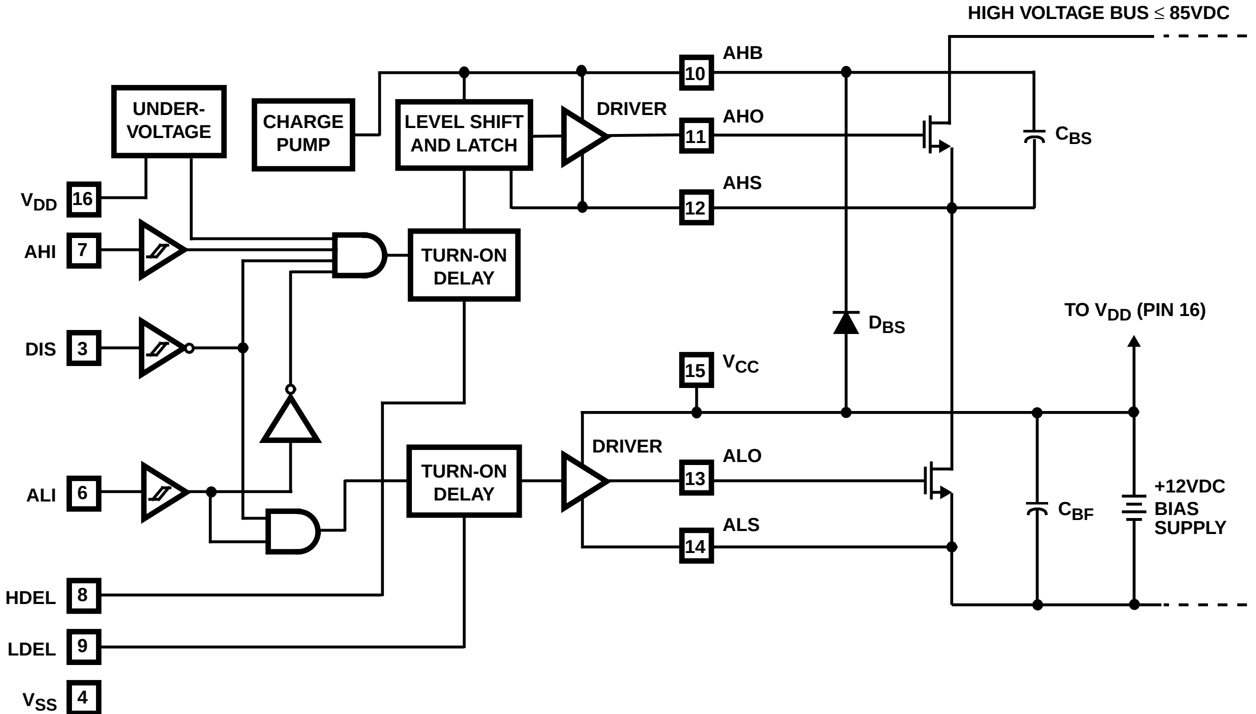


FIGURE 4. HIP4081A BLOCK DIAGRAM

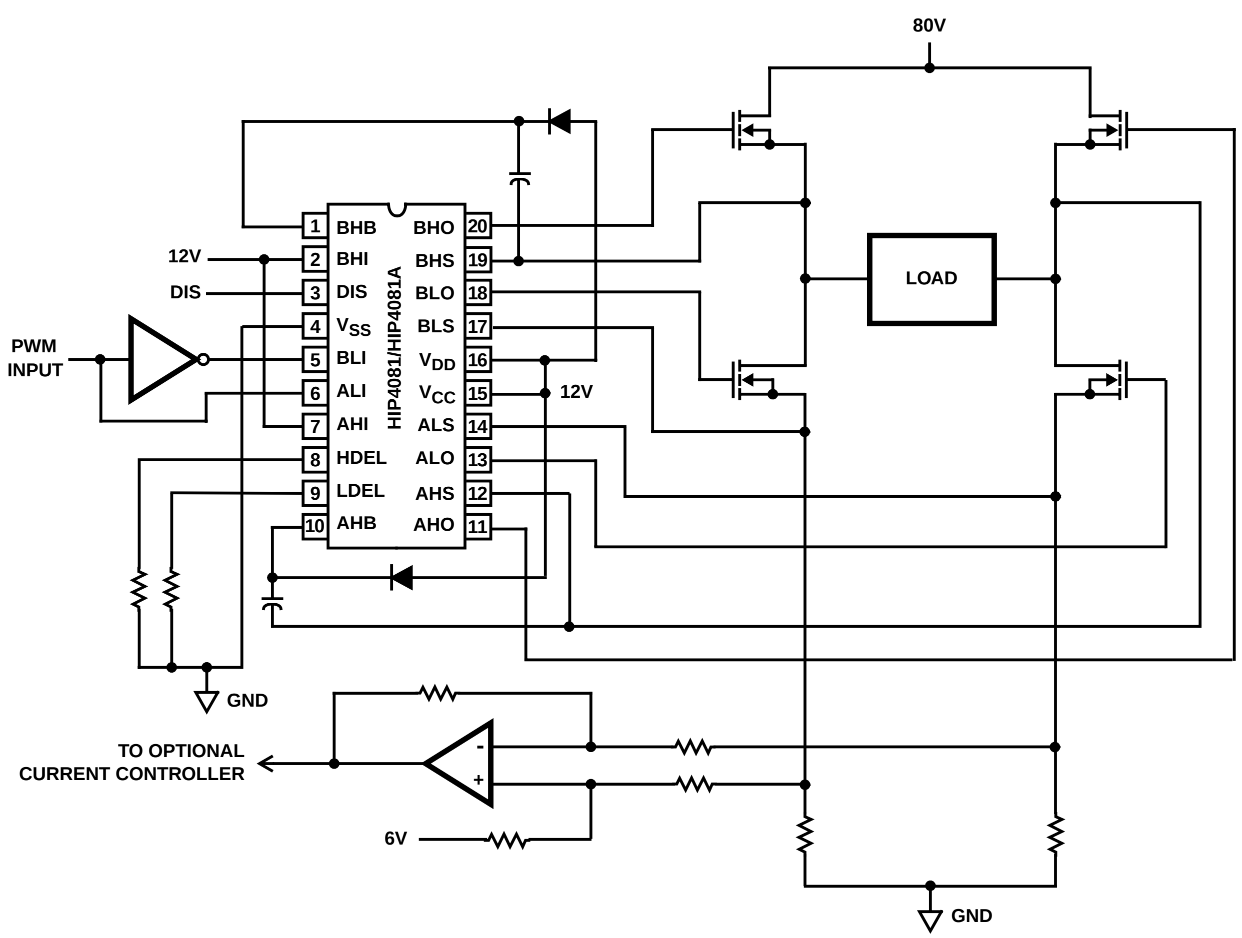


FIGURE 5. TYPICAL APPLICATION (PWM MODE SWITCHING)

3 Pin Configuration

3.1 Pin Assignment

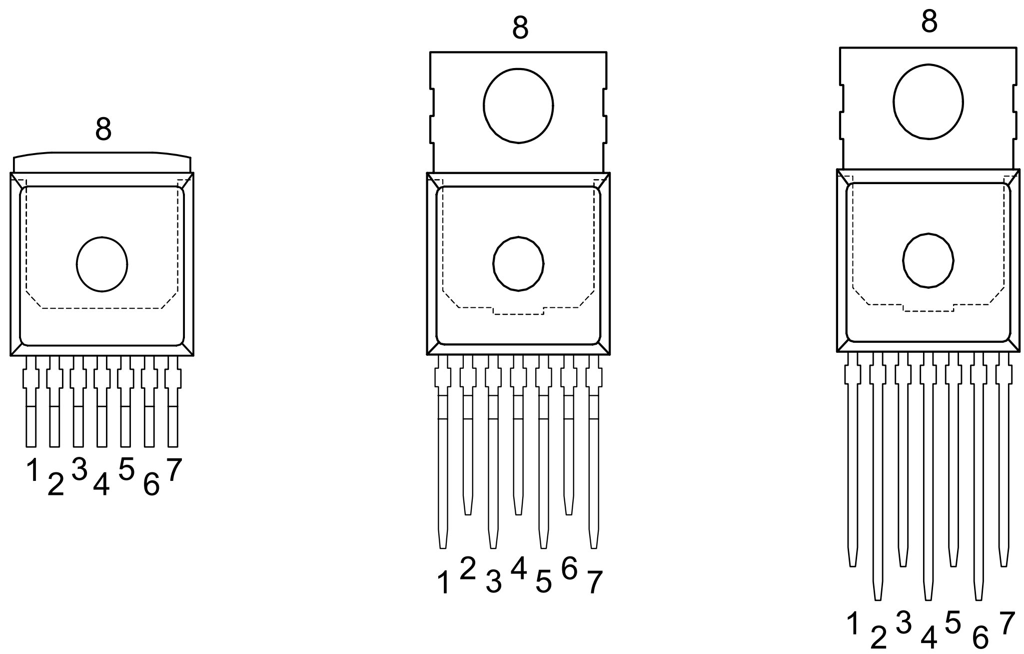


Figure 3 Pin Assignment BTN7960B, BTN7960P and BTN7960S (top view)

3.2 Pin Definitions and Functions

Pin	Symbol	I/O	Function
1	**GND**	**-**	**Ground**
2	IN	I	Input Defines whether high- or lowside switch is activated
3	INH	I	Inhibit When set to low device goes in sleep mode
4,8	**OUT**	**O**	**Power output of the bridge**
5	SR	I	Slew Rate The slew rate of the power switches can be adjusted by connecting a resistor between SR and GND
6	IS	O	Current Sense and Diagnostics
7	**VS**	**-**	**Supply**

Bold type: pin needs power wiring

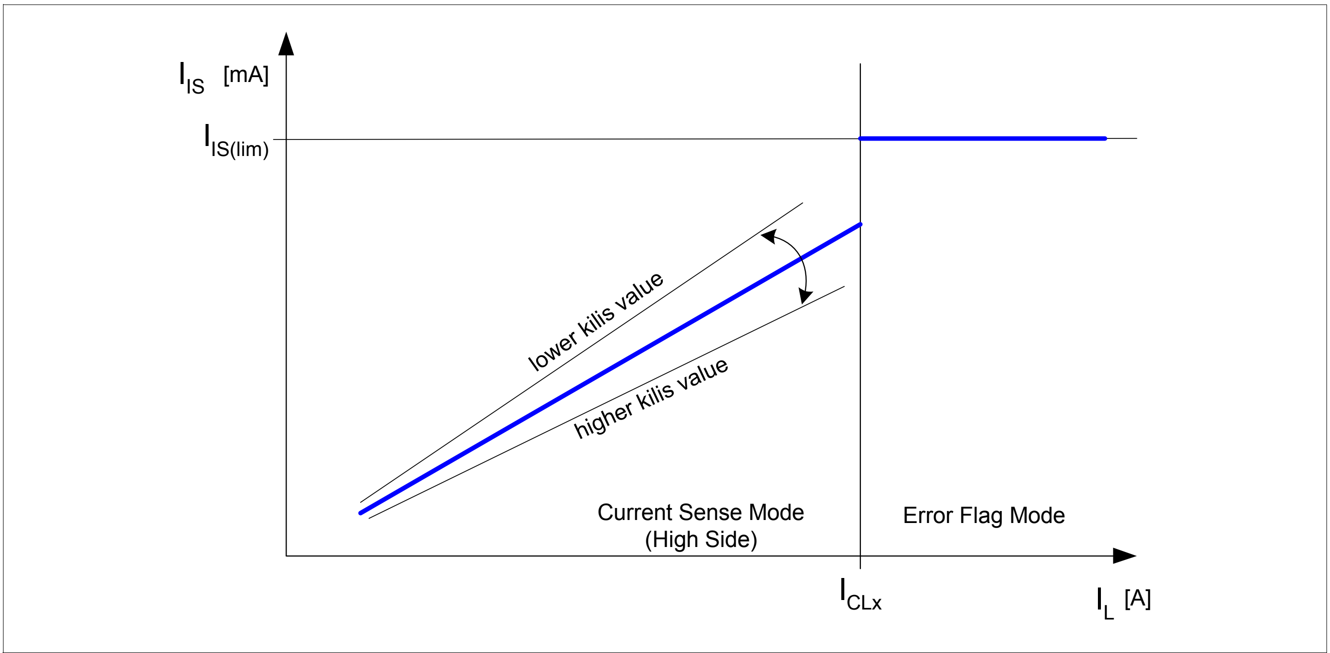


Figure 13 Sense Current vs. Load Current

5.4.5 Truth Table

Device State	Inputs		Outputs			Mode
	INH	IN	HSS	LSS	IS	
Normal Operation	0	X	OFF	OFF	0	Stand-by mode
	1	0	OFF	ON	0	LSS active
	1	1	ON	OFF	CS	HSS active
Over-Voltage (OV)	X	X	ON	OFF	1	Shut-down of LSS, HSS activated, error detected
Under-Voltage (UV)	X	X	OFF	OFF	0	UV lockout
Overtemperature or Short Circuit of HSS or LSS	0	X	OFF	OFF	0	Stand-by mode, reset of latch
	1	X	OFF	OFF	1	Shut-down with latch, error detected
Current Limitation Mode	1	1	OFF	ON	1	Switched mode, error detected[1)]
	1	0	ON	OFF	1	Switched mode, error detected[1)]

1) Will return to normal operation after t_{CLS}; Error signal is reset after 2*t_{CLS} (see **Chapter 5.3.4**)

Inputs	Switches	Status Flag IS
0 = Logic LOW	OFF = switched off	CS = Current sense mode
1 = Logic HIGH	ON = switched on	1 = Logic HIGH (error)
X = 0 or 1		

5.4.6 Electrical Characteristics - Control and Diagnostics

V_S = 8 V to 18 V, T_j = -40 °C to +150 °C, all voltages with respect to ground, positive current flowing into pin (unless otherwise specified)

Pos.	Parameter	Symbol	Limit Values			Unit	Conditions
			Min.	Typ.	Max.		
Control Inputs (IN and INH)							
5.4.1	High level Voltage INH, IN	$V_{INH(H)}$ $V_{IN(H)}$	– –	1.75 1.6	2.15 2	V	–
5.4.2	Low level Voltage INH, IN	$V_{INH(L)}$ $V_{IN(L)}$	1.1	1.4	–	V	–
5.4.3	Input Voltage hysteresis	V_{INHHY} V_{INHY}	– –	350 200	– –	mV	–
5.4.4	Input Current high level	$I_{INH(H)}$ $I_{IN(H)}$	–	30	150	µA	$V_{IN} = V_{INH}$ = 5.3 V
5.4.5	Input Current low level	$I_{INH(L)}$ $I_{IN(L)}$	–	25	125	µA	$V_{IN} = V_{INH}$ = 0.4 V
Current Sense							
5.4.6	Current Sense ratio in static on-condition $k_{ILIS} = I_L / I_{IS}$	k_{ILIS}	 6 5.5 5	 8.5 8.5 8.5	 11 11.5 12.5	10^3	R_{IS} = 1 kΩ I_L = 30 A I_L = 15 A I_L = 5 A
5.4.7	Maximum analog Sense Current, Sense Current in fault Condition	$I_{IS(lim)}$	4	5	6.5	mA	V_S = 13.5 V R_{IS} = 1kΩ
5.4.8	Isense Leakage current	I_{ISL}	–	–	1	µA	V_{IN} = 0 V or V_{INH} = 0 V
5.4.9	Isense Leakage current, active high side switch	I_{ISH}	–	1	80	µA	$V_{IN} = V_{INH}$ = 5 V I_L = 0 A

6 Application Information

Note: The following information is given as a hint for the implementation of the device only and shall not be regarded as a description or warranty of a certain functionality, condition or quality of the device.

6.1 Application Example

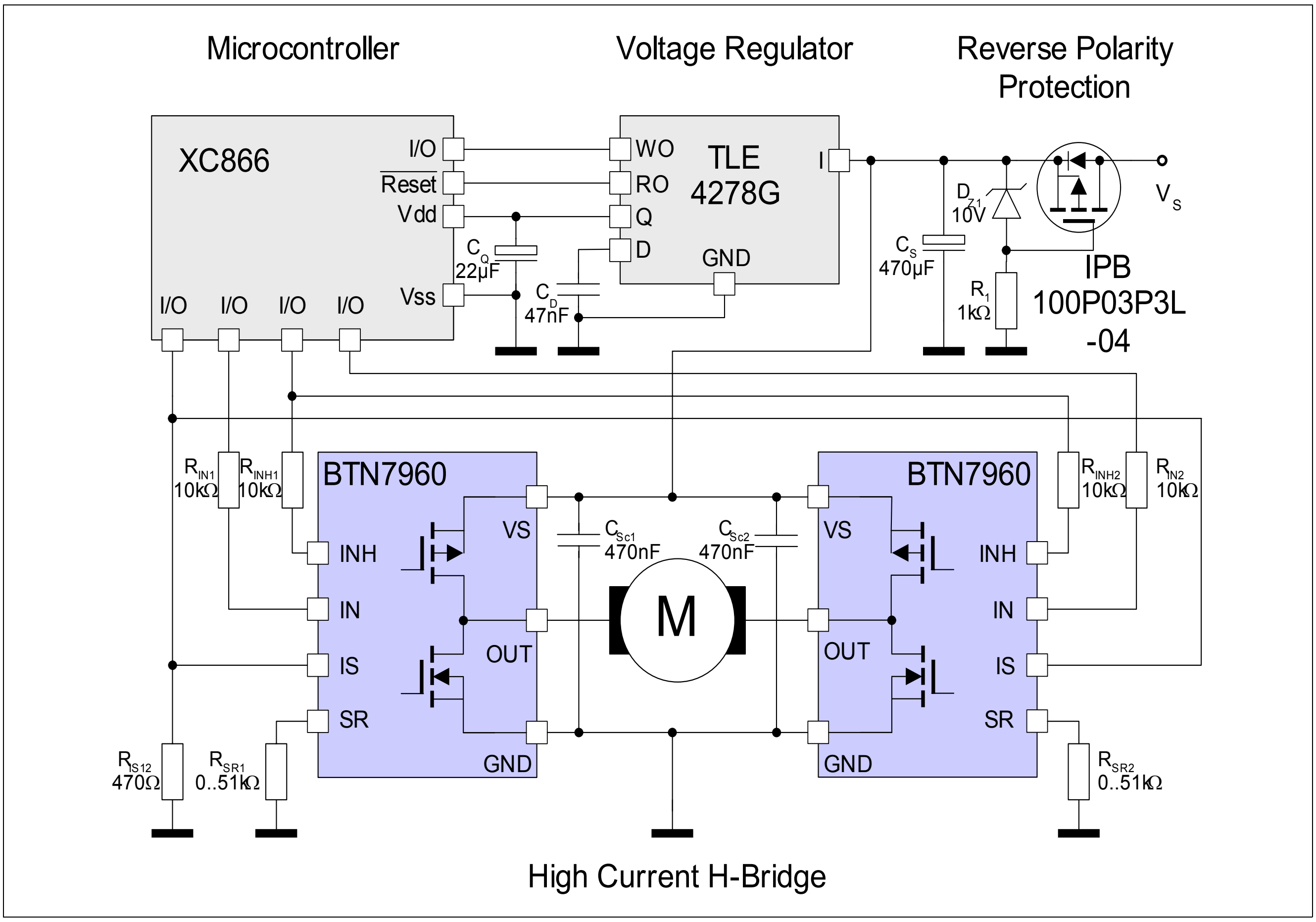


Figure 14 Application Example: H-Bridge with two BTN7960

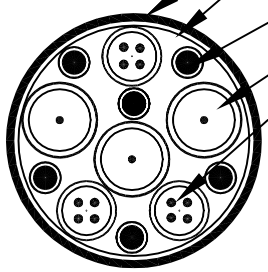
Note: This is a simplified example of an application circuit. The function must be verified in the real application.

6.2 Layout Considerations

Due to the fast switching times for high currents, special care has to be taken to the PCB layout. Stray inductances have to be minimized in the power bridge design as it is necessary in all switched high power bridges. The BTN7960 has no separate pin for power ground and logic ground. Therefore it is recommended to assure that the offset between the ground connection of the slew rate resistor, the current sense resistor and ground pin of the device (GND / pin 1) is minimized. If the BTN7960 is used in a H-bridge or B6 bridge design, the voltage offset between the GND pins of the different devices should be small as well.

A ceramic capacitor from VS to GND close to each device is recommended to provide current for the switching phase via a low inductance path and therefore reducing noise and ground bounce. A reasonable value for this capacitor would be about 470 nF.

The digital inputs need to be protected from excess currents (e.g. caused by induced voltage spikes) by series resistors in the range of 10 kΩ.



REV.	DESCRIPTION	DATE
A	UPDATED TO NEW CABLE	2/2/99
B	ADDED FALMAT NUMBER	3/99
C	CHANGED JACKET PRINTING	9/00
D	CHANGED SPEC. 12 PER VENDOR	070203
E	SEE ECN EC-00049	9APR09
F	SEE ECN EC-00753 SW	23MAY11

SPECIFICATIONS:

1. 3 EA. 75 OHM COAXIAL CABLE, RG-59/U MODIFIED, 22(7)TC, SOLID POLYETHEYLENE DIELECTRIC, 95% T.C. BRAD, ADHESIVE/MYLAR TAPE JACKET, 0.187" O.D., DC RESISTANCE 16.6 OHMS/1000 FT, ATTENUATION 1.4DB/100 FT @ 10 MHz.
2. 3 EA. 20AWG TWISTED SHIELDED QUADS WITH ALUMINUM MYLAR 22 AWG STRANDED DRAIN WIRE EACH WITH OVERALL CLEAR MYLAR FOR SHIELD ISOLATION; INDIVIDUAL QUAD WIRES STRANDED WITH 0.010" IRRADIATED PVC INSULATION.
3. 6 EA. 16AWG PVC INSULATED STRANDED WIRE.
4. CONDUCTOR COLORS AS LISTED BELOW.
5. ALUMINUM MYLAR WRAP AROUND ENTIRE CABLE ASSEMBLY, WITH DRAIN
6. OVERALL KEVLAR BRAID STRENGTH MEMBER WITH 1000 POUNDS BREAKING STRENGTH.
7. JACKET, ETHANE ZHF90AT0, 0.040" NOMINAL WALL HFFR (58244).
8. JACKET PRINTED: "ROS NUCLEAR UNDERWATER CABLE P/N 30-12460-01" (WHITE INK 1/8" MIN)
9. OVERALL OUTER DIAMETER 0.620 NOMINAL.
10. TEMPERATURE RATING: -30C TO +80C.
11. VOLTAGE RATING: 300V
12. MINIMUM BEND RADIUS 10" MIN., 280 LBS/MFT NET WT.
13. INSULATION: IR > 10 MEGOHMS AT 500 VOLTS DC.

SINGLE WIRE CABLE COLORS

WHT/RED
WHT/ORG
WHT/YEL
WHT/GRN
WHT/BLU
WHT/VIO

QUAD CABLE COLORS

NO.1	NO.2	NO.3
BLK	ORG	VIO
BRN	YEL	GRY
WHT	GRN	WHT/BLK
RED	BLU	WHT/BRN

-03	-02	-01	ITEM NO.	PART OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	MATERIAL SPECIFICATION
		X			FALMAT	FM 012799PB3
QTY/ASSY						

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

TOLERANCES
.X = ± .030
.XX = ± .010
.XXX = ± .005
ANGULAR = ± 30'

NEXT ASSEMBLY:

SURFACE TEXTURE: √

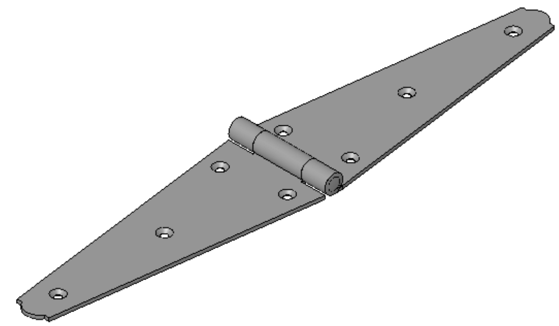
PREPARED	AEV	2/99
CHECKED	D. MYERS	6/28/99
QA	O. CORREA	7/6/99
RELEASED BY		

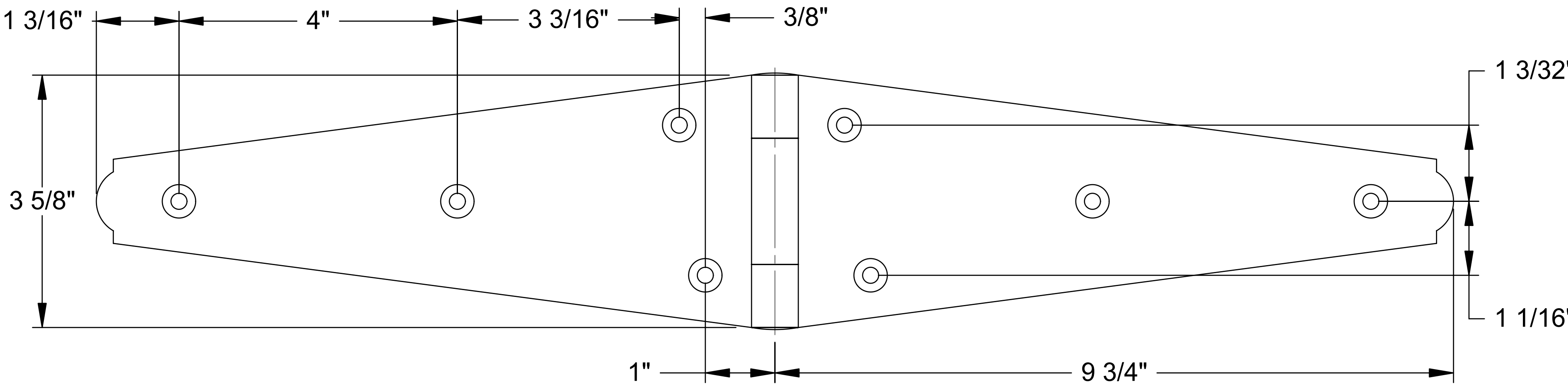
RemoteOceanSystems

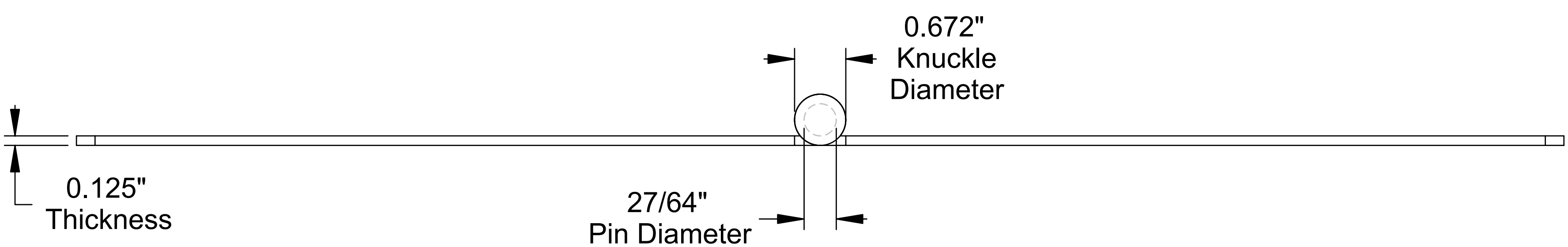
DRAWING, UNDERWATER VIDEO CABLE (NUCLEAR)
CA- 30-12460

SIZE	CAGE CODE	DWG NO.	REV
A	2T637	30-12460	F

SCALE 2:1 | WT N/A | SHEET 1 OF 1







Hinge uses #14 flat head screws.

McMASTER-CARR CAD	PART NUMBER 1526A55
http://www.mcmaster.com © 2007 McMaster-Carr Supply Company	Steel Strap Hinge with Zinc-Plated Finish

Unless otherwise specified, dimensions are in inches. Information in this drawing is provided for reference only.

Material Safety Data Sheet

May be used to comply with OSHA's Hazard Communication Standard, 29CFR 1910 1200 Standard must be consulted for specific requirements

OSPHO METAL TREATMENT

QUICK IDENTIFIER
Common Name (used on label and list)

SECTION 1 –

Manufacturer's Name	THE SKYBRYTE COMPANY
Address	3125 PERKINS AVENUE
City, State, and ZIP	CLEVELAND, OHIO 44114
Signature of Person Responsible for Preparation (Optional)	S. L. PITCHER
Emergency Telephone No	800-424-9300 (CHEMTREC)
Other Information Calls	703-527-3887 (CHEMTREC DIRECT) 216-771-1590 (SKYCO)
Date Prepared	MARCH 26, 2007

SECTION 2 – HAZARDOUS INGREDIENTS/IDENTITY

Hazardous Component(s) (chemical & common name(s))	OSHA PEL	ACGIH TLV	Other Exposure Limits	% (optional)	CAS NO
PHOSPHORIC ACID SOLUTION (75%)	1 mg/m^3	1 mg/m^3	3 mg/m^3 STEL	45.0%	7664-38-2

Section 313 Supplier Notification: This product contains the following toxic chemicals subject to the requirements of section 313 of the Emergency Planning and Community Right-To-Know Act of 1986 (4O CFR 372) :

VOC = 0%

CHEMICAL NAME:		% BY WIEGHT	DOT Hazard: Class 8
PHOSPHORIC ACID SOLUTION (75%)	CAS# 7664-38-2	45.0%	UN# 1805 PG III

All ingredients of this product are listed in compliance withSection 15 of the Toxic Substance Control Act (T.S.C.A.)

