

MONTANA STATE UNIVERSITY

Department of Electrical and Computer Engineering

EELE 488R CAPSTONE: ELECTRICAL ENGINEERING DESIGN I

And

EMEC 489R CAPSTONE: MECHANICAL ENGINEERING DESIGN I

AUVSI ROBOSUB

By

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AUVSI Competition Submarine

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Executive Summary

The newest manifestation of Montana State University's Autonomous Underwater Vehicle team is Blue November, the second rendition of Sanka, a fully autonomous submarine built to take part in the 17th annual AUVSI/ONR RoboSub Competition held in July 2013 at Point Loma Naval Base in San Diego, California. Although many of the same design theories have survived since last year because they worked, the most recent rendition of the sub will feature an enhanced frame, electronics tube, new electronics rack, new pneumatics set-up, new torpedo set up, new camera location, and modified end cap design. Much time has also been spent creating a new software logic that is more accurate, more robust, will be easier to adapt to future models, and well documented. Focus was maintained on modularity and previous modularity was enhanced in the new design which will allow for future upgrades and the replacement of failed parts. This ideal can also be seen in the easy, flexible build process requiring very little tooling which allows assembly without the need for much more than a hex key. Although most of the mechanical and electrical components were largely developed by their respective undergraduate students, it was crucial to have crossover members who could integrate into both fields to stimulate and foster communication between teams, ensuring neither side was surprised by the other at the end of the semester and that the final product would come together smoothly. This was done by advisor Dr. Todd Kaiser, through proper team communication, and through good inter-team relations.

Introduction

Every year since 1997 the Association for Unmanned Vehicles International (AUVSI) and the U.S. Office of Naval Research (ONR) have partnered together to host an international RoboSub competition in San Diego. This July, as it has in the three years previous, MSU will again partake in this competition with funding coming from the Naval Sea Systems Command (NAVSEA) – Keyport out of Washington. Last year over 30 teams participated originating from all over the world. Students from places like Florida, Utah, Virginia, France, Canada, China, and India all converged on SPAWAR System Center – Pacific's TRANDEC research pool at the Naval Base Point Loma to prove that they could build a fully autonomous submarine that could correctly navigate an obstacle course, racking up the highest number of points by completing as many tasks as possible within the 20 minute time limit. While the competition is the same for every team, each school has a different amount of funding and sponsorship involvement. MSU is fortunate enough to build on a budget of \$20,000, which has historically been quite sufficient to prepare for many of the tasks that are to be faced. The difference in funding also spawns a variety in approaches from cheaply ingenious to richly sophisticated technologies.

According to AUVSI and ONR, the goal of this competition is to “advance the development of Autonomous Underwater Vehicles (AUV’s) by challenging a new generation of engineers to perform realistic missions in an underwater environment.” There is also hope that young engineers will develop interest in and ties with organizations that develop these AUV technologies. While every team is eager to secure one of the four cash prizes for top contenders, the competition itself finds many of the mariners talking candidly about their designs, accepting critiques, offering suggestions, and, in the worst-case scenarios, trading parts and tools.

Project Needs

The purpose of this project was to come up with a renovated design of the current Autonomous Underwater Vehicle (AUV) as well as upgrade the existing design so that both designs will be capable of competing in the Association for Unmanned Vehicle Systems International (AUVSI) competition held July, 2013.

Problem Definition

The primary objective of the AUV design project was to complete a series of tasks completely autonomously through the use of a variety of sensors, with no interaction or communication with any persons or external computers. During the execution of mission objectives, the AUV must be able to recover from any navigation and computing errors that may occur. The design of the AUV must prevent sensitive electrical components from contacting the water and have an easily accessible kill switch for use in the event of an uncontrollable error. Systems that include power, computer processing, sensors, and propulsion must be safely incorporated into the AUV and calibrated to maximize AUV efficiency and task completion. All parts of the submarine must submerge and remain submerged for the duration of the competition run.

Project Requirements

The following Level 1 requirements of rendition were derived from the rules provided for the previous year’s competition in addition to the priorities voiced by the project sponsor, Mike Kapus and the project advisor, Dr. Todd Kaiser:

- The vessel must comply with all size, weight, buoyancy, and safety requirements of the competition.
- The entire vessel must be modular for future expandability and relatively lightweight while being able to protect the fragile components within
- The Vessel must be able to go to a depth and maintain that depth
- The Vessel must be able to recognize a color and track a line
- The vessel must be able to navigate through the competition start gate and complete at least one competition task
- The vessel must have proper reference documents and other documentation for easy repairs and troubleshooting

AUVSI RoboSub Iterations

This is currently the fourth year of designing, building, and competing in the NAVSEA AUVSI Competition. Each successive design has been built on the previous year’s design by prioritizing the areas with the largest room for improvement. This has led to a steady improvement in the design and

sub functionality from year to year with an end goal of having a fully functional sub which is actively competing at the international competition each year. As the sub currently being designed is based on the previous ones built; proper documentation of mechanical designs, electrical architecture and software development of past subs has been crucial. However the past years have not made these documents easily accessible. A portion of the current team's work has been compiling past documentation and condensing them into easily accessible folders. The following figures show the improvement made year to year and added complexity of the RoboSub designs.

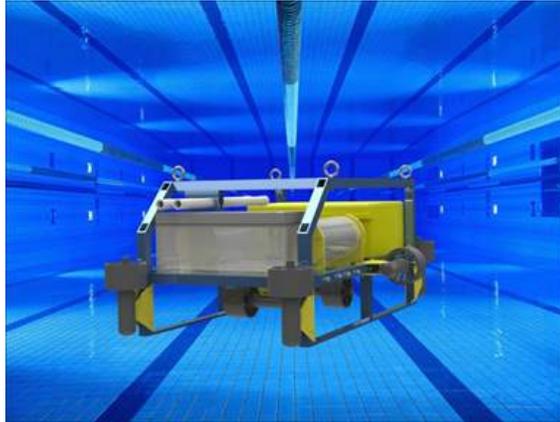


Figure 1: The first design created by a MSU competition team in 2010.

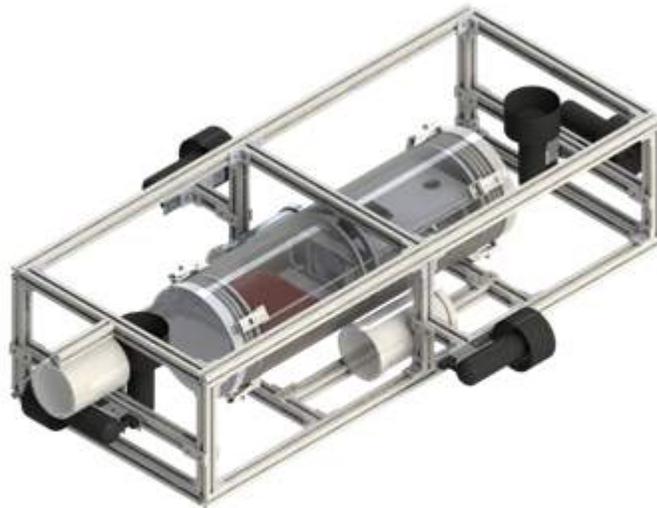


Figure 2: The second iteration design completed in 2011.

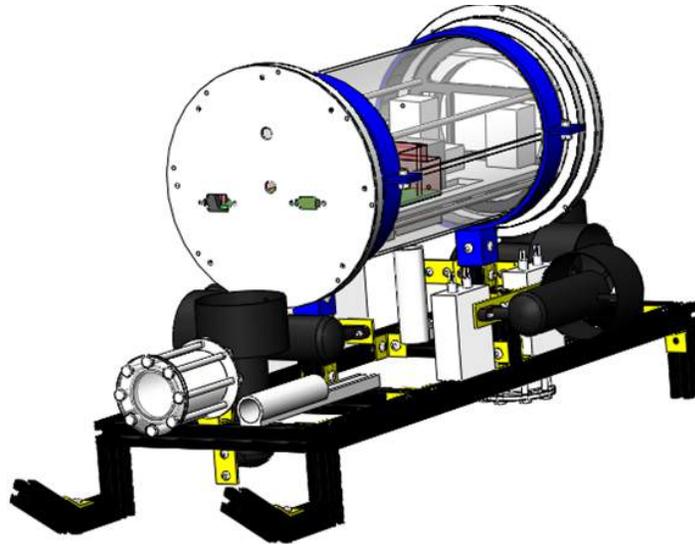


Figure 3: The design completed in 2012 codenamed SANKA.

The major areas of improvement in the 2013-2014 RoboSub, codenamed BLUE NOVEMBER, have been improved frame, end cap, heat dissipation, and camera placement as well as a simplified pneumatic system and computer/electrical architecture. The 2012-2013 RoboSub, SANKA, will from a low mechanical level, be very similar to the Blue November sub design while housing identical electrical hardware. This allows us to have two mechanically functioning subs giving us the flexibility to troubleshoot both potential future mechanical problems and future electrical issues simultaneously. If only one sub was available and a leak is discovered with Blue November, it will have to be taken out of the pool which would halt testing of programs being written for the tasks. Instead, the mechanical issues can be solved and Sanka can then be used to continue testing the modified task programming.

Mechanical Design

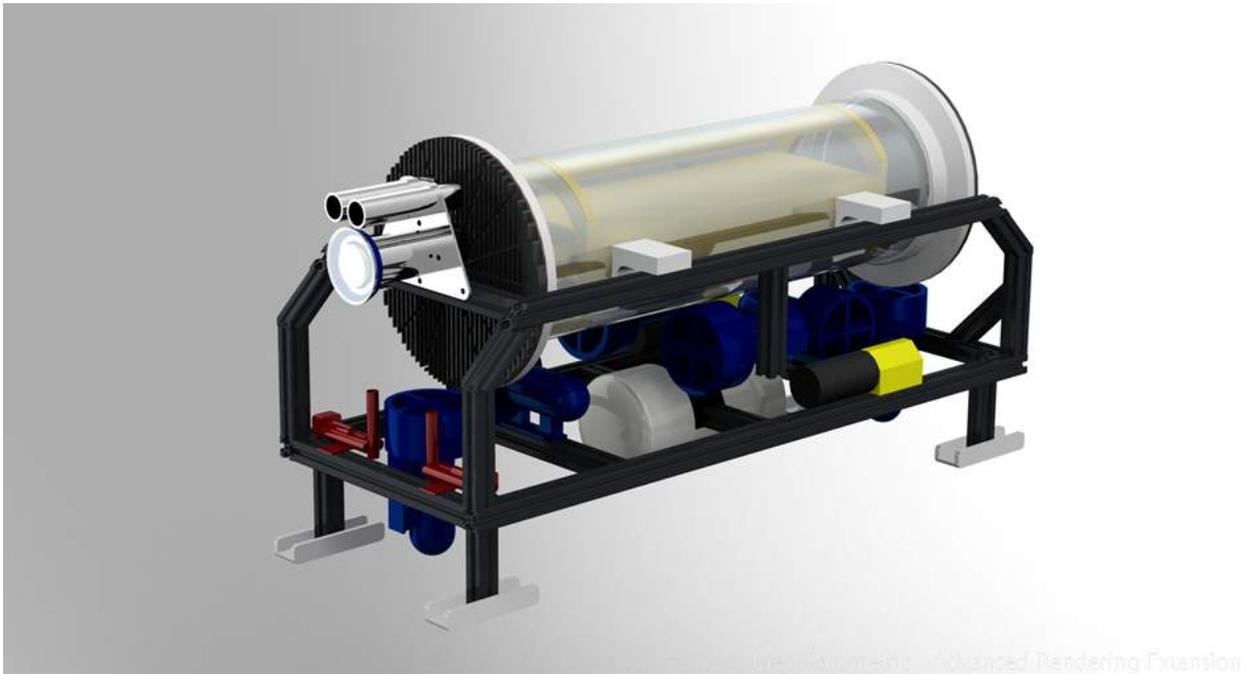


Figure 4: The full assembly design of this year's team codenamed BLUE NOVEMBER.

Sanka, the submarine from the previous year, had a very solid mechanical design. This year's team decided very early in the design process to not change the overall design in a major way. The Blue November design team has selected several areas of Sanka which require the most improvement but will not affect the mechanical soundness. Sanka's pneumatic system, end cap design, frame design, and placement of the front camera and torpedo launchers were designated as the redesign areas. The design process and the final selected assemblies of each of these are discussed in detail below. Each individual component which will be used in the final assembly has an individual part drawing which can be found in Appendix B and enforced with calculations found in Appendix E.

External Pneumatic System

A functioning pneumatic system is critical for several of the competition tasks. To complete these tasks there are two mechanical systems which require pressurized CO₂ to operate. To save weight only one CO₂ tank is used with T-junctions and solenoid valves to control the pressure burst and direct the CO₂ to the two systems. Sanka's design team housed the pneumatic system internally in the main chassis tube with unneeded tubing between each junction. This extra tubing and internally housed system, shown in fig. 5, complicated accessing the electronics rack, required extra holes drilled into the main chassis tube, and further filled an already packed tube.

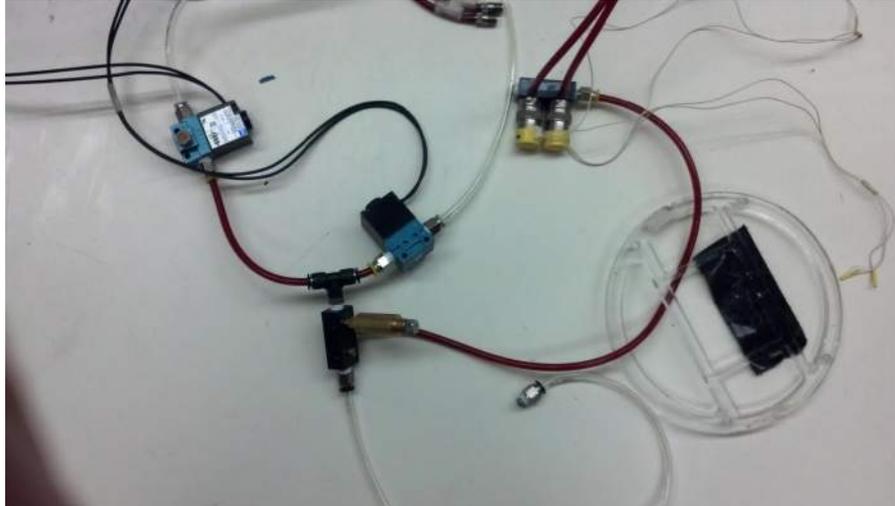


Figure 5: Sanka's pneumatic system laid out to demonstrate extra tubing.

With these problems in mind a new pneumatic system was designed. First the system was decided to be kept externally which would free space and allow for less holes to be drilled into the end cap, lessening the chance of leaking which will damage the critical and expensive electronic boards. It was also decided to house the system in its own pressure vessel to offset the weight of the pneumatic system as well keep the system dry for operation. Finally the T-Junctions were simplified and compacted to cut the extra tubing that was used in the previous design.

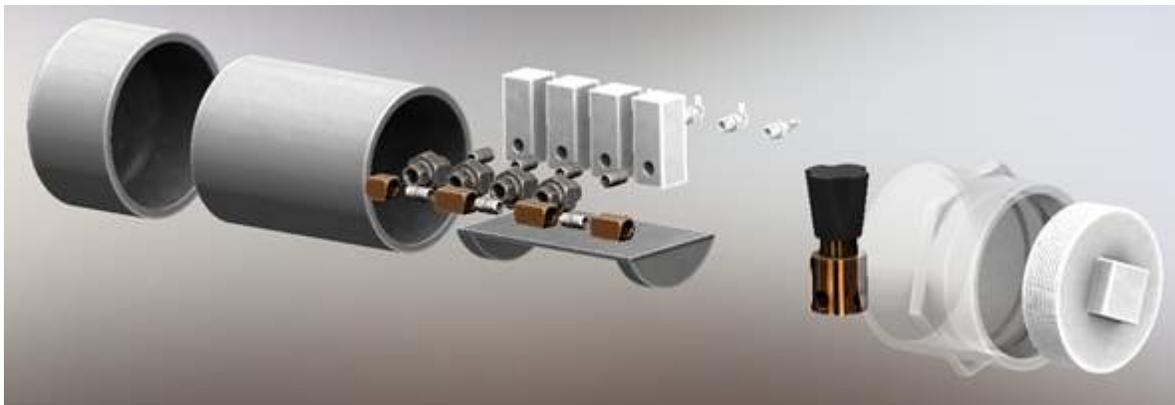


Figure 6: An exploded view of the newly designed pneumatic system.

The new design, in fig. 6 above, requires one CO2 tank which connects to a check valve which regulates the pressure to 100 psi and can handle pressures up to 3000 psi. The check valve feeds the pressure into a four-junction system with four exits. Each exit is controlled by an in-line solenoid valve which will allow flow to the two torpedoes and the two droppers. Each solenoid valve operates on a 12 V input. The pneumatic system will be housed in PVC piping with a solid end cap on one end and a threaded cap on the other.

End Cap Design

Two parts of the end cap have been changed from the previous year's design. The seal between the end cap and the flange attached to the main chassis tube, the thickness and shape of the end cap, and the clamping device for the rear end cap have been redesigned for Blue November. These changes are discussed in detail below.

Heat Fins & Gasket

The Sanka team had used a flat and solid aluminum, 2 inch thick plate, and O-rings between the end cap and chassis tube to seal the main chassis tube. During initial testing of Sanka it was noticed that the internal temperature of the sub was climbing dangerously close to the 50 degrees Celsius mark which is the maximum temperature the voltage controller board can operate at. A thermal analysis of the sub was also completed and showed that 52.5 degrees Celsius was the point when the internal temperature would reach equilibrium with a pool environment at a temperature of 32 degrees Celsius. To combat this, two design changes were completed. First, the chassis tube was lengthened and pneumatic system removed to allow for a larger volume of air that needs to be heated. Second, heat fins will be added on the front end cap to increase heat dissipation as well as a larger internal CPU fan to keep the air well mixed.

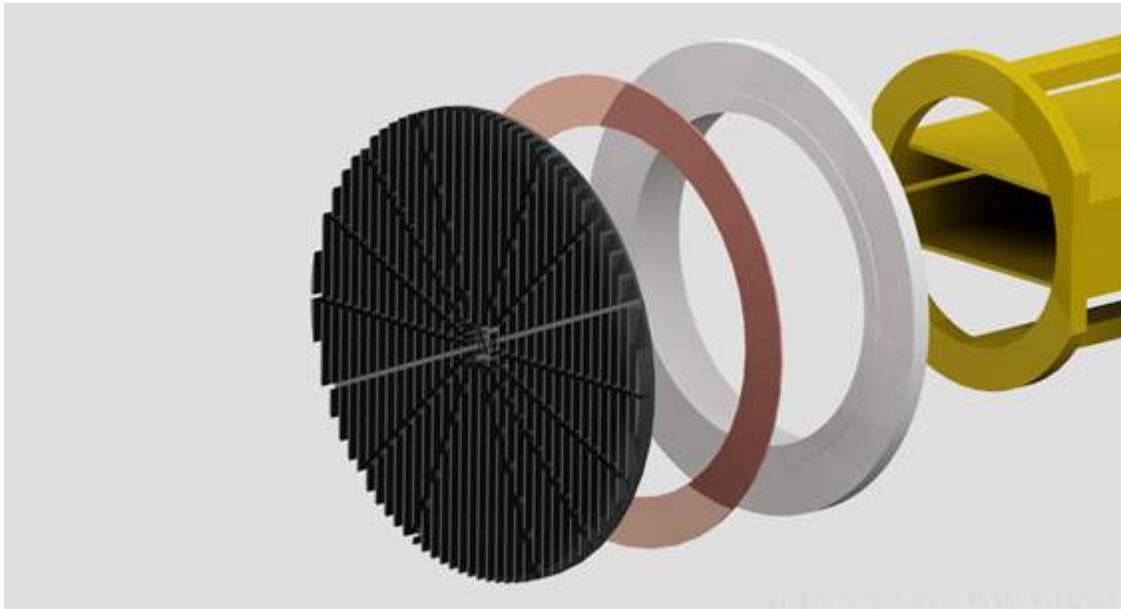


Figure 7: An exploded view showing the newly designed heat fins and gasket seal.

As well as changing the end cap the O-rings are being replaced. During first semester testing of Sanka, the O-rings which were used to seal the tube often popped out and were difficult to deal with. This discouraged the group from removing the end cap which is required to access the electronics rack. The sub also had small amounts of leaking which was attributed to the O-rings not being placed perfectly in their grooves. To simplify the design a gasket has been chosen to replace the O-rings.

Toggle Clamp

One end cap needs to be removed so that the electronic boards can be removed and worked on. The Sanka design had 8 screws on the outer diameter of the end cap which were required to be unscrewed, then screwed back in each time the electronics needed to be checked or worked on. This required time and effort, which in a competition setting, could prove to be costly. The Blue November design is to use four toggle clamps shown in fig. 8 below. This design was chosen for ease of use factor as well as quick access to the electronics.



Figure 8: A part model of the toggle clamps which will be used to secure the end cap.

Frame Design

The frame on Sanka did not have any easy places which allowed for the sub to be picked up and moved around outside of the pool. It also had two large steel rings which allowed for the chassis tube to be attached to the frame. Blue November has changed both of these. First the frame has been extended to mid-level of the submarine to allow for easy picking up by hand to move it to and from the pool. Second the chassis tube will be attached to the frame by four PVC mounts with a strong plastic to plastic adhesive. These PVC mounts will then be bolted on to the frame. This will cut the weight that was previously created by the large steel rings. An analysis of the strength required for the mounts if the sub was dropped from four feet has been done and is shown in the calculations appendix.



Figure 9: An assembly drawing showing the raised frame design and the PVC mounts.

Camera Placement & Torpedo Launcher Placement

The camera and torpedo launchers were placed on the top part of the submarine in the Sanka design. This could cause problems when trying to hit required targets because it is not in-line with the center of the submarine. Blue November has camera and torpedo launchers placed in-line with the center of the sub.

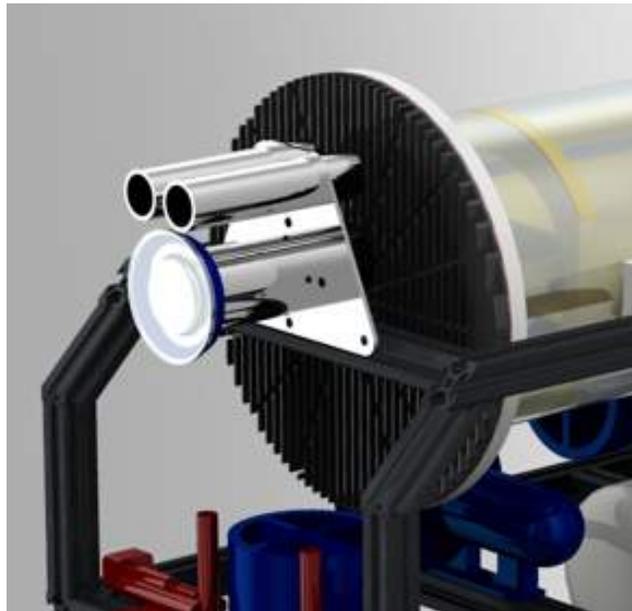


Figure 10: A close up view of the inline mounted cameras and torpedo launchers.

Electronic Rack

The electronics rack needs to hold 8 controller boards, 2 sensor boards, a full computer and various switches and power strips. All of these components have pins and connections which need to be periodically adjusted, checked for loose connections, or re-wired. The Sanka electronics rack was bolted together and each board was bolted the chassis rack. Four pins which were parallel along the length of

the rack were used to keep the spacing. To work on individual boards all four pins needed to be unscrewed and the entire assembly needed to be taken apart. The electronics were not easily accessed and the connection pins could not be checked. For ease of access a new rack, termed a “Clamshell” design, was created. This design will be capable of being flipped open by having a hinged side which allows quick checking of electrical components.



Figure 11: An open view of the Clamshell electronic rack which will be used in Blue November.