This information should be included in all MSDS sheets that are distributed.

SECTION 3 – PHYSICAL & CHEMICAL CHARACTERISTICS

Boiling Point	240F
Specific Gravity ($H_2O=1$)	1.22+/-.04
Vapor Pressure (mm Hg)	UNK
Vapor Density (Air = 1)	N/A
Solubility in Water	100% pH < 2 (strong acid)
Reactivity in Water	NONE
Appearance and Odor	GREEN LIQUID WITH TYPICAL ACIDIC ODOR
Melting Point	N/A

SECTION 4 – FIRE & EXPLOSION DATA

Flash Point	N/A F C
Method Used	NON-FLAMMABLE
Flammable Limits in Air % by Volume — LEL Lower	N/A
UEL Upper	N/A
Auto-Ignition Temperature	N/A
Extinguisher Media	N/A
Special Fire Fighting Procedures	N/A
Unusual Fire and Explosion Hazards	MAY DECOMPOSE TO RELEASE OXYGEN AROUND 400C (750F). WILL PRODUCE IRRITATING PHOSPHORIC OXIDE FUMES UNDER FIRE CONDITIONS.

SECTION 5 – PHYSICAL HAZARDS (REACTIVITY DATA)

Stability: Unstable ☐ / Stable ☒ — Conditions to Avoid: AVOID CONTACT WITH STRONG ALKALIES

Incompatability (Materials to Avoid): REACTION WITH METALS WILL LIBERATE HYDROGEN GAS. (EXTREMELY FLAMMABLE!)

Hazardous Decomposition Products: PHOSPHORIC ACID FUMES. (STRONG IRRITANT)

Hazardous Polymerization: May Occur ☐ / Will Not Occur ☒ — Conditions to Avoid: AVOID CONTACT WITH STRONG ALKALIES. (WILL PRODUCE VIOLENT ACID/BASE NEUTRALIZATION REACTION.)

SECTION 6 – HEALTH HAZARDS

1 Acute: STRONG IRRITANT - SLIGHTLY TOXIC

2 Chronic: SLIGHTLY TOXIC - CAUSES BURNS TO EXPOSED TISSU

Signs and Symptoms of Exposure: LIQUID IS CORROSIVE TO EYES AND SKIN, MIST PRODUCES IRRITATION TO EYES, THROAT, AND LUNGS.

Medical Conditions Generally Aggravated by Exposure: EMPHYSEMA, ASTHMA OR OTHER CONDITIONS RESULTING IN DECREASED RESPIRATORY FUNCTION.

Chemical Listed as Carcinogen or Potential Carcinogen: National Toxicology Program Yes ☐ No ☒ — I A R C Monographs Yes ☐ No ☒ — OSHA Yes ☐ No ☒

Emergency and First Aid Procedures: CALL A PHYSICIAN IMMEDIATELY, INGESTION - GIVE LARGE QUANTITIES OF WATER. " DO NOT INDUCE VOMITING" SKIN AND EYES - FLUSH WITH WATER

ROUTES OF ENTRY

1 Inhalation: YES

2 Eyes: YES

3 Skin: YES

4 Ingestion: PRIMARY HAZARD

SECTION 7 – SPECIAL PRECAUTIONS AND SPILL/LEAK PROCEDURES

Precautions to be Taken in Handling and Storage: USE GOGGLES AND/OR FACE SHIELDS, RUBBER APRONS, GLOVES AND BOOTS WHERE SPLASHING OR LIQUID CONTACT MAY BE EXPECTED.

Other Precautions: AIRBORNE MIST - USE NIOSH/MSHA ACID GAS RESPIRATOR WITH FULL FACE PIECE. KEEP STORED IN SUITABLE CONTAINER.

Steps to be Taken in Case Material is Released or Spilled: WEAR SUITABLE PROTECTIVE CLOTHING. EYE PROTECTION, AND RESPIRATOR. NEUTRALIZE WITH SODA ASH AND FLUSH THE AREA WITH LARGE AMOUNTS OF WATER.

Waste Disposal Methods (Consult federal, state, and local regulations): NEUTRALIZE WITH SODA ASH OR LIME AND DISCHARGE INTO A TREATMENT SYSTEM IN ACCORDANCE WITH LOCAL REGULATIONS.

SECTION 8 – SPECIAL PROTECTION INFORMATION/CONTROL MEASURES

Respiratory Protection (Specify Type): NIOSH/MSHA ACID GAS WITH FULL FACE PIECE.

Ventilation: Local Exhaust: ADEQUATE TO MEET PEL — Mechanical (General): N/A — Special: N/A — Other: N/A

Protective Gloves: ACID RESISTANT — Eye Protection: CHEMICAL GOGGLES

Other Protective Clothing or Equipment: RUBBER APRON AND BOOTS AS NECCESSARY.

Work/Hygienic Practices: STORE AND HANDLE AS STRONG ACID. WASH BEFORE EATING OR DRINKING.

IMPORTANT

Do not leave any blank spaces. If required information is unavailable, unknown, or does not apply, so indicate.

Technical Data Sheet

LOCTITE® 271™

November 2010

PRODUCT DESCRIPTION

LOCTITE® 271™ provides the following product characteristics:

Technology	Acrylic
Chemical Type	Dimethacrylate ester
Appearance (uncured)	Red LMS
Fluorescence	Positive under UV light LMS
Components	One component - requires no mixing
Viscosity	Low
Cure	Anaerobic
Secondary Cure	Activator
Application	Threadlocking
Strength	High

LOCTITE® 271™ is designed for the permanent locking and sealing of threaded fasteners. The product cures when confined in the absence of air between close fitting metal surfaces and prevents loosening and leakage from shock and vibration. Typical applications include the locking and sealing of large bolts and studs (up to M25).

Mil-S-46163A

LOCTITE® 271™ is tested to the lot requirements of Military Specification Mil-S-46163A. **Note:** This is a regional approval. Please contact your local Technical Service Center for more information and clarification.

ASTM D5363

Each lot of adhesive produced in North America is tested to the general requirements defined in paragraphs 5.1.1 and 5.1.2 and to the Detail Requirements defined in section 5.2.

UL Classification

Classified by Underwriters Laboratories Inc.® MH8007 - Fire hazard is small. No flash point in liquid state. Ignition temperature 304°C. For use in devices handling gasoline, petroleum oils, natural gas (pressure not over 300 PSIG), butane and propane not exceeding 2 in. pipe size. **Note:** This is a regional approval. Please contact your local Technical Service Center for more information and clarification

TYPICAL PROPERTIES OF UNCURED MATERIAL

Specific Gravity @ 25 °C 1.1

Flash Point - See MSDS

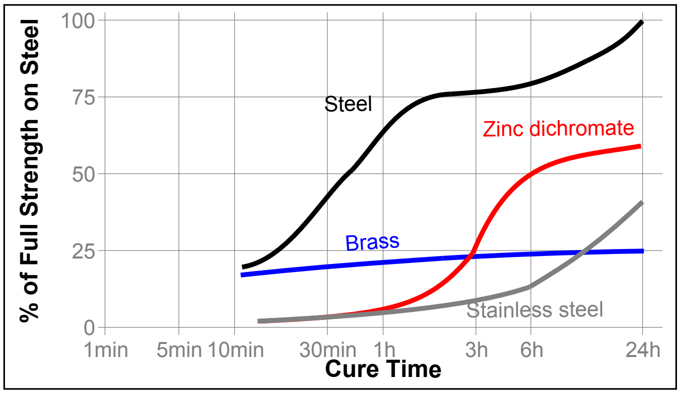
Viscosity, Brookfield - RVT, 25 °C, mPa·s (cP):

Spindle 1, speed 10 rpm 400 to 600 LMS

TYPICAL CURING PERFORMANCE

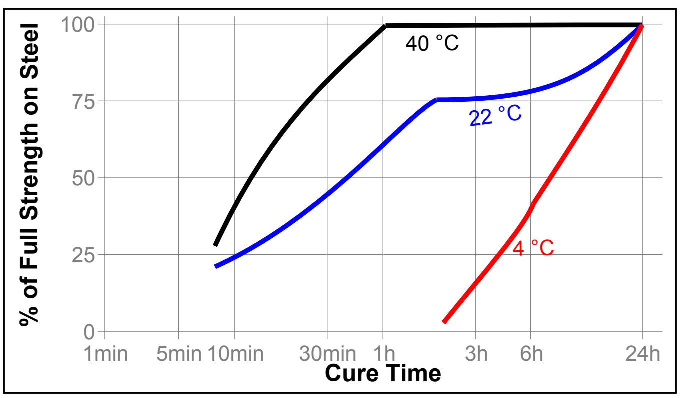
Cure Speed vs. Substrate

The rate of cure will depend on the substrate used.The graph below shows the breakaway strength developed with time on M10 steel nuts and bolts compared to different materials and tested according to ISO 10964.



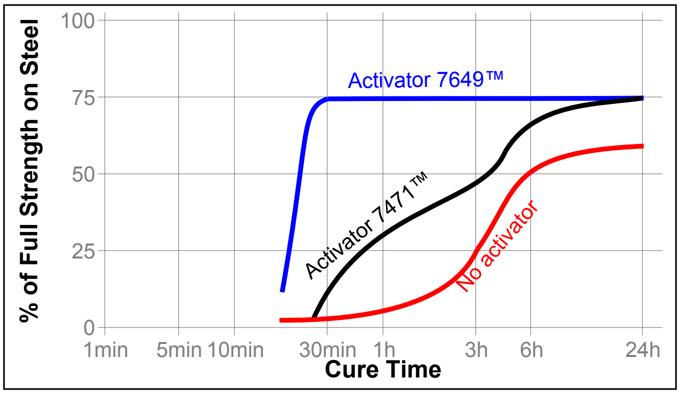
Cure Speed vs. Temperature

The rate of cure will depend on the temperature. The graph below shows the breakaway strength developed with time at different temperatures on M10 steel nuts and bolts and tested according to ISO 10964.



Cure Speed vs. Activator

Where cure speed is unacceptably long, or large gaps are present, applying activator to the surface will improve cure speed. The graph below shows the breakaway strength developed with time on M10 zinc dichromate steel nuts and bolts using Activator 7471™ and 7649™ and tested according to ISO 10964.



TYPICAL PERFORMANCE OF CURED MATERIAL

Adhesive Properties

After 90 minutes @ 22 °C

Breakaway Torque, ISO 10964:

3/8 x 16 steel nuts (grade 2) and bolts (grade 5)	N·m (lb.in.)	8.5 to 25.4[LMS] (75 to 225)

Prevail Torque, ISO 10964:

3/8 x 16 steel nuts (grade 2) and bolts (grade 5)	N·m (lb.in.)	16.9 to 34[LMS] (150 to 300)

After 24 hours @ 22 °C

Breakaway Torque, ISO 10964:

3/8 x 16 steel nuts (grade 2) and bolts (grade 5)	N·m (lb.in.)	16.9 to 34[LMS] (150 to 300)
3/8 x 16 cadmium nuts and bolts	N·m (lb.in.)	4.5 to 14.1[LMS] (40 to 125)
3/8 x 16 zinc nuts and bolts	N·m (lb.in.)	4.5 to 14.1[LMS] (40 to 125)
M10 steel nuts and bolts	N·m (lb.in.)	17 to 40 (150 to 350)

Prevail Torque, ISO 10964:

3/8 x 16 steel nuts (grade 2) and bolts (grade 5)	N·m (lb.in.)	22.6 to 40[LMS] (200 to 355)
3/8 x 16 cadmium nuts and bolts	N·m (lb.in.)	16.9 to 34[LMS] (150 to 300)
3/8 x 16 zinc nuts and bolts	N·m (lb.in.)	16.9 to 34[LMS] (150 to 300)
M10 steel nuts and bolts	N·m (lb.in.)	23 to 40 (200 to 350)

TYPICAL ENVIRONMENTAL RESISTANCE

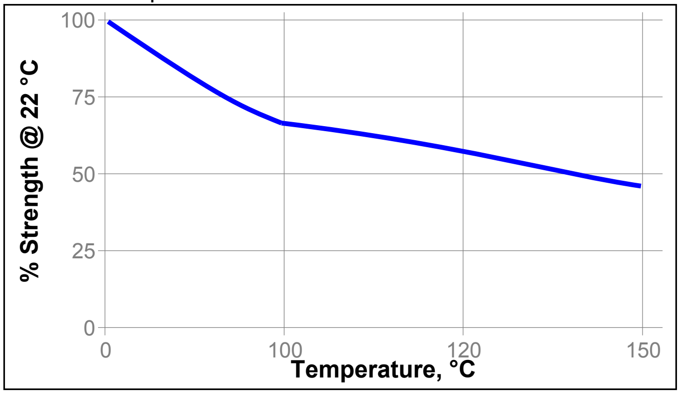
Cured for 24 hours @ 22 °C

Breakaway Torque, ISO 10964:

M10 steel nuts and bolts

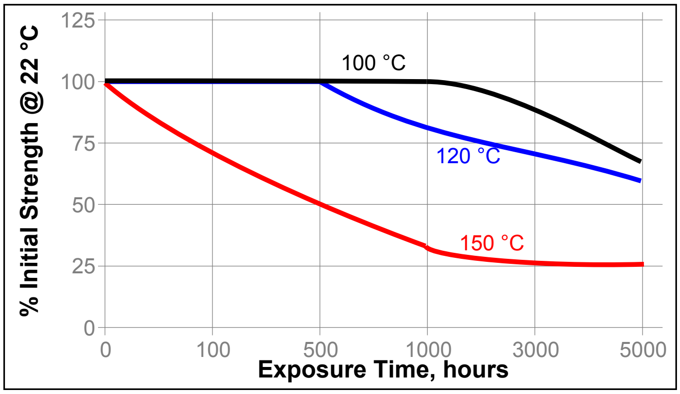
Hot Strength

Tested at temperature



Heat Aging

Aged at temperature indicated and tested @ 22 °C



Chemical/Solvent Resistance

Aged under conditions indicated and tested @ 22 °C.

		% of initial strength		
Environment	**°C**	**100 h**	**500 h**	**1000 h**
Motor oil (MIL-L-46152)	125	85	85	75
Unleaded gasoline	22	100	100	95
Leaded Gasoline I	22	100	100	100
Brake fluid	22	100	100	100
Ethanol	22	95	95	95
Acetone	22	95	95	95
1,1,1 Trichloroethane	22	100	95	95
Water/glycol 50/50	87	100	85	85

GENERAL INFORMATION

This product is not recommended for use in pure oxygen and/or oxygen rich systems and should not be selected as a sealant for chlorine or other strong oxidizing materials

For safe handling information on this product, consult the Material Safety Data Sheet (MSDS).

Where aqueous washing systems are used to clean the surfaces before bonding, it is important to check for compatibility of the washing solution with the adhesive. In some cases these aqueous washes can affect the cure and performance of the adhesive.

This product is not normally recommended for use on plastics (particularly thermoplastic materials where stress cracking of the plastic could result). Users are recommended to confirm compatibility of the product with such substrates.

Directions for use:

For Assembly

1. For best results, clean all surfaces (external and internal) with a LOCTITE® cleaning solvent and allow to dry.
2. If the material is an inactive metal or the cure speed is too slow, spray all threads with Activator 7471™ or 7649™ and allow to dry.
3. Shake the product thoroughly before use.
4. To prevent the product from clogging in the nozzle, do not allow the tip to touch metal surfaces during application.
5. **For Thru Holes**, apply several drops of the product onto the bolt at the nut engagement area.
6. **For Blind Holes**, apply several drops of the product down the internal threads to the bottom of the hole.
7. **For Sealing Applications**, apply a 360° bead of product to the leading threads of the male fitting, leaving the first thread free. Force the material into the threads to thouroughly fill the voids. For bigger threads and voids, adjust product amount accordingly and apply a 360° bead of product on the female threads also.
8. Assemble and tighten as required.

For Disassembly

1. Apply localized heat to nut or bolt to approximately 250 °C. Disassemble while hot.

For Cleanup

1. Cured product can be removed with a combination of soaking in a Loctite solvent and mechanical abrasion such as a wire brush.

Loctite Material Specification[LMS]

LMS dated August 23, 1999. Test reports for each batch are available for the indicated properties. LMS test reports include selected QC test parameters considered appropriate to specifications for customer use. Additionally, comprehensive controls are in place to assure product quality and consistency. Special customer specification requirements may be coordinated through Henkel Quality.

Storage

Store product in the unopened container in a dry location. Storage information may be indicated on the product container labeling.

Optimal Storage: 8 °C to 21 °C. Storage below 8 °C or greater than 28 °C can adversely affect product properties. Material removed from containers may be contaminated during use. Do not return product to the original container. Henkel Corporation cannot assume responsibility for product which has been contaminated or stored under conditions other than those previously indicated. If additional information is required, please contact your local Technical Service Center or Customer Service Representative.

Conversions

(°C x 1.8) + 32 = °F
kV/mm x 25.4 = V/mil
mm / 25.4 = inches
µm / 25.4 = mil
N x 0.225 = lb
N/mm x 5.71 = lb/in
N/mm² x 145 = psi
MPa x 145 = psi
N·m x 8.851 = lb·in
N·m x 0.738 = lb·ft
N·mm x 0.142 = oz·in
mPa·s = cP

Note

The data contained herein are furnished for information only and are believed to be reliable. We cannot assume responsibility for the results obtained by others over whose methods we have no control. It is the user's responsibility to determine suitability for the user's purpose of any production methods mentioned herein and to adopt such precautions as may be advisable for the protection of property and of persons against any hazards that may be involved in the handling and use thereof. In light of the foregoing, **Henkel Corporation specifically disclaims all warranties expressed or implied, including warranties of merchantability or fitness for a particular purpose, arising from sale or use of Henkel Corporation's products. Henkel Corporation specifically disclaims any liability for consequential or incidental damages of any kind, including lost profits.** The discussion herein of various processes or compositions is not to be interpreted as representation that they are free from domination of patents owned by others or as a license under any Henkel Corporation patents that may cover such processes or compositions. We recommend that each prospective user test his proposed application before repetitive use, using this data as a guide. This product may be covered by one or more United States or foreign patents or patent applications.

Trademark usage

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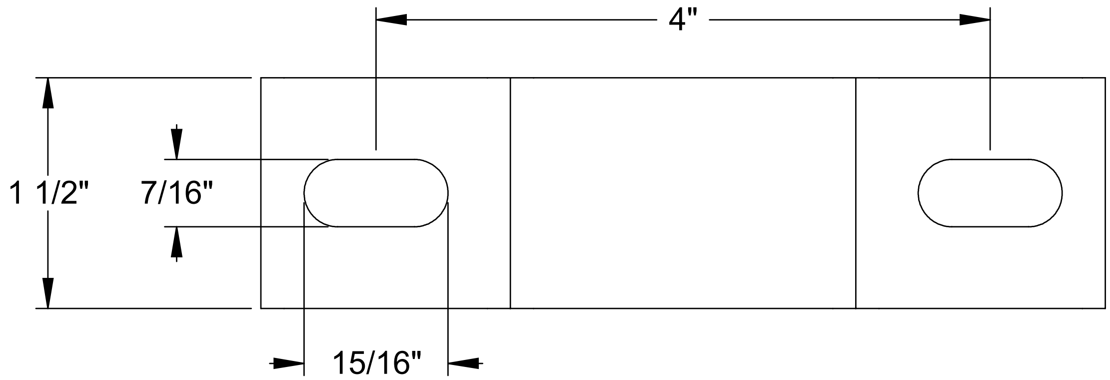
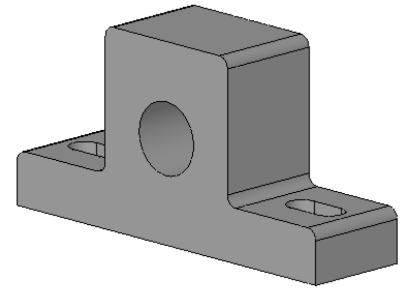
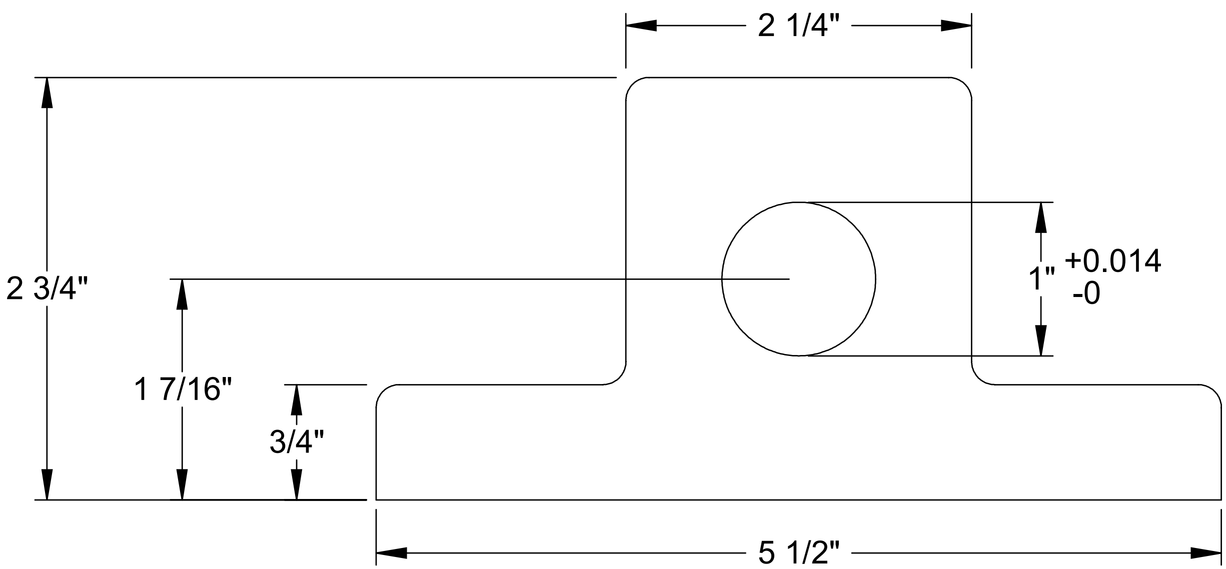
Reference 1.6







McMASTER-CARR® CAD

PART NUMBER **6254K24**

http://www.mcmaster.com

UHMW Polyethelene Base-Mounted Bearing

SDP/SI
PHONE: 516.328.3300 • FAX: 516.326.8827 • WWW.SDP-SI.COM

ABEC 3
.0002 / .0005 RADIAL PLAY

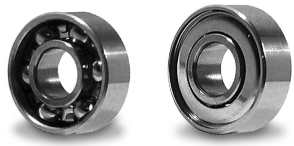
Precision Component

› MATERIAL:

440C Stainless Steel

› LOAD RATING

Bearing Code	Dynamic lbf	Static lbf
1504	16	5.3
1805	28	9.6
2507	35	12.1
1809	19	6.5
3109	60	22.0
2512	33	12.2
3112	60	22.0
3712	60	22.0
3712W	73	29.0
5012	73	29.0
3115	45	17.0
3118	45	17.0
3718	76	31.0
5018	148	64.0
3725	43	21.0
5025	88	40.0
6225	168	77.0
5031	93	43.0
8737	575	305.0
11250	885	505.0
13762	1040	650.0
16275	1620	1030.0



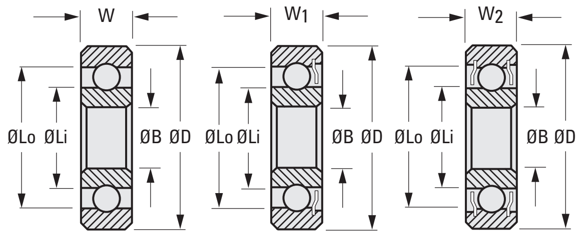


Fig. 1
NO SHIELD

Fig. 2
SINGLE SHIELD

Fig. 3
DOUBLE SHIELD

INCH COMPONENT CATALOG NUMBER

A 7Y55 – □□□□□□□□□

Fig. 1 No Shield **P**
Fig. 2 Single Shield **PS**
Fig. 3 Double Shield **PSS**

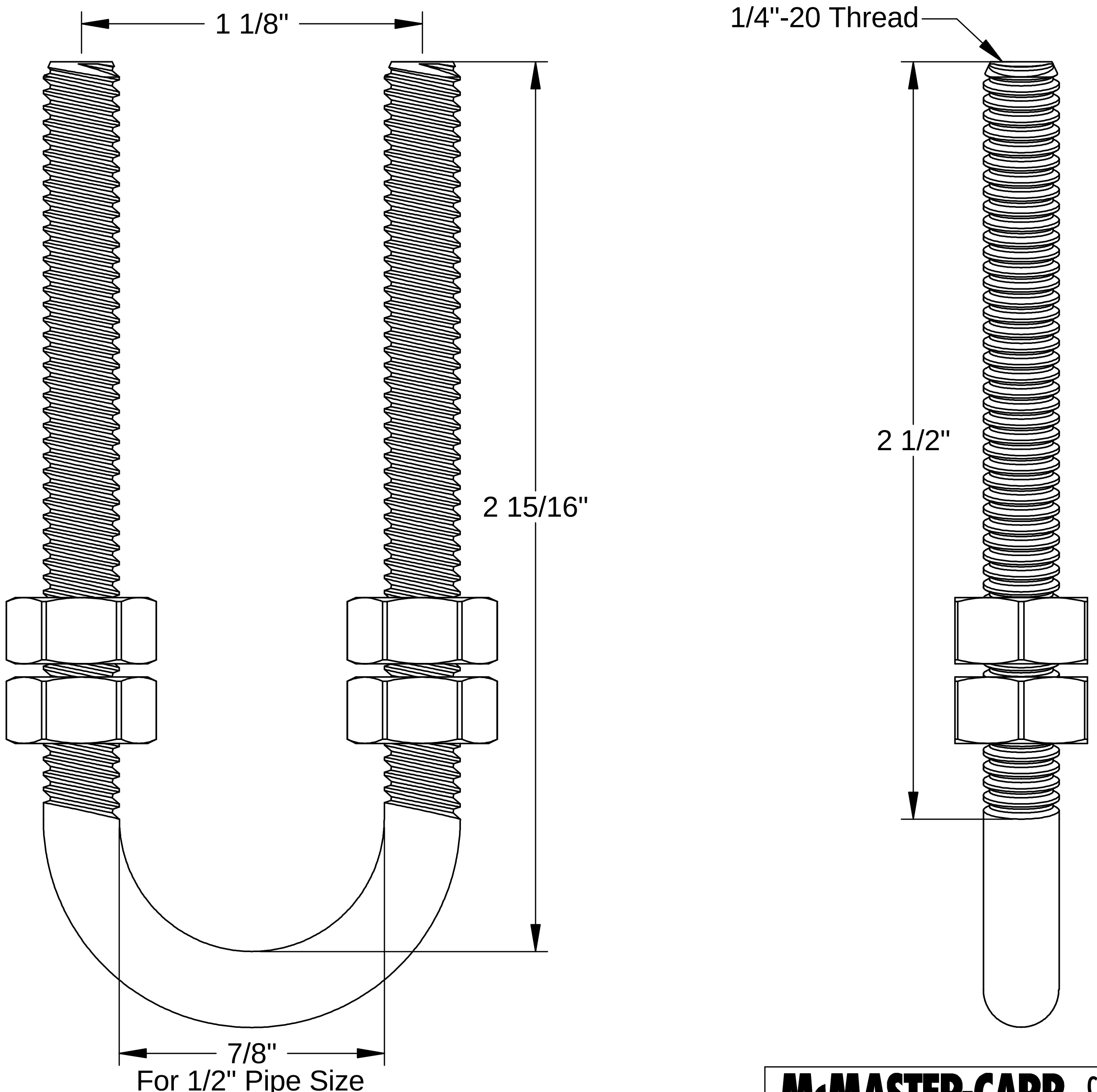
Bearing Code

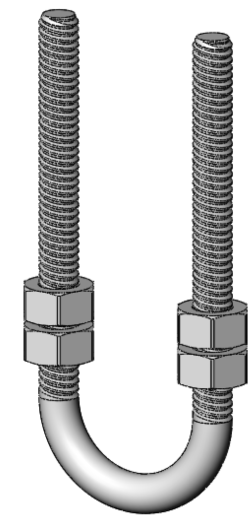
Lubrication
Leave Blank for Oil, MIL-L-6085A
M Grease, MIL-G-23827A
G Grease, Beacon 325 Commercial
Other lubricants available on special order.

Example:
A 7Y55-PS3718 is an ABEC 3, Single-Shielded Bearing with 3/16 Bore and 3/8 O.D.