RAIL MOUNTS	CHASIS TO FRAME INTERFACE	TENSILE YEILDING/SHEAR FRACTURE	POOR HANDLING	CHASSIS TUBE	TOP LEVEL ASSEMBLY	VISIBLE STRAIN OR FRACTURE	5
THRUSTER	MOVEMENT	NO PROP MOVEMENT	BAD WIRING OR DIRECT SHOCK TO THRUSTER BODY	NONE	MISSION PROGRAMING	TESTING	4
FEET	SYSTEM PROTECTION	TENSILE YEILDING/SHEAR FRACTURE	POOR HANDLING	COMPONENT ASSEMBLIES	PNUEMATICS SYSTEM	VISIBLE STRAIN OR FRACTURE	2
CAMERA	VISION	LOSS OF VISION	POOR WIRING, LEAKING, SHOCK IMPULSE	NONE	MISSION PROGRAMING	LOSS OF VISUAL FEED	4
ELECTRONIC SLED HINGE AND LOCK	LOCKS SLED	BENDING / SHEAR FAILURE	POOR HANDLING	NONE	NONE	STANDARD USE	1
DROPPER TUBE	HOLDS DROPPER	BRITTLE FRACTURE	POOR HANDLING	NONE	MISSION PROGRAMING	VISUAL FRACTURE	3
PNUEMATIC ACTUATORS	RELEASES DROPPERS	LOSS OF AIR PRESSURE	FAILURE PNUEMATIC LINE	PNUEMATIC SYSTEM	MISSION PROGRAMING	TESTING	3
SOLENIOD VALVES	FIRES TORPEDOES AND RELEASES DROPPERS	NO RELEASE OF CO2 FOR PNUEMATIC FUNCTIONS	ELECTRICAL POWER LOSS OR BAD VALVE	PNEUMATIC VALVE RACK	PNUEMATICS SYSTEM	TESTING	3
BATTERY	POWER SUPPLY	DISCONNECTION OF BATTERY	POOR MOUNTING	ALL	TOP LEVEL ASSEMBLY	LOSS OF VISUAL DISPLAY	4
INTERNAL FAN	FORCE CONVECTION COOLING	FAILS TO CIRCULATE AIR	POOR ELECTRICAL CONNECTION	CHASSIS TUBE	MAIN ELECTRONIC SYSTEM	TEMPERATURE SENSOR	4

Bill of Materials

Item No	Description	Supplier	Unit Cost	Units	Total Cost
	PRESSURE VESSEL				
8585K48	8" OD PC Tube	McMaster-Carr	\$40.51	2	\$81.02

9246K64	12"x36"x1/2" Al Sheet	McMaster-Carr	\$105.57	1	\$105.57
9246K83	12"x12"x1 1/2" Al Sheet	McMaster-Carr	\$114.58	2	\$229.16
8740K39	1 1/2"x2"x12" Type I PVC	McMaster-Carr	\$26.51	2	\$53.02
5135A33	500lb U-Bolt Right Angle Toggle Clamps	McMaster-Carr	\$35.97	8	\$287.76
47065T147	1" Double Al T-Slot Fastener (pc 4)	McMaster-Carr	\$4.29	1	\$4.29
				Sub-Total	\$760.82
	BATTERY CHASSIS				
4880K76	2" Un-threaded PVC Coupler	McMaster-Carr	\$1.07	4	\$4.28
4880K847	2" Un-threaded PVC Plug	McMaster-Carr	\$1.93	4	\$7.72
48925K96	2"x5' PVC Pipe	McMaster-Carr	\$9.42	1	\$9.42
47065T142	1" Single Al T-Slot Fastener (pc 4)	McMaster-Carr	\$2.30	1	\$2.30
				Sub-Total	\$23.72
	FRAME				
47065T101	1"x48" Extruded Al T-Slot	McMaster-Carr	\$14.20	6	\$85.20
47065T186	6" 90deg Al Brace	McMaster-Carr	\$15.67	2	\$31.34
98015K18	12"x12"x1/8" Al Sheet	McMaster-Carr	\$28.34	1	\$28.34
47065T147	1" Double Al T-Slot Fastener (pc 4)	McMaster-Carr	\$4.29	3	\$12.87
8733K65	1 1/2"x1"x24" Nylon	McMaster-Carr	\$9.85	2	\$19.70
47065T142	1" Single Al T-Slot Fastener (pc 4)	McMaster-Carr	\$2.30	11	\$25.30
47065T223	90deg Extruded Al T-Slot Bracket	McMaster-Carr	\$3.98	40	\$159.20
				Sub-Total	\$361.95
	EE CHASSIS				
89015K28	12"x24"x1/8" Al Sheet	McMaster-Carr	\$48.17	2	\$96.34

87025K125	12"x24"x1/2" Type II PVC	McMaster-Carr	\$59.72	1	\$59.72
9542K322	1/2"x3/4"x36" UHMW	McMaster-Carr	\$9.24	6	\$55.44
1658A17	1 1/4"x12" Stainless Piano Hinge	McMaster-Carr	\$8.59	1	\$8.59
1889A34	300 Series Stainless Latch	McMaster-Carr	\$4.89	2	\$9.78
92185A542	1/4"-20x1 " Stainless Cap Screw (pc 10)	McMaster-Carr	\$4.08	1	\$4.08
90585A540	1/4"-20x3/4 " Stainless Flat Head Cap Screw (pc 10)	McMaster-Carr	\$4.57	2	\$9.14
90910A735	#6-32x1/2" Stainless Button Head Torx Screw (pc25)	McMaster-Carr	\$8.76	1	\$8.76
				Sub-Total	\$251.94
	PNEUMATIC CHASSIS				
3811T11	Brass High-PSI Regulator	McMaster-Carr	\$270.98	1	\$270.98
7877K25	Pneumatic Solenoid Valve	McMaster-Carr	\$30.07	4	\$120.28
4464K483	1/8" Stainless Union	McMaster-Carr	\$13.57	4	\$54.28
2684K14	1/8" Male x 1/8" Female 90deg Elbow	McMaster-Carr	\$13.65	1	\$13.65
50785K321	1/8" Female x Male x Female Brass-T	McMaster-Carr	\$3.34	3	\$10.02
4830K111	1/8"x3/4" Threaded Pipe Stainless	McMaster-Carr	\$1.32	7	\$9.24
4880K58	4" PVC Cap Un-threaded	McMaster-Carr	\$5.70	1	\$5.70
48925K98	4"x5' PVC Pipe	McMaster-Carr	\$27.01	1	\$27.01
4880K88	4" Unthreaded x NPT	McMaster-Carr	\$5.18	1	\$5.18
2389K81	4" NPT Plug	McMaster-Carr	\$5.23	1	\$5.23
1487T1	1/8" PVC Tubing (25ft)	McMaster-Carr	\$8.75	1	\$8.75
5463K485	1/8" Tube-to-1/8"Male 90deg Elbow	McMaster-Carr	\$6.05	4	\$24.20
				Sub-Total	\$555.22
				Total	\$1953.69

List of Tools

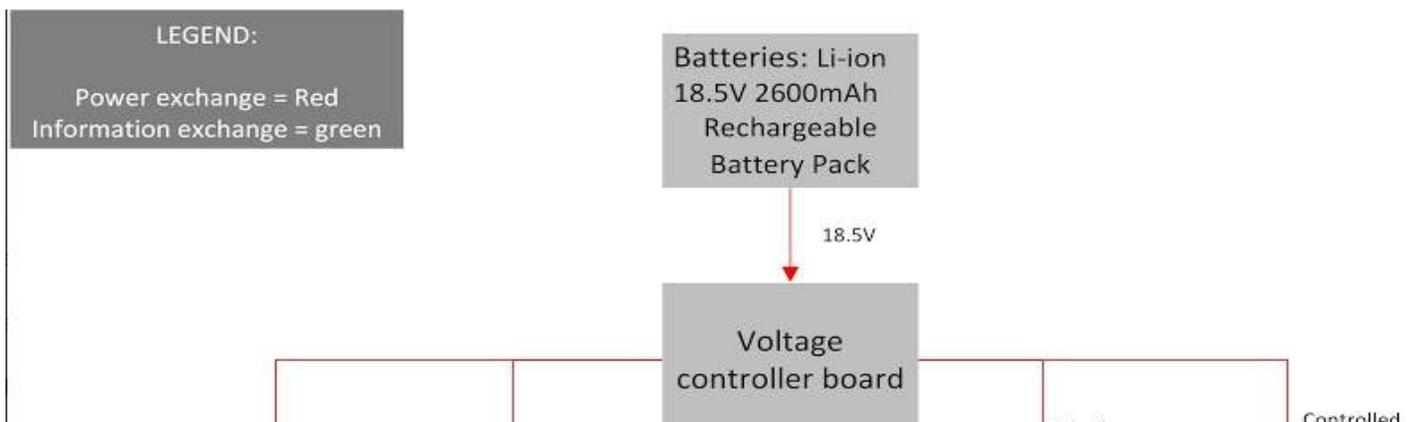
The following list is a summary of the tools that will be required to complete the majority of operations required to build Blue November.

- T10 Torque Bit
- 5/32" Hex Bit
- Vertical Mill
- 1/2" End Mill
- 1/4" End Mill
- Rotary Table
- Counter Sink Bit
- Counter Bore Bit
- 1/4" Drill Bit
- Band Saw
- 1/4"-20 Tap
- #6-32 Tap

Electrical Hardware Design

The electrical hardware of the old sub was quite sufficient. The electrical hardware was designed based on the implementation of a full motherboard system. There are many reasons a full motherboard system was chosen over a single microchip based implementation. The full motherboard allows for real time monitoring of the system along with allowing software changes without having to upload and re-upload code to a microchip. The motherboard also allows for greater modularity of parts as well as easy upgrades and changes to the system. A few changes were made to the electrical hardware but on the whole, the hardware was kept the same as the design that was done last year because the design worked and functioned well. There were still many modifications made to the current electronic layout, the future electronic layout, and the documentation of the electronics all of which were absent in the Sanka iteration of the sub. The following subsections will introduce the electrical systems in full and how they work.

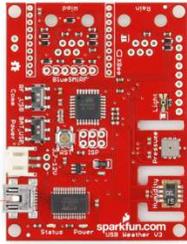
The Electrical Block Diagram



In understanding the electrical system of the sub, the first step is to gain a basic understanding of how the general parts interface. The above block diagram does just that. It introduces all of the necessary parts in generality and how they are interconnected. The block diagram is based on the current implementations of the electronics in the Sanka sub which are known to function and work as intended. This diagram is an overview of the general parts necessary to make the sub function. In the Blue November implementation, this block diagram will hold, although the specific electrical components may change.

Internal Electrical Wiring with Component Pictures

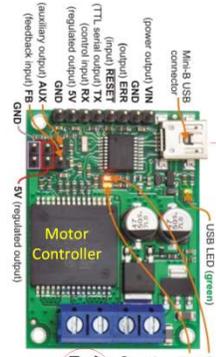
USB Weather 2.0 Onboard/internal temperature, pressure, humidity sensor



To mobo usb



Connected to its board and then from the board to a mobo usb



6 pairs of these, each one goes to its respective motor outside on the sub chassis

A motor outputs B

A motor outputs A

6 pairs of these go to top connector on voltage relay and ground

6 of these come out, to a usb hub powered by the batteries and then

To Cameras



3 pin fan connector wire for cpu heat sink fan

Bottom right 2 pins to pwr button on mobo

Parallel hookup of pin 5,6,7,10 to hard drive and hot and ground of power

24pin to 24 pin

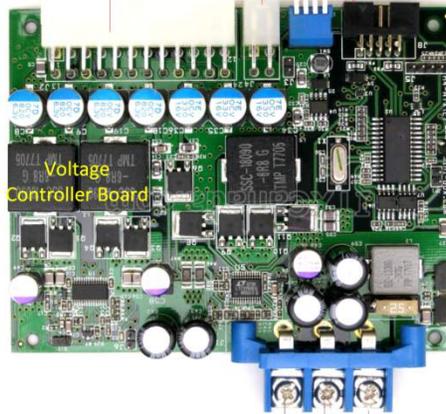
4 pin to 4 pin

Top 5 pins to usb # 2

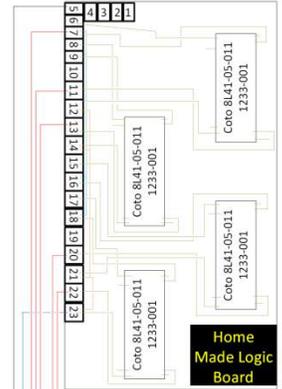


To pin A0 on arduino mega

External Pressure Sensor



Ground, 5 volt power (red), and 12 volt power (yellow)



Home Made Logic Board



Capacitor

Relay switch

Kill switch

Kill switch

Voltage Power Strips

Ground

+5 volts

+12 volts

+14 volts

To usb hub

To two led strips

Power from batteries

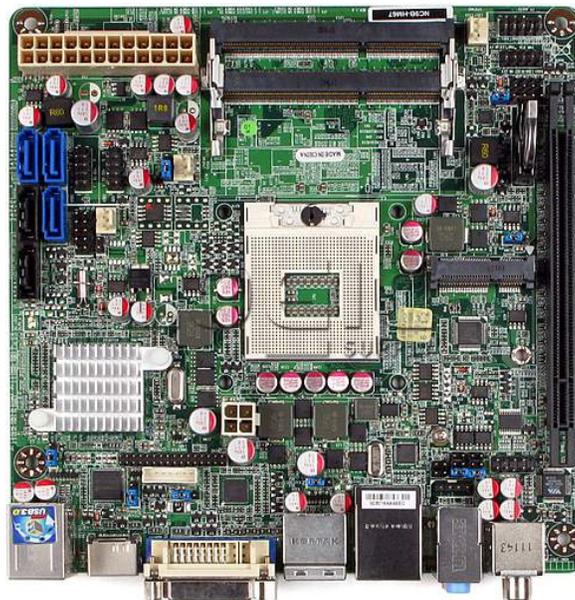
Figure 12: A wiring diagram for the current electronics in Sanka.

The above diagram is how the Sanka iteration is currently wired. All of the wires are shown and where each one goes to on its specific component. The purpose of this document is to give knowledge of the current wiring in case any wiring problems arise. With this document, a person should be able to hook up the electrical components of the sub from scratch.

Individual Components Currently Installed on the Sanka Sub

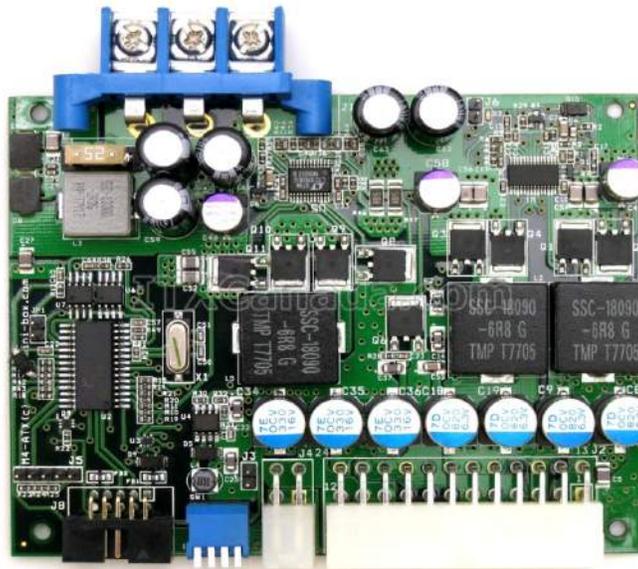
The following sections discuss in detail each of the individual electronic components which will be used to operate Blue November. The electronics will be replicated from the previous design so that the programming can be refined for the current architecture.

Motherboard



The Motherboard is the main hub of the electronics, it is what runs all of the other electronics except for the voltage controller board. The current motherboard aboard Sanka is the nc9b-hm67-mini-itx-motherboard. The specific information needed on this motherboard is available in Appendix D. This motherboard gives us the platform which allows us to use existing free software to develop multitasking and multiple interfacing tools to run the sub. It sufficiently interfaces all of the components and does most of the major computing necessary to run the sub and allow for autonomous operation.

Voltage Controller Board

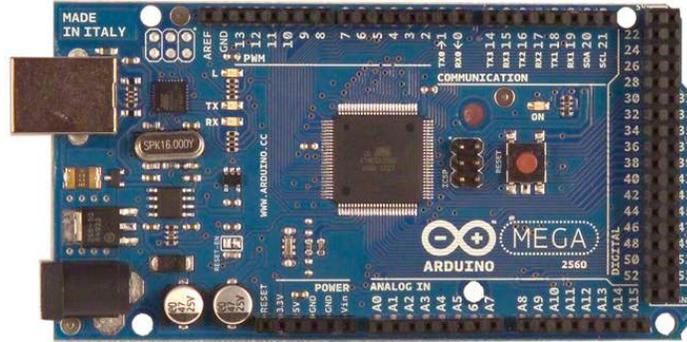


The voltage controller board is what routes electrical power from the batteries to the entire system. The data sheet can be found in appendix D. The current voltage controller board on Sanka is the M4-ATX board. This board has outputs to a 5, 12, and battery level available. The tolerances and voltage levels can be changed using the hardware monitor for the board. This board is included because it allows specific voltage outputs that are necessary to power the other electrical components on the sub. It also allows the sub to power on and off safely as well as acting as a surge protector for the rest of the electrical components. It effectively controls and monitors power input from the batteries and properly distributes it to the rest of the electrical components. One useful thing that was noticed but never seen in the data sheet was the blinking LED in the middle of the board when power is applied. The following chart shows the functions of the led light.

Table 1: A guide for interpreting the meaning of the led lights in the submarine.

LED	Status
Light is blinking slowly	not enough power is being applied to the board
light is blinking rapidly	proper power level is applied to the board, board is booting up
solid green light	board is on and functioning properly

Microcontroller Board



The microcontroller interfaces the pneumatics and the pressure sensor to the motherboard. It allows the motherboard to communicate and control the pneumatics and the pressure sensor. The microcontroller in Sanka is the arduino mega 2560 and the full data sheet can be found in appendix D. The microcontroller allows for external control and part modularity because it runs its own program and interface that can be changed to adapt to specific parts. It currently overlooks and controls the pneumatics and pressure sensor and then reports back to the motherboard.

Power Capacitor



The power capacitor allows for stable power delivery from the batteries to the voltage controller board. If there is a sudden power drop from the batteries, the capacitor can provide power for a short time while the batteries stabilize their power output. The capacitor also allows for proper shutdown of the system. When the batteries are shut off, the voltage controller realizes it but still needs power for a short time in order to properly shut down the motherboard and components. The capacitor gives the power necessary to do this. However, this is a substantial amount of power which is why the capacitor is so large (10000 micro farads in Sanka).

Pressure Sensor



The pressure sensor in Sanka is a p51 media sensor pressure sensor and allows the sub to know what depth it is at. It interfaces with the arduino microcontroller which takes the raw data and turns it into a useful depth reading. It is molded into the end cap so that it is in direct contact with the surrounding water. Without the pressure sensor, the sub would not be able to control or maintain a depth.

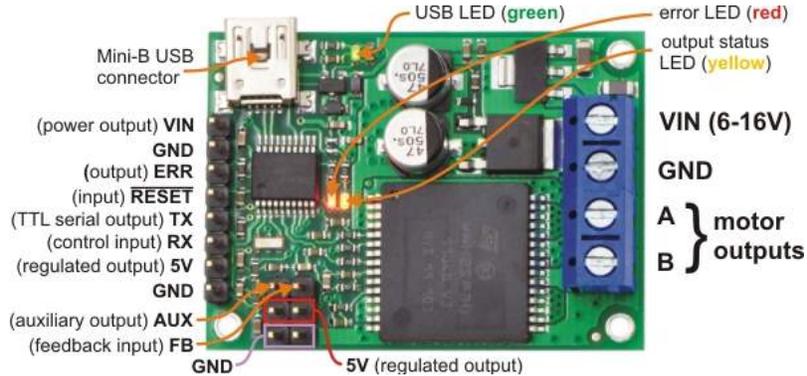
Inertial Measurement Unit



The IMU is an electrical component which allows the sub to know its location in three dimensional space. It records acceleration and orientation in three dimensional space. Currently, Sanka employs a digital compass GEDC-6 IMU unit. The unit is not currently used in the software design but when integrated, it will allow the sub to realize itself in three dimensional space and react accordingly. The IMU gives the sub the information it needs to follow a heading without visual help.

Internal Pressure and Temperature Sensor

Motor Controller



The motor controller is the interface between the motherboard and the motor thrusters that move the sub. There are six motor controllers, one for each engine that are connected to an usb hub and then to the motherboard. The motor controllers are also connected directly to the 12 volt power strip. The CPU and motherboard then interface with the motor controllers which then turn the motor thrusters on and off to control the subs movement. The motor controllers are pololu-jrk-12V motor controllers and the data sheets can be found in the appendix D.

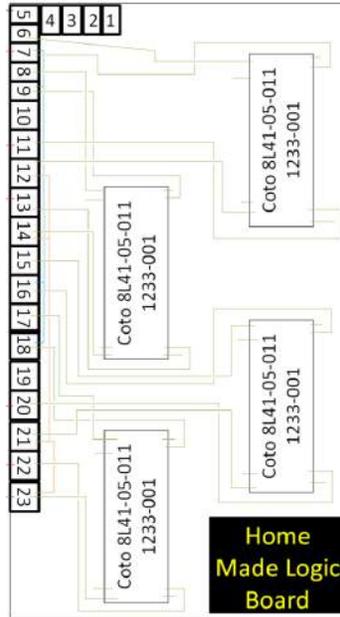
Motor Thrusters



Sanka is controlled by six SeaBotix-BTD-150 motor thrusters. These motor thrusters allow Sanka to control itself and move around in three dimensions in the water. Two of the thrusters are pointed

horizontally side to side, two vertically and two from front to back. These thrusters are essential to the function of the sub and are connected to the motor controllers which control when they turn on and off.

Home Made Logic Board



The homemade logic board allows the arduino to power the pneumatics. This board interfaces with the pneumatics and the arduino and serves as a switching board to each of the four pneumatic valves using relays. The data sheet for each of the relays can be found in appendix D.

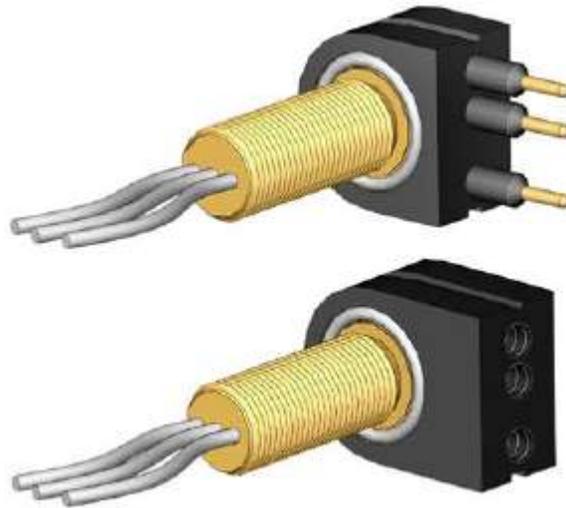
Cameras



The Sanka uses two external cameras that connect to the motherboard using the USB 3.0 ports. The top camera is a Flea3 that is housed in a waterproof case. The bottom camera is a Microsoft HD life cam studio camera. These cameras allow the sub to control itself based on its surroundings using a visual interface. The cameras can be used to find colors and accurately shoot torpedoes. These cameras allow Sanka to find and complete missions, and are essential to the sub.

All of these components interface with each other to make Sanka functional and able to carry out its purpose. These components must be able to interface flawlessly with each other in order for the sub to properly function. Without the electrical components, the sub would just be a useless chassis.

Wet Connects



The above picture shows the wet connects that will be used in the Blue November version of the submarine. The existing wet connects in Sanka have been having some problems with leaking during the pool tests. This has been due to their design which requires both sides of the connector to be screwed down tightly to keep the water out of the electronics vessel. The problem is that when unplugging the external connectors, their external seals must be unscrewed causing the actual wet connects in the end cap to loosen. This is also a consequence of the connectors plugging in perpendicular to the end cap.

The new wet connects will correct these issues by having the connectors plug in parallel to the end cap, and having no external sheath to screw down. This will make new connections faster and eliminate the torquing that loosened the older wet connects and keep water from ever leaking onto the electronics.