Bearing Code	B Bore Dia. +.0000 -.0002	D Outer Ring Dia. +.0000 -.0003	Width +.000 -.005			Land Dia. (Ref.)		
			W Fig. 1	W_1 Fig. 2	W_2 Fig. 3	Li Inner All	Lo Outer Fig. 1	Lo Outer Fig. 2 & 3
1504	.0469	.1562	.0625	.0937	.0937	.081	.124	.134
1805	.0550	.1875	.0781	.0937	.1094	.093	.159	.167
2507	.0781	.2500	.0937	.1094	.1406	.122	.193	.205
1809	.0937	.1875	.0625	.0937	.0937	.118	.161	.167
3109	.0937	.3125	.1094	.1094	.1406	.173	.270	.282
2512	.1250	.2500	.0937	.0937	.1094	.161	.216	.228
3112	.1250	.3125	.1094	.1094	.1406	.173	.270	.282
3712	.1250	.3750	.1094	.1094	.1406	.173	.270	.282
3712W	.1250	.3750	.1562	.1562	.1562	.200	.300	.321
5012	.1250	.5000	.1719	.1719	.1719	.200	.300	.321
3115	.1562	.3125	.1094	.1094	.1250	.221	.279	.285
3118	.1875	.3125	.1094	.1094	.1250	.221	.279	.285
3718	.1875	.3750	.1250	.1250	.1250	.235	.325	.341
5018	.1875	.5000	.1562	.1960	.1960	.276	.412	.433
3725	.2500	.3750	.1250	.1250	.1250	.285	.344	.348
5025	.2500	.5000	.1250	.1250	.1875	.330	.431	.452
6225	.2500	.6250	.1960	.1960	.1960	.364	.510	.544
5031	.3125	.5000	.1562	.1562	.1562	.362	.450	.460
8737	.3750	.8750	.2188	.2812	.2812	.521	.741	.783
11250	.5000	1.1250	.2500	.3125	.3125	.701	.913	.965
13762	.6250	1.3750	.2812	.3438	.3438	.852	1.133	1.233
16275	.7500	1.6250	.3125	.4375	.4375	1.020	1.345	1.415

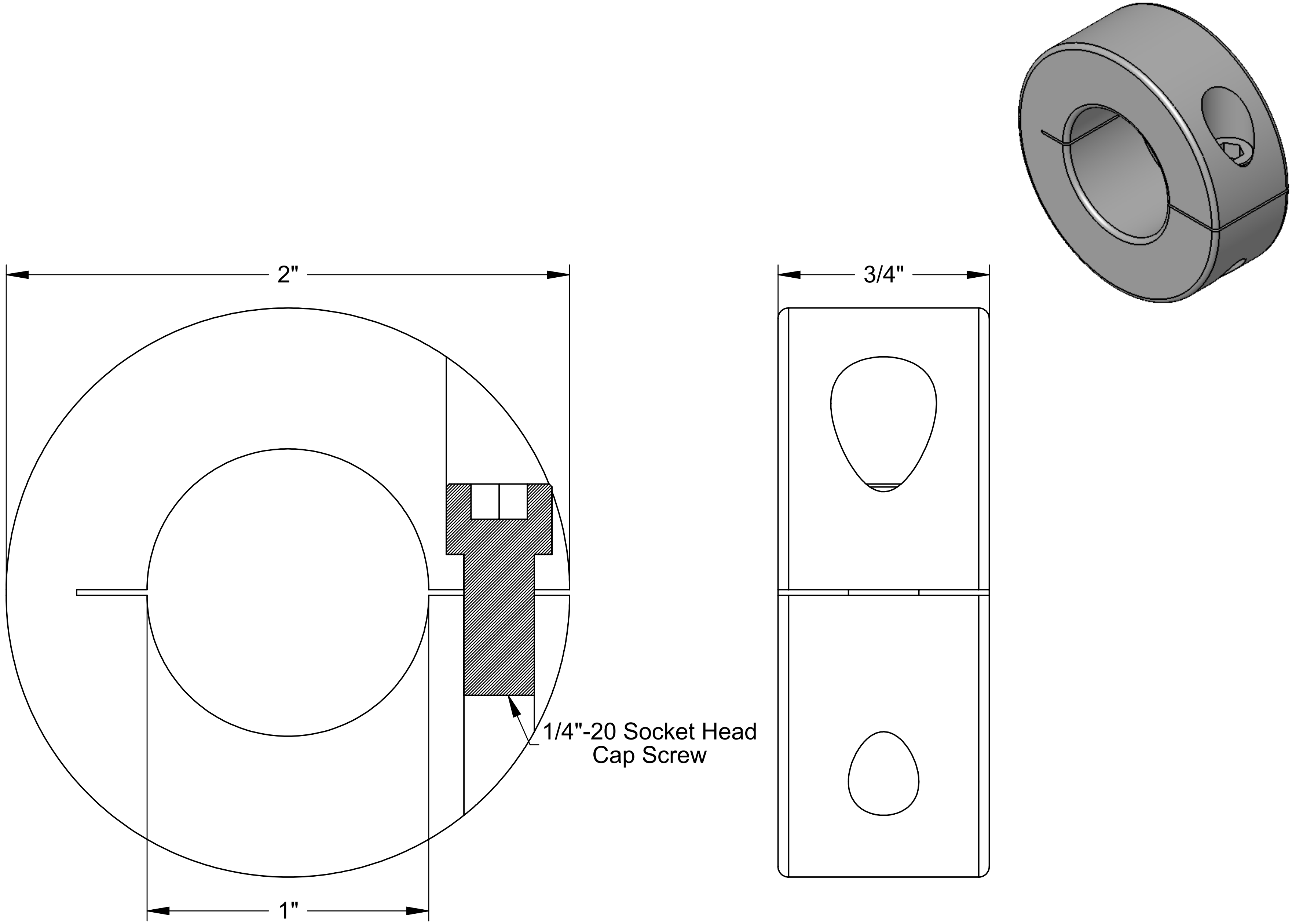
REV: 6.8.11 JC



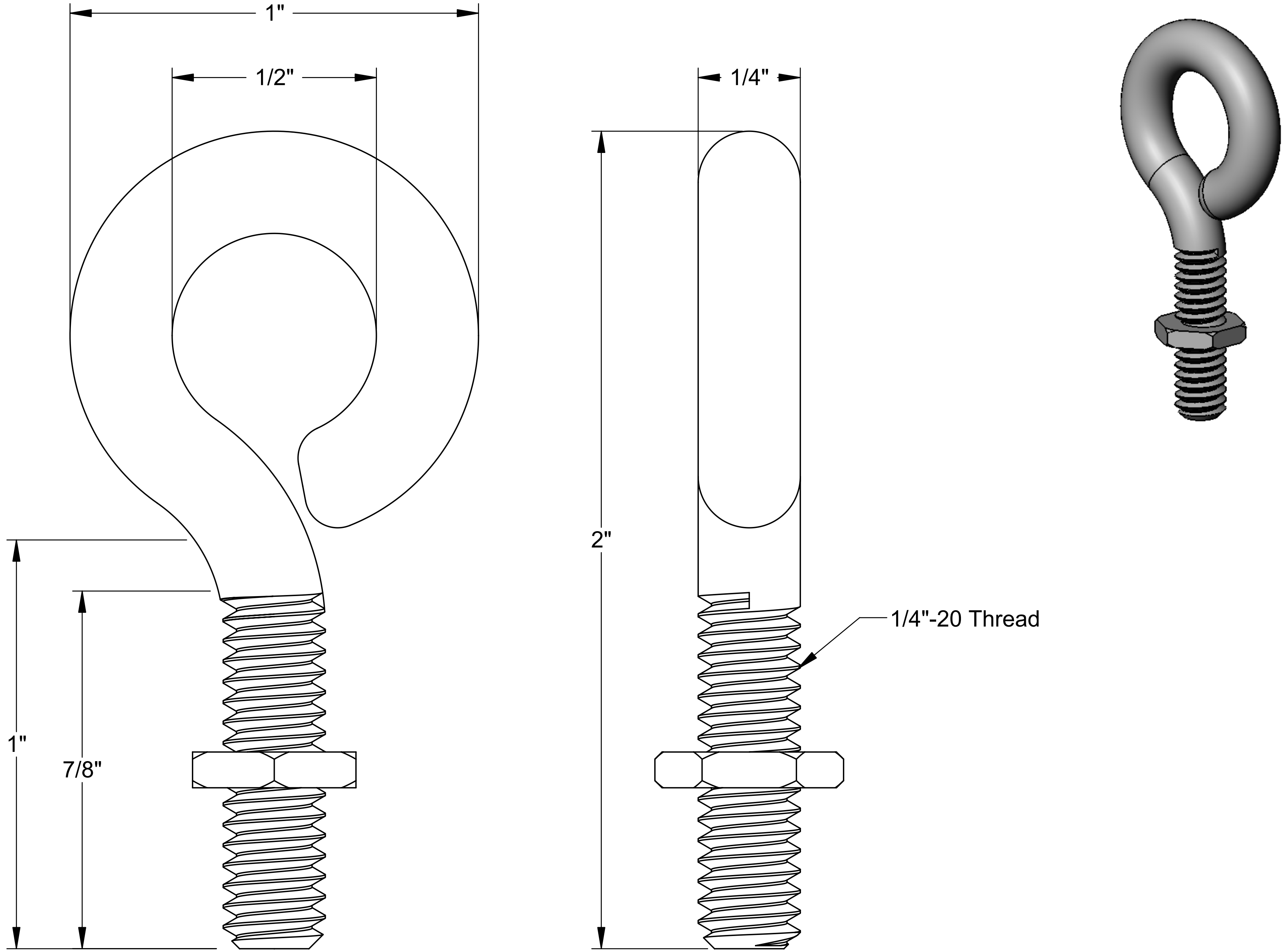


McMASTER-CARR	PART NUMBER 8862T21
http://www.mcmaster.com (c) 2004 McMaster-Carr Supply Company	Hot Dipped Galvanized Steel Extended-Length U-Bolt

Unless otherwise specified, dimensions are in inches. Information in this drawing is provided for reference only.

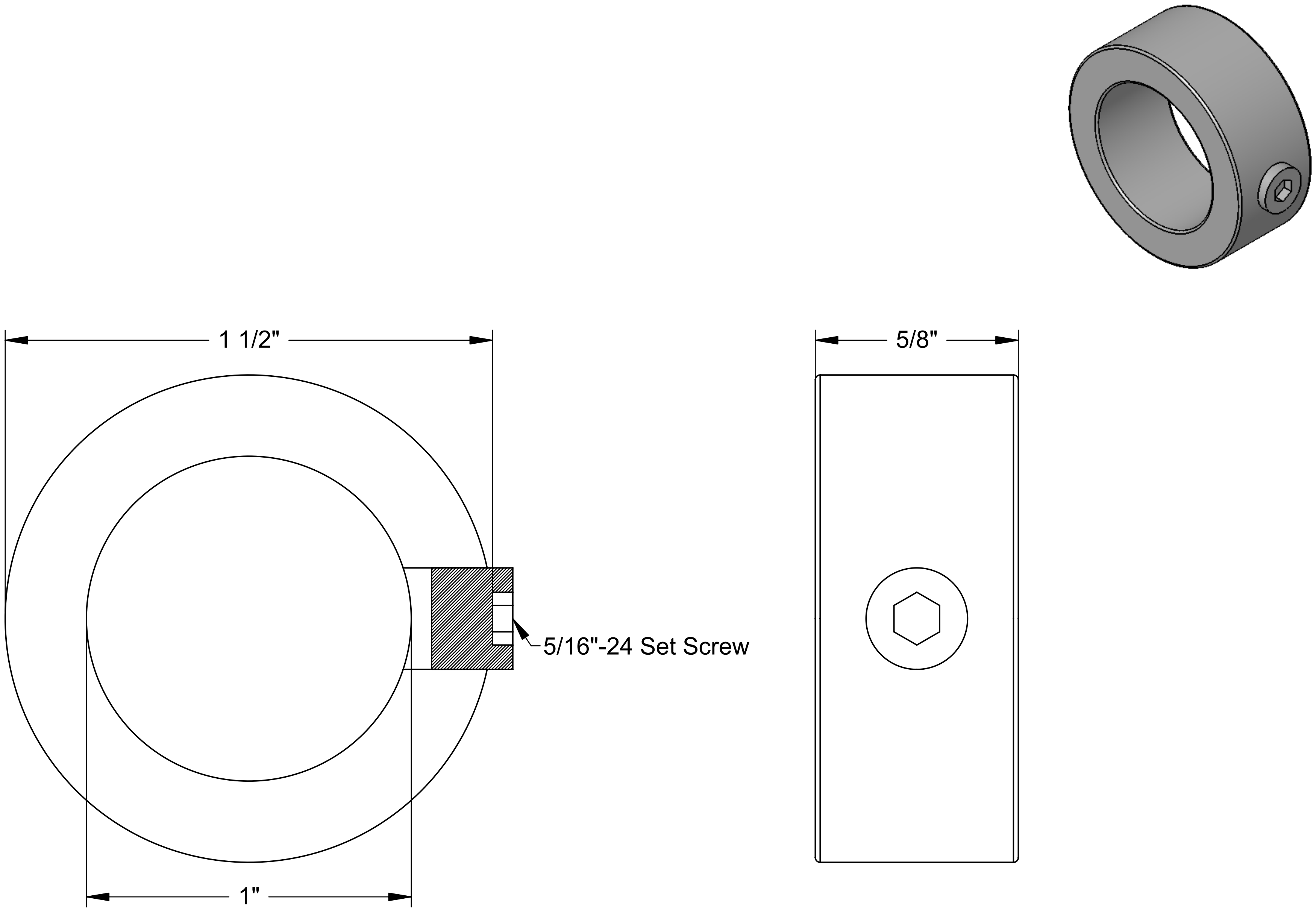


McMASTER-CARR® CAD	PART NUMBER	9410T38
http://www.mcmaster.com © 2011 McMaster-Carr Supply Company Information in this drawing is provided for reference only.	Delrin® Acetal Resin One-Piece Clamp-On Shaft Collar	



McMASTER-CARR® CAD	PART NUMBER	9489T17
http://www.mcmaster.com © 2008 McMaster-Carr Supply Company	Zinc-Plated Steel Light Duty Eyebolt with Nut	

Unless otherwise specified, dimensions are in inches. Information in this drawing is provided for reference only.



McMASTER-CARR CAD

PART NUMBER 9943K29

http://www.mcmaster.com

Type 316 Stainless Steel Set Screw Shaft Collar

Unless otherwise specified, dimensions are in inches. Information in this drawing is provided for reference only.

AMERSHIELD

March 2012
Revision of November 2011

DESCRIPTION	Polyester-Acrylic Aliphatic Polyurethane
PRINCIPAL CHARACTERISTICS	– Unique, high-solids, high build coatings – Outstanding weather resistance with excellent color and gloss retention – VOC compliant – Tough, flexible, and abrasion resistant finish – Good chemical and stain resistance – Direct to metal and concrete in protected environments – SSPC SP 36 Level 3
COLOR* AND GLOSS	Gloss Custom Colors * *Certain colors (especially yellow, orange and red) may require additional coats to achieve adequate hiding, particularly when applied over dark or contrasting primer colors. Yellow, red, and other bright colors will typically fade faster than other colors due to the replacement of lead-based pigments with lead-free pigments in these colors.*
BASIC DATA	
Volume solids	73% ± 3%
VOC*	2.2 lbs/gal (264 g/L) * *For compliance with regulations which require < 100 g/L, Amershield VOC can be specified interchangeably*
Recommended	
Dry film thickness	3-6 mils per coat (75-150 microns)
Theoretical Spread Rate	@ 1 mils dft 1171 ft²/gal @ 5 mils dft 234 ft²/gal
Components	2
Shelf Life	2 years from date of manufacture
SURFACE PREPARATION	Coating performance is proportional to the degree of surface preparation. Refer to the application instructions for specifc primers and intermediate coats for application and curing procedures. Ensure epoxies are free from amine blush prior to overcoating. All previous coats must dry and free of contaminants. Adhere to all minimum and maximum topcoat times for specific primers and intermediate coats. Aged epoxy coatings may require abrading prior to applying Amershield.
Steel	– Abrasive blast to SSPC SP-6 or higher with a 1.0-3.0 mils surface profile
Aluminum	– Lightly abrasive blast with a fine abrasive
Concrete / Masonry	– See specific primer
ENVIRONMENTAL CONDITIONS	
Ambient temperatures	40°F to 120°F (-6°C to 49°C) With Amercoat 866M Accelerator 32°F to 100°F (0°C to 36ºC) Surface temperature must be at least 5°F above the dew point temperature.
Material temperatures	With Amercoat 866M Accelerator 40°F to 90°F (5°C to 32ºC)
Relative humidity	85% maximum
Surface temperature	Amershield 40°F to 120°F (-6°C to 49°C) With Amercoat 866M Accelerator 32°F to 100°F (0°C to 36ºC) Surface temperature must be at least 5°F above the dew point temperature.

AMERSHIELD

General air quality
Area should be sheltered from airborne particulates and pollutants. Ensure good ventilation during application and curing. Provide shelter to prevent wind from affecting spray patterns.

INSTRUCTIONS FOR USE

Mixing ratio by volume
4 parts base to 1 part hardener

Pre-mix base component with a pneumatic air mixer at moderate speeds to homogenize the container. Add hardener to base and agitate with a power mixer for 1-2 minutes until completely dispersed

Pot life

Temperature	50°F	70°F	90°F
Amershield	5 hours	2.5 hours	1.5 hours
Amershield with 866M accelerator	2 hours	1 hours	30 minutes

Airless spray
28:1 pump or larger, 0.013-0.015 fluid tip
Can be applied with plural component equipment

Air spray
Thin up to 20%, standard conventional equipment, 0.070" fluid orifice. A moisture and oil trap in the main line is essential. Product is sensitive to moisture contamination.

Brush & roll
Use a high quality natural bristle brush and / or solvent resistant, 1/4" or 3/8" nap roller. Ensure brush / roller is well loaded to avoid air entrainment. Multiple coats may be necessary to achieve adequate film build. Amercoat 851 flow control additive can be used to for enhanced flow and leveling with brush and roll application. Multiple coats may be required to achieve proper film build and hiding with roller application.

Thinner
Amercoat 65 (xylene), Amercoat 101 (recommended for > 90 °F), Amercoat 911

Cleaning solvent
Amercoat 12 Cleaner or Amercoat 65 thinner (xylene)

Primers
Amercoat 68HS, Amercoat 68MCZ, Amercoat 370, Amercoat 385, Amercoat 399, Amerlock 2/400, Pittguard Epoxies, Amercoat 435, Amercoat 256

Safety precautions
For paint and recommended thinners see safety sheet 1430, 1431 and relevant material safety data sheets

This is a solvent borne paint and care should be taken to avoid inhalation of spray mist or vapor as well as contact between the wet paint and exposed skin or eyes.

DRY/CURE TIMES

Amershield @ 5 mils dft

	40°F	50°F	70°F	90°F
Dry to touch	8 hours	4 hours	2.5 hours	1 hour
Dry through	5 days	72 hours	10 hours	5 hours
Dry to recoat	72 hours	48 hours	8 hours	4 hours
Maximum recoat	168 hours	168 hours	96 hours	12 hours

Amershield with 866M Accelerator @ 5 mils dft

	20°F	32°F	50°F	70°F	90°F
Dry to touch	8 hours	4 hours	75 minutes	25 minutes	10 minutes
Dry through	16 hours	10 hours	6 hours	3 hours	2 hours
Dry to recoat	16 hours	8 hours	4 hours	2 hours	1.5 hours
Maximum recoat	96 hours	48 hours	24 hours	12 hours	6 hours

AMERSHIELD

PRODUCT QUALIFICATIONS

- Compliant with USDA Incidental Food Contact Requirements
- Nuclear Service Level 2
- NFPA Class A Flame Spread

AVAILABILITY

Packaging

Available in 1-gallon and 5-gallon kits
1-gallon kits have 0.8 gallons of base and 0.2 gallons of hardener
5- gallon kits have 4 gallons of base and 1 gallon of hardener

Product codes

AM -3	White base
AM -9	Black base
AM -T1	Deep Tint base
AM -T2	Light Tint base
AM -T3	Neutral Tint base
AM -T4	Red Tint base
AM -T5	High Hiding Yellow Tint base
AM -71	Safety Red base
AM-81	Safety Yellow base
AM-23	Pearl Gray base
AM -B	Hardener (Part B)

Worldwide statement

While it is always the aim of PPG Protective & Marine Coatings to supply the same product on a worldwide basis, slight modification of the product is sometimes necessary to comply with local or national rules/circumstances. Under these circumstances an alternative product data sheet is used.

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This data sheet supersedes all previous versions and it is the user's responsibility to ensure that this data sheet is current prior to using the product. The English text of this document shall prevail over any translation thereof.

LIMITATION OF LIABILITY

The information in this data sheet is based upon laboratory tests we believe to be accurate and is intended for guidance only. All recommendations or suggestions relating to the use of the products made by PPG Protective & Marine Coatings, whether in technical documentation, or in response to a specific enquiry, or otherwise, are based on data which to the best of our knowledge are reliable. The products and information are designed for users having the requisite knowledge and industrial skills and it is the end-user's responsibility to determine the suitability of the product for its intended use.

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The data contained herein are liable to modification as a result of practical experience and continuous product development.

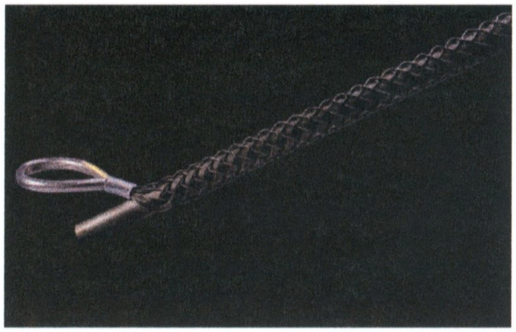
This data sheet replaces and annuls all previous issues and it is therefore the user's responsibility to ensure that this sheet is current prior to using the product. The current data sheets are maintained at www.ppgpmc.com

The English text of this document shall prevail over any translation thereof.

Non-Metallic (Aramid) Cable Grips / Cable Support Grips

NO - Non-Metallic (Aramid) Offset Eye Cable Grip

Similar to the single eye cable grip described above, but for use when offset positioning is required and the cable passes completely through the cable grip.



Slingco part no.	Type	Size range	Lattice length	Approx breaking strength (lbs)
Offset eye single weave non-metallic grip				
ZCS2810	NO1	0.38 - 0.75"	24"	2,460
ZCS2811	NO2	0.75 - 1.25"	24"	3,580
ZCS2921	NO3	1.00 - 1.50"	24"	3,580
ZCS2812	NO4	1.25 - 1.50"	24"	4,920
ZCS2813	NO5	1.50 - 2.00"	24"	5,820
Offset eye double weave non-metallic grip				
ZCS2814	NO11	1.25 - 1.50"	24"	9,860
ZCS2815	NO12	1.50 - 2.00"	24"	11,880
ZCS2816	NO13	2.00 - 2.50"	24"	15,900
ZCS2817	NO14	2.50 - 3.00"	24"	15,900
ZCS2818	NO15	3.00 - 4.00"	24"	15,900

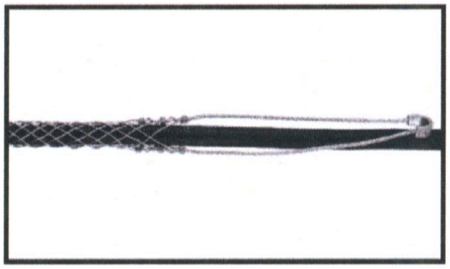
Thimble Eye Heavy Duty Cable Support Grip

Slingco offers a range of support grips designed to support the cable weight as it hangs vertically or horizontally. They are the ideal solution for taking the strain off connectors and wall sockets and are available in four different designs to suit most applications.

Slingco part no.	Type	Size range	Lattice length	Approx breaking strength (lbs)
ZCS2844	SGHD1	0.31 - 0.40"	25"	1,485
ZCS2845	SGHD2	0.40 - 0.60"	26"	2,295
ZCS2846	SGHD3	0.60 - 0.80"	28"	2,900
ZCS2847	SGHD4	0.80 - 0.99"	29"	4,550
ZCS2848	SGHD5	0.99 - 1.19"	29"	5,450
ZCS2849	SGHD6	1.19 - 1.58"	31"	7,800
ZCS2850	SGHD7	1.58 - 1.98"	39"	10,750
ZCS2851	SGHD8	1.98 - 2.37"	39"	10,750
ZCS2852	SGHD9	2.37 - 2.77"	47"	14,000
ZCS2853	SGHD10	2.77 - 3.55"	47"	14,000
ZCS2854	SGHD11	3.55 - 4.33"	47"	18,000

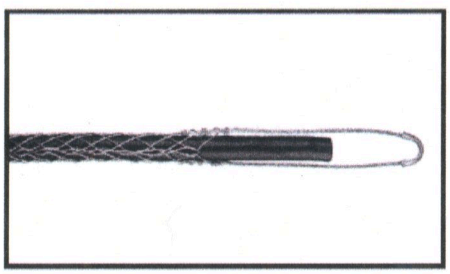
Standard – Single Eye

- Amtec Support Grips are made from stranded bronze wire.
- Stainless steel, medium lengths and or specials, please consult the factory.



Single Eye, Closed Mesh

Part Number	Dia. Ra.	Description	Approx. Breaking Strength	Eye Length	Mesh Length
2201-013	.50-.62	R-050-SE	530 LBS.	7	10
2201-014	.63-.74	R-062-SE	790 LBS.	8	10
2201-015	.75-.99	R-075-SE	1020 LBS.	8	13
2201-016	1.00-1.24	R-100-SE	1610 LBS.	9	14
2201-017	1.25-1.49	R-125-SE	1610 LBS.	10	15
2201-018	1.50-1.74	R-150-SE	1610 LBS.	12	17
2201-019	1.75-1.99	R-175-SE	2150 LBS.	14	19
2201-020	2.00-2.49	R-200-SE	3260 LBS.	16	21
2201-021	2.50-2.99	R-250-SE	3260 LBS.	18	23
2201-022	3.00-3.49	R-300-SE	4900 LBS.	21	25
2201-023	3.50-3.99	R-350-SE	4900 LBS.	24	27



Single Eye, Lace Closing

Part Number	Dia. Ra.	Description	Approx. Breaking Strength	Eye Length	Mesh Length
2202-013	.50-.62	RS-050-SE	530 LBS.	7	10
2202-014	.63-.74	RS-062-SE	790 LBS.	8	10
2202-015	.75-.99	RS-075-SE	1020 LBS.	8	13
2202-016	1.00-1.24	RS-100-SE	1610 LBS.	9	14
2202-017	1.25-1.49	RS-125-SE	1610 LBS.	10	15
2202-018	1.50-1.74	RS-150-SE	1610 LBS.	12	17
2202-019	1.75-1.99	RS-175-SE	2150 LBS.	14	19
2202-020	2.00-2.49	RS-200-SE	3260 LBS.	16	21
2202-021	2.50-2.99	RS-250-SE	3260 LBS.	18	23
2202-022	3.00-3.49	RS-300-SE	4900 LBS.	21	25
2202-023	3.50-3.99	RS-350-SE	4900 LBS.	24	27

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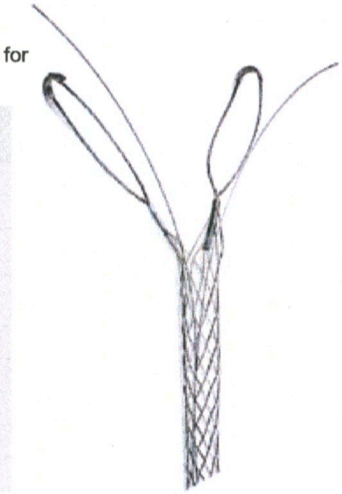
00811 Series
DOUBLE EYE – SINGLE WEAVE – SPLIT MESH (Lace-up)

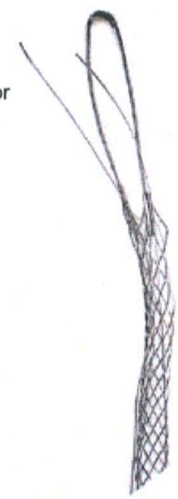
Fitted with a double eye, for permanent installations where the cable end is not available for assembly of the support grip, the support grip may be laced over the mid-span.



Galvanized Part No.	Stainless Part No.	Size Range	Approx. Mesh Length	Approx. Breaking Strength	Weight
00811-051	00811-051S	0.50" to 0.62"	5"	900 LB	0.05 LB
00811-063	00811-063S	0.63" to 0.74"	10"	1,750 LB	0.12 LB
00811-079	00811-079S	0.75" to 0.99"	10"	2,100 LB	0.15 LB
00811-098	00811-098S	1.00" to 1.24"	13"	3,050 LB	0.21 LB
00811-118	00811-118S	1.25" to 1.49"	13"	3,050 LB	0.21 LB
00811-150	00811-150S	1.50" to 1.99"	15"	3,050 LB	0.24 LB
00811-197	00811-197S	2.00" to 2.49"	19"	5,700 LB	0.55 LB
00811-252	00811-252S	2.50" to 2.99"	19"	5,700 LB	0.88 LB
00811-299	00811-299S	3.00" to 3.49"	19"	14,250 LB	1.10 LB
00811-350	00811-350S	3.50" to 3.99"	20"	14,250 LB	1.32 LB

00812 Series
OFFSET EYE – SINGLE WEAVE – SPLIT MESH (Lace-up)

For permanent installations where the support point is offset and the cable end is not available for assembly of the support grip, the support grip may be laced over the mid-span.