Experimental Power Draw

An experimental max power draw test was executed and it was found that the sub could draw a maximum of 6.2 amps at 14.4 volts which meant that it could draw a continuous 89.28 watts of power. This meant that at maximum power draw, the batteries were guaranteed to last at least an hour. This was considered sufficient as the sub only needed to last about a half hour for its run at the competition.

Experimental Temperature Test

In order to accurately model how hot the internals the sub would get under the worst possible conditions, we performed a worst case scenario test in the Sanka sub. This test involved running the CPU at maximum load and turning on all the engines, while having the sub sealed as if it were to be

submerged. This setup allows us to find the maximum temperature the sub could ever reach. This temperature would never be reached realistically for a few reasons. First is that when the sub is submerged, the contact with the water will remove some of the heat away from the sub. Second is that the sub will never actually be run at this kind of load, since the operating load is never this high. We will design our new sub around these constraints to make sure we will never run into a thermal issue.

Sanka Quick Reference Component List

Name	Technical Name	Product ID	Do we have a data sheet for it? Yes/No
Batteries	Tenergy Li-ion 18.5V 2600mAh Rechargeable Battery Pack	31941	No
Voltage Controller Board	M4-ATX 6V-30V DC-DC Converter	PWR-M4-ATX	Yes
Motherboard	nc9b-hm67-mobile-mini-itx-motherboard	127D160T001088	Yes
External Pressure Sensor	SENSOR 50PSI 5/8" 7/16-20 UNF 5V	Digi key P51-50-A-A-136-5V-000-000	yes
Capacitor	type 381 LX 1038 Capacitor 35WV 10000uf	381LX103M035J452	yes
Memory	crucial 2.5 inch solid state drive 128 Gb	N/A	Yes
7 port usb hub	plugable usb 2.0 7 port plug	N/A	no
Micro controller board	Arduino Mega 2560	N/A	Yes
Motor Controllers	pololu jrkl2v12 usb motor controller	N/A	Yes
Internal pressure, temp, humidity	Usb weather 2.0 board by sparkfun	N/A	Yes
Motors and Thruster	Seabotix thrusters BTD150	N/A	Yes
Top Camera	Flea3 Color USB 3.0 Camera	FL3-U3-1352C-CS	no
	GEDC-6 Starter Kit Plus (include GEDC-6 AHRS, NDS-1 Dev Kit & RM-1 Adapter Kit)	GEDC-6	Yes
IMU + IMU board			
pneumatic 3 way valve	3-Way Elec. Valve, N-C, Manifold Mount, Wire Leads, 12 VDC	N/A	yes
Mac 3 way valve	mac 12VDC 6 Watts vac to 150psi	111B-550BAAA	No
kill switches			
logic board			
relay switch	tyco electronics TE Connectivity 1432772-1	1432772-1	yes

Sanka Electrical Purchased Components

Order Date	Arrive Date	Name	Qty.	Order #	Part ID	Price	Shipping	Other Info
10-25-2012	10-30-2012	<u>Jetway</u> Motherboard	× 1	N/A	127D160T001 088	\$159.99	\$6.98	Newegg
		M4-ATX 6V-30V DC-DC	× 1	N/A	PWR-M4-ATX	\$89.50	\$9.45	Mini-box
		Intel Core i5 Mobile CPU	× 1	N/A	2L231089A46 88	\$249.99	\$0.00	Newegg
11-14-2012	11-20-2012	<u>Tenergy</u> TB6AC4 Four-Channel	× 1	36912 7	1429	\$199.99	\$11.55	all-battery.com
	11-26-2012	<u>Tenergy</u> Li-ion 18.5V 2600mAh Rechargeable	×12	36913 2	31941	\$649.68	\$12.16	all-battery.com
		<u>Duracell</u> <u>Procell</u> AAA	× 1	102- 21753	CF-YQ7Y-3PXX	\$11.25	\$7.24	Amazon
		<u>Duracell</u> <u>Procell</u> AA	× 1	52- 34362	QH-LBY9-ZUUO	\$11.70		
11-29-2012	12-5-2012	Flea3 Color USB 3.0	× 1	N/A	FL3-U3-13S2C-CS	\$695.00	N/A	Edmund-optics.co
	N/A	<u>Theia</u> SY110M Wide Angle, Low	× 1	N/A	N/A	\$248.00	N/A	
	N/A	USB 3.0 Cable. Male A	× 1	N/A	N/A	\$10.00	N/A	Newegg
12-03-2012	N/A	GEDC-6 Starter Kit Plus (include GEDC-6	× 1	N/A	GEDC-6	\$1,500.00	N/A	TheDigital - Compass.com

Sanka Electrical Budget

Component	Cost
Computer	\$700
Motherboard	200
CPU	250
RAM	50
PSU (x2 for backup)	200
Sensors	\$2050
IMU	2000
USB Pressure Sensor	50
Cameras	\$1800
Power	\$1000
Batteries	750
Charger	250
Travel (2 people, 5 days)	\$2350
Flights	1000
Hotel	650
Food	500
Admin Supplies	200
Total	\$7900
Budget	\$9800
Surplus	\$1900

Blue November Budget

CPU	Intel Core i3 4130T	\$140
Motherboard	ASRock B85M-ITX	\$80
Memory	Crucial Ballistix Tactical Tracer 8GB 1600MHZ	\$110
SSD	Samsung 840 Evo 120GB	\$100
Power Supply	M4-ATX-HV 250w	\$90
OS	Windows 7 Enterprise	\$150
CPU Cooler	Noctua NH-L9I	\$50

Total
\$720

Electrical Software Design

Software Introduction

This section introduces the software that is used to develop and run the current version of the RoboSub. This foundation of software will be built upon and improved for the next iteration of the submarine.

The RoboSub uses the Microsoft Robotics Development Studio (MRDS). The main motivation for choosing this was to help provide structure and organization to the complex software required for an autonomous robot. It is built on the C# language and programmed best with Visual Studio. It helps to skim the first four chapters of the book "Professional Microsoft Robotics Developer Studio" which can be found in hard copy in the senior design lab, or in PDF form in the Capstone 2012-2013\Electrical : Software\Books folder.

This studio handles all of the necessary multi-threading so that as a programmer you can concentrate on writing the subroutines, and not have to worry about how everything is going to be able to run simultaneously. The portion of MRDS that handles this is called the Concurrency Coordination Runtime (CCR)

MRDS is built on top of the .NET framework, and uses the C# language. Each "class" file as it is called in Java is referred to as a "service" in MRDS. All code is written and compiled using Visual Studio, but to organize how the services interact, a utility which is part of MRDS called the DSS Manifest Editor is used.

DSS stands for Distributed Software Services, and is the second major portion of MRDS. This allows the processing to occur on multiple cores, or even multiple computers across a network! This multi-processor feature is not necessary for our application, but it is an inseparable part of MRDS.

Notice that there are XML comments within each service. These are necessary, as the DSS Manifest Editor is actually just a way to edit the XML manifests that tell the services how to interact.

A key part of the interactions between the different services is the C# concept of "Subscribing." One object will publish an event, which other objects subscribe to. This way, an object only needs to pay attention to its own concerns, and will respond appropriately only when certain events happen. See chapter 11 in the Head First C# book for a more detailed explanation. This book can be found in PDF format in the Capstone 2012-2013\Electrical : Software\Books folder.

Along with the C# code, two additional pieces of software that the RoboSub relies upon for operation are RoboRealm and Arduino code.

The Arduino microprocessor acts as a way for the computer's USB interface to communicate with the depth pressure sensor and the pneumatic valves. The arduino code is comprised of only one file which can be viewed and edited in the Arduino environment, which is open-source.

The RoboRealm program is the final piece of the necessary software, and it's used as to processes raw images sent from the camera via USB 3.0. After processing the image to identify the location and shape of objects, this information is sent to the C# code via a TCP socket.

RoboRealm is the only third-party program in the RoboSub which must be purchased (Other than VisualStudio which is free to students.) We will keep using RoboRealm as it provides solid visual processing for us.

Getting Started using the RoboSub Software

This section will guide the first-time user through everything they need to know to operate the RoboSub with its current programming.

We begin assuming that the hardware is correctly connected and the batteries are fully charged. First, power on the RoboSub by flipping up the two switches on the end cap to turn on the machine. There will be a delay of around 10 seconds as the power system charges up, then the sub should respond by turning on the blue and gold LED lights.

Manual control:

In order to control the RoboSub, you will be connecting an Ethernet cable to the RoboSub. This cable is attached to a spool that is connected to a wireless router. Power on the router. Power up the laptop and start Windows 8 using the following password, taking note of the zero and the exclamation point.

Password: R0bosub!

Click on the Remote Desktop button in the taskbar to access the RoboSub's computer, using the same password as for the laptop.

Once the RoboSub desktop appears, start the RoboRealm program by clicking on the icon of a checkerboard in the taskbar. In the RoboRealm program, click the "Camera" button near the bottom of the window. You can turn off image processing by unclicking the "**Run**" button near the top of the window, which will allow you to view the raw images from the camera.

Now double click the "Start RoboSub" shortcut on the desktop. You will have four windows open: RoboRealm, the dashboard, console window, and depth chart.

Locate the depth control on the dashboard.

With the RoboSub floating on the surface of the water, click the calibrate button to calibrate the depth sensor.

You may now play around with the various manual controls, using the RoboRealm preview window of the front camera to see where you are going.

If you want to use the keyboard for movement control, click the "**Enable**" button. The up, down, left, and right arrow keys control forward, backward, turn left, and turn right respectively. The comma and period keys, respectively, are strafe left and right. Keyboard control will revert to dashboard control after a couple minutes. Simply click the "**Enable**" button again to resume.

Autonomous mode:

By selecting the "Wait and then Start" mission from the mission planner on the RoboSub dashboard, you will have 60s to disconnect the Ethernet cable and place the sub in the water. Unfortunately, all this currently does is cause the sub to dive to 4ft and swim forward for a few seconds and then stop.

The other missions in the mission planner drop-down menu are unfinished, and are the focus of future development and testing.

RoboRealm vision program:

This program allows us to obtain and filter data from the two cameras. The various filters being applied to the current camera are listed in the box below the video. They are listed in the order they are being applied, which can be critically important, as a blob filter should be applied after a color filter when looking for items of a single color.

Additional filters that may be applied are listed in the box to the left of the preview, and may be added to the current camera by clicking the “**Add**” button at the bottom of the window. Any of the filters applied to the camera may have their parameters changed by clicking on the filter name, then clicking the “**Edit**” button.

In order to view the unfiltered visuals from the camera, unclick the “**Run**” button near the top of the RoboRealm window. This will stop all filters from running and show the raw camera data.

To switch between the forward and down cameras, click the “**Options**” button near the “**Run**” button. Then select between the cameras using the drop down box.

NDS-1 IMU GUI program:

This program, accessed by clicking on the button that looks like an aircraft gauge in the taskbar, will give a convenient display of all the current IMU data. It will also output the data stream to a CSV file, if desired.

Do not leave this program running while running the RoboSub service, otherwise the RoboSub console will display an error in connecting to the IMU.

If any problems connecting to the IMU are encountered, refer to Appendix A for troubleshooting help.

Hardware Monitor:

There is also a hardware monitoring program, which can be opened via its desktop shortcut. This will allow you to see the current temperatures inside the CPU chip, as well as the temperature on the board. This is useful for design and troubleshooting, but is not necessary for the proper control of the RoboSub.

Browser interface:

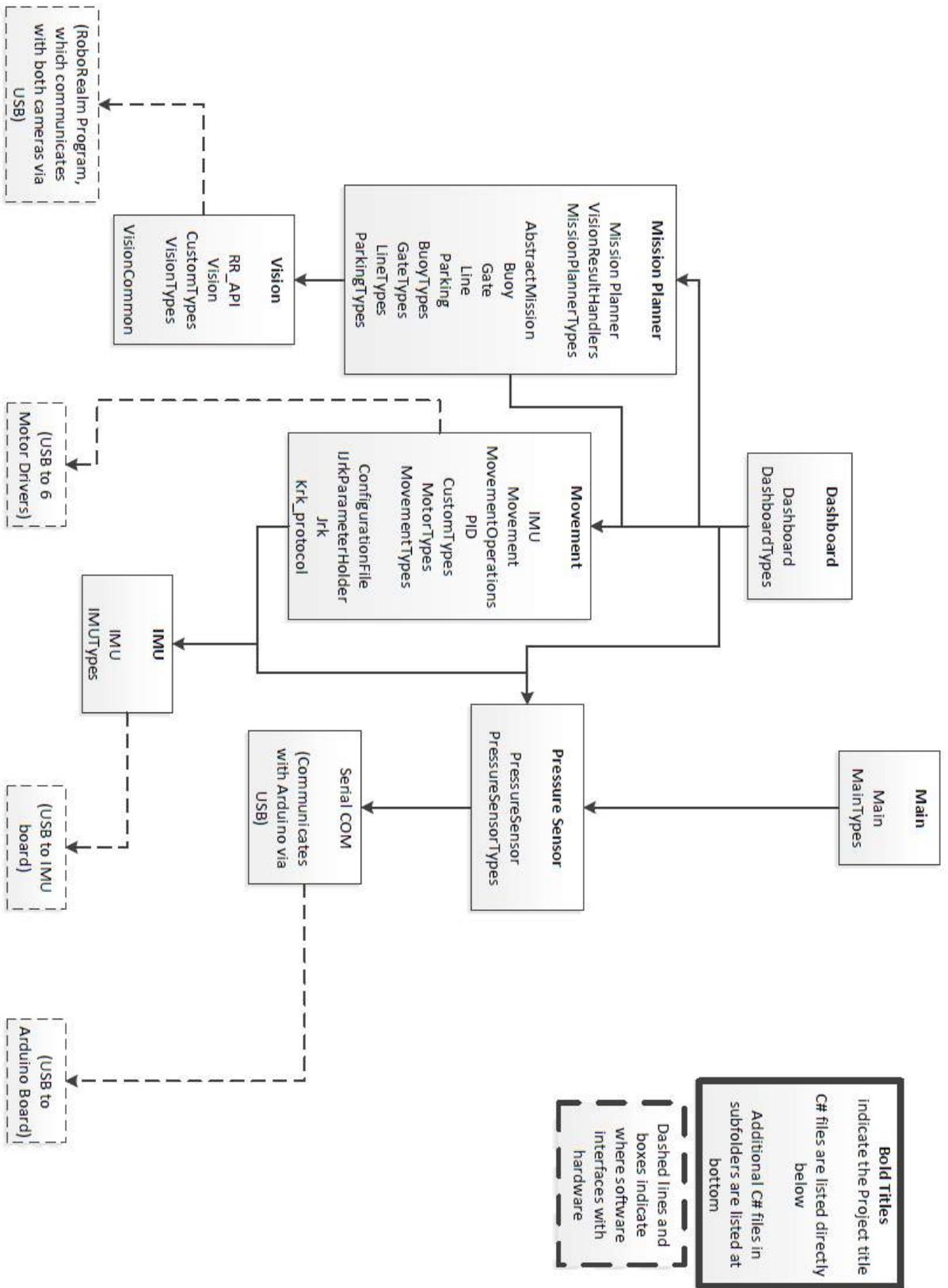
Since MRDS is set to use TCP socket number 50000 to communicate within the computer, it is possible to access information about the services while they are running via a web browser.

Open Chrome and type “localhost:50000” into the URL bar. You will now see several menus that can be used to access each of the RoboSub's services and peripherals.

Using the bench power supply:

You may also use one of the battery-charging cables with banana plugs to power the sub from a 14V DC bench power supply. Only one cable is needed, as the second battery is simply used to extend the working life of the RoboSub.

Software Block Diagram



The software block diagram is shown on the previous page.

This solid lines and boxes in the diagram display how the various project files are arranged within the DSS Manifest Editor, showing the relationship between each block of programming.

For instance, the Mission Planner project directly relies on both the Vision and Movement projects, and the Movement relies on the Pressure Sensor and IMU, while the Dashboard controls access the Mission Planner, Movement, and Pressure Sensor projects.

Dashed lines and blocks show where the software communicates with other programs (such as RoboRealm) or with the hardware.

Looking at the C# Software up close

Viewing the code:

Start Microsoft Visual Studio Professional 2012 and open the solution file by going to:

File > Recent Projects and Solutions > Main.sln

If no recent solutions exist, then you can find the file in

C:\Users\robocorp\Microsoft Robotics Dev Studio 4\Projects\RDSrobosub\Main

Be aware that there are two separate Visual Studio solutions for the RoboSub. The first is **Main.sln**, and the second is **Dashboard.sln**. The Dashboard solution will be in the Dashboard folder instead of the Main folder.

All of the files should be visible in the Solution Explorer window to the right.

After changing any of the code, you can test it by pressing F6, or clicking on Build > Build Solution. The RoboSub service must not be running while you build the project, but may be run as soon as the build is complete. There may be small compiler errors the first time you try to build which should go away simply by building the solution again.

Arduino code:

The Arduino microcontroller is used to communicate with the depth pressure sensor and the pneumatic valves that fire the torpedoes and release the droppers.

The code for the Arduino simply translates communications with the C# code via USB into the actions necessary for activating the pneumatic valves or reading the pressure sensor.

The .ino file can be opened with the Arduino API and can be found in:

C:\Users\robocorp\Microsoft Robotics Dev Studio 4
 \Projects\RDSrobosub\Arduino\RoboSub_Sensors

RoboRealm API:

The RoboRealm API guide may be found, along with tutorials and example code at:

<http://www.roborealm.com/help/API.php>

Under the Vision project, there is a C# file RR_API.cs that is already set up to simplify communication with RoboRealm.

Backing up the files:

The simplest way to back up the code completely, without missing any of the compiled files, is to copy the entire "**Microsoft Robotics Dev Studio 4**" folder. This includes the Arduino code.

What Works and What Does Not

There are thousands of lines of code already written for the sub, much of which is not functioning. Our attention will be focused on getting the specific missions under the Mission Planner project to work.

Currently, manual control via the dashboard GUI works well. This means that the Movement, Main, Dashboard, and Pressure Sensor projects are the ones that are working. The exception to this being the depth control, which does not send the sub to the exact target depth. For example: Entering "4" as the target depth will send the submarine down to around 9ft below the surface. This can be adjusted and re-calibrated by changing the PSI_PER FOOT constant in the PressureSensor.cs file.

The IMU project does not work because this portion of the program is freezing when trying to retrieve data from the IMU. It appears that the IMU heading was central to the way that the sub was to understand motion, as it tries to lock onto a compass heading from 0-359 and then move forward holding that heading. The heading could then be adjusted, based on visual information, to make a turn.

The Vision project may be working well enough to leave unaltered, though without further testing, it is hard to tell. We have had some limited success in the lab with having the sub recognize a colored line and begin to track it.

As a reminder, pay attention to what is being displayed in the console window while the RoboSub service is running. This is where error messages, along with messages displaying the current operations the RoboSub is attempting are shown.

C# project files in more detail

C# is an object-oriented programming language that

More information on the basics of programming with C# can be found in the Head First

This next section will briefly describe the contents and what is done in each of the C# project files. Note that there are multiple C# files for each project, and multiple projects in the Main solution, but only one project in the Dashboard solution.

Every project has a C# file titled *ProjectNameTypes.cs*, where the italics are replaced with the actual project's name. This file is essential and allows modification of the basic operations on that project object, such as Get or Subscribe. The enums are also fully defined in these files, which is where the complete list of method commands for the corresponding file may be found.

There are additional C# files in the MissionPlanner and Movement projects that are located in a sub-folder. This is where much of the code for the specific missions and motor drivers is hiding.

NOTICE: there is potential for confusion, as there are also two IMU.cs files, one is under the IMU project, and one under the Movement project. They are completely different!

Dashboard.sln

Dashboard:

The dashboard is the custom Graphical User Interface (GUI) for controlling the RoboSub. Keyboard, Mission planner, pneumatics all have manual controls. Depth, vision and heading all allow their PID values to be changed.

DashboardForm.cs contains the graphical design with the button layout.

Main.sln

Main:

The primary purpose of this project is to calibrate and then continuously poll the pressure sensor in the main loop. No known problems here.

IMU:

This opens the communications with the IMU board and is intended to continuously retrieve raw data from the IMU and process it into usable information.

Experimentally, every time we have run the sub, this project has frozen when trying to read the IMU data.

Mission Planner:

This project is where the behavior for each specific mission would be specified. Currently, the WaitThenStart mission appears to be the only one that functions. This mission sends the sub down to a depth of 4ft, then moves it straight forward on a timer in order to get it through the starting gate. It is then supposed to identify the buoy.

The specific missions, such as Line, Parking, and Buoy can all be found in the sub-folder under the MissionPlanner project. Current development is concerned with getting the Line mission to implement a search pattern, notice a black line on the bottom of the pool, and follow that line to the other end of the pool.

Movement:

This large project allows all of the RoboSub's movements to be controlled with simple commands. The possible commands include moving forward, strafing left or right, and turning. For each command, there are two parameters, one for the power level of the motor, and one for the duration, in milliseconds, that the thruster is to be on. It is possible to leave the motors on indefinitely by setting the duration to 0.

It communicates to the 6 motor driver boards via USB.

The IMU C# file here acts as a sort of wrapper to ease the importing of data from the IMU for the purpose of maintaining a heading when moving. The idea seems to be that when a non-rotational movement is being made, the IMU heading will keep the sub positioned.

PressureSensor:

This project handles all of the interactions with the Arduino, which include the pressure sensor, torpedo launcher, and marker dropper. No problems are apparent here.

Vision:

This project contains code for interacting with the RoboRealm program, as well as four methods that are intended to provide vision-related operations.

These four prototype methods are for Gate, Line, Buoy, and Parking tasks. As of yet, I don't know that any of these work, though they need specific testing.

The RR_API file contains a variety of testing routines for exploring the connection with RoboRealm.

Notice that the manifest flowchart shows that only the Mission Planner is using the Vision project directly.

Conclusion

Our project is to produce an autonomous submarine capable of completing multiple visual and spatial tasks. In order to do so, the submarine consists of a water-tight vessel protecting the electronics from the pool environment, batteries providing electrical power, and a complement of torpedoes and marker droppers.

The purpose of our submarine is to compete in the annual international AUVSI competition in San Diego. There it will dive to a depth of approximately 5ft, pass through the entry gate, and proceed along the line at the bottom of the pool to the first task. Depending on the actual arrangement in the competition pool, the submarine will bump into the correctly-colored buoy, hover over the designated parking space, fire torpedoes through the appropriate targets, and drop weighted markers into the designated bin, all completely of its own accord.

To compete well, we have examined the design of the previous year's submarine and found the overall mechanical design to be functional, but containing several areas that could be improved. Likewise, the electrical hardware does not require a complete re-design, but rather some adjustments to how the components are connected, and how they are physically arranged. The general software has a lot of potential, but was severely under-developed.

A new frame has been designed, as well as a new pressure vessel to house the pneumatics.

Our mission this year is to build our improved version, called Blue November, and focus on developing the current software so that the Artificial Intelligence (AI) of the submarine is capable of handling the competition tasks.

Looking Ahead

This year we have focused on researching the previous year's submarine (Sanka) design, and documenting its features for future development. We are also building a revised model of the submarine, which we will implement with continual improvements of the existing software.

Ideally, with the subsequent year's version, they will be able to focus more on improving the software, as opposed to documenting and organizing the existing version.

In two years time, the next group to approach this competition will have found a series of improvements that they may want to implement and build their own sub once again.

Appendix A: Troubleshooting Documentation

Troubleshooting: IMU (GEDC-6 and its board from digital compass)

So the IMU quit working. Here is a simple bullet point list that should help fix your problems.

1. If you are using usb, make sure that the RS232 jumper pin on the board is not connected. The jumper is J3-2, J3-3 and should be labeled as RS232
 2. Plug in all of your components. Then go into the computer control panel hardware and sound devices and printers
 3. This shows you all of your connected devices, by right clicking on a device, you can go into the properties. In the properties, go to the hardware tab and click properties, then click change settings. This allows you to view and change the settings of each connected component depending on the component you first right clicked on.
 4. Using the above method, change the IMU to one of the first 16 serial communication ports that is not being used, if they are all full, move one device to a higher port and then move the IMU to the port that was just freed up.
- NOTE: If you do not know the name of the IMU device, simply disconnect it and reconnect it. It will disappear from the devices and then reappear and you will know which one it is.
5. Try connecting to the device using the software from digital compass. If this does not work, continue
 6. Next, disconnect the board from any support it is on by unscrewing the four screws at each corner of the board. Retry the software connection. If this does not work, continue.
 7. After you have done all the previous steps, and with the board unscrewed from its supporting material (supporting material is usually a plastic board that it is screwed to), then short the outside pin of the DTR jumper to the ground in the corner of the board by the mini usb connection.