Galvanized Part No.	Stainless Part No.	Size Range	Approx. Mesh Length	Approx. Breaking Strength	Weight
00812-051	00812-051S	0.50" to 0.62"	5"	900 LB	0.05 LB
00812-063	00812-063S	0.63" to 0.74"	10"	1,750 LB	0.09 LB
00812-079	00812-079S	0.75" to 0.99"	10"	2,100 LB	0.11 LB
00812-098	00812-098S	1.00" to 1.24"	13"	3,050 LB	0.17 LB
00812-118	00812-118S	1.25" to 1.49"	13"	3,050 LB	0.19 LB
00812-150	00812-150S	1.50" to 1.99"	15"	3,050 LB	0.19 LB
00812-197	00812-197S	2.00" to 2.49"	19"	5,700 LB	0.56 LB
00812-252	00812-252S	2.50" to 2.99"	19"	5,700 LB	1.01 LB
00812-299	00812-299S	3.00" to 3.49"	19"	14,250 LB	1.23 LB
00812-350	00812-350S	3.50" to 3.99"	20"	14,250 LB	1.32 LB

00820 Series
SINGLE EYE – DOUBLE WEAVE – CLOSED MESH

For heavy duty permanent installations where the cable end is available for assembly of the support grip. For heavy duty permanent installations, horizontal or vertical, where the cable end is available for assembly of the support grip.

Galvanized Part No.	Stainless Part No.	Size Range	Approx. Mesh Length	Approx. Breaking Strength	Weight
00820-039	00820-039S	0.38" to 0.74"	25"	5,800 LB	0.42 LB
00820-079	00820-079S	0.75" to 1.12"	25"	6,650 LB	0.60 LB
00820-118	00820-118S	1.13" to 1.49"	30"	10,000 LB	1.11 LB
00820-157	00820-157S	1.50" to 1.99"	34"	13,800 LB	1.50 LB

Always read Breaking Strength, safety and technical data information.
The Approx. Mesh Length is measured at an average grip diameter.

For Stainless Steel grips, reduce Approx. Breaking Strength by 10%.

Gland Design, O-Ring and Other Elastomeric Seals (SAE AS5857)
Standard Gland Width for Zero, One, and Two Backup Rings in Inches

Gland and AS568 Dash Number	O-Ring Cross Section W Min.	O-Ring Cross Section W Max.	Backup Ring Width Max.	Gland Width G No Backup Ring Min.	Gland Width G No Backup Ring Max.	Gland Width G One Backup Ring Min.	Gland Width G One Backup Ring Max.	Gland Width G Two Backup Rings Min.	Gland Width G Two Backup Rings Max
001	.037	.043	--	.090	.095	--	--	--	--
002	.047	.053	--	.095	.100	--	--	--	--
003	.057	.063	--	.105	.110	--	--	--	--
004 to 007	.067	.073	.056	.115	.120	.174	.184	.230	.240
008 to 028	.067	.073	.056	.105	.110	.164	.174	.220	.230
104 to 109	.100	.106	.060	.150	.160	.210	.220	.275	.285
110 to 149	.100	.106	.060	.140	.150	.200	.210	.265	.275
210 to 247	.135	.143	.065	.185	.195	.250	.260	.320	.330
325 to 349	.205	.215	.090	.270	.280	.360	.370	.455	.465
425 to 460	.269	.281	.130	.345	.355	.475	.485	.610	.620

Design Chart 4-1 A: Gland Design, O-Ring and other Elastomeric Seals (SAE AS5857)

Gland Design, O-Ring and Other Elastomeric Seals (SAE AS5857)
Standard Gland Diametral Clearance Dimensions in Inches

Gland and AS568 Dash Number	O-Ring Cross-Section W Min.	O-Ring Cross-Section W Max.	Diametral Clearance D Max. Exterior	Diametral Clearance D Max. Interior
001	.037	.043	.004	.004
002	.047	.053	.004	.004
003	.057	.063	.004	.004
004 to 012	.067	.073	.004	.004
013 to 029	.067	.073	.005	.005
104 to 109	.100	.106	.004	.004
110 to 126	.100	.106	.004	.004
127 to 129	.100	.106	.005	.006
130 to 132	.100	.106	.006	.006
133 to 140	.100	.106	.006	.007
141 to 149	.100	.106	.007	.007
210 to 222	.135	.143	.005	.005
223 to 224	.135	.143	.006	.006
225 to 227	.135	.143	.006	.007
228 to 243	.135	.143	.007	.007
244 to 245	.135	.143	.008	.007
246 to 247	.135	.143	.008	.008
325 to 327	.205	.215	.006	.006
328 to 329	.205	.215	.006	.007
330 to 345	.205	.215	.007	.007
346 to 349	.205	.215	.008	.007
425 to 438	.269	.281	.009	.009
439 to 445	.269	.281	.009	.010
446	.269	.281	.010	.010
447 to 460	.269	.281	.011	.010

Design Chart 4-1 B: Gland Design, O-Ring and Other Elastomeric Seals (SAE AS5857)

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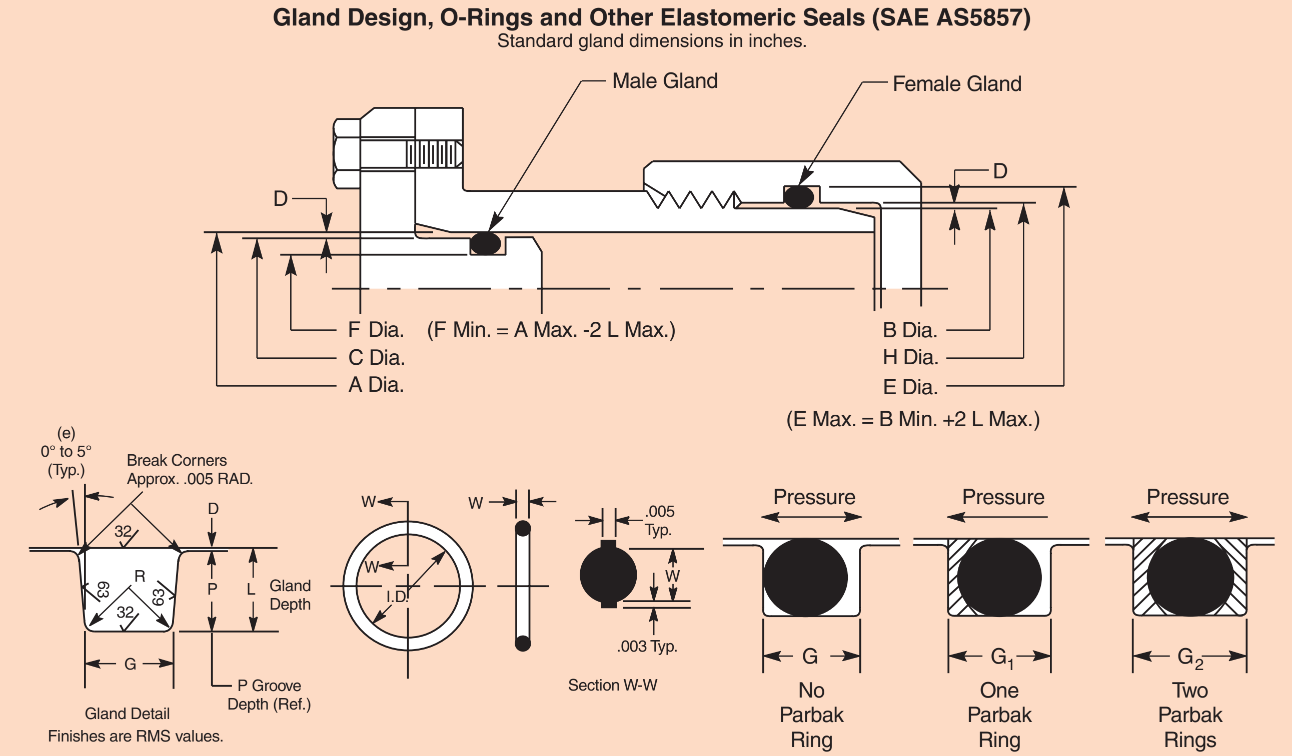

Gland Design, O-Ring and Other Elastomeric Seals (SAE AS5857)

Gland and AS568 Dash No.	Piston or Cylinder OD C	Cylinder Bore ID A	Gland OD F	Rod or Gland Sleeve OD B	Rod Bore ID H	Gland ID E
001	0.084	0.087	0.035	0.033	0.036	0.087
	0.083	0.086	0.034	0.032	0.035	0.086
002	0.116	0.119	0.048	0.048	0.051	0.119
	0.115	0.118	0.047	0.047	0.050	0.118
003	0.149	0.152	0.063	0.063	0.066	0.152
	0.148	0.151	0.062	0.062	0.065	0.151
004	0.183	0.186	0.078	0.076	0.079	0.185
	0.182	0.185	0.077	0.075	0.078	0.184
005	0.215	0.218	0.110	0.108	0.111	0.217
	0.214	0.217	0.109	0.107	0.110	0.216
006	0.228	0.231	0.123	0.123	0.126	0.232
	0.227	0.230	0.122	0.122	0.125	0.231
007	0.259	0.262	0.154	0.154	0.157	0.263
	0.258	0.261	0.153	0.153	0.156	0.262
008	0.291	0.294	0.186	0.185	0.188	0.294
	0.290	0.293	0.185	0.184	0.187	0.293
009	0.324	0.327	0.219	0.217	0.220	0.326
	0.323	0.326	0.218	0.216	0.219	0.325
010	0.355	0.358	0.250	0.248	0.251	0.357
	0.354	0.357	0.249	0.247	0.250	0.356
011	0.418	0.421	0.313	0.310	0.313	0.419
	0.417	0.420	0.312	0.309	0.312	0.418
012	0.483	0.486	0.378	0.373	0.376	0.482
	0.482	0.485	0.377	0.372	0.375	0.481
013	0.548	0.552	0.443	0.435	0.438	0.545
	0.547	0.550	0.441	0.433	0.437	0.543

Gland and AS568 Dash No.	Piston or Cylinder OD C	Cylinder Bore ID A	Gland OD F	Rod or Gland Sleeve OD B	Rod Bore ID H	Gland ID E
014	0.611	0.615	0.506	0.498	0.501	0.608
	0.610	0.613	0.504	0.496	0.500	0.606
015	0.673	0.677	0.568	0.560	0.563	0.670
	0.672	0.675	0.566	0.558	0.562	0.668
016	0.736	0.740	0.631	0.623	0.626	0.733
	0.735	0.738	0.629	0.621	0.625	0.731
017	0.798	0.802	0.693	0.685	0.688	0.795
	0.797	0.800	0.691	0.683	0.687	0.793
018	0.861	0.865	0.756	0.748	0.751	0.858
	0.860	0.863	0.754	0.746	0.750	0.856
019	0.923	0.927	0.818	0.810	0.813	0.920
	0.922	0.925	0.816	0.808	0.812	0.918
020	0.989	0.993	0.884	0.873	0.876	0.983
	0.988	0.991	0.882	0.871	0.875	0.981
021	1.051	1.055	0.946	0.935	0.938	1.045
	1.050	1.053	0.944	0.933	0.937	1.043
022	1.114	1.118	1.009	0.998	1.001	1.108
	1.113	1.116	1.007	0.996	1.000	1.106
023	1.176	1.180	1.071	1.060	1.063	1.170
	1.175	1.178	1.069	1.058	1.062	1.168
024	1.239	1.243	1.134	1.123	1.126	1.233
	1.238	1.241	1.132	1.121	1.125	1.231
025	1.301	1.305	1.196	1.185	1.188	1.295
	1.300	1.303	1.194	1.183	1.187	1.293
026	1.364	1.368	1.259	1.248	1.251	1.358
	1.363	1.366	1.257	1.246	1.250	1.356

Design Table 4-1: Gland Design, O-Ring and Other Elastomeric Seals (SAE AS5857)

Static O-Ring Sealing

Gland Design, O-Ring and Other Elastomeric Seals (SAE AS5857) (Continued)

Gland and AS568 Dash No.	Piston or Cylinder OD C	Cylinder Bore ID A	Gland OD F	Rod or Gland Sleeve OD B	Rod Bore ID H	Gland ID E
027	1.426	1.430	1.321	1.310	1.313	1.420
	1.425	1.428	1.319	1.308	1.312	1.418
028	1.489	1.493	1.384	1.373	1.376	1.483
	1.488	1.491	1.382	1.371	1.375	1.481
029	0.284	0.287	0.121	0.123	0.126	0.289
	0.283	0.286	0.120	0.122	0.125	0.288
104	0.284	0.287	0.121	0.123	0.126	0.289
	0.283	0.286	0.120	0.122	0.125	0.288
105	0.315	0.318	0.152	0.154	0.157	0.320
	0.314	0.317	0.151	0.153	0.156	0.319
106	0.347	0.350	0.184	0.185	0.188	0.351
	0.346	0.349	0.183	0.184	0.187	0.350
107	0.380	0.383	0.217	0.217	0.220	0.383
	0.379	0.382	0.216	0.216	0.219	0.382
108	0.412	0.415	0.249	0.248	0.251	0.414
	0.411	0.414	0.248	0.247	0.250	0.413
109	0.475	0.478	0.312	0.310	0.313	0.476
	0.474	0.477	0.311	0.309	0.312	0.475
110	0.539	0.543	0.377	0.373	0.376	0.540
	0.538	0.541	0.375	0.371	0.375	0.538
111	0.602	0.606	0.440	0.435	0.438	0.602
	0.601	0.604	0.438	0.433	0.437	0.600
112	0.666	0.670	0.504	0.498	0.501	0.665
	0.665	0.668	0.502	0.496	0.500	0.663
113	0.732	0.736	0.570	0.560	0.563	0.727
	0.731	0.734	0.568	0.558	0.562	0.725
114	0.798	0.802	0.636	0.623	0.626	0.790
	0.797	0.800	0.634	0.621	0.625	0.788
115	0.861	0.865	0.699	0.685	0.688	0.852
	0.860	0.863	0.697	0.683	0.687	0.850
116	0.923	0.927	0.761	0.748	0.751	0.915
	0.922	0.925	0.759	0.746	0.750	0.913
117	0.989	0.993	0.827	0.810	0.813	0.977
	0.988	0.991	0.825	0.808	0.812	0.975
118	1.051	1.055	0.889	0.873	0.876	1.040
	1.050	1.053	0.887	0.871	0.875	1.038
119	1.114	1.118	0.952	0.935	0.938	1.102
	1.113	1.116	0.950	0.933	0.937	1.100
120	1.176	1.180	1.014	0.998	1.001	1.165
	1.175	1.178	1.012	0.996	1.000	1.163
121	1.239	1.243	1.077	1.060	1.063	1.227
	1.238	1.241	1.075	1.058	1.062	1.225
122	1.301	1.305	1.139	1.123	1.126	1.290
	1.300	1.303	1.137	1.121	1.125	1.288
123	1.364	1.368	1.202	1.185	1.188	1.352
	1.363	1.366	1.200	1.183	1.187	1.350
124	1.426	1.430	1.264	1.248	1.251	1.415
	1.425	1.428	1.262	1.246	1.250	1.413
125	1.489	1.493	1.327	1.310	1.313	1.477
	1.488	1.491	1.325	1.308	1.312	1.475
126	1.551	1.555	1.389	1.373	1.376	1.540
	1.550	1.553	1.387	1.371	1.375	1.538
127	1.614	1.618	1.452	1.435	1.439	1.602
	1.613	1.616	1.450	1.433	1.437	1.600
128	1.676	1.680	1.514	1.498	1.502	1.665
	1.675	1.678	1.512	1.496	1.500	1.663
129	1.739	1.743	1.577	1.560	1.564	1.727
	1.738	1.741	1.575	1.558	1.562	1.725
130	1.802	1.807	1.641	1.623	1.627	1.790
	1.801	1.805	1.639	1.621	1.625	1.788
131	1.864	1.869	1.703	1.685	1.689	1.852
	1.863	1.867	1.701	1.683	1.687	1.850
132	1.927	1.932	1.766	1.748	1.752	1.915
	1.926	1.930	1.764	1.746	1.750	1.913
133	1.989	1.994	1.828	1.810	1.815	1.977
	1.988	1.992	1.826	1.808	1.813	1.975
134	2.052	2.057	1.891	1.873	1.878	2.040
	2.051	2.055	1.889	1.871	1.876	2.038
135	2.115	2.120	1.954	1.936	1.941	2.103
	2.114	2.118	1.952	1.934	1.939	2.101
136	2.177	2.182	2.016	1.998	2.003	2.165
	2.176	2.180	2.014	1.996	2.001	2.163
137	2.240	2.245	2.079	2.061	2.066	2.228
	2.239	2.243	2.077	2.059	2.064	2.226
138	2.302	2.307	2.141	2.123	2.128	2.290
	2.301	2.305	2.139	2.121	2.126	2.288
139	2.365	2.370	2.204	2.186	2.191	2.353
	2.364	2.368	2.202	2.184	2.189	2.351
140	2.427	2.432	2.266	2.248	2.253	2.415
	2.426	2.430	2.264	2.246	2.251	2.413
141	2.490	2.495	2.329	2.311	2.316	2.478
	2.488	2.493	2.327	2.309	2.314	2.476
142	2.552	2.557	2.391	2.373	2.378	2.540
	2.550	2.555	2.389	2.371	2.376	2.538
143	2.615	2.620	2.454	2.436	2.441	2.603
	2.613	2.618	2.452	2.434	2.439	2.601
144	2.677	2.682	2.516	2.498	2.503	2.665
	2.675	2.680	2.514	2.496	2.501	2.663
145	2.740	2.745	2.579	2.561	2.566	2.728
	2.738	2.743	2.577	2.559	2.2564	2.726
146	2.802	2.807	2.641	2.623	2.628	2.790
	2.800	2.805	2.639	2.621	2.626	2.788
147	2.865	2.870	2.704	2.686	2.691	2.853
	2.863	2.868	2.702	2.684	2.689	2.851
148	2.927	2.932	2.766	2.748	2.753	2.915
	2.925	2.930	2.764	2.746	2.751	2.913
149	2.990	2.995	2.829	2.811	2.816	2.978
	2.988	2.993	2.827	2.809	2.814	2.976
210	0.989	0.993	0.767	0.748	0.751	0.976
	0.988	0.991	0.765	0.746	0.750	0.974
211	1.051	1.055	0.829	0.810	0.813	1.038
	1.050	1.053	0.827	0.808	0.812	1.036
212	1.114	1.118	0.892	0.873	0.876	1.101
	1.113	1.116	0.890	0.871	0.875	1.099
213	1.176	1.180	0.954	0.935	0.938	1.163
	1.175	1.178	0.952	0.933	0.937	1.161
214	1.239	1.243	1.017	0.998	1.001	1.226
	1.238	1.241	1.015	0.996	1.000	1.224

Design Table 4-1: Gland Design, O-Ring and Other Elastomeric Seals (SAE AS5857)

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Gland Design, O-Ring and Other Elastomeric Seals (SAE AS5857) (Continued)

Gland and AS568 Dash No.	Piston or Cylinder OD C	Cylinder Bore ID A	Gland OD F	Rod or Gland Sleeve OD B	Rod Bore ID H	Gland ID E
215	1.301	1.305	1.079	1.060	1.063	1.288
	1.300	1.303	1.077	1.058	1.062	1.286
216	1.364	1.368	1.142	1.123	1.126	1.351
	1.363	1.366	1.140	1.121	1.125	1.349
217	1.426	1.430	1.204	1.185	1.188	1.413
	1.425	1.428	1.202	1.183	1.187	1.411
218	1.489	1.493	1.267	1.248	1.251	1.476
	1.488	1.491	1.265	1.246	1.250	1.474
219	1.551	1.555	1.329	1.310	1.313	1.538
	1.550	1.553	1.327	1.308	1.312	1.536
220	1.614	1.618	1.392	1.373	1.376	1.601
	1.613	1.616	1.390	1.371	1.375	1.599
221	1.676	1.680	1.454	1.435	1.438	1.663
	1.675	1.678	1.452	1.433	1.437	1.661
222	1.739	1.743	1.517	1.498	1.501	1.726
	1.738	1.741	1.515	1.496	1.500	1.724
223	1.864	1.869	1.643	1.623	1.627	1.851
	1.863	1.867	1.641	1.621	1.625	1.849
224	1.989	1.994	1.768	1.748	1.752	1.976
	1.988	1.992	1.766	1.746	1.750	1.974
225	2.115	2.120	1.894	1.873	1.878	2.101
	2.114	2.118	1.892	1.871	1.876	2.099
226	2.240	2.245	2.019	1.998	2.003	2.226
	2.239	2.243	2.017	1.996	2.001	2.224
227	2.365	2.370	2.144	2.123	2.128	2.351
	2.364	2.368	2.142	2.121	2.126	2.349
228	2.490	2.495	2.269	2.248	2.253	2.476
	2.488	2.493	2.267	2.246	2.251	2.474
229	2.615	2.620	2.394	2.373	2.378	2.601
	2.613	2.618	2.392	2.371	2.376	2.599
230	2.740	2.745	2.519	2.498	2.503	2.726
	2.738	2.743	2.517	2.496	2.501	2.724
231	2.865	2.870	2.644	2.623	2.628	2.851
	2.863	2.868	2.642	2.621	2.626	2.849
232	2.990	2.995	2.769	2.748	2.753	2.976
	2.988	2.993	2.767	2.746	2.751	2.974
233	3.115	3.120	2.894	2.873	2.878	3.101
	3.113	3.118	2.892	2.871	2.876	3.099
234	3.240	3.245	3.019	2.997	3.002	3.225
	3.238	3.243	3.017	2.995	3.000	3.223
235	3.365	3.370	3.144	3.122	3.127	3.350
	3.363	3.368	3.142	3.120	3.125	3.348
236	3.490	3.495	3.269	3.247	3.252	3.475
	3.488	3.493	3.267	3.245	3.250	3.473
237	3.615	3.620	3.394	3.372	3.377	3.600
	3.613	3.618	3.392	3.370	3.375	3.598
238	3.740	3.745	3.519	3.497	3.502	3.725
	3.738	3.743	3.517	3.495	3.500	3.723
239	3.865	3.870	3.644	3.622	3.627	3.850
	3.863	3.868	3.642	3.620	3.625	3.848
240	3.990	3.995	3.769	3.747	3.752	3.975
	3.988	3.993	3.767	3.745	3.750	3.973
241	4.115	4.120	3.894	3.872	3.877	4.100
	4.113	4.118	3.892	3.870	3.875	4.098

Gland and AS568 Dash No.	Piston or Cylinder OD C	Cylinder Bore ID A	Gland OD F	Rod or Gland Sleeve OD B	Rod Bore ID H	Gland ID E
242	4.240	4.245	4.019	3.997	4.002	4.225
	4.238	4.243	4.017	3.995	4.000	4.223
243	4.365	4.370	4.144	4.122	4.127	4.350
	4.363	4.368	4.142	4.120	4.125	4.348
244	4.489	4.495	4.269	4.247	4.252	4.475
	4.487	4.493	4.267	4.245	4.250	4.473
245	4.614	4.620	4.394	4.372	4.377	4.600
	4.612	4.618	4.392	4.370	4.375	4.598
246	4.739	4.745	4.519	4.497	4.503	4.725
	4.737	4.743	4.517	4.495	4.501	4.723
247	4.864	4.870	4.644	4.622	4.628	4.850
	4.862	4.868	4.642	4.620	4.626	4.848
325	1.864	1.869	1.523	1.498	1.502	1.848
	1.863	1.867	1.521	1.496	1.500	1.846
326	1.989	1.994	1.648	1.623	1.627	1.973
	1.988	1.992	1.646	1.621	1.625	1.971
327	2.115	2.120	1.774	1.748	1.752	2.098
	2.114	2.118	1.772	1.746	1.750	2.096
328	2.240	2.245	1.899	1.873	1.878	2.223
	2.239	2.243	1.897	1.871	1.876	2.221
329	2.365	2.370	2.024	1.998	2.003	2.348
	2.364	2.368	2.022	1.996	2.001	2.346
330	2.490	2.495	2.149	2.123	2.128	2.473
	2.488	2.493	2.147	2.121	2.126	2.471
331	2.615	2.620	2.274	2.248	2.253	2.598
	2.613	2.618	2.272	2.246	2.251	2.596
332	2.740	2.745	2.399	2.373	2.378	2.723
	2.738	2.743	2.397	2.371	2.376	2.721
333	2.865	2.870	2.524	2.498	2.503	2.848
	2.863	2.868	2.522	2.496	2.501	2.846
334	2.990	2.995	2.649	2.623	2.628	2.973
	2.988	2.993	2.647	2.621	2.626	2.971
335	3.115	3.120	2.774	2.748	2.753	3.098
	3.113	3.118	2.772	2.746	2.751	3.096
336	3.240	3.245	2.899	2.873	2.878	3.223
	3.238	3.243	2.897	2.871	2.876	3.221
337	3.365	3.370	3.024	2.997	3.002	3.347
	3.363	3.368	3.022	2.995	3.000	3.345
338	3.490	3.495	3.149	3.122	3.127	3.472
	3.488	3.493	3.147	3.120	3.125	3.470
339	3.615	3.620	3.274	3.247	3.252	3.597
	3.613	3.618	3.272	3.245	3.250	3.595
340	3.740	3.745	3.399	3.372	3.377	3.722
	3.738	3.743	3.397	3.370	3.375	3.720
341	3.865	3.870	3.524	3.497	3.502	3.847
	3.863	3.868	3.522	3.495	3.500	3.845
342	3.990	3.995	3.649	3.622	3.627	3.972
	3.988	3.993	3.647	3.620	3.625	3.970
343	4.115	4.120	3.774	3.747	3.752	4.097
	4.113	4.118	3.772	3.745	3.750	4.095
344	4.240	4.245	3.899	3.872	3.877	4.222
	4.238	4.243	3.897	3.870	3.875	4.220
345	4.365	4.370	4.024	3.997	4.002	4.347
	4.363	4.368	4.022	3.995	4.000	4.345

Design Table 4-1: Gland Design, O-Ring and Other Elastomeric Seals (SAE AS5857)

Static O-Ring Sealing

Gland Design, O-Ring and Other Elastomeric Seals (SAE AS5857) (Continued)

Gland and AS568 Dash No.	Piston or Cylinder OD C	Cylinder Bore ID A	Gland OD F	Rod or Gland Sleeve OD B	Rod Bore ID H	Gland ID E
346	4.489	4.495	4.149	4.122	4.127	4.472
	4.487	4.493	4.147	4.120	4.125	4.470
347	4.614	4.620	4.274	4.247	4.252	4.597
	4.612	4.618	4.272	4.245	4.250	4.595
348	4.739	4.745	4.399	4.372	4.377	4.722
	4.737	4.743	4.397	4.370	4.375	4.720
349	4.864	4.870	4.524	4.497	4.502	4.847
	4.862	4.868	4.522	4.495	4.500	4.845
425	4.970	4.977	4.519	4.497	4.503	4.959
	4.968	4.974	4.516	4.494	4.501	4.956
426	5.095	5.102	4.644	4.622	4.628	5.084
	5.093	5.099	4.641	4.619	4.626	5.081
427	5.220	5.227	4.769	4.747	4.753	5.209
	5.218	5.224	4.766	4.744	4.751	5.206
428	5.345	5.352	4.894	4.872	4.878	5.334
	5.343	5.349	4.891	4.869	4.876	5.331
429	5.470	5.477	5.019	4.997	5.003	5.459
	5.468	5.474	5.016	4.994	5.001	5.456
430	5.595	5.602	5.144	5.122	5.128	5.584
	5.593	5.599	5.141	5.119	5.126	5.581
431	5.720	5.727	5.269	5.247	5.253	5.709
	5.718	5.724	5.266	5.244	5.251	5.706
432	5.845	5.852	5.394	5.372	5.378	5.834
	5.843	5.849	5.391	5.369	5.376	5.831
433	5.970	5.977	5.519	5.497	5.503	5.959
	5.968	5.974	5.516	5.494	5.501	5.956
434	6.095	6.102	5.644	5.622	5.628	6.084
	6.093	6.099	5.641	5.619	5.626	6.081
435	6.220	6.227	5.769	5.747	5.753	6.209
	6.218	6.224	5.766	5.744	5.751	6.206
436	6.345	6.352	5.894	5.872	5.878	6.334
	6.343	6.349	5.891	5.869	5.876	6.331
437	6.470	6.477	6.019	5.997	6.003	6.459
	6.468	6.474	6.016	5.994	6.001	6.456
438	6.720	6.727	6.269	6.247	6.253	6.709
	6.718	6.724	6.266	6.244	6.251	6.706
439	6.970	6.977	6.519	6.497	6.504	6.959
	6.968	6.974	6.516	6.494	6.501	6.956
440	7.220	7.227	6.769	6.747	6.754	7.209
	7.218	7.224	6.766	6.744	6.751	7.206

Gland and AS568 Dash No.	Piston or Cylinder OD C	Cylinder Bore ID A	Gland OD F	Rod or Gland Sleeve OD B	Rod Bore ID H	Gland ID E
441	7.470	7.477	7.019	6.997	7.004	7.459
	7.468	7.474	7.016	6.994	7.001	7.456
442	7.720	7.727	7.269	7.247	7.254	7.709
	7.718	7.724	7.266	7.244	7.251	7.706
443	7.970	7.977	7.519	7.497	7.504	7.959
	7.968	7.974	7.516	7.494	7.501	7.956
444	8.220	8.227	7.769	7.747	7.754	8.209
	8.218	8.224	7.766	7.744	7.751	8.206
445	8.470	8.477	8.019	7.997	8.004	8.459
	8.468	8.474	8.016	7.994	8.001	8.456
446	8.970	8.977	8.519	8.497	8.504	8.959
	8.967	8.974	8.516	8.494	8.501	8.956
447	9.470	9.478	9.020	8.997	9.004	9.460
	9.467	9.474	9.017	8.994	9.001	9.456
448	9.970	9.978	9.520	9.497	9.504	9.960
	9.967	9.974	9.517	9.494	9.501	9.956
449	10.470	10.478	10.020	9.997	10.004	10.460
	10.467	10.474	10.017	9.994	10.001	10.456
450	10.970	10.978	10.520	10.497	10.504	10.960
	10.967	10.974	10.517	10.494	10.501	10.956
451	11.470	11.478	11.020	10.997	11.004	11.460
	11.467	11.474	11.017	10.994	11.001	11.456
452	11.970	11.978	11.520	11.497	11.504	11.960
	11.967	11.974	11.517	11.494	11.501	11.956
453	12.470	12.478	12.020	11.997	12.004	12.460
	12.467	12.474	12.017	11.994	12.001	12.456
454	12.970	12.978	12.520	12.497	12.504	12.960
	12.967	12.974	12.517	12.494	12.501	12.956
455	13.470	13.478	13.020	12.997	13.004	13.460
	13.467	13.474	13.017	12.994	13.001	13.456
456	13.970	13.978	13.520	13.497	13.504	13.960
	13.967	13.974	13.517	13.494	13.501	13.956
457	14.470	14.478	14.020	113.997	14.004	14.460
	14.467	14.474	14.0147	13.994	14.001	14.456
458	14.970	14.978	14.520	14.497	14.504	14.960
	14.967	14.974	14.517	14.494	14.501	14.956
459	15.470	15.478	15.020	14.997	15.004	15.460
	15.467	15.474	15.017	14.994	15.001	15.456
460	15.970	15.978	15.520	15.497	15.504	15.960
	15.967	15.974	15.517	15.494	15.501	15.956

Design Table 4-1: Gland Design, O-Ring and Other Elastomeric Seals (SAE AS5857)

Parker

Parker Hannifin Corporation • O-Ring Division
2360 Palumbo Drive, Lexington, KY 40509
Phone: (859) 269-2351 • Fax: (859) 335-5128
www.parkerorings.com

product
data sheet

R-Cast™ rod & tube

Applications
- Aquariums
- Displays
- Fountains
- Furniture
- Optical lenses
- Port hole windows
- Sight glass
- Scientific applications
- Hyperbaric chambers
- Vacuum chambers
- Bio-safety chambers
- and more...