NOTE: The outside pin of the DTR jumper is connected to hardware reset of the actual IMU, temporarily shorting it while there is power to the board will effectively reset the board and the IMU. This is a temporary connection, just touch a wire to the DTR pin and ground and then remove the wire and it should be reset. When the board is reset, it is good to note that the baud rate will return to 115200 with one stop bit and no parity. You may have to match the com port settings to these using step 3.

NOTE: Also note that during a reset, all the information on the IMU will be lost, but the program should be saved and implemented by the user from the computer on the digital compass software so this should not be a problem.

8. Now retry the connection using the software and it should work properly
 9. If this does not work, delete the IMU drivers and reinstall them. The drivers can be found in the properties menu which is described in section 3. To do this, delete the drivers, then unplug and re plug in the IMU and the drivers should automatically reinstall
 10. If this does not work, unplug all of your devices except the IMU and repeat steps 1-9
- If none of the above solves your problem, lay the IMU on the table and smash it with a hammer. Then take the IMU home and place it in an oven preheated to 400 degrees F for a period of 2 hours and 15 minutes. Finally call the Digital Compass and tell them what happened and ask why it quit working and how they can help

Troubleshooting: Arduino (specifically the pressure sensor)

So now the pressure sensor isn't working. Good work champ. Here is what you want to do.

NOTE: first you must realize that the Arduino is like a little high maintenance. It can react poorly based on what order the usb's are plugged in, or on how the program is run. But hopefully this document will be like candy to a crying baby.

1. Connect all of your devices to the motherboard. In the control panel, go to hardware and sound devices and printers. This should show a list of all the connected devices. On this list, you can right click on a device to change its properties. Change the Arduino so that it is on a lower com port. Preferably 1-6. Make sure that it is the only device on that com port. For a more detailed description go to IMU troubleshooting part 3.
2. After changing the com port, unplug all of the devices except the Arduino device. Open the Arduino software and in the options, make sure the proper port is showing. Then try uploading the code and running it. This should work, if it does not, then the problem is most likely with the com port communicating with the Arduino software. This is assuming that your code is working properly. You may have to switch the com port and try again.
3. After you have got the Arduino working on its own, continue on but read the following note carefully.

NOTE: The Arduino is prejudice against the order of which it is connected to the motherboard and how the software is run. What this means is that if the Arduino is plugged in first and then all of the other components are plugged in, it may have some interfacing problems in the usb hub with the other components. Because of this, except for the cameras, it is better to hook the Arduino in as the last component. The software also is in a partial "same state" operation. This means that if you plug in the Arduino while the Arduino software is open, it most likely will not recognize it and will not run properly. This is because you started the Arduino program without the Arduino plugged in so it is stuck in that state. The simple fix is to exit the program and restart it.

4. After considering the above note, play with starting and restarting the Arduino software and see if you can get it to work.
5. If this does not work, combine step 4 with unplugging and plugging in the usb components in different orders until it works.
6. If this still does not work, one more thing must be considered. The Arduino may also be cranky about what usb device it shares the usb hub with. It may prefer sharing with one component over another. This is ok because there are two hubs on the mother board, simply try rearranging the devices until the Arduino is happy.
7. If none of the above steps works, then the error is either in the programming code or in the device which is hooked up to the Arduino. Check both of these and then retry the above steps.

Software References:

- The book “Professional Microsoft Robotics Developer Studio” which can be found in hard copy in the senior design lab, or in PDF form in the Capstone 2012-2013\Electrical : Software\Books folder.
- The book “Head First C#” which can be found in the same folder in PDF format.
- RoboRealm Tutorials and API website: <http://www.roborealm.com/help>

Appendix B: Mechanical Part Drawings

SUBASSEMBLY CODES

F- FRAME
PN- PNEUMATIC
D- DYNAMIC
MPV- MAIN PRESSURE VESSEL
CAM- CAMERA
T- TORPEDO
DR- DROPPER
EEC- ELECTRICAL CHASSIS

SUB-ASSEMBLIES

FRAME

F-000 FRAME
F-001 ANGLE BAR
F-002 T-SLOT BAR
F-003 FOOT
F-004 PNEUMATIC MOUNT

PNEUMATICS

PN-000 EXPLODED VIEW PNEUMATIC SYSTEM
PN-001 PVC END CAP
PN-002 PVC PIPE
PN-003 MALE/FEMALE ELBOW
PN-004 MALE/FEMALE T-JOINT
PN-005-007 UNIONS
PN-008 NPT THREADED PIPE
PN-009 SOLENOID VALVE
PN-010 MALE/TUBE ELBOW
PN-011 ALUMINUM PLATE
PN-012-13 PRESSURE REGULATOR
PN-014 NPT PLUG
PN-015 BRACE
PN-016 NPT TO 4" PVC PIPE

DYNAMIC

D-001 DYNAMICS

MAIN PRESSURE VESSEL

MPV-000 PRESSURE VESSEL EXPLODED VIEW
MPV-001 FINNED CAP
MPV-002 TUBE
MPV-003 GASKET
MPV-004 END CAP
MPV-005 SUPPORT

MPV-006 FLANGE

CAMERA

CAM-001 FRONT CAMERA
CAM-002 BRACKET

TORPEDO

T-000 CAMERA/TORPEDO BRACKET
T-001 TORPEDO TUBE
T-002 TORPEDO

DROPPER

DR-001 DROPPER TUBE

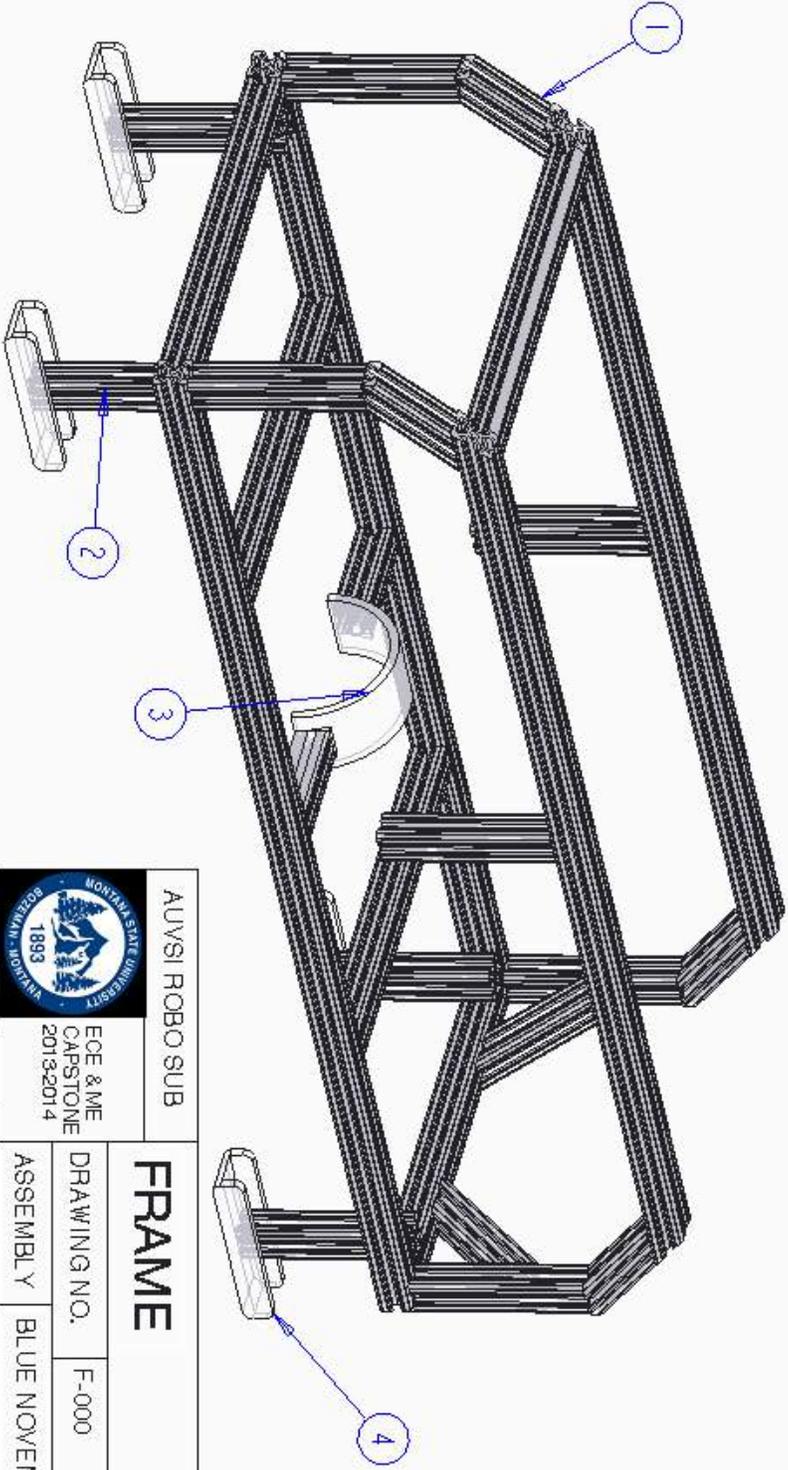
EE CHASSIS

EEC-000 EE CHASSIS

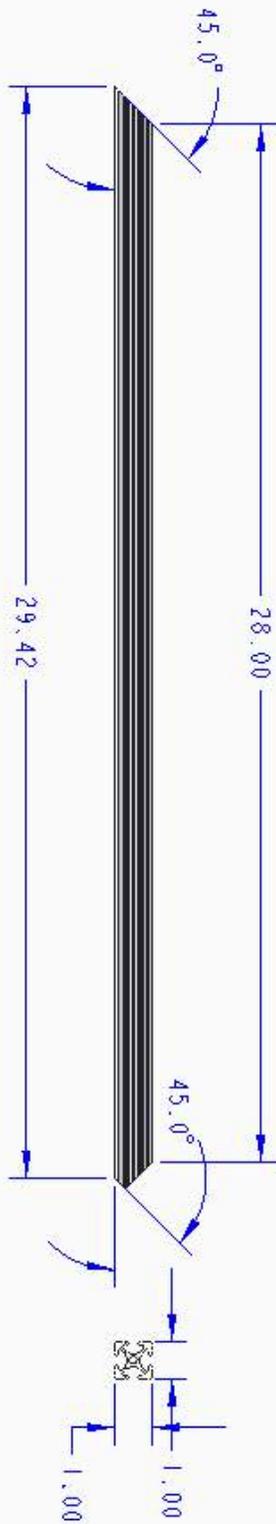
BATTERY

B-001 BATTERY SOCKET
B-000 BATTERY

ITEM NO.	QUANTITY	DESCRIPTION	MATERIAL	PART NO.
1	2	ANGLE BAR	ALUMINUM	F-001
2	20'	T-SLOT BAR	ALUMINUM	F-002
3	1	PNEUMATIC MOUNT	PVC	F-004
4	4	FOOT	NYLON	F-003

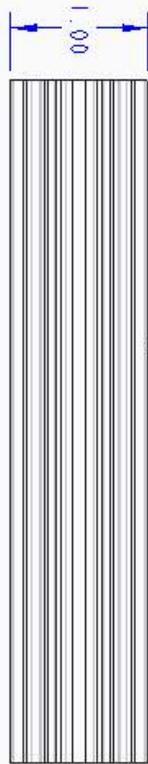
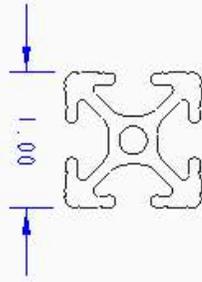


AUVSI ROBO SUB				FRAME	
ECE & ME		DRAWING NO.		F-000	
CAPSTONE		ASSEMBLY		BLUE NOVEMBER	
2013-2014		DRAFTER		ALEXREAD	
SCALE	1:4	REV	A	DATE	DEC 3
MATERIAL	N/A				A



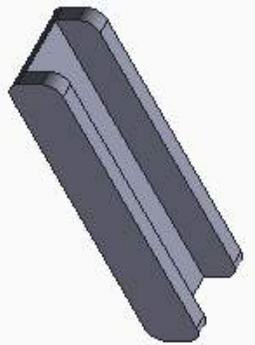
NOTE: CROSS-SECTION IS
 MCMMASTER 1" EXTRUDED
 ALUMINUM T-SLOT BAR

AUYSI ROBO SUB				ECE & ME CAPSTONE 2013-2014	
ANGLE BAR				DRAWING NO. F-001	
SCALE 1:4		REV A		DRAFTER ALEXREAD	
MATERIAL ALUMINUM		ASSEMBLY		FRAME	
		DATE		DEC 2	
				A	

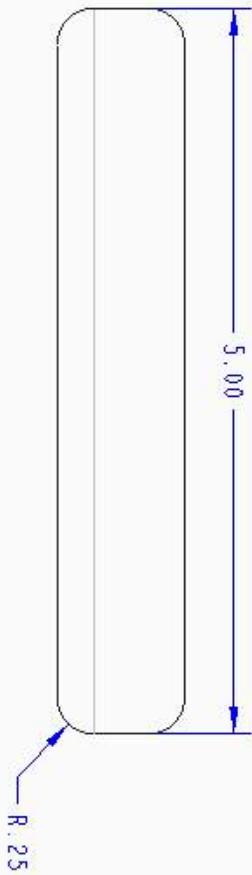
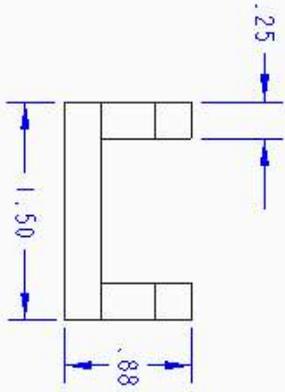


VARIABLE LENGTH

AUYSI ROBO SUB				ECE & ME CAPSTONE 2013-2014	
T-SLOT BAR				DRAWING NO. F-002	
SCALE 1:1		REV A		ASSEMBLY FRAME	
MATERIAL ALUMINIUM		DRAFTER		ALEXREAD	
DATE			DEC 2		A



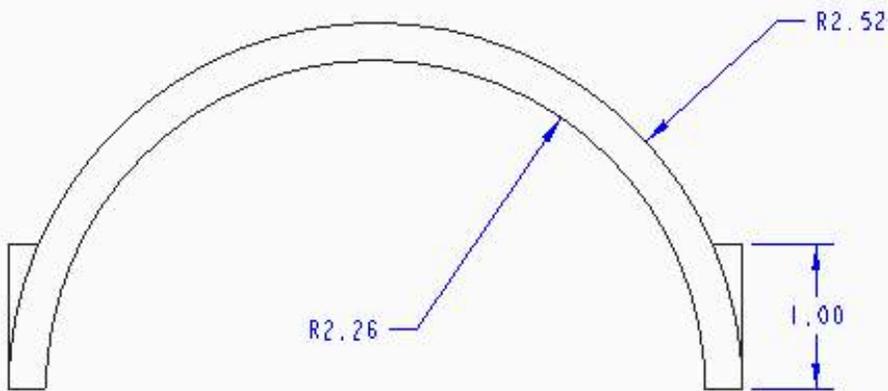
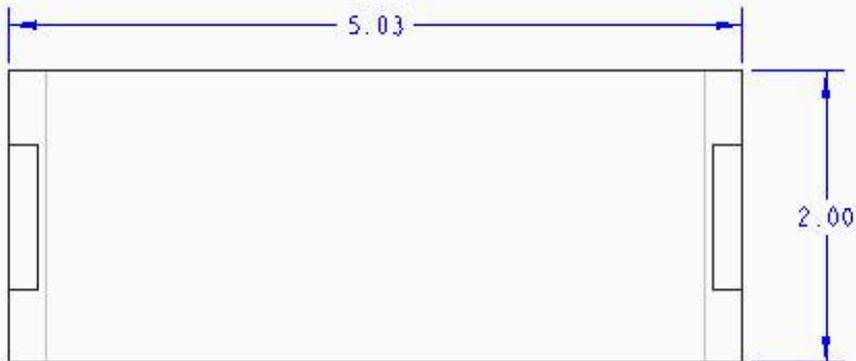
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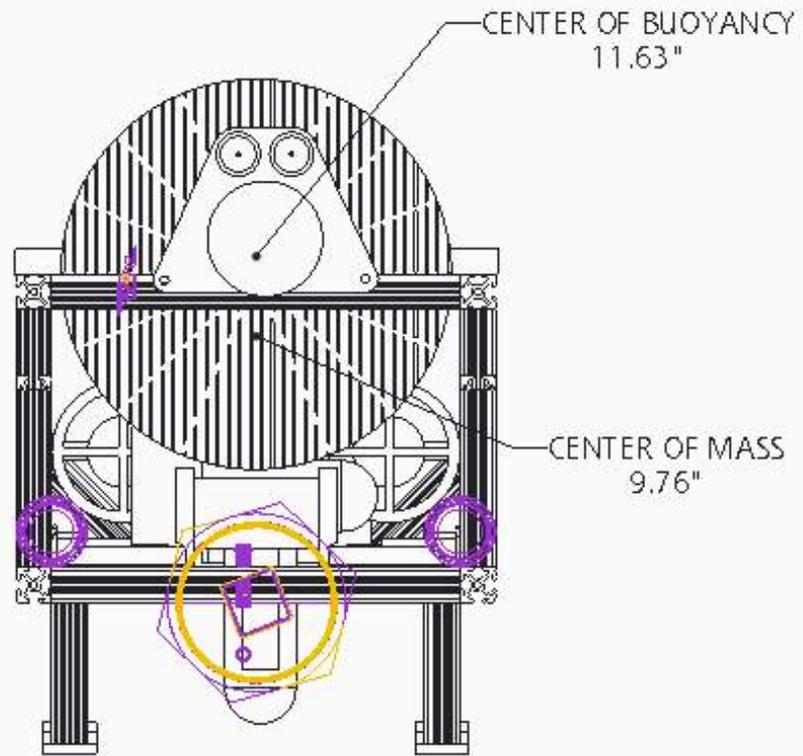
AUYSI ROBO SUB				FOOT	
		ECE & ME CAPSTONE 2013-2014		DRAWING NO. F-003	
		ASSEMBLY		FRAME	
SCALE	1:1	REV	A	DRAFTER	ALEXREAD
MATERIAL	NYLON	DATE	DEC 2	A	



SCALE 0.500

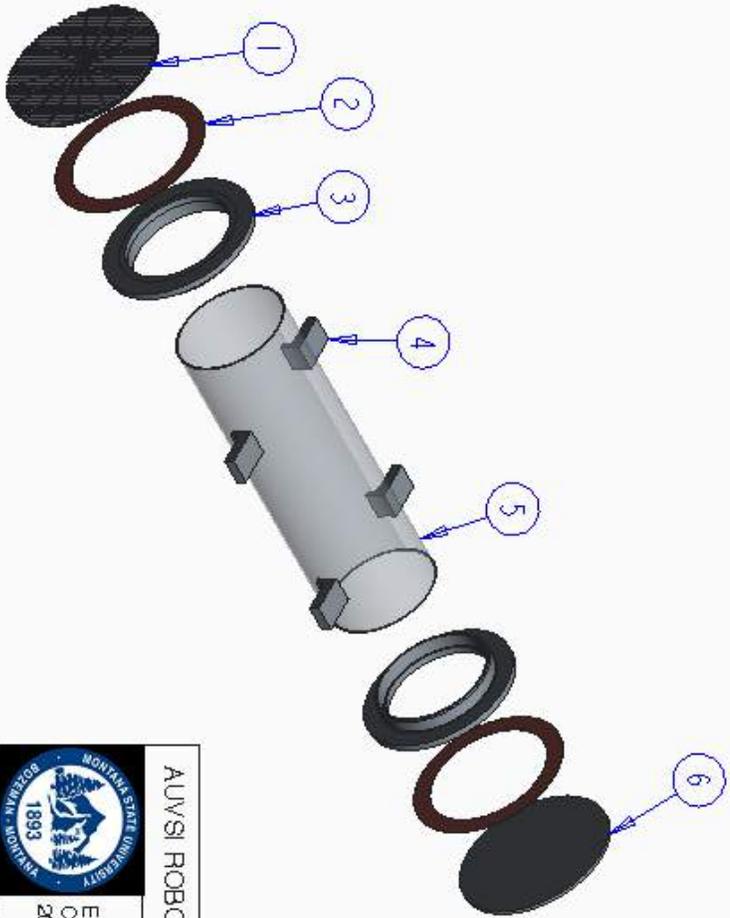


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 MONTANA STATE UNIVERSITY BOZEMAN - MONTANA 1893				ECE & ME		CAPSTONE	
				2013-2014		DRAWING NO. F-004	
				ASSEMBLY		FRAME	
SCALE 1:1		REV A		DRAFTER		ALEX READ	
MATERIAL PVC				DATE		DEC 3 A	

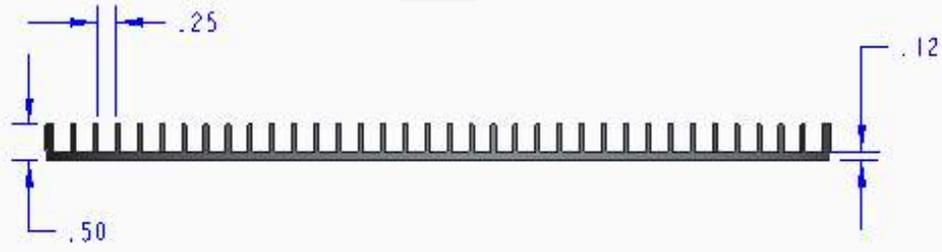
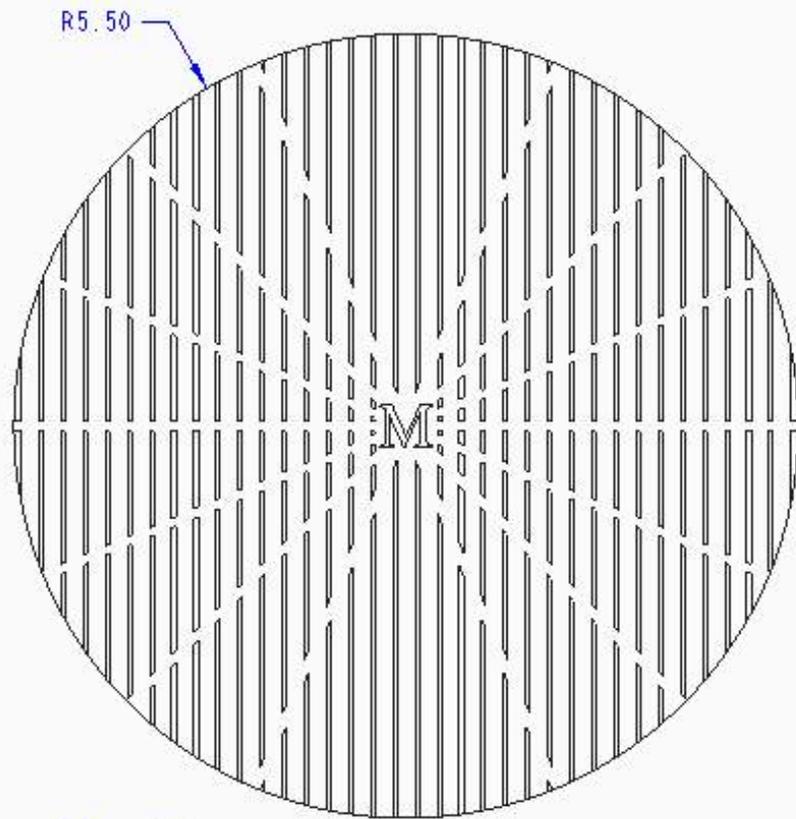


AUVSI ROBO SUB				DYNAMICS				
 MONTANA STATE UNIVERSITY 1893 BOZEMAN, MONTANA								ECE & ME CAPSTONE 2013-2014
				SCALE		N/A	REV	A
MATERIAL		N/A			DRAFTER		ALEX READ	
					DATE		DEC 2	A