Benefits
- Outstanding optical clarity
- Excellent UV properties
- High impact resistance - 17x greater than glass and 4x greater than concrete
- Superb weatherability - won't yellow or show signs of aging
- Structural & can be engineered to support weight
- UVT available

Color Availability
- Clear

Custom colors available by special order

Surface Finishes
- Frosted finish
- Gloss finish

Edge Finishes
- Saw cut
- Polished edge
- Radius
- Chamfer

Fabrication Options Available
- Forming
- Bonding
- Drilling
- Cutting
- Routing

Reynolds Polymer Technology, Inc.• 607 Hollingsworth Street • Grand Junction, CO 81505 • 800.433.9293 • 970.241.4700
RPT Asia, Limited • 109/15 Moo 4 Eastern Seaboard Industrial Estate • Soi ESIE 6B • Pluakdaeng Rayong 21140 Thailand
reynoldspolymer.com

Way Beyond Ordinary®

R-Cast™ rod & tube

Warranty
10 years

Care & Cleaning
To polish out scratches and restore original lustre, we recommend our R-Cast™ Care Kit to maintain your acrylic R-Cast™ Rods & Tubes.
Standard soap and water is also acceptable.
Avoid using solvent-based cleaners on R-Cast™ Rods & Tubes.
Please contact us with any questions regarding cleaners.

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R-Cast™ rod & tube

R-Cast™ Acrylic Rod

Diameter in (mm)	Minimum Length in (m)	Maximum Length in (m)
4.0 (102)	**48** (1.22)	**48** (1.22)
4.5 (114)	**48** (1.22)	**48** (1.22)
5.0 (127)	**48** (1.22)	**48** (1.22)
5.5 (140)	**48** (1.22)	**60** (1.52)
6.0 (152)	**48** (1.22)	**60** (1.52)
6.5 (165)	**48** (1.22)	**60** (1.52)
7.0 (178)	**48** (1.22)	**60** (1.52)
7.5 (191)	**48** (1.22)	**60** (1.52)
8.0 (203)	**48** (1.22)	**60** (1.52)
8.5 (216)	**48** (1.22)	**60** (1.52)
9.0 (229)	**48** (1.22)	**60** (1.52)
9.5 (241)	**48** (1.22)	**60** (1.52)
10.0 (254)	**48** (1.22)	**60** (1.52)
10.5 (267)	**48** (1.22)	**60** (1.52)
11.0 (279)	**48** (1.22)	**60** (1.52)
11.5 (292)	**48** (1.22)	**60** (1.52)
12.0 (305)	**48** (1.22)	**60** (1.52)

Also Available: UVT, custom diameter and cut-to-length sizes.

R-Cast™ Rod Tolerances

Diameter in	(mm)	Tolerance in	(mm)
4 - 6	(102 - 152)	**± .045**	(1.143)
6 - 12	(152 - 305)	**± .090**	(2.286)

R-Cast™ Standard Cut Tolerance

in	(mm)
+0.25/- 0.00	(+6.35/- 0.00)

R-Cast™ acrylic rods meet the tolerances and physical properties specified in ASTM D-5436-99 for Type UVA finish 1 cast acrylic rods.

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R CAST by Reynolds POLYMER TECHNOLOGY, INC. Way Beyond Ordinary.

product data sheet

R-Cast™ rod & tube

R-Cast™ Acrylic Tube

O.D. in	(mm)	Wall Thickness 0.25" (6.4)	0.375" (9.5)	0.50" (12.7)	0.75" (19.1)	1.0 (25.4)	Standard Length in	(m)
7.0	(178)	x	x	x	x		**72**	(1.83)
7.0	(178)	x	x	x	x		**96**	(2.44)
8.0	(203)	x	x	x	x		**72**	(1.83)
9.0	(229)	x	x	x	x		**96**	(2.44)
9.5	(241)	x	x	x	x		**72**	(1.83)
10.0	(254)	x	x	x	x		**72**	(1.83)
10.6	(270)	x	x	x	x	x	**52**	(1.32)
11.0	(279)	x	x	x	x	x	**72**	(1.83)
12.0	(305)	x	x	x	x	x	**72**	(1.83)
12.0	(305)	x	x	x	x	x	**96**	(2.44)
13.0	(330)	x	x	x	x	x	**90**	(2.29)
14.0	(356)	x	x	x	x	x	**96**	(2.44)
16.0	(406)	x	x	x	x	x	**96**	(2.44)
18.0	(457)	x	x	x	x	x	**96**	(2.44)
20.0	(508)	x	x	x	x	x	**96**	(2.44)
24.0	(610)	x	x	x	x	x	**96**	(2.44)
25.5	(648)	x	x	x	x	x	**96**	(2.44)
27.5	(699)	x	x	x	x	x	**84**	(2.13)
32.6	(828)	x	x	x	x	x	**96**	(2.44)
35.0	(889)	x	x	x	x	x	**90**	(2.29)
36.0	(914)	x	x	x	x	x	**96**	(2.44)
42.5	(1,080)		x	x	x	x	**90**	(2.29)
44.7	(1,140)		x	x	x		**90**	(2.29)
60.0	(1,520)				x		**132**	(3.35)
72.0	(1,830)					x	**90**	(2.29)
96.0	(2,440)					x	**90**	(2.29)

Also available: UVT, Custom O.D., Custom Wall and Cut-to-Length Sizes.

O.D. in	(mm)	Tolerance in	(mm)
7 - 12	(178 - 305)	**±.06**	(±1.50)
13 -18	(330 - 457)	**±.08**	(±2.03)
20 - 27.5	(508 - 699)	**±.10**	(±2.54)
32.6	(828)	**+.25/-.10**	(+6.35/-2.54)
36	(914)	**±.10**	(±2.54)
42.5	(1,080)	**+.00/-.28**	(+0.00/-7.11)
44.7 - 60	(1,140 - 1,520)	**±.10**	(±2.54)
72	(1,830)	**+.10/-.30**	(+2.54/-7.62)
96	(2,440)	**+.10/-.50**	(+2.54/-12.7)

- Quoted upon request: UVT, Custom O.D., Custom Wall and Cut-to-Length Sizes
- All cylinders larger than 27.50" (699mm) require a wooden shipping crate. Call for pricing.
- Minimum order length of 72" (1.83m) for 60" (1.52m) O.D. cylinders.
- Minimum order length of 90" (2.29m) for 72" (1.83m) O.D. and 96" (2.44m) O.D. cylinders.
- Contact RPT for wall thickness tolerance

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product
data sheet

R-Cast™ rod & tube

Manufacturing
R-Cast™ Rods & Tubes are monolithically cast polymethyl methacrylate (PMMA). R-Cast™ Rods & Tubes are manufactured to meet strict internationally accepted structural standards.

Short Term Loading
Impact, live, and seismic loading conditions are short term and infrequent conditions. All R-Cast™ Rods & Tubes can be designed to handle these conditions.

Safety Glazing
Meets ANSI Z 97.1 for safety glazing material used in buildings.
Approved for safety glazing according to model building codes.
Suitable for use in Consumer Products Safety Commission, Safety Standard for Architectural Glazing Material under 16 CFR 1201, Categories 1 & 11.

FDA Approval
R-Cast™ Rods & Tubes are approved by the U.S. Food and Drug Administration for use as a surface suitable for food preparation.

Reynolds Polymer Technology, Inc.• 607 Hollingsworth Street • Grand Junction, CO 81505 • 800.433.9293 • 970.241.4700
RPT Asia, Limited • 109/15 Moo 4 Eastern Seaboard Industrial Estate • Soi ESIE 6B • Pluakdaeng Rayong 21140 Thailand
reynoldspolymer.com

R CAST by Reynolds POLYMER TECHNOLOGY, INC. Way Beyond Ordinary.

product
data sheet

R-Cast™ rod & tube

R-Cast™
Physical Properties

Property	ASTM Method	US Customary Units	Average Value	Metric Units	Average Value
MECHANICAL					
Tensile Strength	ASTM-D638	psi	10800	Kg/cm^2	759
Tensile Modulus	ASTM-D638	psi	450000	Kg/cm^2	31×10^3
Tensile Elongation	ASTM-D638	%	4.0	-	-
Flexural Strength	ASTM-D790	psi	16000	Kg/cm^2	1125
Compression Strength	ASTM-D695	psi	17500	Kg/cm^2	1230
Shear Strength	ASTM-D732	psi	10000	Kg/cm^2	703
IZOD Impact Strength, notched @ 1/8"	ASTM-D256	ft-lbs/inch	0.414	J/m	22.1
Rockwell Hardness (M Scale)	ASTM-D785	-	103	-	-
Deformation Under Load @ 4,000 psi @ 73°F	ASTM-D621	%	0.85	-	-
OPTICAL					
Light Transmittance (0.1" nominal thickness)	ASTM-D1003	%	92	-	-
Haze	-	%	< 1	-	-
Refractive Index @ 77°F	ASTM-D542	-	1.49	-	-
THERMAL					
Heat Deflection Temperature	ASTM-D648	°F	226	°C	108
Coefficient of Expansion @ 60°F	ASTM-D696	in/in/°F	4.0×10^{-5}	mm/mm/°C	7.2×10^{-5}
MISCELLANEOUS					
Water Absorption, Equilibrium, 24 hrs @ 73°F	ASTM-D570	%	0.2	-	-
Specific Gravity	ASTM-D792	-	1.19	-	-

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R-Cast™ rod & tube

Chemical Resistance

R = Resistant
R-Cast™ Rods & Tubes withstand this substance for long periods and at temperatures up to 120° F (49° C).

LR = Limited Resistance
R-Cast™ Rods & Tubes only resist the action of this substance for short periods at room temperature. The resistance for a particular application must be determined.

N = Non Resistant
R-Cast™ Rods & Tubes are not resistant to this substance. It either swelled, was attacked, dissolved or was damaged in some manner.

Plastic materials can be attacked by chemicals in several ways. The methods of fabrication and/or conditions of exposure of R-Cast™ Rods & Tubes, as well as the manner in which the chemicals are applied, can influence final results even for "R" coded chemicals. Some of these factors are listed below.

Fabrication - Stress generated while sawing, sanding, machining, drilling, polishing, and/or forming.

Exposure - Length of exposure, stresses induced during the life of the product due to various loads, changes in temperatures, etc.

Chemical	Code
Acetic Acid (5%)	R
Acetic Acid (Glacial)	N
Acetic Anhydride	LR
Acetone	N
Acrylic Paints & Lacquers	LR
Ammonia (aqueous solution)	R
Ammonium chloride (Saturated)	R
Ammonium Hydroxide (10%)	R
Ammonium Hydroxide (Conc.)	R
Aniline	N
Battery Acid	R
Benzaldehyde	N
Benzene	N
Bituminous Emulsion	N
Bromine	N
Butanol	LR
Butyl Acetate	N
Calcium Chloride (Saturated)	R
Calcium Hypochlorite	R
Carbon Tetrachloride	N
Cement	R
Chlorine Water	LR
Chloroform	N
Chromic Acid (40%)	N
Citric Acid (10%)	R
Cottonseed Oil (Edible)	R
Detergent Solution	R
Diesel Oil	R
Diethyl Ether	N
Dimethyl Formamide	N
Dioctyl Phthalate	N
Ethyl Acetate	N
Ethyl Alcohol (50%)	LR
Ethyl Alcohol (95%)	N
Ethylene Dichloride	N
Ethylene Glycol	R
2-Ethylhexyl Sebacate	R
Formaldehyde (40%)	R
Formic Acid (2%)	R
Formic Acid (40%)	LR
Gasoline (Regular, Leaded)	LR
Glycerine	R
Glycerol	R
Glycol	R
Heptane	R
Hexane	R
Hot Bitumen	LR

Chemical	Code
Hydrochloric Acid	R
Hydrofluoric Acid (40%)	N
Hydrogen Peroxide (3%)	R
Hydrogen Peroxide (28%)	N
Isooctane	R
Isopropyl Alcohol	LR
Kerosene	R
Lacquer Thinner	N
Lactic Acid (80%)	LR
Methane	R
Methyl Alcohol (50%)	LR
Methyl Alcohol (100%)	N
Methyl Ethyl Ketone (MEK)	N
Methylene Chloride	N
Mineral Oil	R
Mortar	R
Motor Fuel (benzene-free)	R
Motor Fuel (with benzene)	N
Muriatic Acid (20%)	R
Nitric Acid (10%)	R
Nitric Acid (40%)	LR
Nitric Acid (Conc.)	N
Oil Paints (pure)	R
Olive Oil	R
Oxygen	R
Ozone	R
Phenol Solution (5%)	N
Phosphoric Acid (10%)	R
Plaster of Paris	R
Soap Solution (Ivory)	R
Sodium Carbonate (2%)	R
Sodium Carbonate (20%)	R
Sodium Chloride (10%)	R
Sodium Hydroxide (1%)	R
Sodium Hydroxide (10%)	R
Sodium Hydroxide (60%)	R
Stearic Acid	R
Sulfuric Acid (3%)	R
Sulfuric Acid (30%)	R
Sulfuric Acid (Conc.)	N
Thinners (general)	N
Toluene	N
Trichloroethylene	N
Turpentine	LR
Urine	R
Water (Distilled)	R
Xylene	N

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Way Beyond Ordinary®

TECHNICAL DATA SHEET

LOCTITE®
THREADLOCKER
RED 271™

Henkel Corporation
Professional and Consumer Adhesives
Rocky Hill, CT 06067
Phone 1-800-624-7767
Fax (440) 250-7863
www.henkel.com www.loctiteproducts.com

Item #	Package	Size
209741	Carded Tube	0.20 fl. oz.

DESCRIPTION

Loctite® Threadlocker Red 271™ is designed for the permanent locking and sealing of threaded fasteners. The product cures when confined in the absence of air between close fitting metal surfaces. It protects threads from rust and corrosion and prevents loosening from shock and vibration. It is only removable once cured by heating up parts to 500°F (260°C).

RECOMMENDED FOR:

Use on metal fasteners up to 1" (25 mm) in diameter such as bolts on decks, ready-to-assemble furniture, mounts, rings, gear bolts and frame bolts.

NOT RECOMMENDED FOR:

- Use on plastic parts, particularly thermoplastic materials where stress cracking of the plastic could result.
- Use in pure oxygen and/or oxygen rich systems and should not be selected as a sealant for chlorine or other strong oxidizing materials.

FEATURES & BENEFITS:

Feature	Benefits
Protects threads..	Prevents rusting of threads
High strength..	Permanent seal, prevents tampering
Locks threads..	Prevents loosening of metal fasteners caused by vibrations

DIRECTIONS

Tools Typically Required:
Utility knife, damp cloth.

Safety Precautions:
Keep out of reach of children.

Preparation:
Protect work area. Parts to be sealed must be clean and dry. Shake the product thoroughly before use.
Note: To prevent the product from clogging in the nozzle, avoid touching the bottle tip to the metal surface.

Application:

For Thru Holes:
Apply several drops of the product onto the bolt at the nut engagement area.

For Blind Holes:
Apply several drops of the product down the internal threads to the bottom of the hole.

For Sealing Applications:
Apply a 360° bead of product to the leading threads of the male fitting, leaving the first thread free. Force the material into the threads to thoroughly fill the voids. For bigger threads and voids, adjust product amount accordingly and apply a 360° bead of product on the female threads also.

Assemble parts and tighten as required. Sets in approximately 10 minutes and fully cures in 24 hours.

Clean-up
Clean adhesive residue immediately with a damp cloth. Cured product can be removed with a combination of soaking in methylene chloride and mechanical abrasion such as a wire brush.

For disassembly, heat parts up to 482°F (250°C) and separate parts while hot.

STORAGE AND DISPOSAL

Not damaged by freezing. Close the tube tightly after each use. Store product in the unopened container in a dry location. Optimal storage is between 46°F (8°C) to 70°F (21°C).

LABEL PRECAUTIONS

Contains methacrylate ester. Avoid eye and skin contact. For eye contact, flush with water for 15 minutes; call a physician. For skin contact, wash thoroughly with soap and water. If swallowed, do not induce vomiting. Obtain medical attention. **KEEP OUT OF THE REACH OF CHILDREN.**

Refer to the Material Safety Data Sheet (MSDS) for further information

DISCLAIMER

The information and recommendations contained herein are based on our research and are believed to be accurate, but no warranty, express or implied, is made or should be inferred. Purchasers should test the products to determine acceptable quality and suitability for their own intended use. Nothing contained herein shall be construed to imply the nonexistence of any relevant patents or to constitute a permission, inducement or recommendation to practice any invention covered by any patent, without authority from the owner of the patent.

TECHNICAL DATA

Typical Uncured Physical Properties		Typical Application Properties	
Color:	Red	Application Temperature:	Apply above 50°F (10°C)
Appearance:	Liquid	Odor:	Minimal
Base:	Methacrylate ester	Set Time:	10 minutes
Specific Gravity:	1.10	Cure Time:	24 hours
Viscosity:	500 cps @ 10 rpm		
Flashpoint:	> 200°F (93°C)		
VOC Content:	< 8 g/L (0.82% by weight)		
Shelf Life:	24 months from date of manufacture (Unopened)		
Lot Code Explanation:	For example:		

7GAC98873

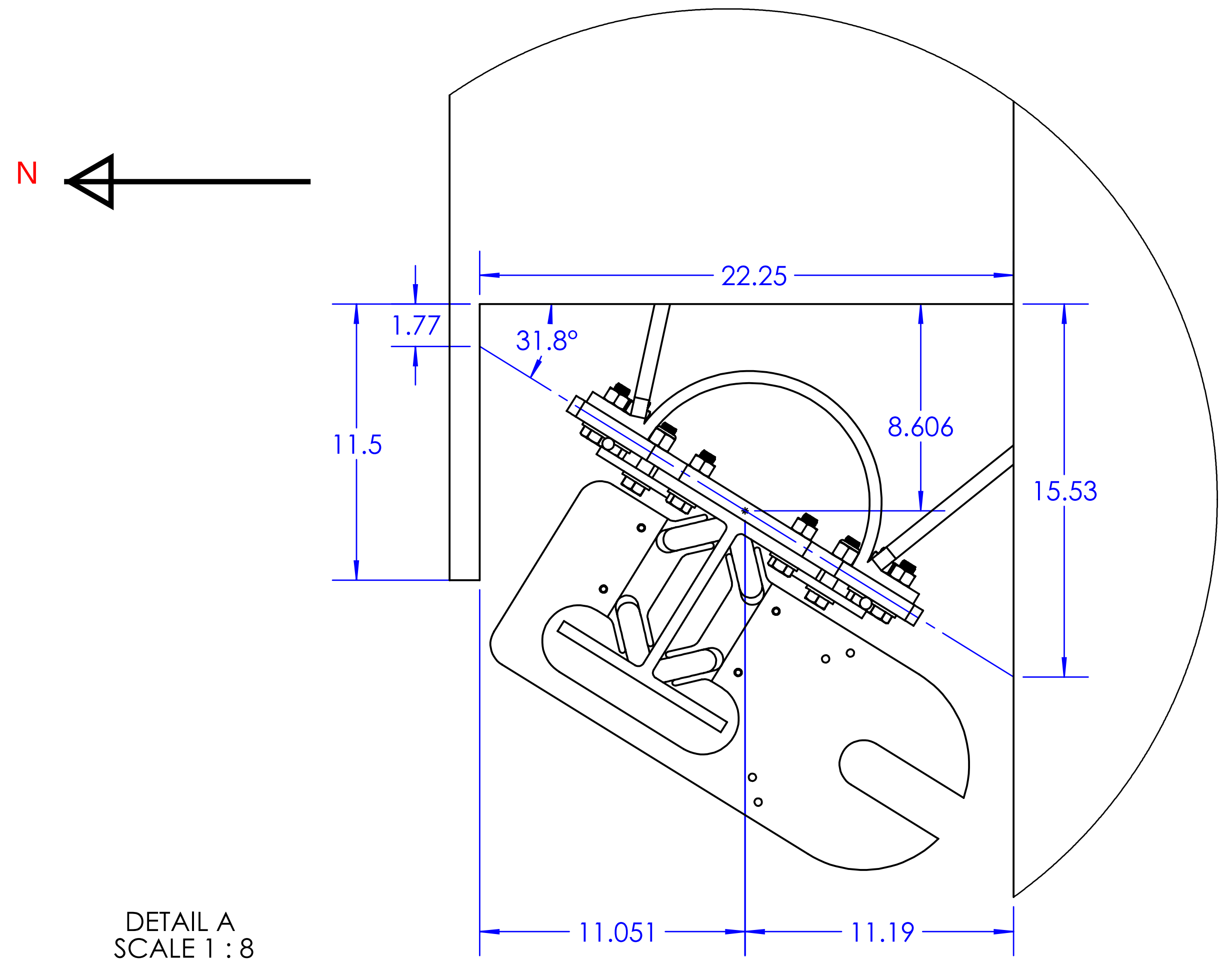
(Lot code stamped on crimped end of tube)

7 = Last Digit in the Year of Manufacture
7 = 2007
(i.e. 7 = 2007, 8 = 2008, 9 = 2009, etc)

G = Month within Year of Manufacture
G = 7th Letter of the Alphabet
G = July
(i.e. A = Jan, B = Feb, C = March, etc)

Typical Cured Performance Properties

Color:	Red
Service Temperature:	-65°F (-54°C) to 300°F (149°C)
Cured form:	Non-flammable, hard solid
Clean-Up:	Uncured: Wipe with damp cloth. Cured: Remove with a combination of soaking in methylene chloride and mechanical abrasion such as a wire brush. For disassembly: Heat parts up to 482°F (250°C) and separate parts while hot.
After 90 minutes @ 72°F (22°C):	
Breakaway Torque: *3/8 X 16 steel nuts (grade 2) and bolts (grade 5)*	75 to 225 lb·in (8.5 to 25.4 N·m)
Prevail Torque: *3/8 X 16 steel nuts (grade 2) and bolts (grade 5)*	150 to 300 lb·in (16.9 to 34 N·m)
After 24 hours @ 72°F (22°C):	
Breakaway Torque: *3/8 X 16 steel nuts (grade 2) and bolts (grade 5)*	150 to 300 lb·in (16.9 to 34 N·m)
3/8 X 16 cadmium nuts and bolts	40 to 125 lb·in (4.5 to 14.1 N·m)
3/8 X 16 zinc nuts and bolts	40 to 125 lb·in (4.5 to 14.1 N·m)
M10 steel nuts and bolts	150 to 350 lb·in (17 to 40 N·m)
Prevail Torque:	
3/8 X 16 steel nuts (grade 2) and bolts (grade 5)	200 to 355 lb·in (22.6 to 40 N·m)
3/8 X 16 cadmium nuts and bolts	150 to 300 lb·in (16.9 to 34 N·m)
3/8 X 16 zinc nuts and bolts	150 to 300 lb·in (16.9 to 34 N·m)
M10 steel nuts and bolts	200 to 350 lb·in (23 to 40 N·m)
Specifications:	Tested to the requirements of: ▪ Military Specification Mil-S-46163A ▪ ASTM D 5363



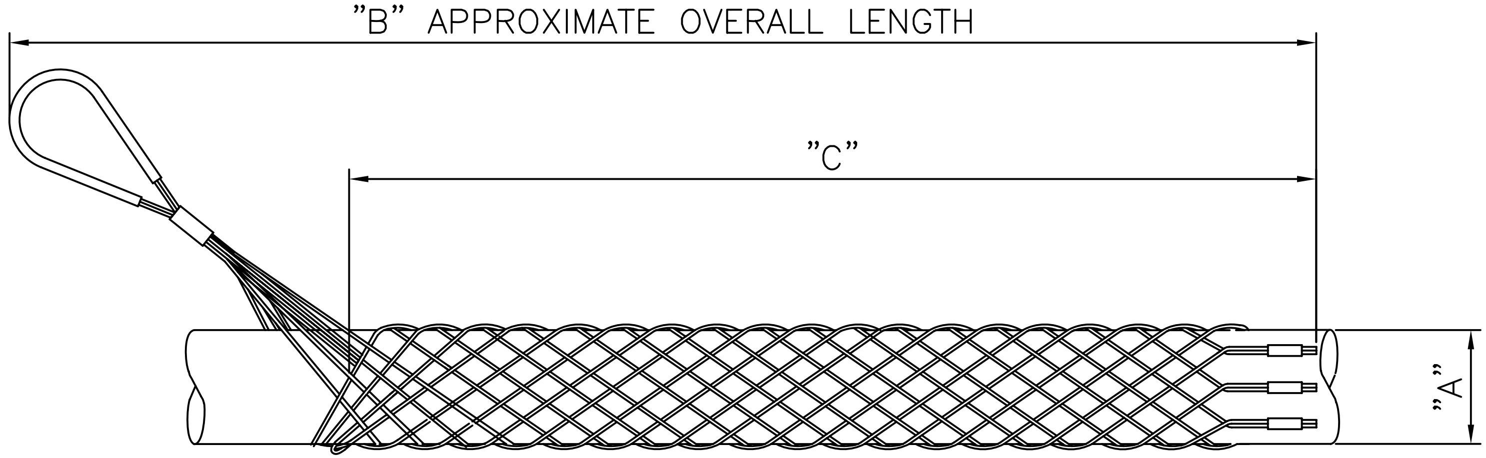
DETAIL A
SCALE 1 : 8

Mechanical Engineering CAL POLY

SCALE: 1:8	LEC SEC:	TITLE: TOP BRACKET AS INSTALLED IN FIELD
UNITS: INCH	LAB SEC:	MATERIAL:
NEXT ASSY:	TOLERANCE:	NAME: MICHEAL MACHADO
DWG #:	DATE:	SIGNATURE:

5 4 3 2 1

DATA SHEET



REMOVE ALL SHARP EDGES
DO NOT SCALE
IF IN DOUBT ASK
DO NOT ALTER THIS DRAWING

NON CONDUCTIVE OFF SET EYE SINGLE / DOUBLE WEAVE						
CODE No	SIZE RANGE	WEAVE PATTERN	Ø "A" NOMINAL	"B" LENGTH	"C" LENGTH	CALCULATED BREAK LOAD
ZCS2810	10 - 20mm 0.39 - 0.78"	SINGLE	15mm 0.59"	750mm 29.5"	600mm 23.6"	1100Kgs. 2464Lbs.
ZCS2811	20 - 30mm 0.78 - 1.18"	SINGLE	25mm 1.00"	750mm 29.5"	600mm 23.6"	1600Kgs. 3584Lbs.
ZCS2812	30 - 40mm 1.18 - 1.57"	SINGLE	35mm 1.37"	750mm 29.5"	600mm 23.6"	2200Kgs. 4928Lbs.
ZCS2813	40 - 50mm 1.57 - 1.96"	SINGLE	45mm 1.77"	750mm 29.5"	600mm 23.6"	2600Kgs. 5824Lbs.
ZCS2814	30 - 40mm 1.18 - 1.57"	DOUBLE	35mm 1.37"	750mm 29.5"	600mm 23.6"	4400Kgs. 9856Lbs.
ZCS2815	40 - 50mm 1.57 - 1.96"	DOUBLE	45mm 1.77"	750mm 29.5"	600mm 23.6"	5300Kgs. 11872Lbs.
ZCS2816	50 - 65mm 1.96 - 2.55"	DOUBLE	57.5mm 2.26"	750mm 29.5"	600mm 23.6"	7100Kgs. 15904Lbs.
ZCS2817	65 - 80mm 2.55 - 3.14"	DOUBLE	72.5mm 2.85"	750mm 29.5"	600mm 23.6"	7100Kgs. 15904Lbs.
ZCS2818	80 - 100mm 3.14 - 3.93"	DOUBLE	90mm 3.54"	750mm 29.5"	600mm 23.6"	7100Kgs. 15904Lbs.