ITEM NO.	QUANTITY	DESCRIPTION	PART NO.	MATERIAL
1	1	FINNED CAP	MPV-001	ALUMINUM
2	2	GASKET	MPV-003	RUBBER
3	2	FLANGE	MPV-006	POLYCARB.
4	4	SUPPORT	MPV-005	NYLON
5	1	TUBE	MPV-002	POLYCARB.
6	1	END CAP	MPV-004	ALUMINUM

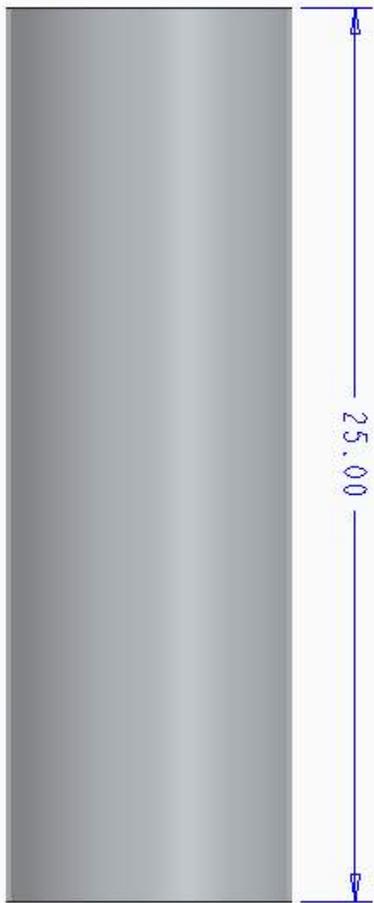
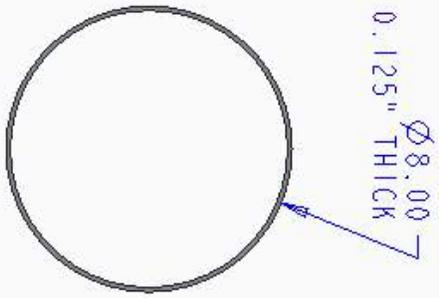


AUYSI ROBO SUB		 ECE & ME CAPSTONE 2013-2014		PRESSURE VESSEL	
SCALE	1:10	REV	A	DRAWING NO.	MPV-000
MATERIAL	ALUMINUM	DRAFTER	ALEX READ	ASSEMBLY	BLUE NOVEMBER
		DATE	DEC 3		A



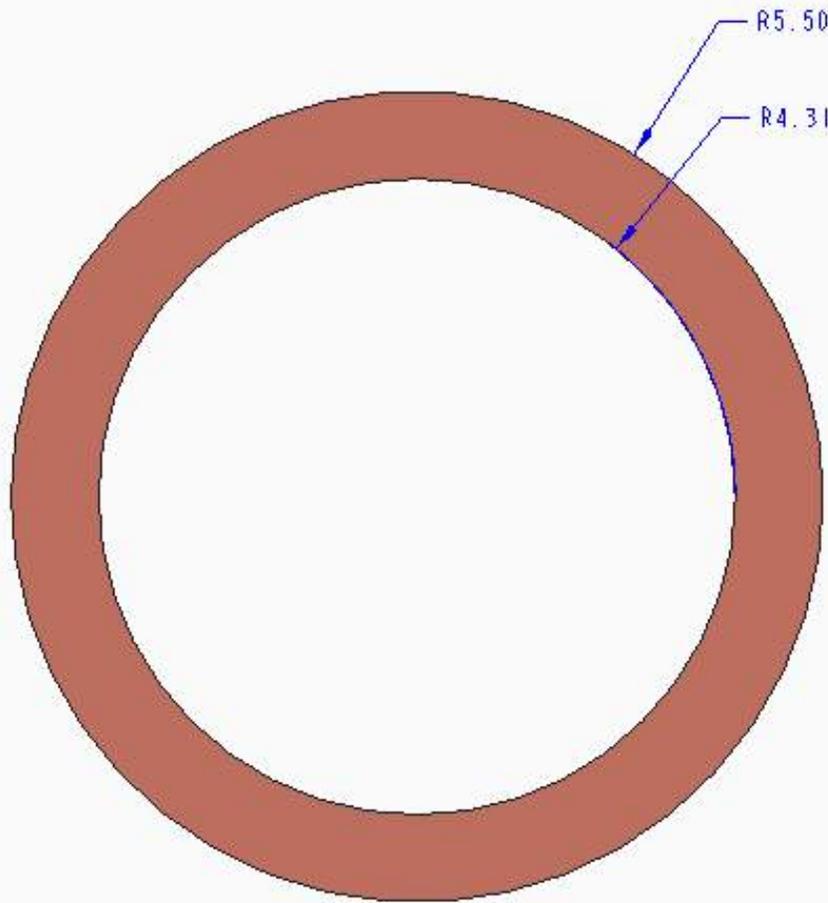
MANUFACTURING NOTES:
 MILL 35 0.25" SLOTS
 SEPARATED BY .06"
 AND SYMMETRIC RADIAL
 SLOTS OF 0.125" THICKNESS

AUYSI ROBO SUB				FINNED CAP			
 ECE & ME CAPSTONE 2013-2014				DRAWING NO.		MPV-001	
				ASSEMBLY		PRESSURE VESSEL	
SCALE	1:4	REV	A	DRAFTER		ALEX READ	
MATERIAL		ALUMINUM		DATE		DEC 2	A



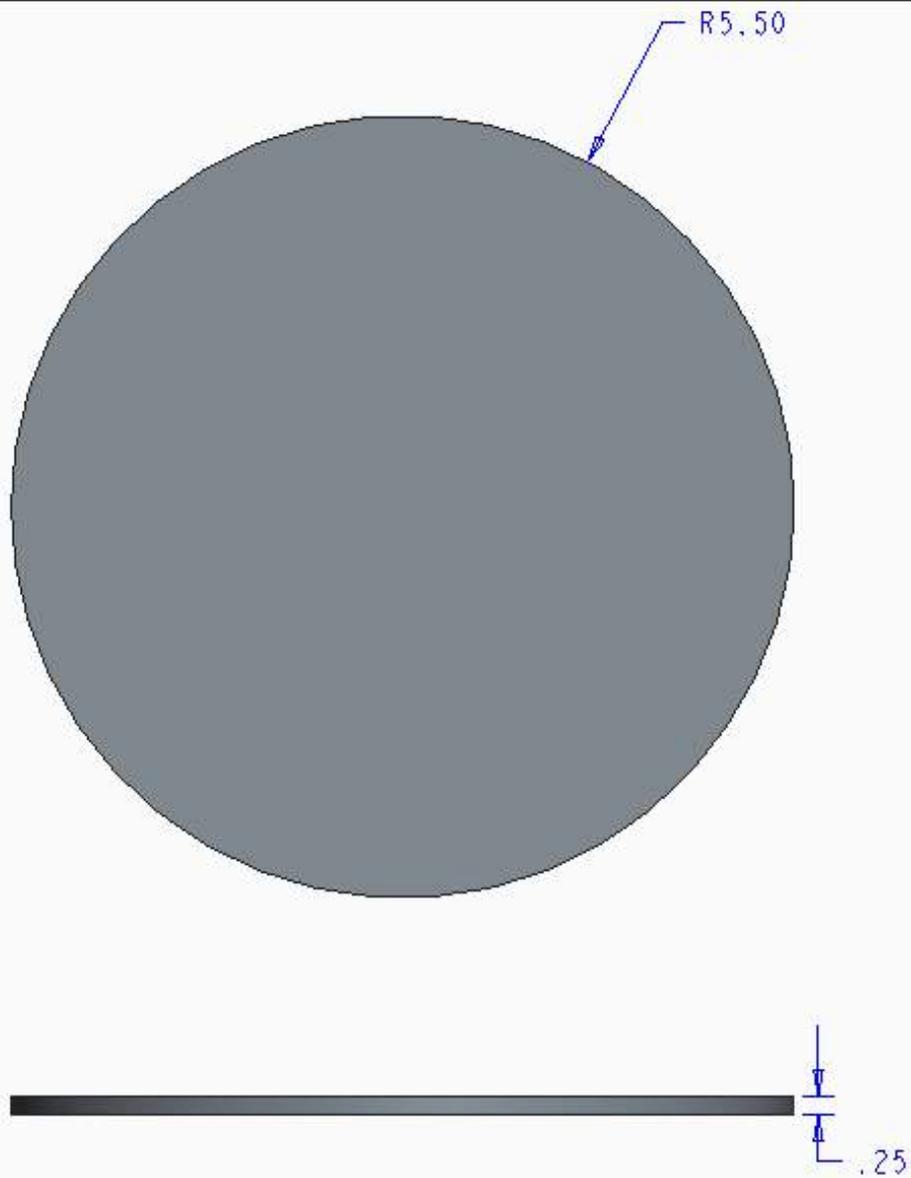
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				CAPSTONE			
		2013-2014		ASSEMBLY		PRESSURE VESSEL	
SCALE	1:4	REV	A	DRAFTER	ALEXREAD		
MATERIAL	POLYCARBONATE	DATE	DEC 3			A	

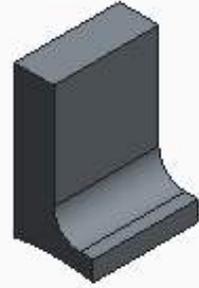


NOTE: 1/16" THICK

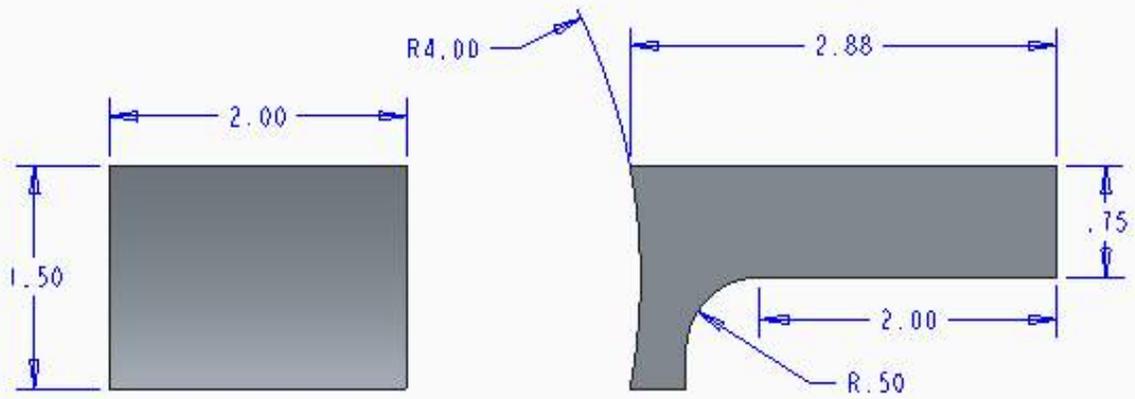
AUVSI ROBO SUB				GASKET			
 MONTANA STATE UNIVERSITY BOZEMAN - MONTANA 1893 ECE & ME CAPSTONE 2013-2014				DRAWING NO.		MPV-003	
				ASSEMBLY		PRESSURE VESSEL	
SCALE	1:2	REV	A	DRAFTER		ALEX READ	
MATERIAL		RUBBER		DATE	DEC 3	A	



AUVSI ROBO SUB				END CAP			
 MISSOURI STATE UNIVERSITY 1893 FOREMAN • HORTON				ECE & ME CAPSTONE 2013-2014		DRAWING NO. MPV-004	
				ASSEMBLY		PRESSURE VESSEL	
SCALE	1:2	REV	A	DRAFTER		ALEX READ	
MATERIAL ALUMINUM				DATE		DEC 3	A



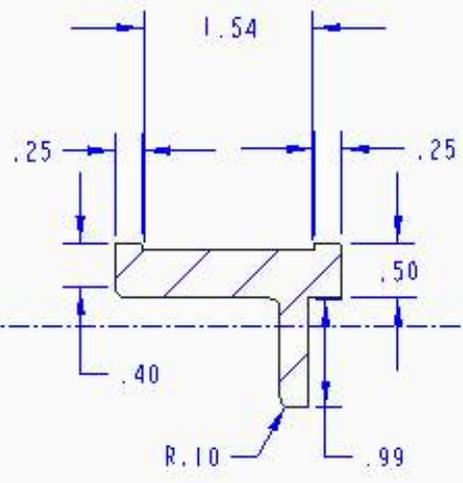
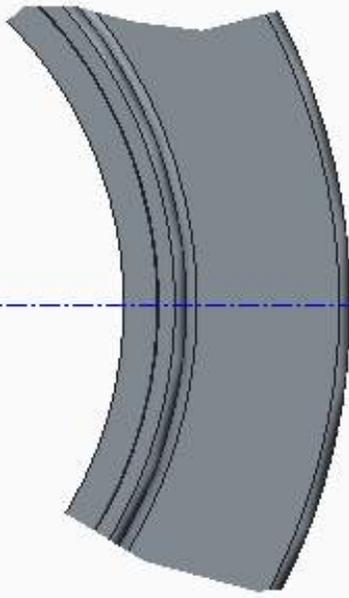
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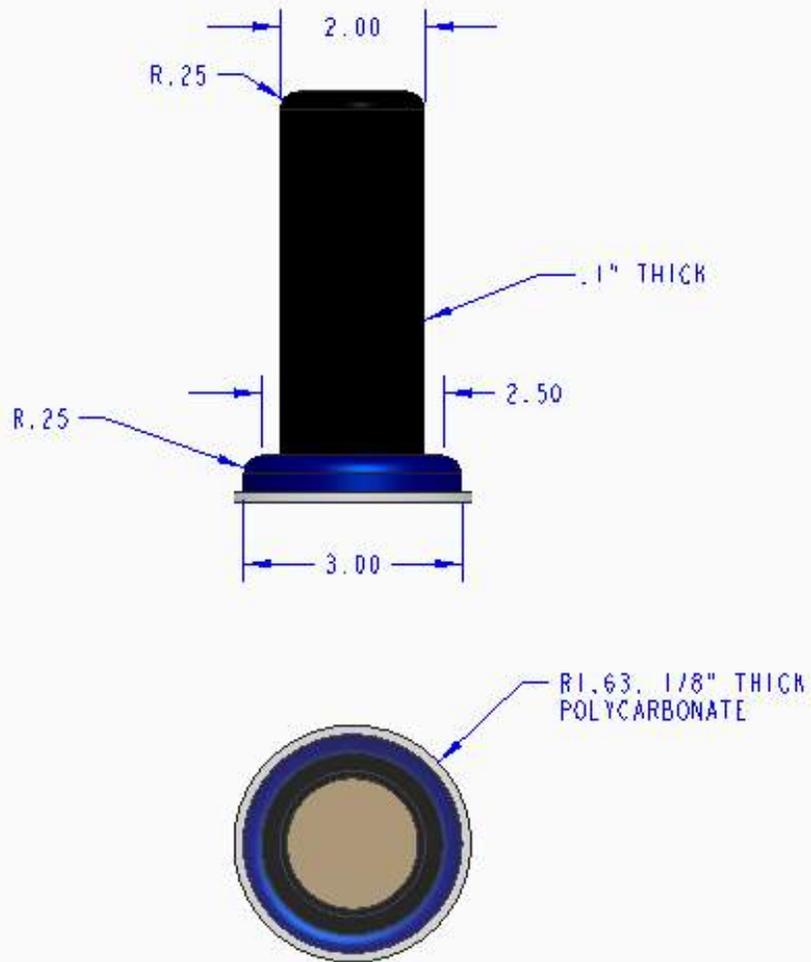
AUYSI ROBO SUB				SUPPORT			
 ECE & ME CAPSTONE 2013-2014							
				SCALE		1:1	REV
DRAFTER		ALEX READ					
MATERIAL		PVC		DATE		DEC 3	A



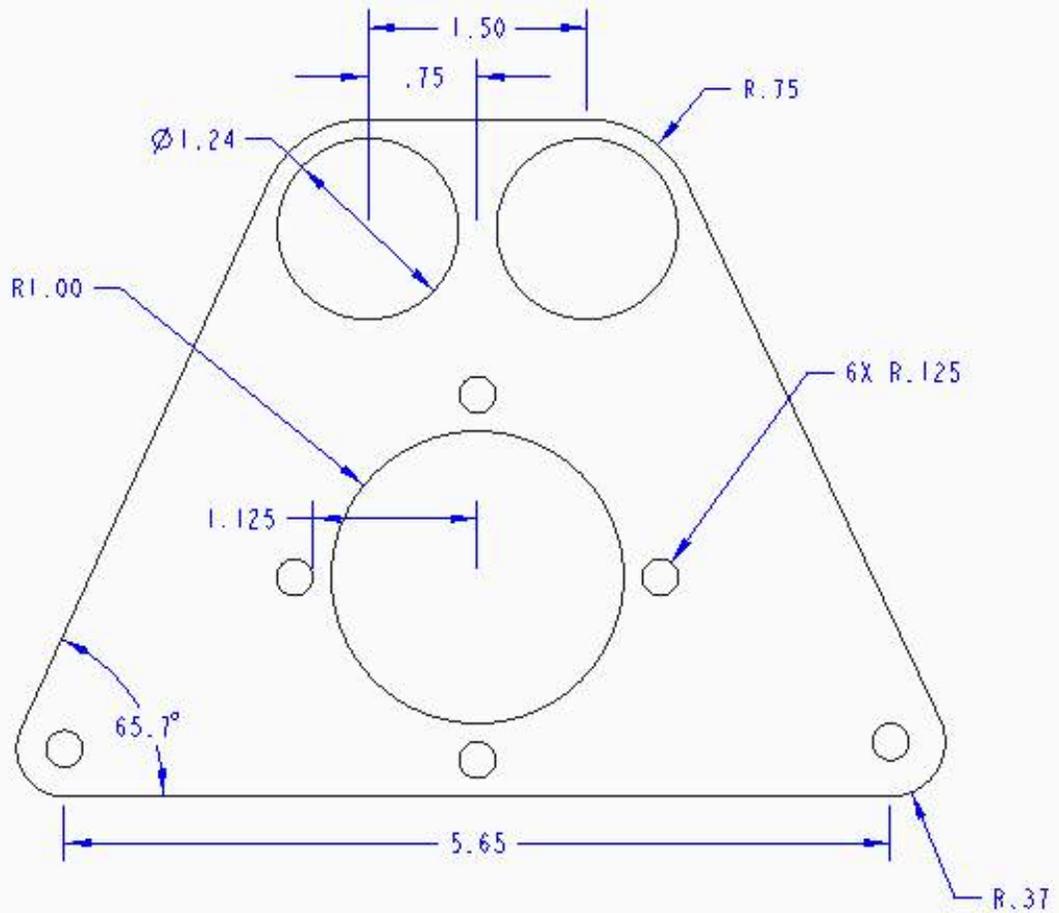
SCALE 0.250



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		ASSEMBLY	PRESSURE VESSEL
SCALE	1:2	REV	A
DRAFTER	ALEX READ		
MATERIAL	POLYCARB.	DATE	DEC 3 A

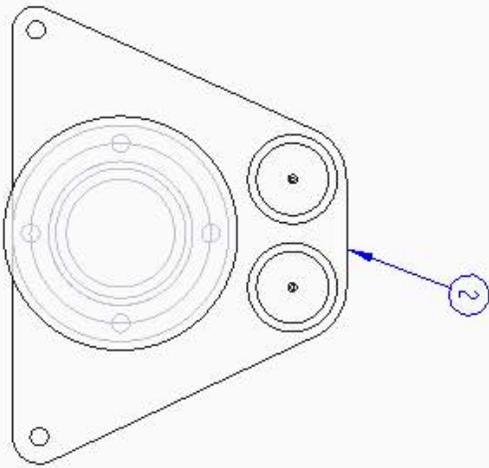
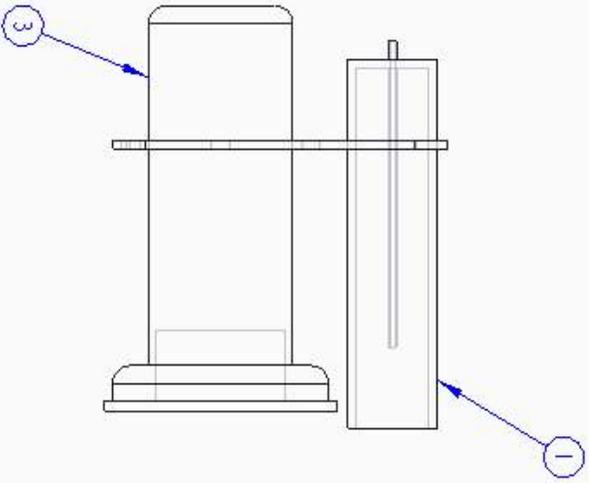


AUVSI ROBO SUB				FRONT CAM			
 MONTANA STATE UNIVERSITY 1893 BOZEMAN - MONTANA				ECE & ME CAPSTONE 2013-2014		DRAWING NO. CAM-001	
				ASSEMBLY		CAMERA/TORPEDO BRACKET	
SCALE	1:2	REV	A	DRAFTER		ALEX READ	
MATERIAL		ALUMINUM			DATE	DEC 3	A



AUVSI ROBO SUB			BRACKET		
 MONTANA STATE UNIVERSITY 1893 BOZEMAN - MONTANA			ECE & ME CAPSTONE 2013-2014		DRAWING NO. CAM-002
SCALE 1:1			REV A		ASSEMBLY CAMERA/TORPEDO BRACKET
MATERIAL ALUMINUM			DRAFTER ALEX READ		DATE DEC 3
					A

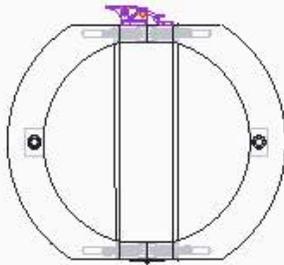
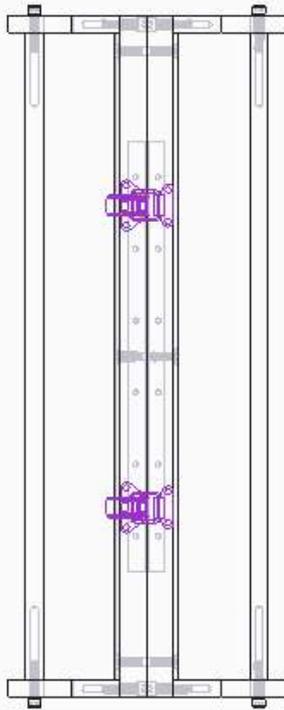
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2	1	BRACKET	ALUMINUM	CAM-002
3	1	FRONT CAMERA	ALUMINUM	CAM-001



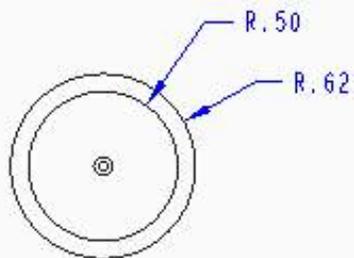
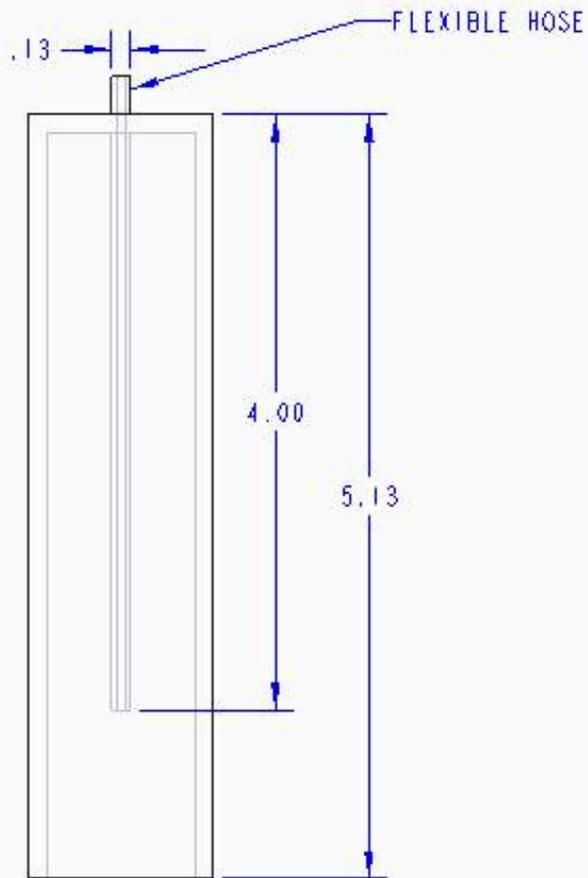
AUYSI ROBO SUB		CAMERA/TORPEDO BRACKET	
		EOE & ME CAPSTONE 2013-2014	
SCALE	1:2	REV	A
DRAWING NO.	T-000	DRAFTER	ALEXREAD
ASSEMBLY	BLUE NOVEMBER	DATE	DEC 3
MATERIAL	N/A		A