MACHINING LIMITS ±0.25mm (0.010") UNLESS OTHERWISE STATED
ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED

3rd Angle Projection

DO NOT SCALE
IF IN DOUBT, ASK.

MATERIALS -

REV.	DATE:	COMMENTS:	INITIALS:
E			
D			
C			
B	10-01-11	Kgs. ADDED TO CAL. BREAK LOAD	CM

SLINGCO LIMITED
Station Road
Facit
Lancashire
OL12 8LJ
ENGLAND
Tel: +44 (0) 1706 855 558
Fax: +44 (0) 1706 855 559
e.mail: sales@slingco.com
http://www.slingco.com

PROJECT:

TITLE: NON CONDUCTIVE OFF SET EYE CABLE SOCKS DATA SHEET

DWG. No: ZCS2810 TO ZCS2818 DATA SHEET

DATE: 19-10-10
DRAWN BY: CLIVE M
SCALE: NTS
SHEET SIZE: A4
APPROVED: DD
REV. B

AMICO

seasafe®

FIBERGLASS GRATING & STRUCTURAL SYSTEMS

A GIBRALTAR INDUSTRIES COMPANY

DESIGN GUIDE

Revised: 9/2006

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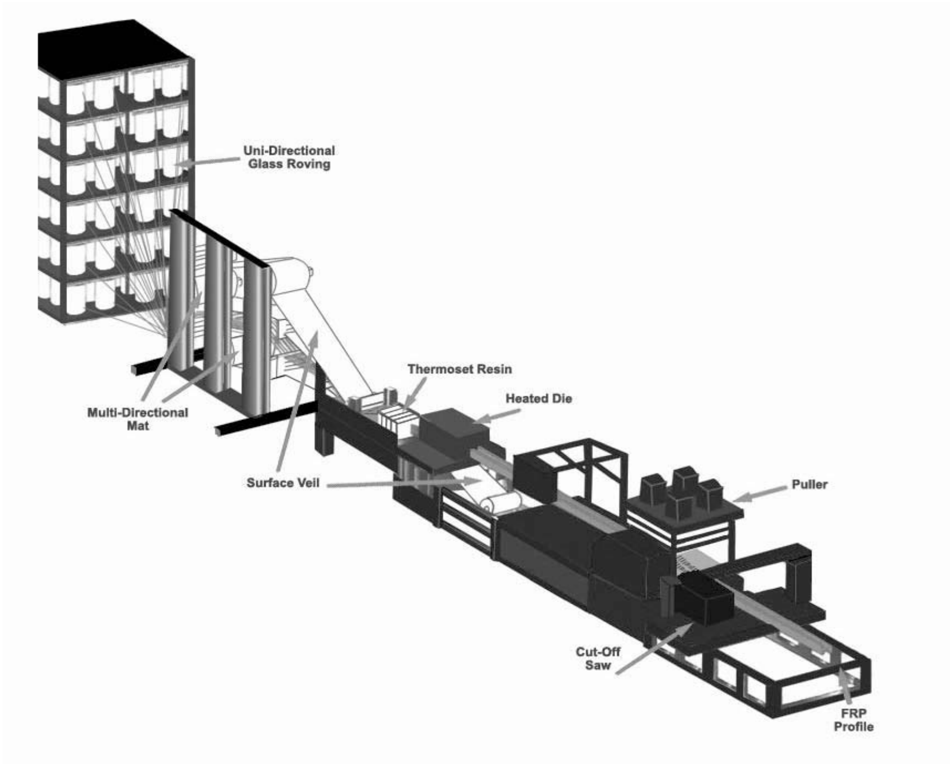
PULTRUSION PROCESS



Pultrusion is the continuous processing of raw materials by pulling resin-rich reinforcements through a heated steel die to form profiles of constant cross section of continuous length.

Pultrusion gets its name from the method by which the profiles are made. Raw materials are literally pulled by what is called the "puller." The puller is the machine made of pulling pads, which grip the product, and a drive system that keeps the product moving. The puller is located just before the cut-off saw.

The process starts with the reinforcements. Typically, unidirectional glass roving begins the process. This is the fiber that runs along the length of the profile. Then, the fiberglass mat is added, which is a multidirectional reinforcement. Next, the glass reinforcements are "wet-out" with a thermoset resin, typically polyester or vinylester. Finally, just before all the material is pulled into the heated die, surface veil may be added to enhance the surface appearance of the final product.

Next in the pultrusion process is the curing of the composite. The curing or hardening occurs while the wet-out reinforcements are being pulled through the heated die. The heat from the die causes the resin to cure and by the time the part exits the die, a hard part in the exact shape of the die cavity has been formed. The final result is a solid, rigid profile with all the reinforcements laminated within.

The puller then pulls the product exiting the die to the cut-off saw, which cuts it to the desired length.

REINFORCEMENTS

Roving

Roving is made up of fiberglass unidirectional filaments, which are manufactured in continuous rolls. Roving is always present in pultruded products comprising 50% to 70% of the total glass content. In addition to supplying the necessary strength to pull the profile, roving supplies the product with high tensile, flexural properties and is a big contributor to the overall section stiffness.

Generally, fiberglass roving is used in pultrusion to achieve the required properties. In special structural applications where more stiffness is required, graphite roving can be used. Conversely, polyester roving may be used in applications where more flex is needed.

Mat

Continuous strand mat is the remainder of glass reinforcement used in the pultrusion process. Typically, it is 30%-50% of the total glass content. Unlike hand-laid-up or press-molded processes that use short chopped fibers, the pultrusion process must have a multidirectional mat that has good pull strength to facilitate getting it to the die after it has been wet-out with the resin. This continuous strand mat is designed specifically for the pultrusion process and offers good wet-out characteristics, conformability to a variety of shapes, and good physical properties including the required pull strength.

Generally, fiberglass continuous strand mat is used to obtain the desired transverse properties of the product. Whereas the roving ties the composite together in the longitudinal direction, the mat is responsible for tying the composite together in all directions, but mainly in the transverse direction. Although continuous strand mat is suitable for most applications, a variety of products such as woven roving, stitched roving, and woven fabrics can be used in custom applications to increase the desired transverse properties.

Veil

Veils are used to enhance the surface of pultruded profiles. Most widely used today are synthetic veils. A veil is added to the outside of a profile just prior to entrance of the die. As a result, the finished profile has a resin-rich surface that aids in resistance to ultraviolet (UV) degradation and makes the profile more hand-friendly. Since the veil brings more resin to the surface and the resin is the ingredient that gives the corrosion resistance, adding the veil increases the corrosion resistance.

All standard structural shapes are manufactured using a surface veil as well as UV inhibitors to protect against UV degradation.

RESIN SYSTEMS

Generally, two types of resins are most often used in the pultrusion process. They are isophthalic polyester resin and vinylester resin. Each resin is available in a fire retardant version as well as non-fire retardant. In selecting the proper resin, one must consider the environment in which the product will be used. Generally, polyester resin will be adequate to handle most environments. However, the vinylester will handle the more severe applications where better chemical resistance is needed. It is a good idea to check the resin corrosion guide for proper selection of system.

Standard structural shapes are stocked in three series: standard polyester, fire retardant polyester and fire retardant vinylester resin systems.

Standard Polyester (SPR) Resin System

Standard structural shapes are manufactured using isophthalic polyester resin. This resin system is olive green in color and contains UV inhibitors. Polyester resin exhibits good corrosion resistance, good dielectric properties, low thermal conductivity, and excellent mechanical properties.

Fire Retardant Polyester (IFR) Resin System

This resin system exhibits the same characteristics as standard polyester along with a fire retardant rating of 25 or less when tested in accordance with ASTM E-84 and exhibits low smoke generation. Products manufactured using this resin system are gray and yellow in color.

Fire Retardant Vinylester (VFR) Resin System

Being fire retardant, this resin meets a rating of 25 or less when tested per ASTM E-84 and has low smoke generation. It is produced in beige and yellow. This system exhibits excellent corrosion resistance and is capable of higher service temperatures than polyester resin systems.

Generally, these resin systems cover most applications, and can be custom mixed to meet more stringent requirements for a specific application.

TEMPERATURE AND WEATHERING

Design Considerations for Fiberglass Pultrusion When Exposed to Continuous High Temperatures

Property loss is experienced in Fire Retardant (IFR), Polyester, and Vinylester Fiberglass (VFR) pultrusion when exposed to continuous high temperatures. The loss of properties should be considered during the designing stages. The following table shows the percentage of property retention at certain continuous temperatures.

ULTIMATE STRESS	TEMPERATURE	IFR/POLYESTER	VINYLESTER
	100° F (37°C)	85%	90%
	125° F (51°C)	70%	80%
	150° F (65°C)	50%	80%
	175° F (79°C)	NOT RECOMMENDED	75%
	200° F (93°C)	NOT RECOMMENDED	50%

MODULUS OF ELASTICITY	TEMPERATURE	IFR/POLYESTER	VINYLESTER
	100° F (37°C)	100%	100%
	125° F (51°C)	90%	95%
	150° F (65°C)	85%	90%
	175° F (79°C)	NOT RECOMMENDED	88%
	200° F (93°C)	NOT RECOMMENDED	85%

Weathering

After exposure to outdoor weathering, almost all plastics undergo some degradation in surface appearance.

The surface of pultrusions typically have good water and ambient temperature resistance, but are attacked by ultraviolet light.

Ultraviolet light is the light spectrum 290 to 400 nanometers. The light has higher energy and can significantly degrade polymers by breaking chemical bonds or starting chemical reactions that lead to polymer degradation. Fire retardant polyester formulations, which contain a halogen, are typically more susceptible to ultraviolet light degradation, due to the halogen additive.

Ultraviolet light will cause the surface of the pultrusion to fade and lose gloss. Over a longer period of time, fiberglass closest to the surface will be exposed. This condition is known as fiberbloom. Physical Properties are not affected by this surface degradation.

Seasafe, Inc. adds a UV stabilizer to our resin mix formulation. This slows the affects of UV degradation. We also incorporate a layer of polyester veil directly to the surface of the pultrusion during processing. This veil gives a resin rich surface and acts as a barrier between the surface and the top layer of fiberglass reinforcement. Pigments used in our resin formulations also slow the affects of weathering. The best method to protect the pultrusion from the affects of outdoor weathering is to apply a protective coating. Urethane based paints can be used.

TYPICAL COUPON PROPERTIES

Below are test results for typical coupon properties of Seasafe's structural fiberglass profiles (Standard, Fire Retardant, & Vinylester shapes). Properties are derived per the ASTM test method shown. Synthetic surfacing veil and ultraviolet inhibitors are standard.

		ENGLISH		METRIC	
MECHANICAL PROPERTIES	**ASTM**	**Units**	**Value**	**Units**	**Value**
Tensile Stress, LW	D-638	psi	30,000	*MPa*	*206.8*
Tensile Stress, CW	D-638	psi	7,000	*MPa*	*48.2*
Tensile Modulus, LW	D-638	10^6 psi	2.5	*GPa*	*19.3*
Tensile Modulus, CW	D-638	10^6 psi	.8	*GPa*	*5.5*
Compressive Stress, LW	D-695	psi	30,000	*MPa*	*206.8*
Compressive Stress, CW	D-695	psi	15,000	*MPa*	*103.4*
Compressive Modulus, LW	D-695	10^6 psi	2.5	*GPa*	*17.2*
Compressive Modulus,CW	D-695	10^6 psi	1.0	*GPa*	*6.9*
Flexural Stress, LW	D-790	psi	30,000	*MPa*	*206.8*
Flexural Stress, CW	D-790	psi	10,000	*MPa*	*68.9*
Flexural Modulus, LW	D-790	10^6 psi	1.8	*GPa*	*12.4*
Flexural Modulus, CW	D-790	10^6 psi	.8	*GPa*	*5.5*
Modulus of Elasticity, E	Full Section	10^6 psi	2.8	*GPa*	*19.3*
Shear Modulus	——	10^6 psi	0.450	*GPa*	*3.1*
Short Beam Shear	D-2344	psi	4,500	*MPa*	*31.0*
Punch Shear	D-732	psi	10,000	*MPa*	*68.9*
Notched Izod Impact, LW	D-256	ft.-lbs./in.	25	*J/mm*	*1.33*
Notched Izod Impact, CW	D-256	ft.-lbs./in.	4	*J/mm*	*.21*

PHYSICAL PROPERTIES	**ASTM**	**Units**	**Value**	**Units**	**Value**
Barcol Hardness	D-2583	—-	45	*—-*	*45*
24 Hour Water Absorbtion	D-570	% max.	0.45	*% max.*	*0.45*
Density	D-792	lbs./in.^{3}	.062-.070	*g/cc*	*1.72-1.94*
Coefficient of Thermal Expansion, LW	D-696	10^{6} in./in./°C	8	*10^{-6} in./in./°C*	*8*

ELECTRICAL PROPERTIES	**ASTM**	**Units**	**Value**	**Units**	**Value**
Arc Resistance, LW	D-495	seconds	120	*seconds*	*120*
Dielectric Strength, LW	D-149	kv./in.	35	*kv./mm*	*1.37*
Dielectric Strength, PF	D-149	volts/mil.	200	*volts/mil.*	*200*
Dielectric Constant, PF	D-150	@60hz	5	*@60hz*	*5*

Fire Retardant Polyester and Fire Retardant Vinylester Structural Profiles:

FLAMMABILITY PROPERTIES	**ASTM**	**Units**	**Value**
Tunnel Test	E-84	Flame Spread	25 max.
Flammability	D-635	——	Nonburning

LW = Lengthwise   CW = Crosswise   PF = Perpendicular to Laminate Face

TYPICAL PROPERTIES OF THREADED ROD / NUTS

Seasafe's threaded rod and nuts are manufactured using premium vinylester resin containing UV inhibitors. The properties listed below are the result of the ASTM test method indicated.

PROPERTIES	ASTM	UNITS English / *Metric*	VALUE (Diameter - Threads Per Inch (UNC)) 3/8-16 *9.5mm*	1/2-13 *12.7mm*	5/8-11 *15.9mm*	3/4-10 *19.0mm*	1-8 *25.4mm*
Ultimate Transverse Shear (Double Shear)	B-565	lb. *Newton*	4,200 *18,680*	6,800 *30,240*	10,000 *44,480*	13,400 *59,600*	24,000 *106,750*
Longitudinal Compressive Strength	D-695	psi *MPa*	50,000 *344*	50,000 *344*	50,000 *344*	50,000 *344*	50,000 *344*
Flexural Strength	D-790	psi *MPa*	70,000 *482*	70,000 *482*	70,000 *482*	70,000 *482*	70,000 *482*
Flexural Modulus	D-790	psi x 10^6 *GPa*	2.5 *17.2*	2.5 *17.2*	2.5 *17.2*	2.5 *17.2*	2.5 *17.2*
Flammability	D-635			Self-extinguishing for all			
Fire Retardant	E-84				Class 1		
Water Absorption (24 hr. immersion)	D-570	% max.	0.8	0.8	0.8	0.8	0.8
Longitudinal Coefficient of Thermal Expansion	D-696	10^{-6} in./in./°F *10^{-6} mm/mm/°C*	6 *11*	6 *11*	6 *11*	6 *11*	6 *11*
Ultimate Thread Shear using fiberglass nut	——	lb. *Newton*	1,200 *5,337*	2,400 *10,670*	3,600 *16,010*	4,000 *17,790*	8,200 *36,470*
Ultimate Torque Strength fiberglass nut lubricated with SAE 10W30 motor oil		ft.-lb. *NewtonMeter*	12 *16*	18 *24*	35 *47*	75 *101*	110 *149*
Rod Weight	——	lb./ft. *Kg./m*	0.07 *0.104*	0.08 *0.119*	0.2 *0.297*	0.3 *0.447*	0.5 *0.789*
Nut Weight	——	lb. *grams*	0.01 *4.5*	0.02 *9.1*	0.04 *18.1*	0.06 *27.2*	0.14 *63.6*
Nut Dimensions	——	in. (square) x in. (thick) *mm. (square) x mm. (thick)*	.68 x .45 *17.2x11.4*	.86 x .56 *21.8x14.2*	1.06 x .69 *26.9x17.5*	1.24 x .82 *31.5x20.8*	1.63 x 1.1 *41.4x27.9*
Color					Gray		

TYPICAL PROPERTIES OF ROD, BAR, AND FLATSTRIP

Below are test results for typical coupon properties of Seasafe's Rod, Bar, and Flatstrip reinforced with all unidirectional longitudinal fiberglass roving. Properties are derived per the ASTM test method shown.

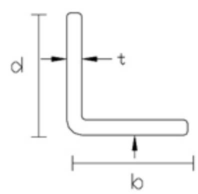
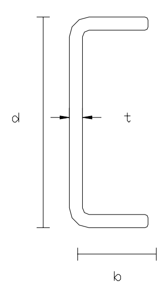
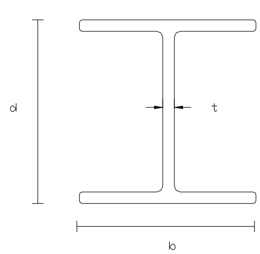
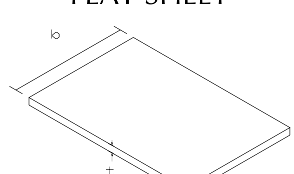
MECHANICAL PROPERTIES	ASTM	UNITS	ROD	BAR	FLATSTRIP
Tensile Stress	D-638	psi	90,000	24,000	90,000
		MPa	*620.5*	*165.5*	*620.5*
Tensile Modulus	D-638	10^6psi	5.0	4.0	5.0
		GPa	*34.7*	*27.6*	*34.7*
Compressive Stress	D-695	psi	60,000	50,000	50,000
		MPa	*413.7*	*344.7*	*344.7*
Flexural Stress	D-790	psi	100,000	90,000	100,000
		MPa	*689.5*	*620.5*	*689.5*
Flexural Modulus	D-790	10^6psi	6.0	4.5	4.5
		GPa	*41.4*	*31.0*	*31.0*
Barcol Hardness	D-2583		60	60	60
Izod Impact	D-256	ft-lbs/in	40	40	40
		J/mm	*2.14*	*2.14*	*2.14*
Density	D-792	lbs/in^3	.065-.075	.065-.075	.065-.075
		gr/cc	*1.80-2.07*	*1.80-2.07*	*1.80-2.07*
Water Absorption (24 hour)	D-570	%	0.2	0.2	0.2

TYPICAL COUPON PROPERTIES OF FLAT SHEET

Below are test results for typical coupon properties of Seasafe's Standard, Fire Retardant and Vinylester Flat Sheet. Properties are derived per the ASTM test method shown. Synthetic surfacing veil and ultraviolet inhibitors are standard.

MECHANICAL PROPERTIES	ASTM	UNITS	THICKNESS (ENGLISH - METRIC)					
			SPR & IFR			VFR		
			1/8" - 3.2	3/16"-1/4" - 4.8 - 6.4	3/8"-1" - 9.5-25.4	1/8" - 3.2	3/16"-1/4" - 4.80-6.4	3/8"-1" - 9.5-25.4
Tensile Stress, LW	D-638	psi - *MPa*	24,000 - *165.5*	24,000 - *165.5*	24,000 - *165.5*	24,000 - *165.5*	24,000 - *165.5*	24,000 - *165.5*
Tensile Stress, CW	D-638	psi - *MPa*	7,500 - *51.7*	10,000 - *68.9*	10,000 - *68.9*	7,500 - *51.7*	10,000 - *68.9*	10,000 - *68.9*
Tensile Modulus, LW	D-638	10^6psi - *GPa*	2.0 - *13.8*	2 - *13.8*	2.0 - *13.8*	2.0 - *13.8*	2.0 - *13.8*	2.0 - *13.8*
Tensile Modulus, CW	D-638	10^6psi - *GPa*	1.0 - *6.9*	1.1 - *7.6*	1.4 - *9.6*	1.0 - *6.9*	1.1 - *7.6*	1.4 - *9.6*
Compressive Stress, LW	D-695	psi - *MPa*	24,000 - *165.5*	24,000 - *165.5*	24,000 - *165.5*	24,000 - *165.5*	24,000 -*165.5*	24,000 -*165.5*
Compressive Stress, CW	D-695	psi - *MPa*	15,500 - *106.9*	16,500 - *113.8*	16,500 - *113.8*	16,500 - *113.8*	17,500 - *120.7*	17,500 - *120.7*
Compressive Modulus, LW	D-695	10^6psi - *GPa*	1.8 - *12.4*	1.8 - *12.4*	1.8 - *12.4*	1.8 - *12.4*	1.8 - *12.4*	1.8 - *12.4*
Compressive Modulus, CW	D-695	10^6psi - *GPa*	1.0 - *6.9*	1.0 - *6.9*	1.0 - *6.9*	1.0 - *6.9*	1.0 - *6.9*	1.0 - *6.9*
Flexural Stress, LW	D-790	psi - *MPa*	35,000 - *241.3*	35,000 - *241.3*	30,000 - *206.8*	35,000 - *241.3*	35,000 - *241.3*	30,000 - *206.8*
Flexural Stress, CW	D-790	psi - *MPa*	15,000 - *103.4*	15,000 - *103.4*	18,000 - *124.1*	15,000 - *103.4*	15,000 - *103.4*	18,000 -*124.1*
Flexural Modulus, LW	D-790	10^6psi - *GPa*	1.6 - *11.0*	2.0 - *13.8*	2.0 - *13.8*	1.6 - *11.0*	2.0 - *13.8*	2.0 - *13.8*
Flexural Modulus, CW	D-790	10^6psi - *GPa*	0.9 - *6.2*	1.1 - *7.6*	1.4 - *9.6*	0.9 - *6.2*	1.1 - *7.6*	1.4 - *9.6*
Perpendicular Shear Stress, LW	D-3946	psi - *MPa*	6,000 - *41.3*	6,000 - *41.3*	6,000 - *41.3*	6,000 - *41.3*	6,000 - *41.3*	6,000 - *41.3*
Perpendicular Shear Stress, CW	D-3946	psi - *MPa*	6,000 - *41.3*	6,000 - *41.3*	6,000 - *41.3*	6,000 - *41.3*	6,000 - *41.3*	6,000 - *41.3*
Bearing Stress, LW	D-953	psi - *MPa*	32,000 - *220.6*	32,000 - *220.6*	32,000 - *220.6*	32,000 - *220.6*	32,000 - *220.6*	32,000 -*220.6*
Notched Izod Impact, LW	D-256	ft-lbs/in-*J/mm*	18.5 - *0.99*	20 - *1.1*	20 - *1.1*	18.5 - *1.0*	20 - *1.1*	20 - *1.06*
Notched Izod Impact, CW	D-256	ft-lbs/in-*J/mm*	5 - *0.27*	5 - *0.3*	5 - *0.3*	5 - *0.3*	5 - *0.3*	5 - *0.27*
PHYSICAL PROPERTIES								
Barcol Hardness	D-2583	----	40.0	40.0	40.0	40.0	40.0	40.0
		----	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*	*40.0*
24 Hour Water Absorption	D-570	% max.	0.6	0.6	0.6	0.6	0.6	0.6
		% max.	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*	*0.6*
Density	D-792	lbs./in.	.062-.070	.062-.070	.062-.070	.062-.070	.062-.070	.062-.070
		g/cc	*1.72-1.94*	*1.72-1.94*	*1.72-1.94*	*1.72-1.94*	*1.72-1.94*	*1.72-1.94*
Coefficient Thermal Expansion,	D-696	10^{-6} in/in./C	8.0	8.0	8.0	8.0	8.0	8.0
LW		*10^{-6} mm/mm/° C*	*8.0*	*8.0*	*8.0*	*8.0*	*8.0*	*8.0*
ELECTRICAL PROPERTIES								
Arc Resistance, LW	D-495	seconds	120.0	120.0	120.0	120.0	120.0	120.0
		seconds	*120.0*	*120.0*	*120.0*	*120.0*	*120.0*	*120.0*
Dielectric Strength, LW	D-149	kv./in.	35	35	35	35	35	35
		kv./mm	*1.37*	*1.37*	*1.37*	*1.37*	*1.37*	*1.37*
Dielectric Strength, PF	D-149	volts/mil.	200.0			200.0		
		volts/mil.	*200.0*			*200.0*		
FLAMMABILITY PROPERTIES FOR IFR & VFR								
Tunnel Test	E-84	Flame Spread 25 max.						
Flammability	D-635	Nonburning						
UL	94	VO						
NBS Smoke Chamber	E-662	Smoke Density 600-700						

CROSS SECTIONAL TOLERANCES

SHAPE	DIMENSION	TOLERANCE % of Nominal	*MAXIMUM OR MINIMUM TOLERANCES
ANGLES 	t = thickness	± 10%	±0.010" min. *±0.26mm min.*
	b = flange width	± 5%	±0.094" max. *±2.4mm max.*
	d = depth	± 5%	± 0.094" max. *±2.4mm max.*
CHANNELS 	t = thickness	± 10%	±0.010" min. *±0.26mm min.*
	b = flange width	± 5%	±0.094" max. *±2.4mm max.*
	d = depth	± 5%	±0.094" max. *±2.4mm max.*
BEAMS 	t = thickness	± 10%	±0.010" min. *±0.26mm min.*
	b = flange width	± 5%	±0.094" max. *±2.4mm max.*
	d = depth	± 5%	±0.094" max. *±2.4mm max.*
FLAT SHEET 	t = thickness	± 10%	±0.040" max. *±1.02mm max.*
	b = width	± 3%	+0.094" max. -0.187" min. *±2.4mm max. -4.8mm min.*

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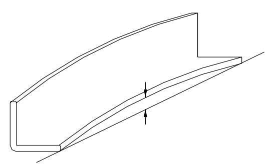
STRAIGHTNESS

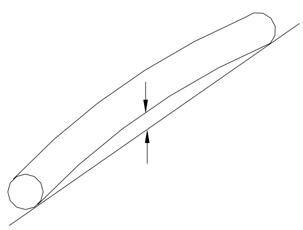
Straightness is measured in the center with the weight of the pultrustion minimizing the deviation by contact with a flat surface.

ANGLE, BEAM AND CHANNEL



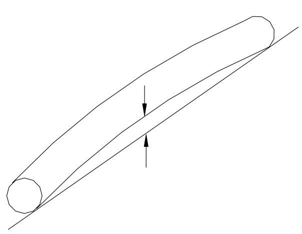
Allowable deviation from straight	
All widths	0.050″/ft. *4.2mm/m*

RODS AND BARS



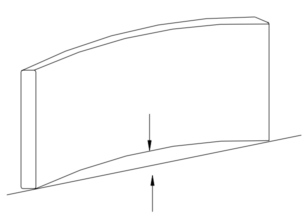
Allowable deviation from straight	
Diameter/Depth	Per Foot Per Meter
Up to 1" *Up to 25.4mm*	0.020″ *1.7mm*
Over 1" *Over 25.4mm*	0.040″ *3.4mm*

ROUND, SQUARE, AND RECTANGULAR TUBE



Allowable deviation from straight	
Diameter/Depth	Per Foot Per Meter
Up to 2" *Up to 50.8mm*	0.020″ *1.7mm*
Over 2" *Over 50.8mm*	0.030″ *2.5mm*

FLAT SHEET AND PLATE



Allowable deviation from straight	
All thickness and widths	0.025″/ft. *2.1mm/m*

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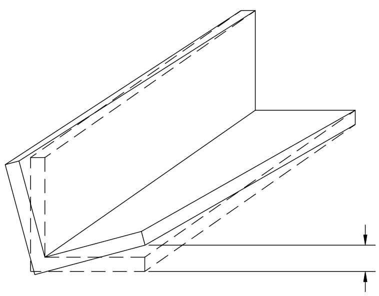
TWIST

Twist is measured with the weight of the pultrusion minimizing the twist.

ALL PROFILES	Allowable twist		
	Width/Depth	In. Per Foot *mm. Per Meter*	Per Piece Max. In./*mm*
	Up to 1.499" *Up to 38.1mm*	tan 1° x width *tan 1°x width x 3.28*	tan 7° x width
	1.500" to 2.999" *38.10mm to 76.2mm*	tan 1/2° x width *tan 1/2°x width x 3.28*	tan 5° x width
	3.000" and over *76.3mm and over*	tan 1/3° x width *tan 1/3° x width x 3.28*	tan 3° x width



ANGULARITY

ALL PROFILES	**Allowable deviation from specific angle**	
	Thickness up to 3/4" *Thickness up to 19mm*	tan 1 1/2° x width of flange in inches *tan 1 1/2° x width of flange in mm*

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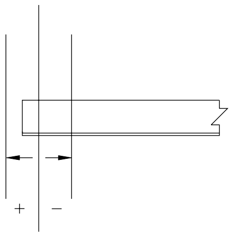
CUT LENGTHS

ALL PROFILES	Allowable deviation from specific length	
	Up to 20' *6.10 meters*	-0, +1/2" /cut length* *-0, +12.7mm/cut length**
	Over 20' to 50' *Over 6.1 to 15.24 meters*	-0, +1" /cut length* *-0, +25.4mm/cut length*

* All parts being cut from stock must allow for blade width.