SCALE 0.150

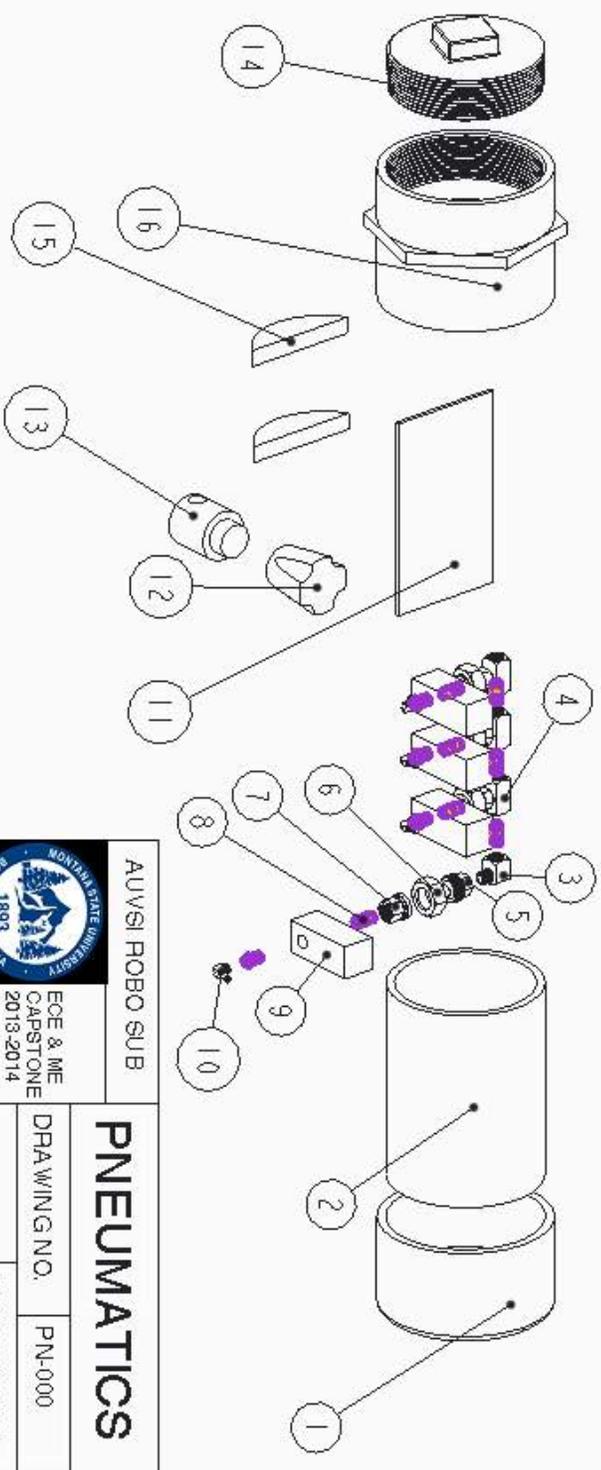


				AUVSI ROBO SUB	
				EE CHASSIS	
SCALE	1:4	REV	A	DRAWING NO.	EE-C-000
MATERIAL	N/A	DRAFTER	ALEXREAD	ASSEMBLY	BLUE NOVEMBER
		DATE	DEC 3		A



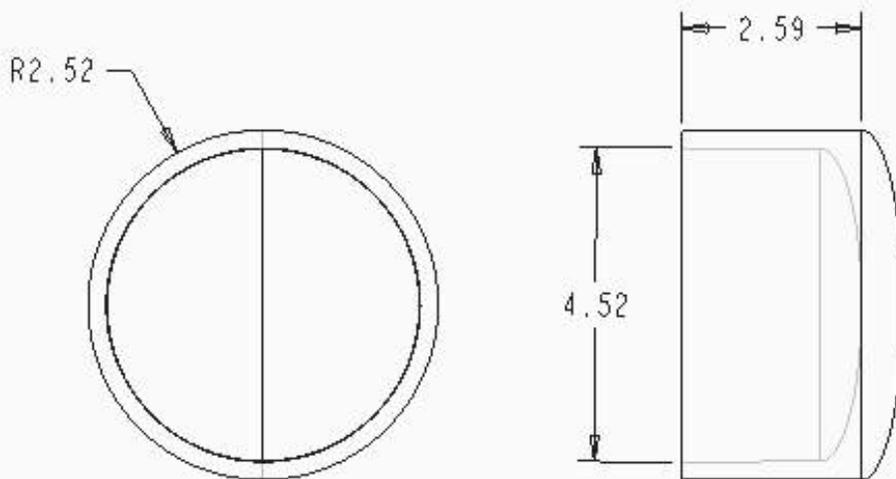
AUVSI ROBO SUB				TORPEDO TUBE		
 ECE & ME CAPSTONE 2013-2014				DRAWING NO.		T-001
				ASSEMBLY		CAMERA/TORPEDO BRACKET
SCALE	1:2	REV	A	DRAFTER		ALEX READ
MATERIAL			ALUMINUM	DATE	DEC 3	A

ITEM	DESCRIPTION	MATERIAL	QTY	PART NO.	ITEM	DESCRIPTION	MATERIAL	QTY	PART NO.
1	4" PVC CAP	PVC	1	4880K58	9	SOL. VALVE	BRASS	4	7877K25
2	4" PVC PIPE	PVC	1	48925K98	10	TUBE/YM ELBOW	S.S.	4	5463K485
3	M/F ELBOW	S.S.	1	2684K14	11	PLATE	ALUMINUM	1	89015K28
4	M/F T-JOINT	BRASS	3	50785K321	12	HANDLE	ABS	2	3811T11
5	UNION	S.S.	4	4464K483	13	REGULATOR	BRASS	1	3811T11
6	UNION	S.S.	4	4464K483	14	NPT PLUG	PVC	1	2389K81
7	UNION	S.S.	4	4464K483	15	BRACE	PVC	2	87025K125
8	THREADED PIPE	S.S.	7	4830K111	16	4" PVC	PVC	1	4880K88

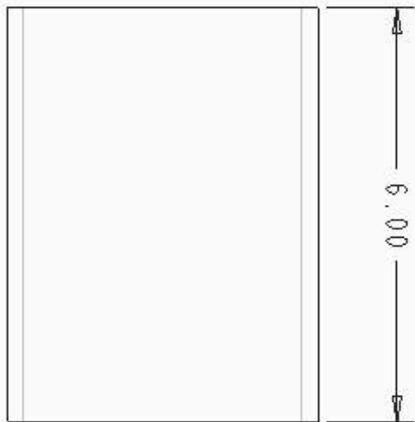
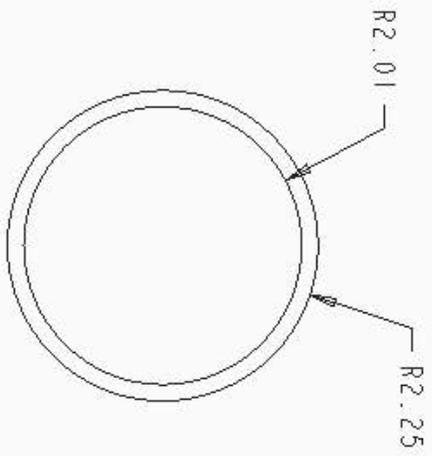


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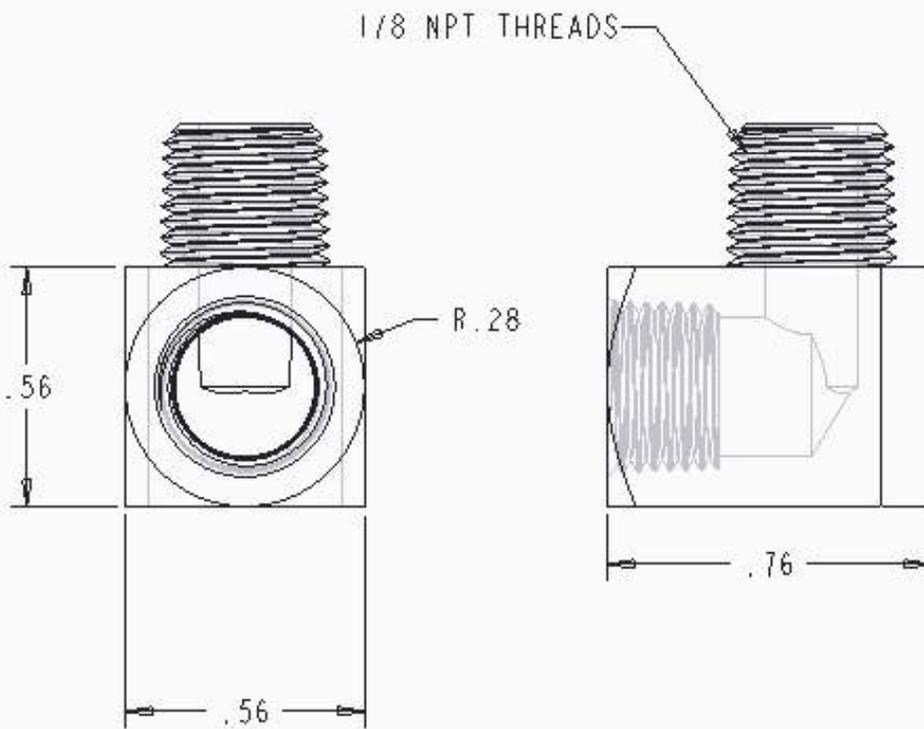
		AUVSI ROBO SUB		PNEUMATICS	
ECE & ME CAPSTONE 2013-2014		DRAWING NO. PN-000		ASSEMBLY PNEUMATICS	
SCALE	1:4	REV	A	DRAFTER	WILSON PLATT
MATERIAL	VARIOUS	DATE	DEC-2	A	



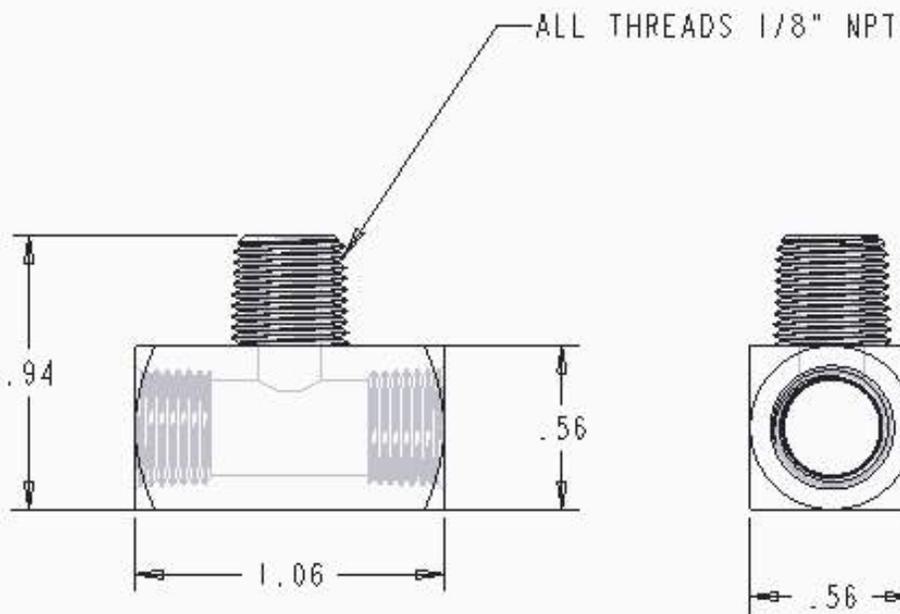
AUVSI ROBO SUB				PVC CAP			
 ECE & ME CA PSTONE 2013-2014				DRAWING NO.		PN-001	
				ASSEMBLY		PNEUMATICS	
SCALE	1:1	REV	A	DRAFTER		WILSON PLATT	
MATERIAL		PVC		DATE	DEC-3	A	



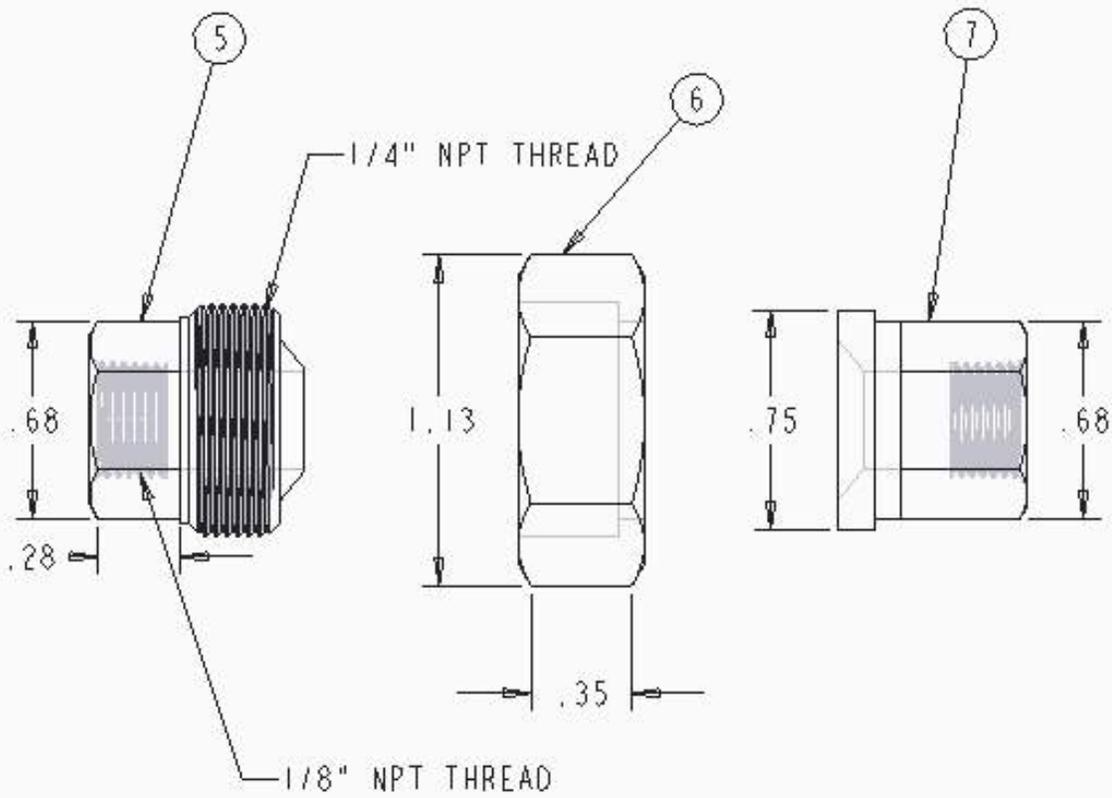
AUVSI ROBO SUB		 ECE & ME CAPSTONE 2013-2014		<h1 style="text-align: center;">PVC PIPE</h1>	
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MATERIAL	PVC	DRAFTER	WILSON PLATT	ASSEMBLY	PNEUMATICS
		DATE	DEC-3		A



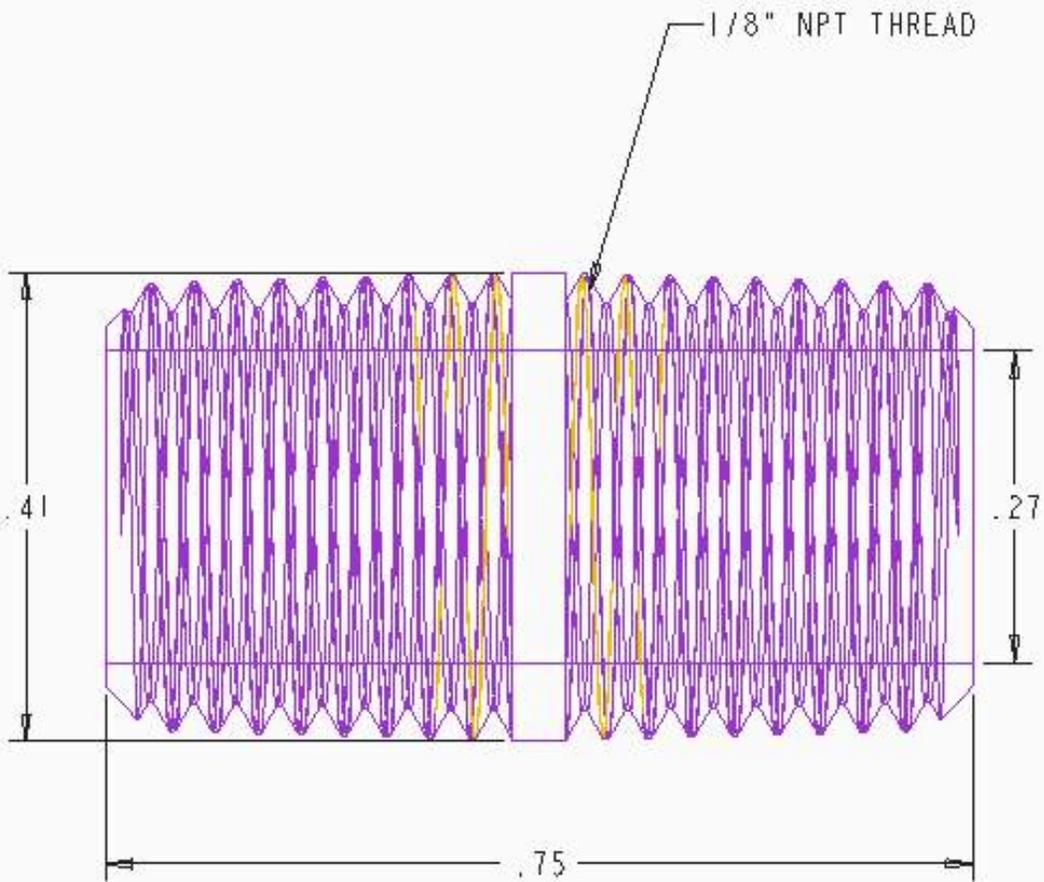
AUVSI ROBO SUB				MALE/FEMALE ELBOW			
 ECE & ME CAPSTONE 2013-2014				DRAWING NO.		PN-003	
				ASSEMBLY		PNEUMATICS	
SCALE	3:1	REV	A	DRAFTER		WILSON PLATT	
MATERIAL		BRASS		DATE	DEC-3	A	



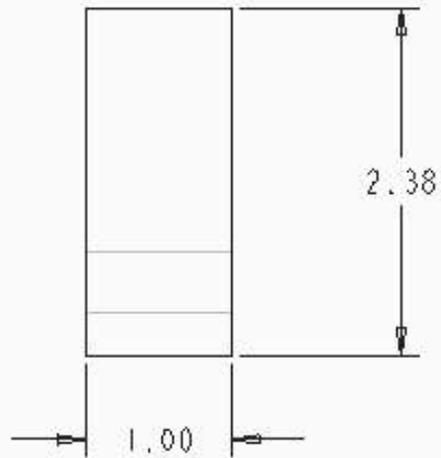
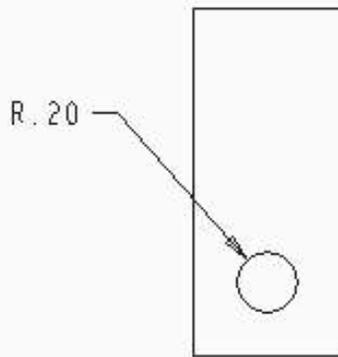
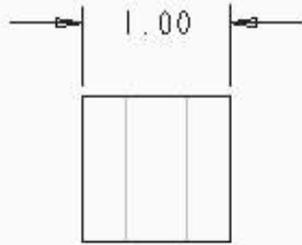
AUVSI ROBO SUB				MALE/FEMALE T-JOINT			
 MONTANA STATE UNIVERSITY 1893 BOZEMAN - MONTANA				ECE & ME		DRAWING NO. PN-004	
				CA PSTONE		ASSEMBLY PNEUMATICS	
SCALE	2:1	REV	A	DRAFTER		WILSON PLATT	
MATERIAL BRASS				DATE	DEC-3	A	



AUVSI ROBO SUB			UNION		
 ECE & ME CAPSTONE 2013-2014					
DRAWING NO.		PM-005-007			
ASSEMBLY		PNEUMATICS			
SCALE	2:1	REV	A	DRAFTER	WILSON PLATT
MATERIAL	STAINLESS STEEL	DATE	DEC-3	A	

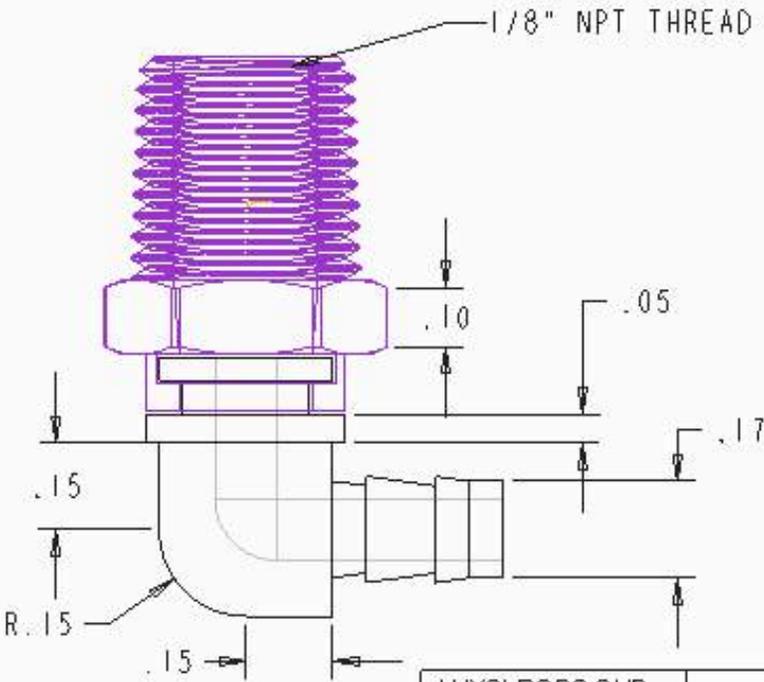
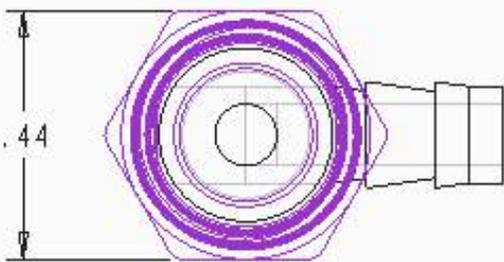


AUVSI ROBO SUB				THREADED PIPE			
 ECE & ME CAPSTONE 2013-2014				DRAWING NO.		PN-008	
				ASSEMBLY		PNEUMATICS	
SCALE	8:1	REV	A	DRAFTER		WILSON PLATT	
MATERIAL		STAINLESS STEEL		DATE	DEC-3	A	

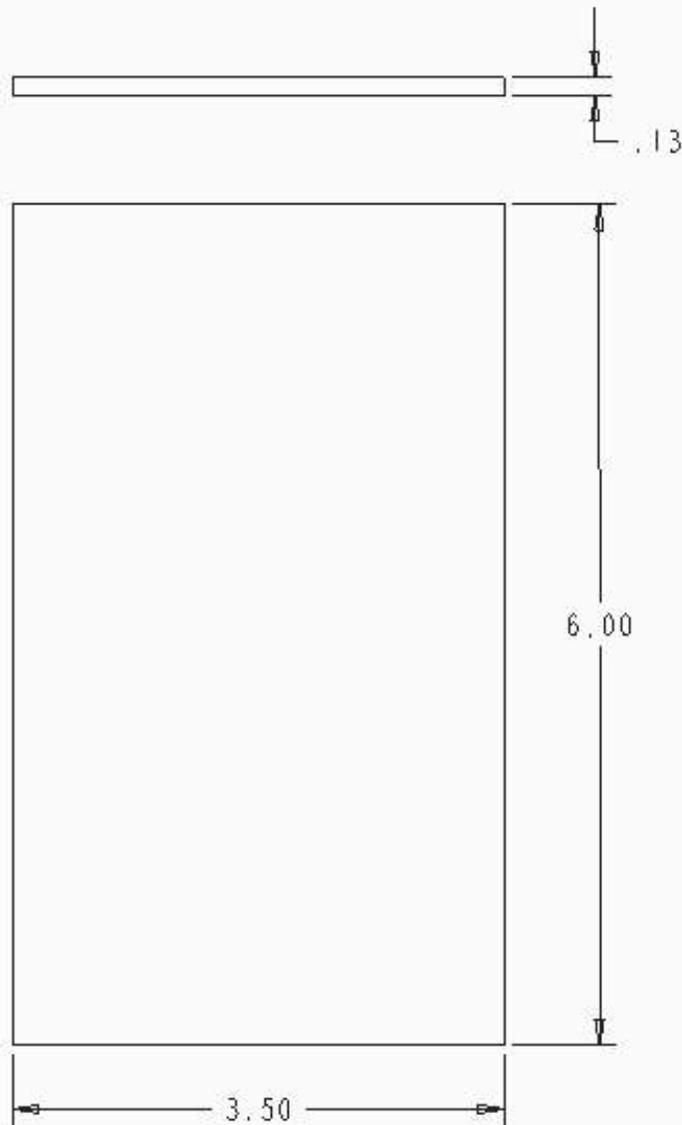


AUYSI ROBO SUB				SOLENOID VALVE			
				ECE & ME CA PSTONE 2013-2014		DRAWING NO. PN-009	
				ASSEMBLY		PNEUMATICS	
SCALE 1:1		REV A		DRAFTER		WILSON PLATT	
MATERIAL BRASS				DATE		DEC-3 A	

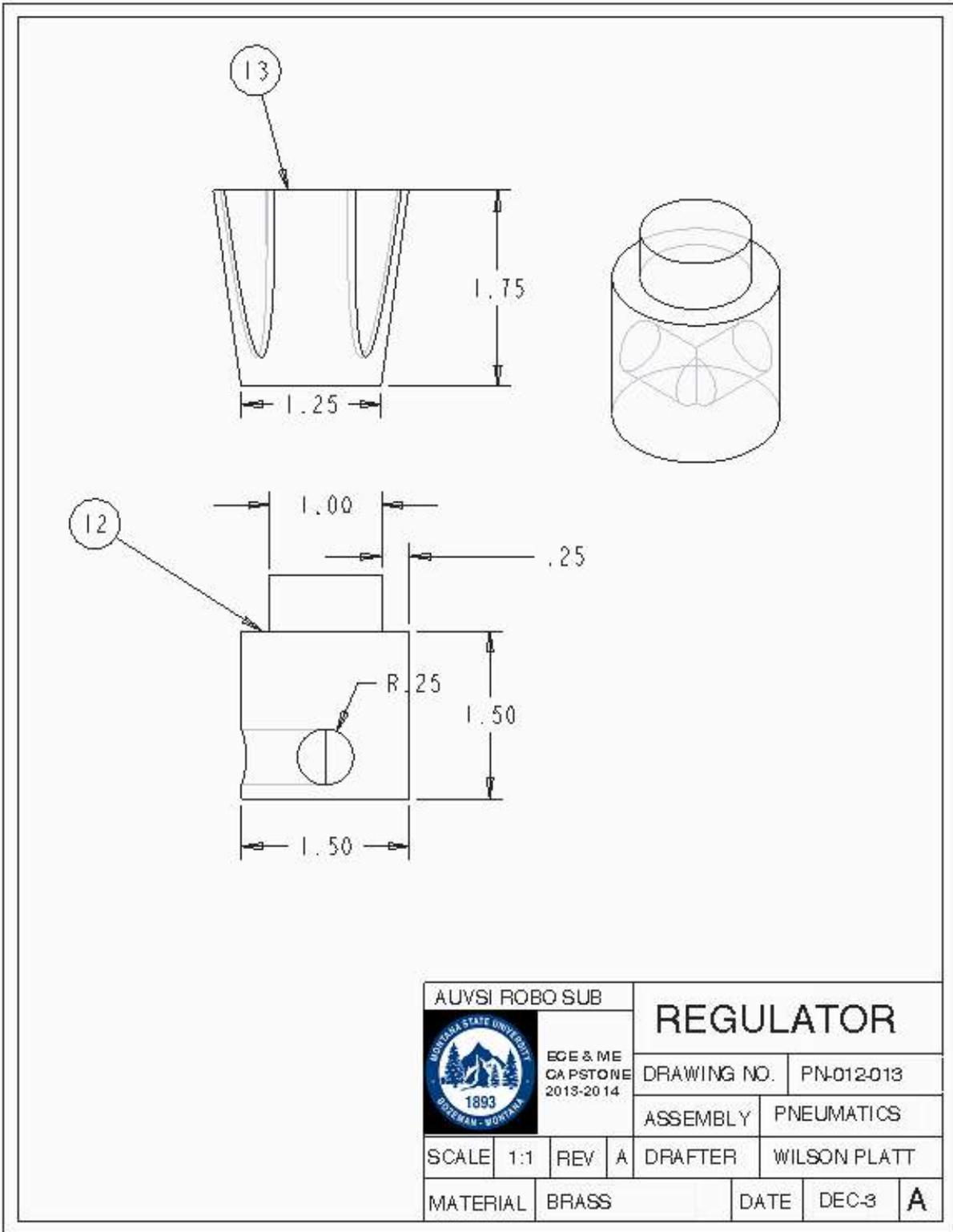
SCALE 2.000



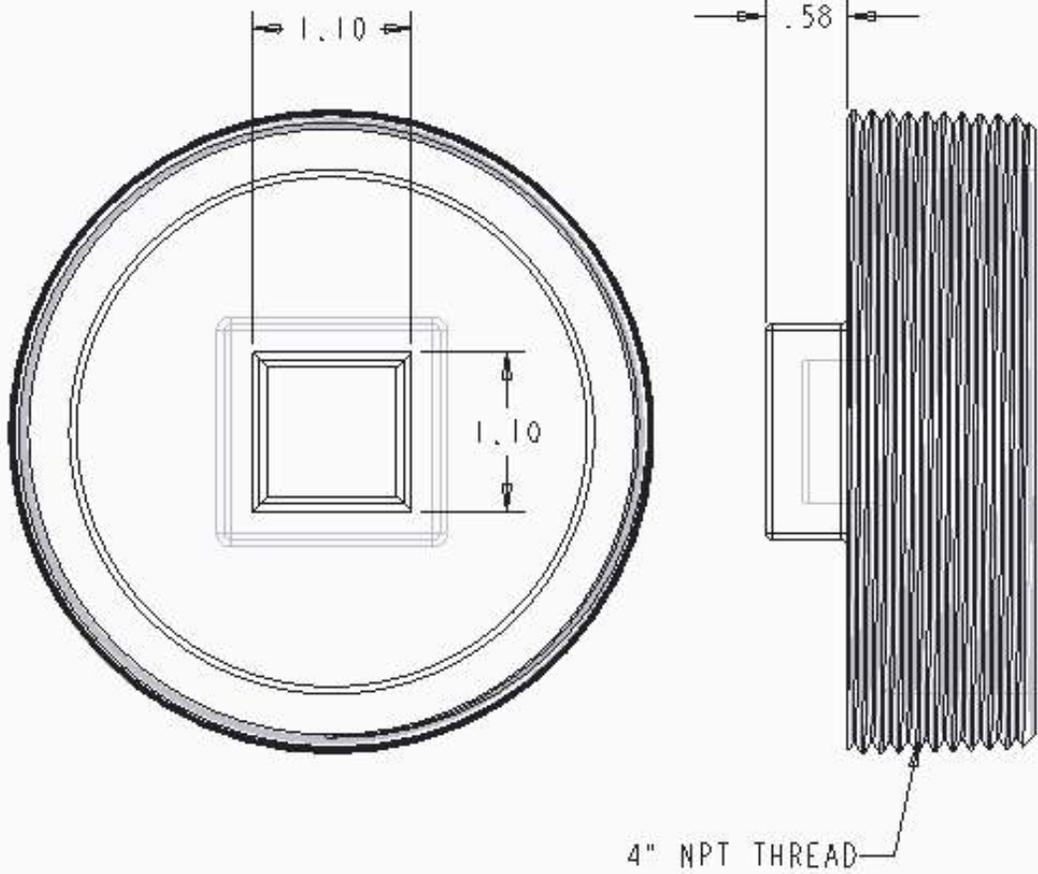
AUVSI ROBO SUB				MALE/TUBE ELBOW			
 ECE & ME CA PSTONE 2013-2014				DRAWING NO.		PN-010	
				ASSEMBLY		PNEUMATICS	
SCALE	4	REV	A	DRAFTER		WILSON PLATT	
MATERIAL		STAINLESS STEEL		DATE		DEC-3	A



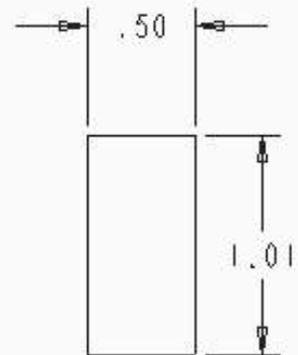
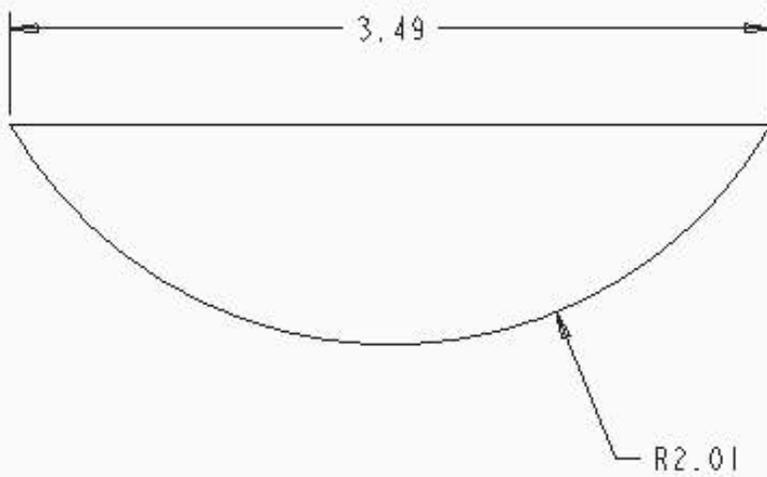
AUVSI ROBO SUB			PLATE			
 ECE & ME GA PSTONE 2013-2014						DRAWING NO.
			ASSEMBLY	PNEUMATICS		
SCALE	1:1	REV	A	DRAFTER	WILSON PLATT	
MATERIAL	ALUMINUM			DATE	DEC-3	A



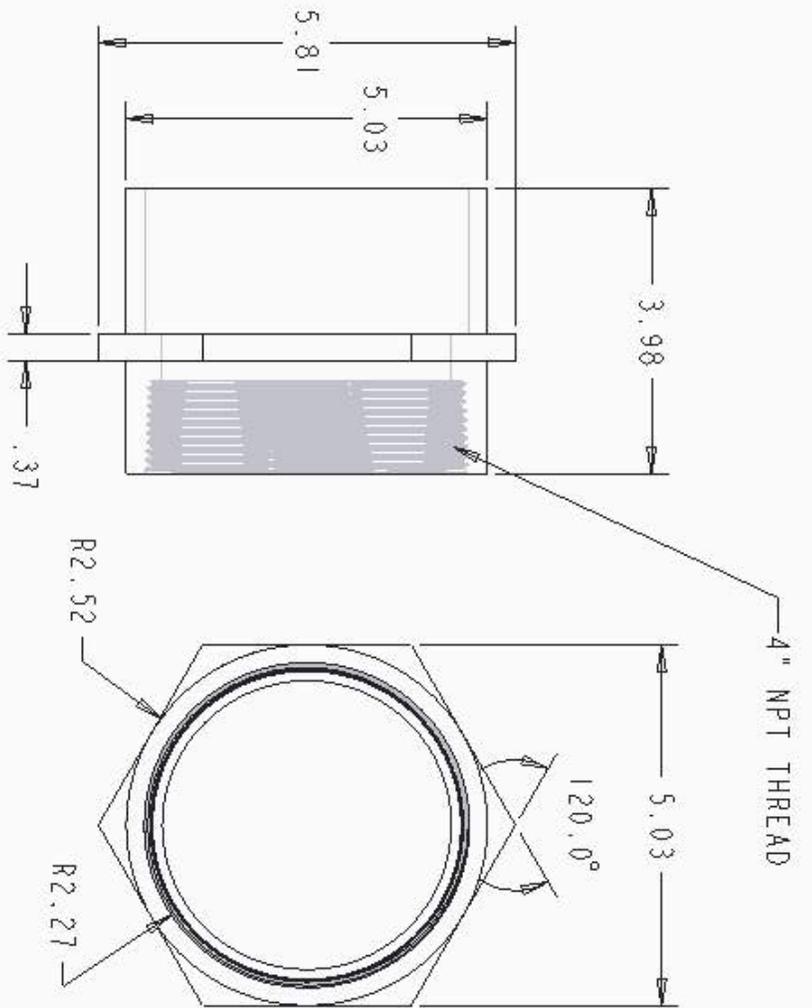
AUVSI ROBO SUB				REGULATOR			
 ECE & ME CAPSTONE 2013-2014				DRAWING NO.		PN-012-013	
				ASSEMBLY		PNEUMATICS	
SCALE	1:1	REV	A	DRAFTER		WILSON PLATT	
MATERIAL		BRASS		DATE		DEC-3	A



AUVSI ROBO SUB				NPT PLUG			
 MONTANA STATE UNIVERSITY 1893 BOZEMAN - MONTANA				ECE & ME		DRAWING NO. PN-014	
				CAPSTONE		ASSEMBLY PNEUMATICS	
2013-2014		DRAFTER		WILSON PLATT			
SCALE	1:1	REV	A	DATE	DEC-3	A	
MATERIAL		PVC					

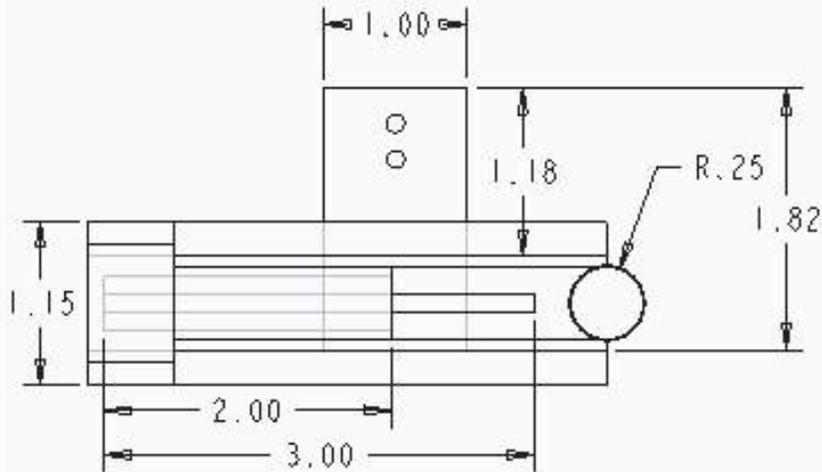


AUVSI ROBO SUB				BRACE			
 MONTANA STATE UNIVERSITY 1893 BOZEMAN - MONTANA				ECE & ME		DRAWING NO. PN-015	
				GA PSTONE		ASSEMBLY PNEUMATICS	
SCALE	3:2	REV	A	DRAFTER		WILSON PLATT	
MATERIAL PVC				DATE	DEC-3	A	



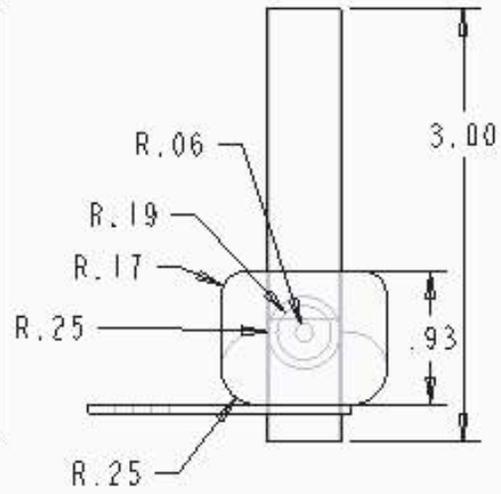
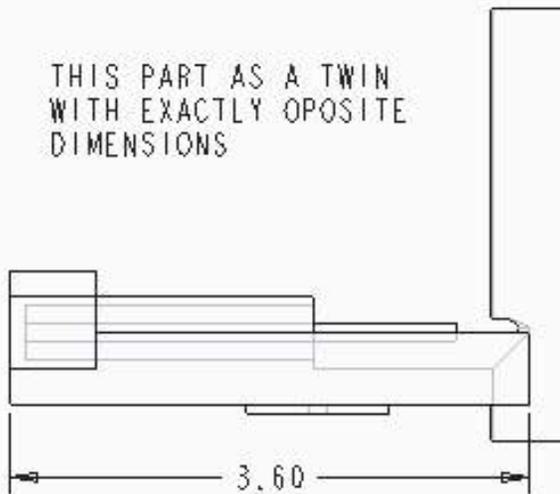
AUYSI ROBO SUB		4" PVC	
		ECE & ME CAPSTONE 2013-2014	
SCALE	1:2	DRAWING NO.	PN-016
MATERIAL	PVC	ASSEMBLY	PNEUMATICS
		DRAFTER	WILSON PLATT
		DATE	DEC-3
			A

ALL DIMENSIONS IN INCHES

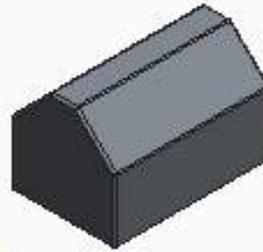


SCALE 0.500

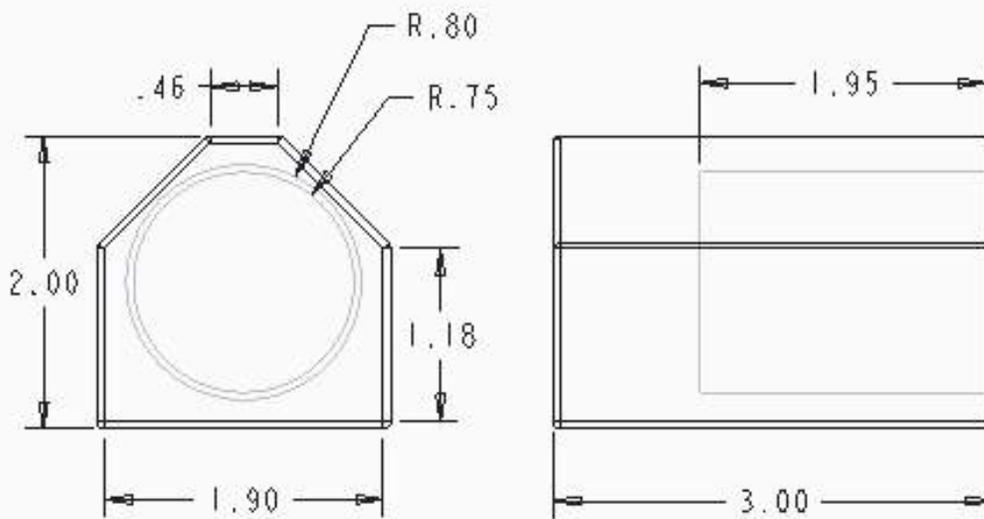
THIS PART AS A TWIN
WITH EXACTLY OPOSITE
DIMENSIONS



AUVSI ROBO SUB				DROPPER TUBE			
 ECE & ME CAPSTONE 2013-2014				DRAWING NO.		DR-001	
				ASSEMBLY		TOP LEVEL	
SCALE	1:1	REV	A	DRAFTER		WILSON PLATT	
MATERIAL		EPOXY		DATE		DEC-3	A



SCALE 0.500

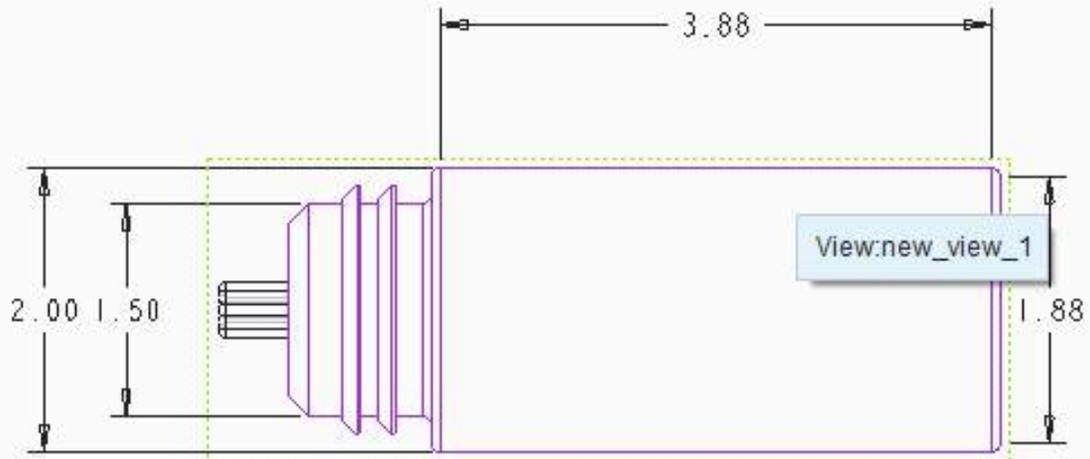


ALL DIMENSIONS ARE IN INCHES

AUVSI ROBO SUB				BATTERY SOCKET			
 MONTANA STATE UNIVERSITY 1893 BOZEMAN, MONTANA				EGE & ME		DRAWING NO. B-001	
				CAPSTONE		BATTERY	
2013-2014		ASSEMBLY		WILSON PLATT			
SCALE	1:1	REV	A	DRAFTER			
MATERIAL		PVC		DATE	DEC-3	A	

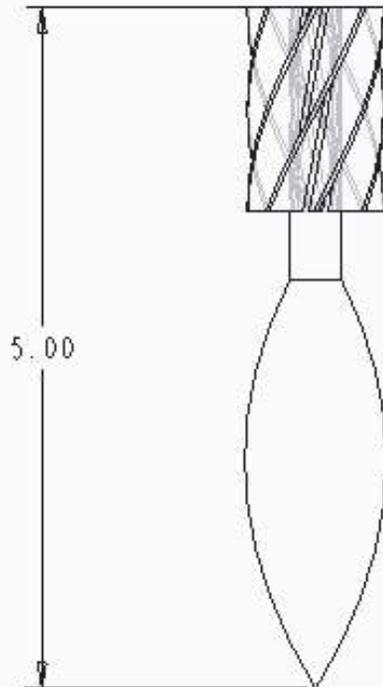
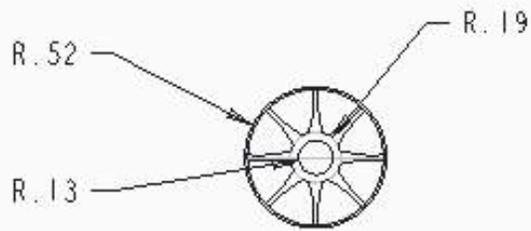


SCALE 0.500



ALL DIMENSIONS ARE IN INCHES

AUVSI ROBO SUB				BATTERY			
 ECE & ME GAPSTONE 2013-2014							
				ASSEMBLY BATTERY			
SCALE	1:1	REV	A	DRAFTER WILSON FLATT			
MATERIAL NEOPRENE		DATE DEC-3		A			



ALL DIMENSIONS ARE IN INCHES

AUVSI ROBO SUB		TORPEDO	
 ECE & ME CAPSTONE 2013-2014			
		ASSEMBLY	TORPEDO
SCALE	1	REV	A
		DRAFTER	WILSON FLATT
MATERIAL		EPOXY	DATE
			DEC-3
			A

Appendix C: Pre-Water Checklist

This checklist is intended to mitigate the common errors that may occur when performing a water test of the submarine, and identify everything that is necessary for using the submarine.