SQUARENESS OF ENDCUT

ALL PROFILES	Allowable deviation from square	
	All thicknesses	tan 1° x width in inches *tan 1° x width in millimeters*

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SECTION PROPERTIES

Elements of Sections of Structural Shapes

The section table values on the following pages have been calculated from nominal dimensions. All shapes shown in the tables are available, but not all are stocked. A shape availability list is included in the manual and, for convenience, availability information is noted on the individual uniform load tables.

Notation

A	cross sectional area (in.^{2} / *mm.*^{2})
b	width of section (in. / *mm.*)
d	depth of section / diameter of rod (in. / *mm.*)
h	length of angle leg (in. / *mm.*)
I	moment of inertia (in.^{4} / *mm.*^{4})
od	outside diameter of tube (in. / *mm.*)
r	radius of gyration (in. / *mm.*)
S	section modulus (in.^{3} / *mm.*^{3})
t	thickness (in. / *mm.*)
t_b	thickness of width dimension (in. / *mm.*)
t_d	thickness of depth dimension (in. / *mm.*)
Wt.	weight of section (lbs./ft. / *kgs./m.*)

H-BEAM

SECTION DIMENSIONS					SECTION PROPERTIES					
					X -X			Y - Y		
d	b	t	A	Wt.	I	S	r	I	S	r
in. *mm.*	in. *mm.*	in. *mm.*	$in.^2$ *$mm.^2$*	lb./ft. *kg./m*	$in.^4$ *$mm.^4$*	$in.^3$ *$mm.^3$*	in. *mm.*	$in.^4$ *$mm.^4$*	$in.^3$ *$mm.^3$*	in. *mm.*
3	3	1/4	2.13	1.64	3.17	2.11	1.22	1.13	0.75	0.73
76.2	*76.2*	*6.4*	*1374.2*	*2.44*	*1319454*	*34577*	*31.0*	*470342*	*12290*	*18.5*
4	4	1/4	2.89	2.15	7.94	3.97	1.66	2.67	1.34	0.96
101.6	*101.6*	*6.4*	*1864.5*	*3.20*	*3304878*	*65057*	*42.2*	*1111338*	*21959*	*24.4*
6	6	1/4	4.39	3.40	28.28	9.43	2.54	9.01	3.00	1.43
152.4	*152.4*	*6.4*	*2832.3*	*5.06*	*11771025*	*154530*	*64.5*	*3750245*	*49161*	*36.3*
6	6	3/8	6.48	4.90	40.17	13.39	2.49	13.52	4.51	1.44
152.4	*152.4*	*9.5*	*4180.6*	*7.29*	*16720016*	*219423*	*63.2*	*5627449*	*73906*	*36.6*
8	8	3/8	8.73	6.49	99.19	24.80	3.37	32.03	8.01	1.92
203.2	*203.2*	*9.5*	*5632.2*	*9.66*	*41285995*	*406399*	*85.6*	*13331893*	*131260*	*48.8*
8	8	1/2	11.51	8.70	126.96	31.74	3.32	42.74	10.69	1.93
203.2	*203.2*	*12.7*	*7425.8*	*12.95*	*52844742*	*520125*	*84.3*	*17789731*	*175178*	*49.0*
10	10	3/8	11.06	8.74	198.53	39.71	4.24	62.54	12.51	2.38
254.0	*254.0*	*9.5*	*7135.5*	*13.01*	*82634425*	*650730*	*107.7*	*26031113*	*205002*	*60.5*
10	10	1/2	14.51	10.90	256.20	51.24	4.21	83.42	16.68	2.4
254.0	*254.0*	*12.7*	*9361.3*	*16.22*	*106638491*	*839673*	*106.9*	*34722026*	*273336*	*61.0*
12	12	1/2	17.51	13.20	452.45	75.45	5.08	144.11	24.02	2.87
304.8	*304.8*	*12.7*	*11296.8*	*19.64*	*188323909*	*1236404*	*129.0*	*59983111*	*393617*	*72.9*

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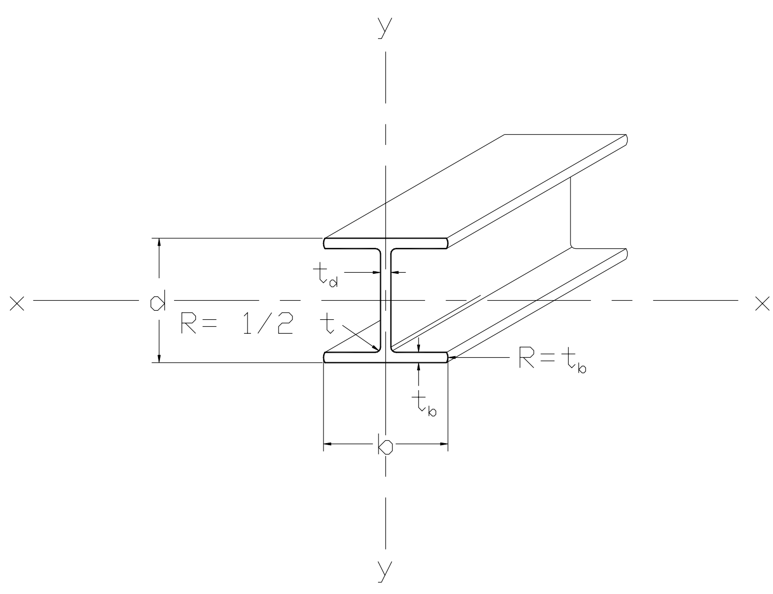


BEAMS

Allowable Uniform Load Tables

Full section 3-point bending tests were conducted on Seasafe's H-Beams, I-Beams, Channels, and Square Tubes. The allowable uniform load tables were generated using these tests results as well as the formulas, properties, and assumptions listed below. Formulas for critical buckling and lateral-torsional buckling are developed from theory presented in Chapter 6 and 7 of the ASCE Structural Plastics Design Manual*.

Notation

A_w	area of web (in.^{2} / *mm.*^{2})
b	flange width (in. / *mm.*)
b_h	1/2 of flange width (in. / *mm.*)
d	depth of section (in. / *mm.*)
E	modulus of elasticity (lbs./in.^{2} /*GPa*)
f_b	actual flexural stress (lbs./in.^{2} / *MPa*)
F_b	maximum allowable flexural stress (lbs./in.^{2} / *MPa*)
F_{aCB}	maximum allowable buckling stress (lbs./in.^{2} / *MPa*)
F_{aLTB}	maximum allowable lateral-torsional buckling stress (lbs./in.^{2} / *MPa*)
f_v	actual shear stress (lbs./in.^{2} / *MPa*)
F_v	maximum allowable shear stress (lbs./in.^{2} / *MPa*)
G	shear modulus (lbs./in.^{2} / *GPa*)
I	moment of inertia (in.^{4} / *mm.*^{4})
J	torsion constant (in.^{4} / *mm.*^{4})
L	length of span (in. / *mm.*)
M	maximum moment (lbs.-in. / *N.-m.*)
S_x	section modulus (in.^{3} / *mm.*^{3})
t	flange thickness (in. / *mm.*)
V	vertical shear force (lbs. / *N.*)
w	uniform load (lbs./in. / *N/m.*)
ν_L	poission's ratio (longitudinal)
ν_T	poission's ratio (transverse)

Assumptions

Beam simply supported at both ends
Uniformly distributed load
Load is applied perpendicular to major axis
Part weight has been deducted in tables

Safety factor of 3.0 for both ultimate material flexural and shear stress and 2.5 for buckling stresses

* ASCE Manuals and Reports on Engineering Practice No. 63, Structural Plastics Design Manual Volumes 1 & 2, 1984

Properties / Allowables

E = 2.8 x 10^6 lbs./in.^{2}
E = 19.3 GPa

G = 450,000 lbs./in.^{2}
G = 3.1 GPa

F_b = 10,000 lbs./in.^{2}
F_b = 68.9 MPa

F_v = 1500 lbs./in.^{2}
F_v = 10.3 MPa

Formulas

$$\Delta = \frac{5wL^4}{384EI} + \frac{wL^2}{8A_w G}$$

$$f_b = \frac{M}{S_x}$$

$$f_v = \frac{V}{A_w}$$

Allowable Critical Buckling Stress for laterally supported H and I Beams

$$F_{aCB} = \frac{\pi^2}{b_h^2 t}\left[.935\sqrt{\left(\frac{Et^3}{12\lambda}\right)\left(\frac{\nu_T Et^3}{12\lambda}\right)} - (.656)\left(\frac{\nu_T Et^3}{12\lambda}\right) + (2.082)\left(\frac{Gt^3}{12}\right)\right] / 2.5$$

$$\lambda = (1 - \nu_L \nu_T)$$

Allowable Lateral-Torsional Buckling Stress for laterally unsupported H and I Beams

$$F_{aLTB} = \left[\frac{C\pi}{S(KL)}\sqrt{EI_y GJ + \frac{d^2\pi^2E^2I_y^2}{(4)(KL)^2}}\right] / 2.5$$

C = 1.13 and K = 1.0 for uniform load simple beam*

Allowable Critical Buckling Stress for Channels laterally supported to eliminate warping and twist

$F_{aCB} = G(t/b)^2$

Allowable Bending Stress for Square Tube (b/t <=16)

F_b= 10,000 psi.

* ASCE Manuals and Reports on Engineering Practice No. 63, Structural Plastics Design Manual Volumes 1 & 2, 1984

8 x 8 x 3/8 H-BEAM

203.2 x 203.2 x 9.5 H-BEAM

ALLOWABLE UNIFORM LOADS (lbs./ft. / *N/m.*)
Laterally Supported

A_w = 2.719 in.² / *1754mm.²*
I = 99.19 in.⁴ / *41285995mm.⁴*

Wt. = 6.49 lbs./ft. / *9.66 kg/m.*
S = 24.80 in.³ / *406399mm.³*

SPAN FT/*m*	NO LATERAL SUPPORT MAX. LOAD	LATERALLY SUPPORTED MAXIMUM LOAD		DEFLECTION L/100	L/150	L/180	L/240	L/360
4/*1.22*	2033/*29666*	2033/*29666*	Fv	----/----	----/----	----/----	----/----	----/----
5/*1.52*	1625/*23714*	1625/*23714*	Fv	----/----	----/----	----/----	----/----	1483/*21636*
6/*1.83*	1353/*19746*	1353/*19746*	Fv	----/----	----/----	----/----	----/----	1028/*15008*
7/*2.13*	1159/*16911*	1159/*16911*	Fv	----/----	----/----	----/----	1106/*16139*	735/*10727*
8/*2.44*	1013/*14786*	1013/*14786*	Fv	----/----	----/----	----/----	812/*11849*	539/*7868*
9/*2.74*	900/*13132*	900/*13132*	Fv	----/----	----/----	815/*11898*	610/*8900*	404/*5902*
10/*3.05*	803/*11716*	809/*11810*	Fv	----/----	752/*10968*	625/*9125*	467/*6820*	309/*4515*
11/*3.35*	556/*8108*	668/*9755*	Fb	----/----	587/*8566*	488/*7123*	364/*5318*	241/*3514*
12/*3.66*	397/*5800*	561/*8182*	Fb	----/----	466/*6797*	387/*5648*	289/*4212*	190/*2777*
13/*3.96*	292/*4265*	477/*6958*	Fb	----/----	375/*5469*	311/*4541*	232/*3382*	152/*2223*
14/*4.27*	220/*3210*	410/*5986*	Fb	----/----	305/*4455*	253/*3696*	188/*2749*	123/*1801*
15/*4.57*	169/*2463*	356/*5202*	Fb	----/----	251/*3669*	208/*3042*	155/*2258*	101/*1474*
16/*4.88*	132/*1922*	313/*4561*	Fb	----/----	209/*3052*	173/*2527*	128/*1872*	83/*1216*
17/*5.18*	104/*1521*	276/*4029*	Fb	266/*3888*	175/*2561*	145/*2118*	107/*1565*	69/*1012*
18/*5.49*	83/*1219*	246/*3584*	Fb	226/*3295*	148/*2165*	123/*1789*	90/*1318*	58/*847*
19/*5.79*	68/*986*	220/*3207*	Fb	193/*2813*	126/*1844*	104/*1521*	77/*1117*	49/*713*
20/*6.10*	55/*805*	198/*2885*	Fb	166/*2417*	108/*1580*	89/*1301*	65/*952*	41/*603*

The part weight has been deducted in the above table.

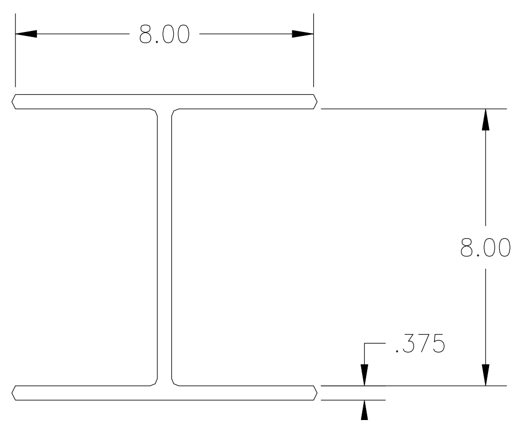
English/ *Metric*

This item is stocked in 20-foot lengths.

Other lengths available in mill run quantities.

The mill run on this item is 400 feet.

Orders for less than mill run quantities will be subject to set-up charges as well as premium per foot cost.



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CORROSION GUIDE

The data in this corrosion guide is based on field service performance, laboratory testing and extrapolated values from our resin manufacturers' recommendations. Data shown is intended as a guide only. It is recommended that for a specific application, testing be done in the actual chemical environment.

The following conditions will effect the suitability of a specific resin laminate:

- Periodic changes in temperature
- Changes in chemical concentrations
- Exposure to vapors only
- Exposure to intermittent splashes and spills
- Load bearing or non-load bearing requirements
- Temperature spikes
- Combinations of chemicals
- Exposure to frequent splashes and spills
- Frequency of maintenance wash down

Chemical Environment	Maximum Recommended Service Temperatures, °F / °C	
	Vinylester	Polyester
Acetic Acid, to 10%	170 / *76*	80 / *26*
Acetic Acid, to 50%	180 / *81*	NR / *NR*
Acetic Acid, Glacial	NR / *NR*	NR / *NR*
Acetone	NR / *NR*	NR / *NR*
Aluminum Chloride	170 / *76*	120 / *49*
Aluminum Hydroxide	140 / *60*	120 / *49*
Aluminum Nitrate	140 / *60*	120 / *49*
Aluminum Sulfate	170 / *76*	120 / *49*
Ammonium Chloride	170 / *76*	120 / *49*
Ammonium Hydroxide, 5%	140 / *60*	NR / *NR*
Ammonium Nitrate, to 50%	170 / *76*	120 / *49*
Ammonium Nitrate, Saturated	170 / *76*	NR / *NR*
Ammonium Persulfate, to 25%	140 / *60*	90 / *32*
Ammonium Phosphate	170 / *76*	120 / *49*
Ammonium Sulfate	170 / *76*	120 / *49*
Amyl Alcohol	80 / *26*	NR / *NR*
Barium Carbonate	170 / *76*	120 / *49*
Barium Chloride	170 / *76*	120 / *49*
Barium Sulfate	170 / *76*	120 / *49*
Benzene	NR / *NR*	NR / *NR*
Benzene Sulfonic Acid 50%	110 / *43*	NR / *NR*
Benzoic Acid	170 / *76*	120 / *49*
Benzyl Alcohol	NR / *NR*	NR / *NR*
Borax	170 / *76*	120 / *49*
Brine (Sodium Chloride Sol.)	170 / *76*	120 / *49*
Bromine, Liquid or Vapor	NR / *NR*	NR / *NR*
Ethyl Alcohol	NR / *NR*	NR / *NR*
Ethylene Glycol	170 / *76*	120 / *49*

Chemical Environment	Maximum Recommended Service Temperatures, °F / °C	
	Vinylester	Polyester
Butyl Acetate	NR / *NR*	NR / *NR*
Butyl Alcohol	80 / *26*	NR / *NR*
Calcium Carbonate	170 / *76*	120 / *49*
Calcium Hydroxide	140 / *60*	120 / *49*
Calcium Hypochlorite	120 / *49*	NR / *NR*
Calcium Nitrate	170 / *76*	120 / *49*
Calcium Sulfate	170 / *76*	120 / *49*
Carbon Disulfide	NR / *NR*	NR / *NR*
Carbon Monoxide Gas	170 / *76*	160 / *60*
Carbon Dioxide Gas	170 / *76*	160 / *60*
Carbon Tetrachloride	70 / *20*	NR / *NR*
Liquid or Vapor	110 / *43*	NR / *NR*
Chlorine, Dry Gas	170 / *76*	NR / *NR*
Chlorine, Wet Gas	170 / *76*	NR / *NR*
Chlorine Water	140 / *60*	NR / *NR*
Chloroform	140 / *60*	NR / *NR*
Chromic Acid, to 5%	110 / *43*	NR / *NR*
Chromous Sulfate	140 / *60*	120 / *49*
Citric Acid	170 / *76*	120 / *49*
Copper Chloride	170 / *76*	170 / *76*
Copper Cyanide	170 / *76*	170 / *76*
Copper Nitrate	170 / *76*	170 / *76*
Crude Oil, Sour	170 / *76*	170 / *76*
Cyclohexane, Liquid and Vapor	170 / *76*	NR / *NR*
Diesel Fuel	140 / *60*	90 / *32*
Ethyl Acetate	NR / *NR*	NR / *NR*
Phosphoric Acid, Vapor	170 / *76*	120 / *49*
Potassium Aluminum Sulfate	170 / *76*	120 / *49*

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Chemical Environment	Maximum Recommended Service Temperatures, °F / ^oC Vinylester	Polyester
Fatty Acids	170 / 76	80 / 26
Ferric Chloride	170 / 76	110 / 43
Ferric Sulfate	170 / 76	110 / 43
Formaldehyde	110 / 43	NR / NR
Fuel Oil	140 / 60	80 / 26
Gasoline, Aviation and Ethyl	140 / 60	80 / 26
Glucose	170 / 76	100 / 37
Glycerine	170 / 76	100 / 37
Hexane	120 / 49	90 / 32
Hydraulic Fluid (Glycol Based)	140 / 60	NR / NR
Hydraulic Fluid Skydraul	140 / 60	NR / NR
Hydrobromic Acid	110 / 43	NR / NR
Hydrochloric Acid, up to 15%	140 / 60	80 / 26
Hydrochloric Acid, Concentrated	110 / 43	NR / NR
Hydrogen Bromide, Dry Gas	140 / 60	80 / 26
Hydrogen Bromine, Wet Gas	140 / 60	NR / NR
Hydrogen Chloride, Dry Gas	170 / 76	80 / 26
Hydrogen Chloride, Wet Gas	170 / 76	80 / 26
Hydrogen Fluoride, Sol or Vapor	140 / 60	NR / NR
Hydrogen Peroxide, to 10%	110 / 43	NR / NR
Hydrogen Sulfide, Dry Gas	140 / 60	80 / 26
Hydrogen Sulfide, Wet Gas	140 / 60	80 / 26
Isopropyl Alcohol	80 / 26	NR / NR
JP-4	140 / 60	80 / 26
Kerosene	140 / 60	110 / 43
Lactic Acid	170 / 76	120 / 49
Lead Acetate	170 / 76	120 / 49
Linseed Oil	170 / 76	100 / 37
Lithium Chloride	170 / 76	120 / 49
Magnesium Carbonate	170 / 76	120 / 49
Magnesium Chloride	170 / 76	120 / 49
Magnesium Hydroxide	170 / 76	100 / 37
Magnesium Nitrate	170 / 76	120 / 49
Magnesium Sulfate	170 / 76	120 / 49
Mercuric Chloride	170 / 76	120 / 49
Mercury Metal	170 / 76	120 / 49
Methyl Ethyl Ketone	NR / NR	NR / NR
Mineral Oil	170 / 76	120 / 49
Monochlorobenzene	NR / NR	NR / NR
Naphtha	140 / 60	120 / 49
Nickel Chloride	170 / 76	120 / 49
Nitric Acid, to 5%	110 / 43	100 / 37
Nitric Acid, Concentrated	NR / NR	NR / NR
Nitric Acid, Vapor	140 / 60	100 / 37
Oleic Acid	170 / 76	120 / 49
Oxalic Acid	170 / 76	120 / 49
Paper Mill Liquor	100 / 37	100 / 37
Phenol Solution or Vapor	NR / NR	NR / NR
Phosphoric Acid	170 / 76	100 / 37
Phosphoric Acid, Salts thereof	170 / 76	120 / 49
Potassium Bicarbonate	110 / 43	100 / 37
Potassium Carbonate, to 10%	110 / 43	NR / NR
Potassium Chloride	170 / 76	120 / 49
Potassium Hydroxide	140 / 60	NR / NR
Potassium Nitrate	170 / 76	120 / 49
Potassium Sulfate	170 / 76	120 / 49
Propylene Glycol	170 / 76	120 / 49
Sodium Acetate	170 / 76	120 / 49
Sodium Benzoate	140 / 60	120 / 49
Sodium Bicarbonate	140 / 60	120 / 49
Sodium Bisulfate	170 / 76	120 / 49
Sodium Bisulfite	170 / 76	120 / 49
Sodium Borate	170 / 76	120 / 49
Sodium Bromide	170 / 76	120 / 49
Sodium Carbonate, to 10%	140 / 60	70 / 20
Sodium Chloride	170 / 76	120 / 49
Sodium Cyanide	170 / 76	120 / 49
Sodium Dichromate	170 / 76	120 / 49
Sodium Di-Phosphate	170 / 76	120 / 49
Sodium Hydroxide, 10%	140 / 60	NR / NR
Sodium Hypochlorite, to 5 1/4%	110 / 43	70 / 20
Sodium Monophosphate	170 / 76	120 / 49
Sodium Nitrate	170 / 76	120 / 49
Sodium Nitrite	170 / 76	120 / 49
Sodium Sulfate	170 / 76	120 / 49
Sodium Tetraborate	140 / 60	120 / 49
Sodium Thiosulfate	140 / 60	120 / 49
Soy Oil	170 / 76	100 / 37
Stearic Acid	170 / 76	120 / 49
Styrene	NR / NR	NR / NR
Sulfamic Acid	170 / 76	120 / 49
Sulfated Detergents	NR / NR	120 / 49
Sulfite Liquor	160 / 71	100 / 37
Sulfur Dioxide, gas-dry	170 / 76	120 / 49
Sulfur Dioxide, gas-wet	170 / 76	70 / 20
Sulfur Trioxide, gas-wet or dry	170 / 76	NR / NR
Sulfuric Acid, to 25%	170 / 76	80 / 26
Tartaric Acid	170 / 76	120 / 49
Tetrachloroethylene	NR / NR	NR / NR
Toluene	NR / NR	NR / NR
Trichloroethylene vapor	NR / NR	NR / NR
Trisodium Phosphate	170 / 76	NR / NR
Urea, 35%	110 / 43	NR / NR
Vinegar	170 / 76	150 / 65
Water, Distilled	180 / 81	150 / 65
Water, Tap	180 / 81	120 / 65
Zinc Chloride	170 / 76	120 / 49
Zinc Nitrate	170 / 76	120 / 49
Zinc Sulfate	170 / 76	120 / 49

8

TABLE I
RECOMMENDED MECHANICAL PROPERTIES FOR PULTRUDED STRUCTURAL SHAPES

PROPERTY	UNITS	TEST METHOD	MINIMUM	
Tensile Strength	psi	D638		
Lengthwise	(MPA)		30,000	(206.80)
Crosswise			6,500	(44.80)
Tensile Modulus	psi x 10^6	D638		
Lengthwise	(GPA)		2.3	(15.85)
Crosswise			0.8	(5.51)
Flexural Strength	psi	D790		
Lengthwise	(MPA)		30,000	(206.80)
Crosswise			10,000	(44.80)
Flexural Modulus	psi x 10^6	D790		
Lengthwise	(GPA)		1.5	(10.30)
Crosswise			0.7	(4.80)
Compressive Strength	psi	D695		
Lengthwise	(MPA)		30,000	(206.80)
Crosswise			10,000	(44.80)
Izod Impact	Ft.-Lbs./in.	D256		
Lengthwise			20	
Crosswise			4	
Apparent Horizontal Shear	psi	D2344		
Lengthwise	MPA		3,000	-20.7

TABLE II
TYPICAL PHYSICAL PROPERTIES OF PULTRUDED STRUCTURAL SHAPES

PROPERTY	UNITS	TEST METHOD	TYPICAL
Barcol Hardness		D2583	
Flatwise			50[1]
Water Absorption	% max.	D570	0.7[2]
Density	Lb./in.^{3} (g/cm^3)	D792	.060 - .068 (1.6 - 1.9)
Specific Gravity		D792	1.6 - 1.0
Coefficient of Thermal Expansion			
Lengthwise	in./in./ °F (in./in./ °C)	D696	2.9×10^{-6} (5.2×10^{-6})
Glass Content	% by Wt.	D2584	50 ± 5

1. Surface veils could cause this number to vary.
2. Maximum value for this composite construction.

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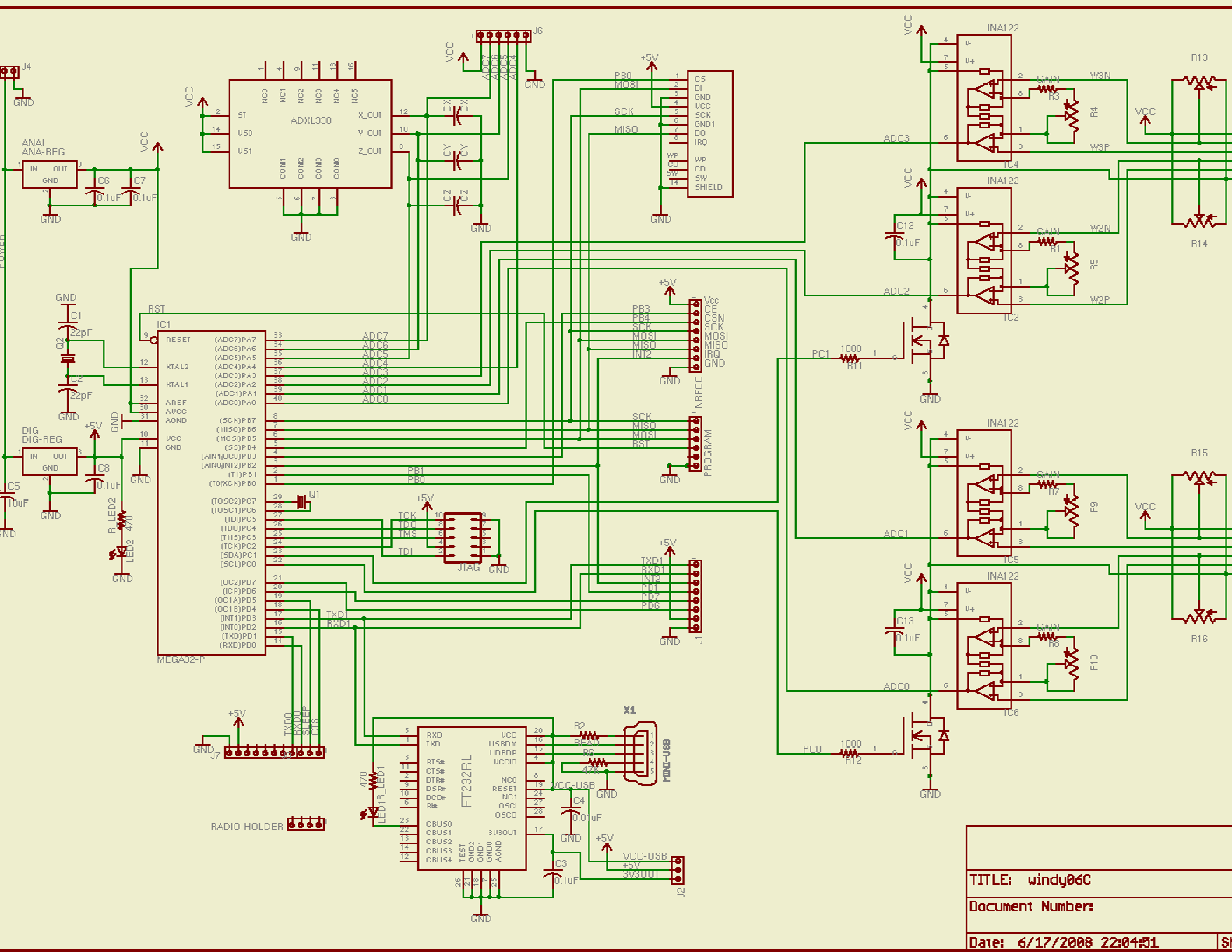
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MEGA32-P
IC1
FT232RL
INA122
IC2
IC4
IC5
IC6
ANA-REG
DIG-REG
NRF00
PROGRAM
JTAG
RADIO-HOLDER
MINI-USB
X1
J1
J2
J4
J6
J7
R13
R14
R15
R16
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Date: 6/17/2008 22:04:51

APPENDIX H:

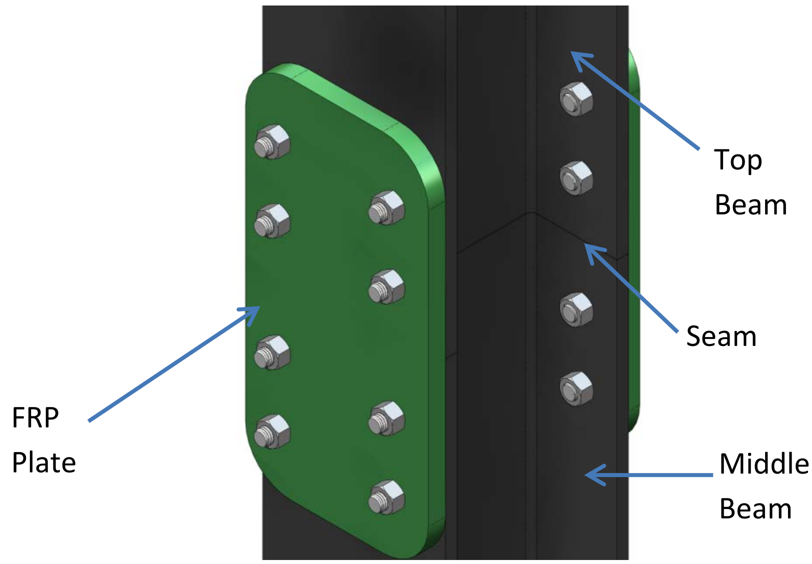
PROCEDURES

Beam Installation Project Execution Plan

(Created by the previous Pier Portal team)

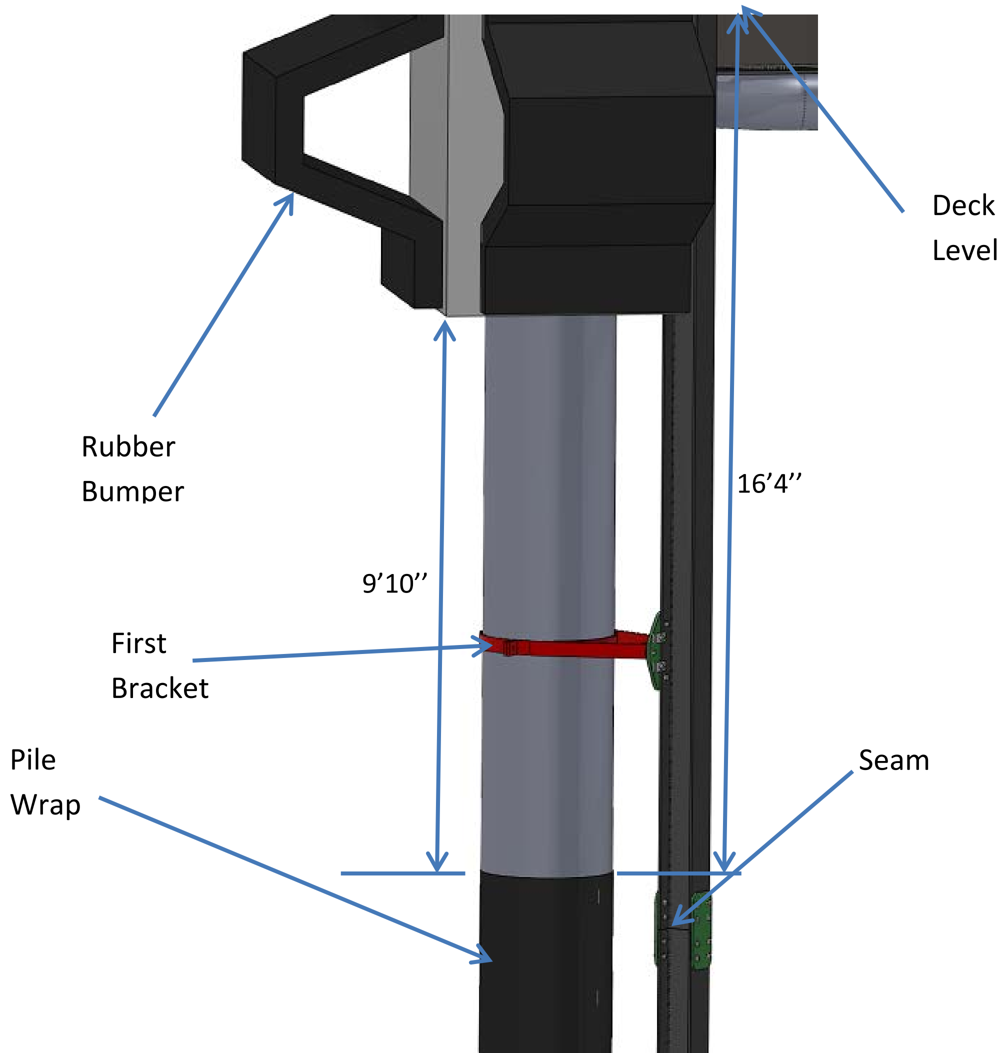
Step1

All three beam sections will be assembled at deck level before April 12th. This will create one 60 foot I-beam from 3 separate 20 foot I-beams connected at 2 locations with FRP seam connection brackets as seen in the figure to the right (See final page for bracket installation overview and letter designation). Approximate pile bracket attachment locations will be indicated on beam (spray painted band or similar marking). The total beam weight after on deck assembly is 602lbs.



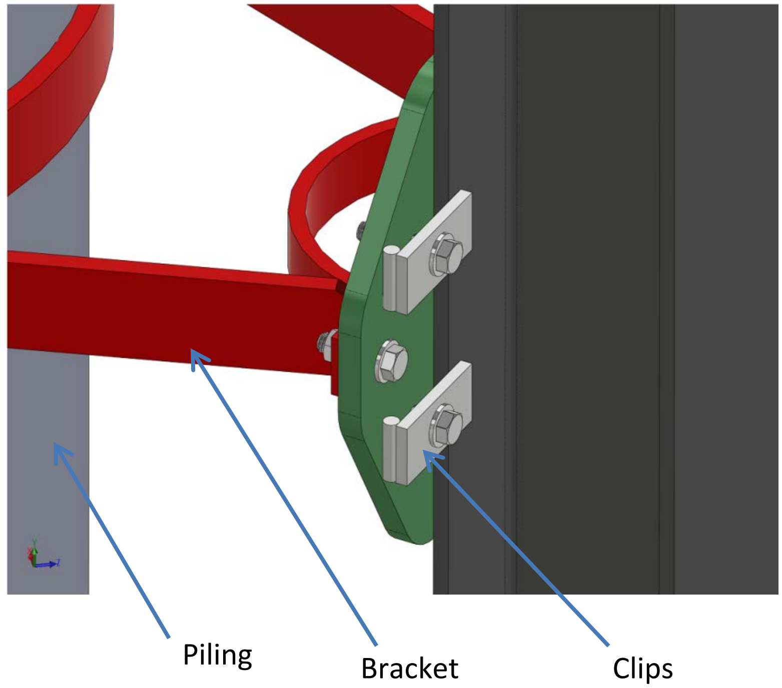
Step 2

The bracket A (top most) and bracket E (bottom most) will be installed before the I-beam is placed in the water. Bracket A will be secured in place prior to April 12th, and will serve as a reference point for the rest of the brackets and beam installation (See figure to the right). Bracket E will be installed (loose fit initially) by divers just above the sea floor. Note: Alternatively, Bracket E is installed after Step 3.



Step 3

The beam will be picked horizontally by the crane using a spreader bar with 3-4 sling points. Floats will be attached to the beam and then placed in the water. Once in the water the crane will reposition to attach to the top of the beam and lifted to the deck level. A worker standing aboard a vessel will secure the beam to the plate with clips already pre-attached to the plate. The beam will be made plum using bracket A as a guide. Bubble levels will be attached near bottom and top of the beam for reference.



Step 4

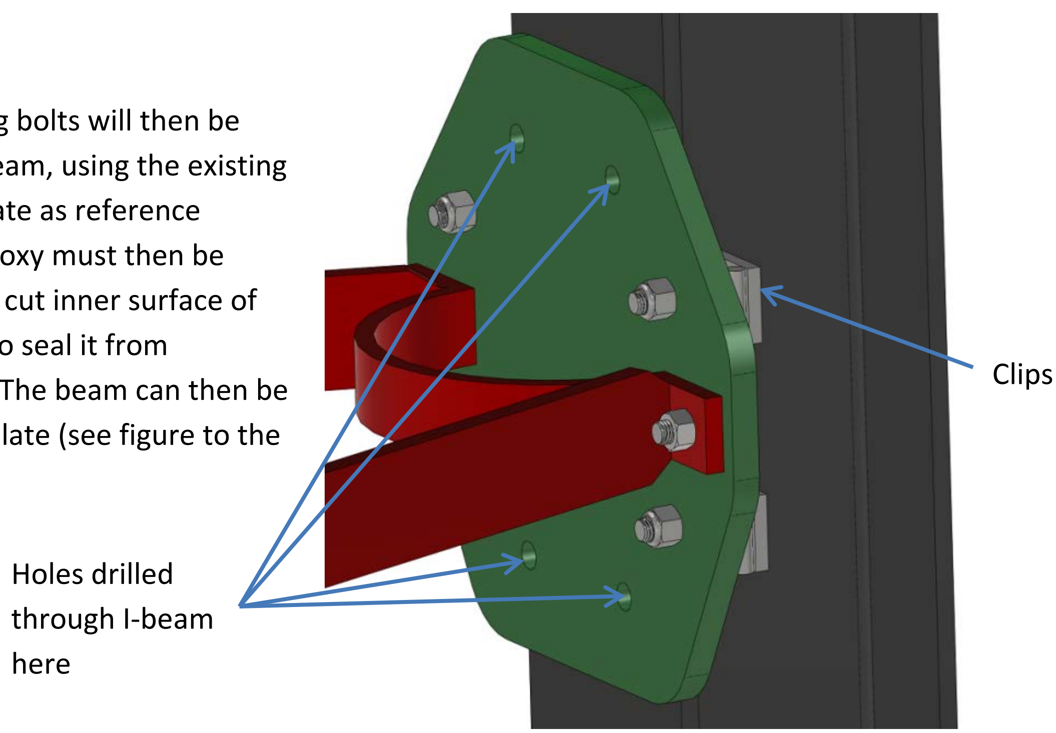
The beam will be secured to bracket E with clips by rotating the clips into the position shown and tightening the bolt to secure the clip. (See figure to the right).

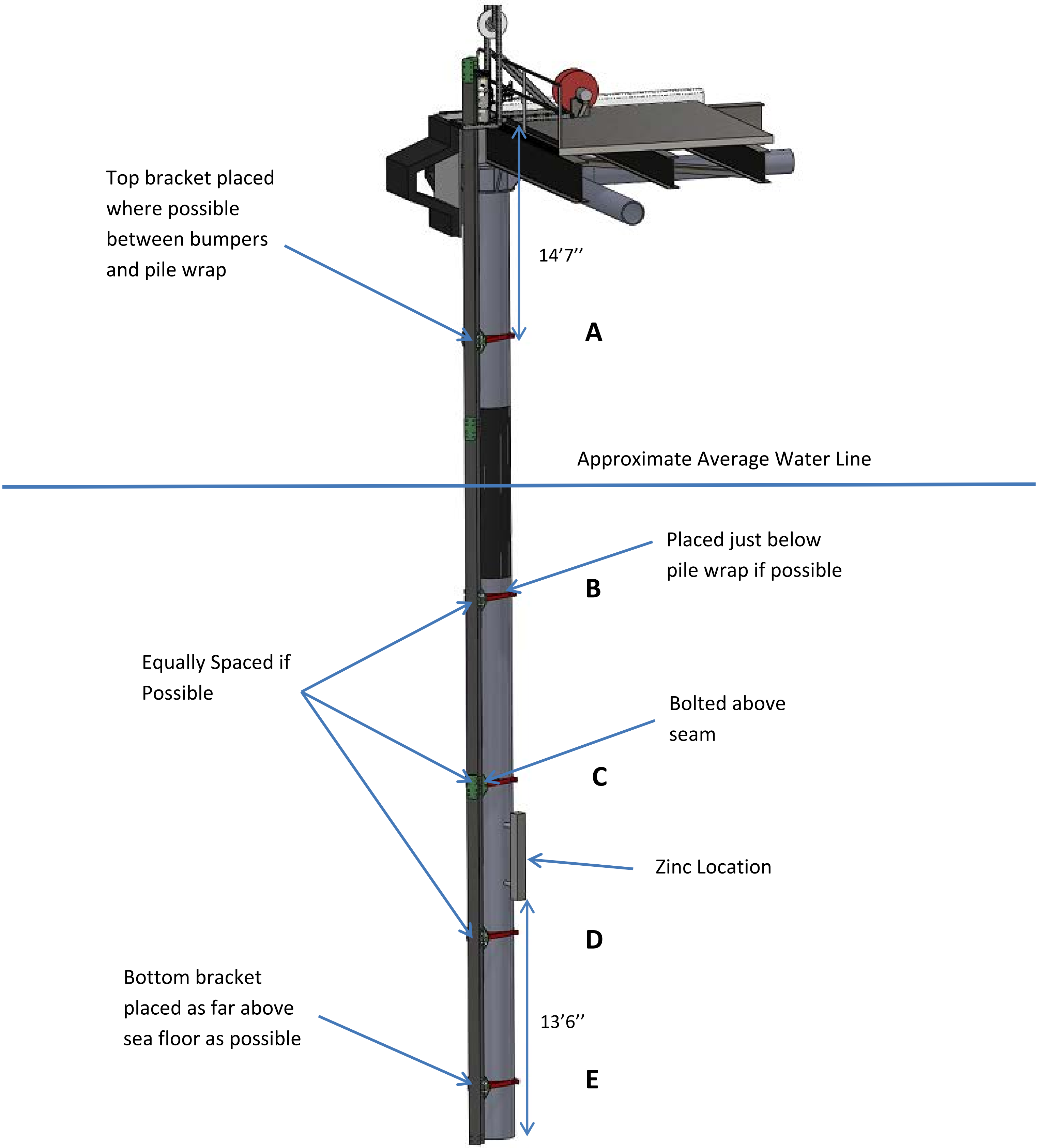
Step 5

The remaining brackets, B, C and D can be installed in any order. Clips (See next page) will be pre-installed on all bracket plates to allow in-water positioning of pile brackets by the divers.

Step 6

Holes for the remaining bolts will then be drilled through the I-beam, using the existing holes in the bracket plate as reference guides. Underwater epoxy must then be applied to the recently cut inner surface of the bolt hole in order to seal it from seawater penetration. The beam can then be bolted to the bracket plate (see figure to the right).





Top bracket placed where possible between bumpers and pile wrap
14'7''
A
Approximate Average Water Line
Placed just below pile wrap if possible
B
Equally Spaced if Possible
Bolted above seam
C
Zinc Location
D
Bottom bracket placed as far above sea floor as possible
13'6''
E

Appendix A

Table 1-A Bracket Location Details

Brackets	Distance above seafloor (approximate)	Notes
Deck	687in (57’3’’)	Defined as top of grating
A	539in (44’11’’)	Placed where possible above pile wrap
B	366in (30’6’’)	Placed just below pile wrap
C	252in (20’1-1/2’’)	Bolted above seam
D	139in (11’7’’)	Equally spaced
E	39in (3’3’’)	Placed as above seafloor for ease of installation

Table 2-A Hardware Details: Length, Quantity and Location Used

Type	Length	Quantity	Location Used
Screw*	2-1/4’’	58	FRP web plates and connection brackets
Nut*		90	All screws except those used for clips
Screw	2-3/4’’	24	Clips
Nylock		25	Clips
Screw	1-3/4’’	28	Outer FRP web plates

* All screws and nuts are 5/8-11, Loctite will be used on all non-lock nuts.

Pod Assembly/Disassembly

The following sections detail the process to remove and install the internal pod structure from the tube. This document was created by the previous Pier Portal team. Installation is nearly the reverse of disassembly with minor differences which will be addressed. Please see attached maintenance chart for specific component replacement procedures as needed.

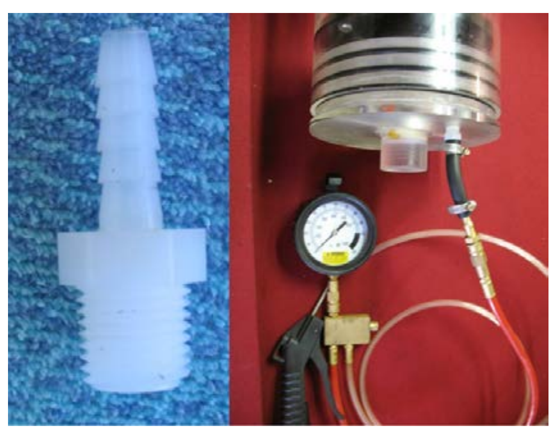
<u>Disassembly</u>

The following steps should be followed carefully to remove pod inner structure without damage.

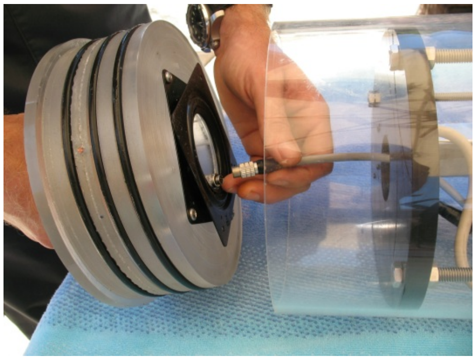
1. Place pod horizontally on floor or table on top of a towel or blanket.

2. Remove vent plug from lower cap using a 5/8" or 16mm wrench.

3. While an assistant holds the tube, firmly grasp the button on the lower cap and pull straight out. If pod has been sealed long enough for this to be overly difficult, thread a pipe tapped (1/4" pipe threads) plug with barbed nipple into the threaded vent hole into the lower cap and raise internal pod pressure to 5 - 10 psi or until the cap begins to move slowly.
   Caution: Do not let the cap come off quickly! Wires connect the lower cap to the structure and allow only 5 to 6 inches of extension.



4. Unscrew threaded wiring connection between internal structure and lower cap. Set the lower cap aside.



5. Rotate tube such that the motor and pinion are at the 6 o'clock position (straight down). Insert fingers into large hole in the lowest platform and pull straight out firmly and evenly until the pinion gear separates from the stationary gear at the top of the pod. While watching the cable in the upper chamber, continue pulling the structure with an even force until the lower chamber is out of the tube.
Caution: Cable in upper chamber can snag on upper light array. If this happens, push structure back in to release snag and rotate structure inside of the tube until the cable is safely oriented.

6. Unscrew threaded wiring connector between structure permanent harness and cable pigtail from the upper cap. Orient the cable so that it lies relatively straight.

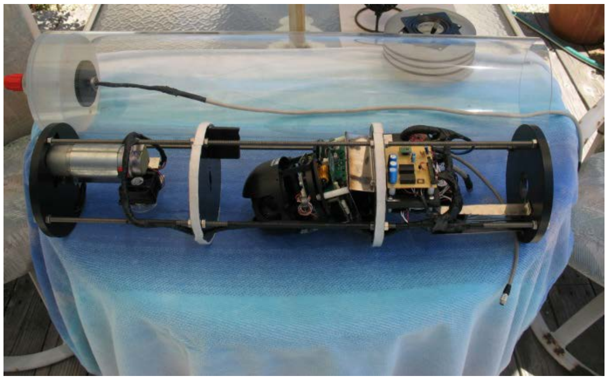
7. Ensuring the remaining portion of cable or its connector do not snag on the lower portion of the structure or any of the electronics therein, continue pulling the structure with a straight even force from the tube. Continue to watch for snags in the upper chamber also. Continue pulling the structure out of the tube until the camera chamber is roughly hallway exposed. Pull the harness connector through the access hole in the lower camera chamber platform and remove the cable from the routing block.

8. The structure will now slide freely from the tube. Ensure the cable does not wrap around the upper LED array or wire connections to the motor/encoder on its way out.
9. Perform inspections of parts as specified in the above maintenance chart, Table 13. Clean, lubricate, and replace parts as necessary. Table 13 suggests frequency, products, and procedures for all foreseen maintenance tasks.

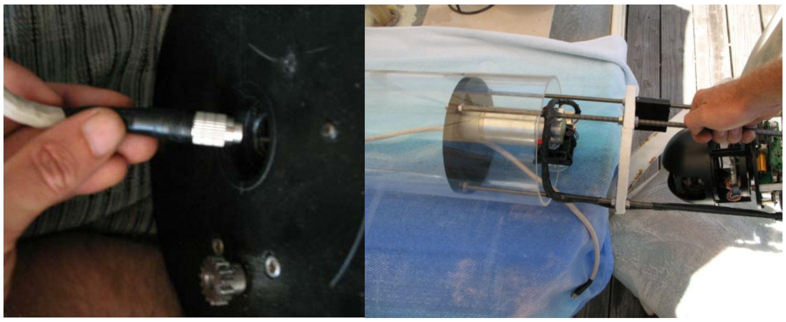
<u>Installation</u>

The following section describes the differences between disassembly and installation.

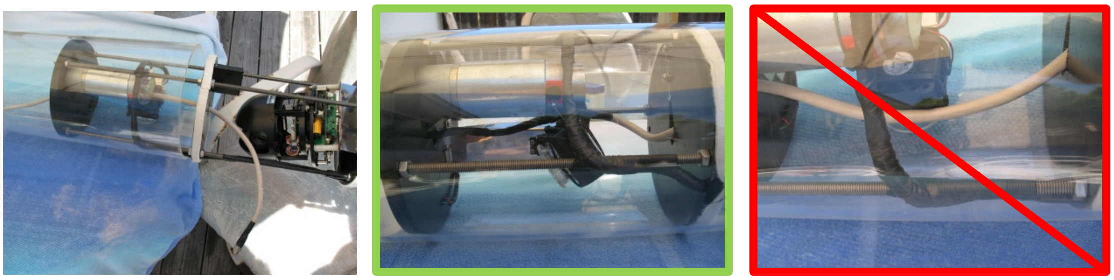
1. Orient the tube horizontally on floor or table on top of a towel or blanket with the magnet inset in the upper cap in the 12 o'clock position (straight up).



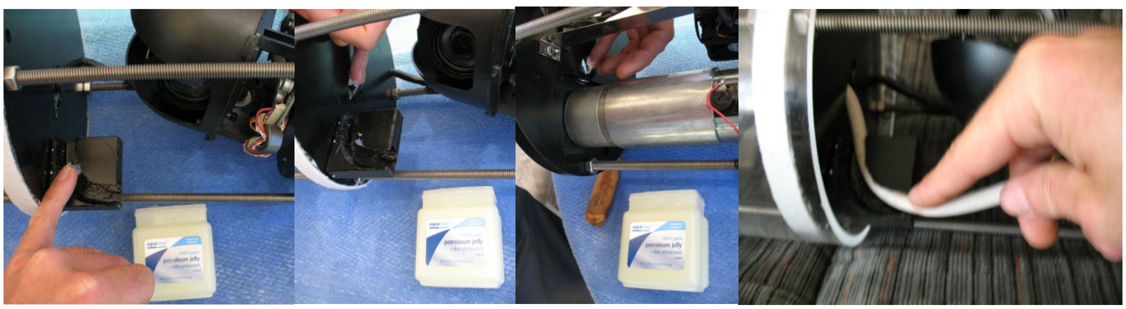
2. Thread the cable through the hole in the upper platform and insert upper platform into the tube. Orient the structure so that the motor is also in the 12 o'clock position.



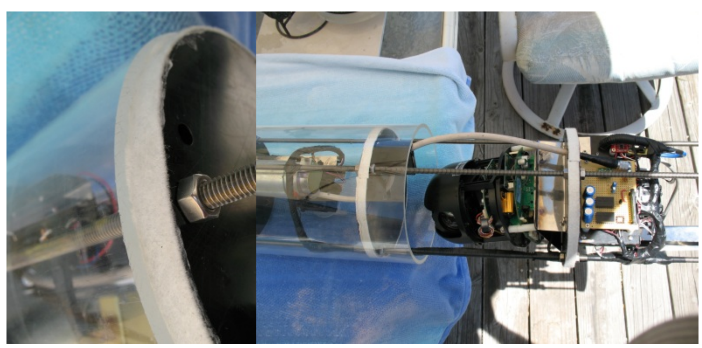
3. Thread cable between motor and the upper light array and through the central hole in the second platform. As the structure is inserted, the cable will attempt to come out of this position. Keep the cable in this position by always keeping the cable taut while pushing the structure into the tube.



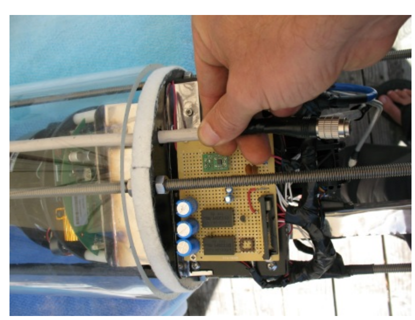
4. Ensuring that cable routing surfaces are well coated with Vasoline or equivalent, thread cable through upper camera chamber platform and around cable routing block.



5. Insert upper camera chamber platform slowly into tube, ensuring that felt does not snag or tear. Press the felt into the tube as necessary for insertion. If felt was just replaced, two sets of hands are useful for this.



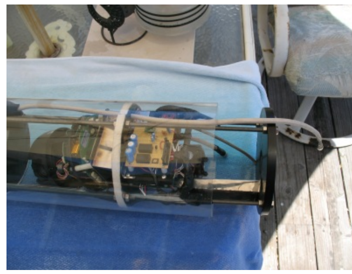
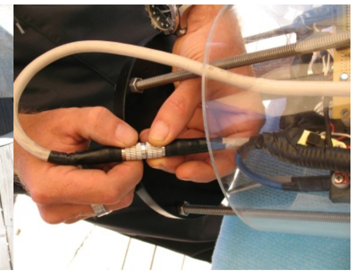
6. While pulling gently on the cable, push structure into tube until camera chamber is halfway exposed. Slowly pull all slack from cable, ensuring that the cable is not binding around upper LED array. Thread cable connector into lower chamber.
Caution: Do not pull directly on cable connector!



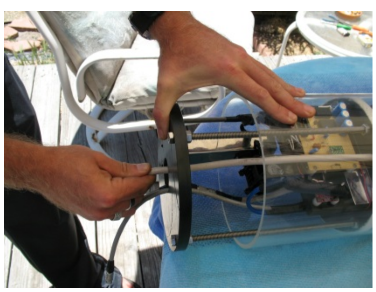
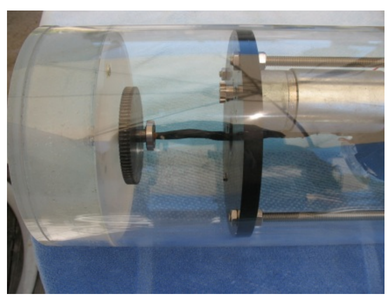
Instead, grasp cable body firmly.

7. Insert lower camera chamber platform slowly into tube, ensuring that felt does not snag or tear. Press the felt into the tube as necessary for insertion. If felt was just replaced, two sets of hands are useful for this. Continue to pull gently on the cable so that the cable is still routed between the motor and upper light array in the upper chamber.

8. Insert structure until lower chamber is roughly halfway exposed. Gently pull all slack from cable, again watching for snags in the upper chamber. The structure can be rotated 180° inside the tube to alleviate snagging or undesired friction points. Connect cable connector to permanent harness connector in lower chamber gently screw them together.

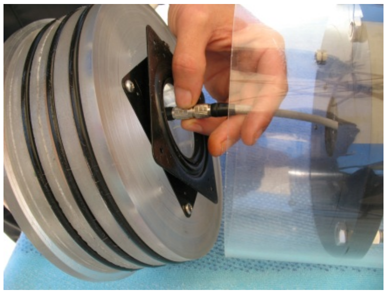
9. Thread small harness connection for lower cap assembly through large hole in lower platform. Then pull the main cable straight down (from the hole in the lower platform of the camera chamber) accessing the cable from the edge of the lower platform for as long as possible as the lower chamber is inserted into the tube. Further pulling can then be applied by reaching the main cable through the large access hole in the lower platform. Pull slack as needed to insert structure so that cable does not kink in between upper cap and structure. Insert structure in this fashion until gears are just shy of being coplanar.

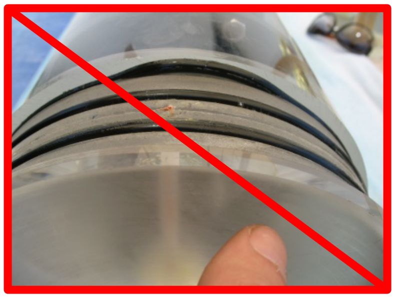




10. Ensure magnet (in upper cap) and motor are still oriented at 12 o'clock. Gently press structure into tube and rotate slightly as necessary to allow gears to mesh.

11. Push any portion of main cable exposed into the lower chamber and fish out the cable for the lower cap as necessary.

12. Ensure lower cap O-rings are in good condition and are well lubed with Moly lube or equivalent. Connect wiring connectors and thread them together gently. Insert cap slowly while pressing the O-rings into their lands as they enter the tube. If O-rings have just been replaced, this takes a lot of force.
Caution: Ensure O-rings do not bulge out and get pinched/torn as cap is pressed in.
Caution: Subconn wiring plug on top of pod is long and semi-fragile. Be careful with it when applying large forces to lower cap.





13. Remove old thread tape from vent plug and re-apply new thread tape. Insert plug and tighten with a 5/8” or 16mm wrench.