First make sure you have the 4 major components:

- The RoboSub
- Ethernet cable spool with wireless router
- Laptop
- Batteries, battery cables, and charging station

Next, before dropping the RoboSub into the nearest pool, it is helpful to be sure that it is ready to go, so before sealing each end cap check:

- Are both batteries fully charged?
- Are both O-rings greased and seated in their grooves?
- Is every pass-through connection on the end cap tightened down or otherwise sealed?
- Are all electronics functional? Check:
 - Both cameras
 - All six motors
 - IMU
 - Pressure sensor

Appendix D: Electronic Component Data Sheets

Type 381LX / 383LX 105 °C High Ripple, Snap-In Aluminum

High Ripple, Long Life, 2, 4 and 5 pin styles available



Adding longer-life and more ripple capability to the excellent value of Type 380L/LX capacitors, the 381L/LX readily handles tough switching power supply input and output circuits and motor-drive bus capacitor applications where the high surface area of multiple units in parallel equals the ripple capability of our Type 520C inverter-grade capacitor. Type 381LX delivers more capacitance per can size while Type 381L gives lower ESR for the same capacitance rating. Type 383L/LX has 4 or 5 leads for stable, reverse-proof mounting.

Highlights

- Top performance in power supplies and motor drives
- 4 times the life of Type 380L/LX
- 2, 4 and 5 leads available
- Big selection of 42 case sizes

Specifications

Temperature Range	-40 °C to + 105 °C ≤ 315 Vdc -25 °C to + 105 °C ≥ 350 Vdc																																							
Rated Voltage Range	10 Vdc to 450 Vdc																																							
Capacitance Range	33 µF to 150,000 µF																																							
Capacitance Tolerance	± 20%																																							
Leakage Current	≤ 3 \sqrt{CV} µA, 4 mA max, 5 minutes																																							
Ripple Current Multipliers	<p>Ambient Temperature</p> <table border="1"> <thead> <tr> <th></th> <th>45 °C</th> <th>60 °C</th> <th>70 °C</th> <th>85 °C</th> <th>105 °C</th> </tr> </thead> <tbody> <tr> <td>381L 383L</td> <td>2.70</td> <td>2.60</td> <td>2.50</td> <td>2.10</td> <td>1.00</td> </tr> <tr> <td>381LX, 383 LX</td> <td>2.35</td> <td>2.20</td> <td>2.00</td> <td>1.70</td> <td>1.00</td> </tr> </tbody> </table> <p>Frequency</p> <table border="1"> <thead> <tr> <th></th> <th>50 Hz</th> <th>60 Hz</th> <th>120 Hz</th> <th>500 Hz</th> <th>1 kHz</th> <th>5 kHz & up</th> </tr> </thead> <tbody> <tr> <td>10-100 Vdc</td> <td>0.93</td> <td>0.95</td> <td>1.00</td> <td>1.05</td> <td>1.08</td> <td>1.15</td> </tr> <tr> <td>160-450 Vdc</td> <td>0.75</td> <td>0.80</td> <td>1.00</td> <td>1.20</td> <td>1.25</td> <td>1.40</td> </tr> </tbody> </table>		45 °C	60 °C	70 °C	85 °C	105 °C	381L 383L	2.70	2.60	2.50	2.10	1.00	381LX, 383 LX	2.35	2.20	2.00	1.70	1.00		50 Hz	60 Hz	120 Hz	500 Hz	1 kHz	5 kHz & up	10-100 Vdc	0.93	0.95	1.00	1.05	1.08	1.15	160-450 Vdc	0.75	0.80	1.00	1.20	1.25	1.40
	45 °C	60 °C	70 °C	85 °C	105 °C																																			
381L 383L	2.70	2.60	2.50	2.10	1.00																																			
381LX, 383 LX	2.35	2.20	2.00	1.70	1.00																																			
	50 Hz	60 Hz	120 Hz	500 Hz	1 kHz	5 kHz & up																																		
10-100 Vdc	0.93	0.95	1.00	1.05	1.08	1.15																																		
160-450 Vdc	0.75	0.80	1.00	1.20	1.25	1.40																																		
Low Temperature Characteristics	Impedance ratio: $Z_{-20°C} / Z_{+20°C}$ ≤ 10 (10 Vdc) ≤ 8 (16–50 Vdc) ≤ 4 (63–100 Vdc) ≤ 3 (150–450 Vdc)																																							
Endurance Life Test	3000 h at full load at 105 °C Δ Capacitance ±20% ESR 200% of limit DCL 100% of limit																																							
Shelf Life Test	1000 h at 105 °C Δ Capacitance ±20% ESR 200% of limit DCL 100% of limit																																							
Vibration	10 to 55 Hz, 0.06" and 10 g max, 2 h each plane																																							
RoHS Compliant																																								

Type 381LX / 383LX 105 °C High Ripple, Snap-In Aluminum High Ripple, Long Life, 2, 4 and 5 pin styles available

Adding longer-life and more ripple capability to the excellent value of Type 380L/LX capacitors, the 381L/LX readily handles tough switching power supply input and output circuits and motor-drive bus capacitor applications where the high surface area of multiple units in parallel equals the ripple capability of our Type 520C inverter-grade capacitor. Type 381LX delivers more capacitance per can size while Type 381L gives lower ESR for the same capacitance rating. Type 383L/LX has 4 or 5 leads for stable, reverse-proof mounting. Highlights - Top performance in power supplies and motor drives - 4 times the life of Type 380L/LX - 2, 4 and 5 leads available Specifications

- Big selection of 42 case sizes

Temperature Range $-40\text{ }^{\circ}\text{C}$ to $+105\text{ }^{\circ}\text{C}$ $\leq 315\text{ Vdc}$ $-25\text{ }^{\circ}\text{C}$ to $+105\text{ }^{\circ}\text{C}$ $\geq 350\text{ Vdc}$ Rated Voltage Range 10 Vdc to 450 Vdc

Capacitance Range 33 μF to 150,000 μF

Capacitance Tolerance $\pm 20\%$

Leakage Current $\leq 3\sqrt{CV}\text{ }\mu\text{A}$, 4 mA max, 5 minutes

Ripple Current Multipliers Ambient Temperature

45 °C 60 °C 70 °C 85 °C 105°C 381L 383L 2.70 2.60 2.50 2.10 1.00 381LX, 383 LX 2.35 2.20 2.00 1.70
1.00 Frequency

50 Hz 60 Hz 120 Hz 500 Hz 1 kHz

Low Temperature Characteristics Impedance ratio: Z

-200C

5 kHz & up

10-100 Vdc 0.93 0.95 1.00 1.05 1.08 1.15

160-450 Vdc 0.75 0.80 1.00 1.20 1.25 1.40

≤ 10 (10 Vdc)

/Z

$+250\text{C}$

≤ 8 (16–50 Vdc) ≤ 4 (63–100 Vdc) ≤ 3 (150–450 Vdc)

Endurance Life Test 3000 h at full load at 105 °C

Δ Capacitance $\pm 20\%$ ESR 200% of limit DCL 100% of limit

Shelf Life Test 1000 h at 105 °C

Δ Capacitance $\pm 20\%$ ESR 200% of limit DCL 100% of limit

Vibration 10 to 55 Hz, 0.06" and 10 g max, 2 h each plane

RoHS Compliant

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Type 381LX / 383LX 105 °C High Ripple, Snap-In Aluminum

High Ripple, Long Life, 2,4 and 5 pin styles available

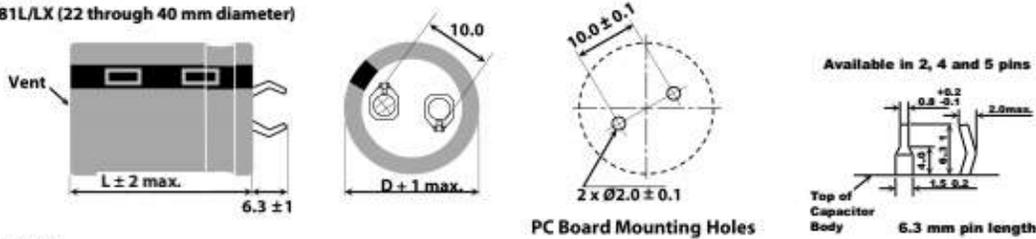
383LX	272	M	200	N08	2	V	+D
Type	Cap	Tolerance	Voltage	Case	Insulation	# of pins	Blank = no end disk if <250V D = end disk, any voltage
381L / LX (2 pins)	100 = 10 μ F	M = \pm 20%	200 = 200 Vdc	2 = PVC	Blank = 2 pins / 4 pins snap-in 6.3mm L		
383L / LX (4 or 5 pins)	101 = 100 μ F				A = 2 pins / 4 pins snap-in 4.0mm L		
	272 = 2700 μ F				V5 = 5 pins snap-in 6.3mm L		
					V = 5 pins standoff		

Outline Drawings

Dimensions shown are in mm

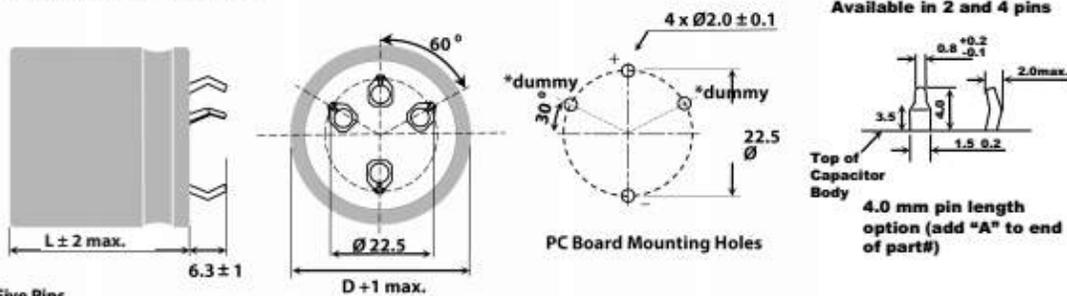
Two Pins

381L/LX (22 through 40 mm diameter)



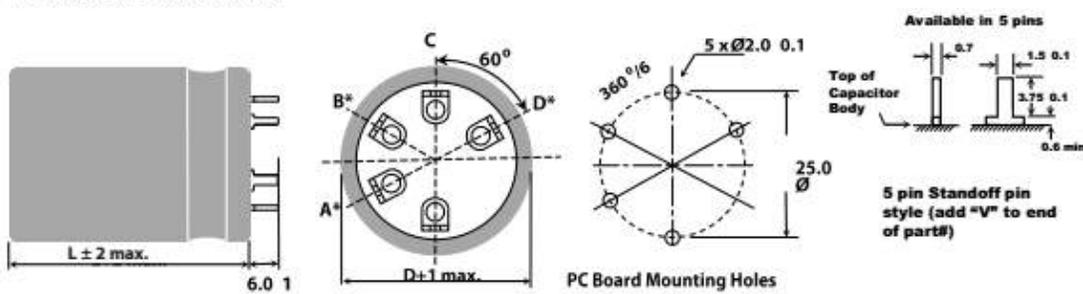
Four Pins

383L/LX (35 and 40 mm diameter)



Five Pins

383L/LX (40 and 50 mm diameter)



Note that for 200 volts and under the insulating end disc is optional - If one is needed add a (+D) to the end of the part numbering system.

Terminal	Connection	
	40 mm Dia.	50 mm Dia.
A	dummy	negative (-)
B	dummy	dummy
C	positive (+)	positive (+)
D	dummy	positive (+)
-	negative (-)	negative (-)

Notes:

* Use dummy terminals for mechanical support only. Make no electrical connection because they resistively connect through the electrolyte to the negative terminal.

** Safety Vent may be on the bottom or on the side of the can.

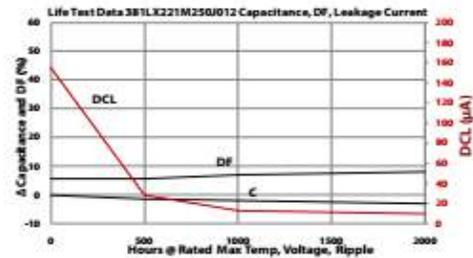
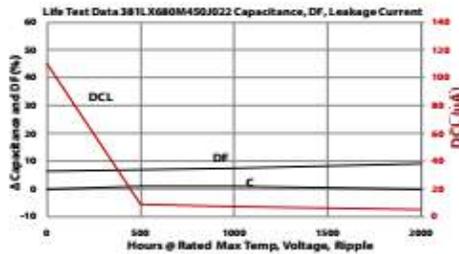
Type 381LX / 383LX 105 °C High Ripple, Snap-In Aluminum

High Ripple, Long Life, 2,4 and 5 pin styles available

Case Code	DIAMETER "D"		LENGTH "L"		Typical Weight (grams)
	mm	inches	mm	inches	
H20	22	0.87	20	0.79	14
H01	22	0.87	25	0.98	16
H02	22	0.87	30	1.18	19
H03	22	0.87	35	1.38	22
H04	22	0.87	40	1.57	24
H45	22	0.87	45	1.77	28
H05	22	0.87	50	1.97	31
J20	25	0.98	20	0.79	16
J01	25	0.98	25	0.98	20
J02	25	0.98	30	1.18	24
J03	25	0.98	35	1.38	27
J04	25	0.98	40	1.57	31
J045	25	0.98	45	1.77	35
J05	25	0.98	50	1.97	38
K20	30	1.18	20	0.79	25
K01	30	1.18	25	0.98	30
K02	30	1.18	30	1.18	35
K03	30	1.18	35	1.38	40
K04	30	1.18	40	1.57	44
K45	30	1.18	45	1.77	48
K05	30	1.18	50	1.97	53

Case Code	DIAMETER "D"		LENGTH "L"		Typical Weight (grams)
	mm	inches	mm	inches	
A20	35	1.38	20	0.79	35
A01	35	1.38	25	0.98	42
A02	35	1.38	30	1.18	48
A03	35	1.38	35	1.38	54
A04	35	1.38	40	1.57	62
A45	35	1.38	45	1.77	67
A05	35	1.38	50	1.97	74
A55	35	1.38	55	2.17	80
A06	35	1.38	63	2.48	88
A07	35	1.38	70	2.76	98
A08	35	1.38	80	3.15	112
A10	35	1.38	105	4.13	144
N04	40	1.57	40	1.57	82
N05	40	1.57	50	1.97	105
N06	40	1.57	63	2.48	130
N08	40	1.57	80	3.15	185
N10	40	1.57	105	4.13	265
B05	50	1.97	50	1.97	136
B06	50	1.97	63	2.48	168
B08	50	1.97	80	3.15	239
B09	50	1.97	92	3.62	241
B10	50	1.97	105	4.13	325

Typical Performance Curves



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More Views



Get CAD files:

EV-3M-12

Valve Porting 3-Way Normally-Closed	Mount Manifold Mount
Connection Type 18" Wire Leads Side (Radial)	Voltage 12 VDC
Series Standard	Pressure Range 28" Hg Vac. to 105 psig
Seals Nitrile	Port Size #10-32

(In Stock)

Qty:

Details

3-Way Elec. Valve, N-C, Manifold Mount, Wire Leads, 12 VDC

See Catalog: [Page 179](#)

Additional Information

Connector	Wire Leads
Air Flow	0.6 scfm @ 100 PSI
Max PSI	0 - 105 PSI
Medium	Air, Gas
Mount	Manifold Mount
Ports	Manifold
Power Consumption	.67 Watts
Response Time	5-10 Milliseconds @ 105 PSI
Temperature Range	30 - 180 F
Voltage	12 VDC
Orifice	0.025"
Wire Size	26 Gauge
Accessories	2020 2021 EVB-2 EVB-3
Air Flow	0.6 scfm @ 100 psig (17 L/min @ 7 bar)
Body Material	Nickel Plated Brass
Connection Type	18" Wire Leads Side (Radial)
Life Cycles	Over 1 Billion
Manifolds	/products/electronic-valve-ev-manifolds
Poppet Travel	0.007"
Port Size	#10-32
Power Consumption	0.67 Watts
Pressure Range	28" Hg Vac. to 105 psig

1 of 2 10/23/2013 7:25 PM

More Views

Get CAD files:

Details

3-Way Elec. Valve, N-C, Manifold Mount, Wire Leads, 12 VDC

See Catalog: Page 179

Additional Information

Connector Wire Leads

Air Flow 0.6 scfm @ 100 PSI

Max PSI 0 - 105 PSI

Medium Air, Gas

Mount Manifold Mount

Ports Manifold

Power Consumption .67 Watts

Response Time 5-10 Milliseconds @105 PSI

Temperature Range 30 - 180 F

Voltage 12 VDC

Orifice 0.025"

Wire Size 26 Gauge

[Accessories 2020 2021 EVB-2 EVB-3](#)

Air Flow 0.6 scfm @ 100 psig (17 L/min @ 7 bar)

Body Material Nickel Plated Brass

Connection Type 18" Wire Leads Side (Radial)

Life Cycles Over 1 Billion

[Manifolds /products/electronic-valve-ev-manifolds](#)

Poppet Travel 0.007"

Port Size #10-32

Power Consumption 0.67 Watts

Pressure Range 28" Hg Vac. to 105 psig

EV-3M-12

Response Time 5 to 10 milliseconds (nominal)

Seals Nitrile

Series Standard

Temperature Range 32 to 180°F (0 to 82°C)

Valve Porting 3-Way Normally-Closed loading

SSI Technologies – Application Note PS-AN2

MediaSensor™ Absolute, Sealed, Gage Pressure Sensors

Family Product Overview

Product Description

The MediaSensor™ (P51) family of bulk micro-machined, absolute, sealed and gage pressure sensors are for both harsh and benign media with superior accuracy over an operating temperature of -40°C to 105°C. These compact, robust sensors measure pressures from 3 PSI to 5,000 PSI and are well suited for a variety of automotive, industrial and commercial applications.

Product Features

- **Superb Accuracy:**
 - +/- 0.5% Full Scale for 75 PSI to 5000 PSI
 - +/- 1% Full Scale for 15 PSI to 60 PSI
 - +/- 2% Full Scale for 3 PSI to 10 PSI
- **Pressure Ranges:** 3 PSI to 5,000 PSI
- **Electronics:**
 - 0.5 – 4.5 Volt output (with 5V input)
 - 0.5 – 4.5 Volt output with overvoltage protection (with 5V input)
 - 1-5 Volt output (with 8 - 30V input)
 - 4 – 20 mA output (with 8 - 30V input)
- **Temperature Range:** -40°C to 105°C
- **Maximum Flexibility:** Custom ASIC provides signal conditioning for calibration and temperature compensation.
- **Standard and custom options available for OEM quantities**
- **Excellent price/performance ratio**



MediaSensor™ Family of Pressure Sensors with integrated signal conditioning

- **Compact, Robust Package:** All laser-welded stainless steel design for optimal media isolation in compact size
- **Chemical Compatibilities:** Any gas or liquid compatible with 304L & 316L Stainless Steel. For example, Motor Oil, Diesel, Hydraulic fluid, brake fluid, water, waste water, Hydrogen, Nitrogen, and Air.
- **Typical Applications:** Refrigeration; Fuel Cells; Pumps; Hydraulics; Process Control; Spraying Systems; Pneumatics; Compressors; Flow; Robotics; Agriculture; Hydrogen Storage

Call us at 1- 888 - 477- 4320

or visit our Website:
<http://ssitechnologies.com>

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SSI Technologies, Inc.

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Revision 3



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Product Description

The MediaSensor™ (P51) family of bulk micro-machined, absolute, sealed and gage pressure sensors are for both harsh and benign media with superior accuracy over an operating temperature of -40°C to 105°C. These compact, robust sensors measure pressures from 3 PSI to 5,000 PSI and are well suited for a variety of automotive, industrial and commercial applications.

Product Features

▪ Superb Accuracy:

- o +/- 0.5% Full Scale for 75 PSI to 5000 PSI
- o +/- 1% Full Scale for 15 PSI to 60 PSI
- o +/- 2% Full Scale for 3 PSI to 10 PSI

- Pressure Ranges: 3 PSI to 5,000 PSI

▪ Electronics:

- o 0.5 – 4.5 Volt output (with 5V input) o 0.5 – 4.5 Volt output with overvoltage protection (with 5V input) o 1-5 Volt output (with 8 - 30V input) o 4 – 20 mA output (with 8 - 30V input)

▪ Temperature Range: -40°C to 105°C

- Maximum Flexibility: Custom ASIC provides signal conditioning for calibration and temperature compensation.

▪ Standard and custom options available for OEM quantities

▪ Excellent price/performance ratio

MediaSensor™ Family of Pressure Sensors with integrated signal conditioning

- Compact, Robust Package: All laser-welded stainless steel design for optimal media isolation in compact size
- Chemical Compatibilities: Any gas or liquid compatible with 304L & 316L Stainless Steel. For example, Motor Oil, Diesel, Hydraulic fluid, brake fluid, water, waste water, Hydrogen, Nitrogen, and Air.
- Typical Applications: Refrigeration; Fuel Cells; Pumps; Hydraulics; Process Control; Spraying Systems; Pneumatics; Compressors; Flow; Robotics; Agriculture; Hydrogen Storage

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Standard Full Scale Pressure Ranges

- Gage: 3, 5, 10, 15, 25, 30, 50, 60, 75, 100, 120, 130, 200, 225, 250 and 300 PSIG
- Sealed: 50, 100, 150, 200, 300, 400, 500, 750, 1000, 1500, 2000, 3000 and 5000 PSIS
- Absolute: 15, 30, 50, 65, 75, 100, 150, 200, 250, 300, 500, 750, 1000, 1500, 2000, and 3000 PSIA

Measurement Technology

In general, pressure measurement technology translates force from an induced pressure into an electrical quantity. The MediaSensor™ family of pressure transducers and transmitters use piezoresistive technology for its sensor signal processing to measure pressure.

A micro-machined stainless steel convoluted diaphragm with a silicon crystal semiconductor is used. Strain gauges (resistive elements) in the silicon crystal are used in a Wheatstone Bridge circuit. When pressure is applied, the resistivity of the strain gauges changes proportional to the pressure applied. Since a single silicon crystal is used it has a low mechanical hysteresis with good linearity.

One leg of the bridge measures the input pressures port. The other leg of the bridge is connected to the reference port the input pressure port is compared to. The connection to this reference port determines the pressure sensing convention used.

The MediaSensor™ family comes in a choice of three pressure sensing type conventions: absolute, gauge (vented or sealed).

Absolute MediaSensors™ measure pressure relative to perfect Vacuum pressure (0 PSI) which remains unchanged regardless of temperature, location or other ambient conditions such as weather. Absolute MediaSensors™ are calibrated to have 0.5 Vdc, 1 Vdc, or 4 mA respectively at 0 PSIA.

There are two different gauge pressure conventions – Vented Gauge and Sealed Gauge. Gauge MediaSensors™ measure pressure relative to ambient room pressure through a port that is vented (open) to the atmosphere. Gauge MediaSensors™ are calibrated to have 0.5 Vdc, 1 Vdc, or 4 mA respectively at 0 PSIG.

Sealed MediaSensors™ measure pressure relative to a port that is connected to a sealed perfect vacuum chamber. Sealed MediaSensors™ are calibrated to 14.5 PSI absolute. Sealed MediaSensors™ are calibrated to have 0.5Vdc, 1 Vdc, or 4 mA respectively at 14.5 PSIA.

The MediaSensor™ takes the two voltage output ports of the Wheatstone bridge and amplifies the signal. Piezoresistive pressure sensors are sensitive to changes in temperature. The MediaSensor™ uses signal conditioning to compensate for temperature and calibration. The output signal is then converted into one of four forms:

- 1) 0.5 – 4.5 Volt ratiometric output (transducer)
- 2) 0.5 – 4.5 V ratiometric output with Overvoltage protection (transducer)
- 3) 1 – 5 volt output (transducer)
- 4) 4 – 20 mA output (transmitters)

Ratiometric outputs vary as a ratio of the supply voltage.

Transmitters are very suitable in applications that use long cables. There is virtually no error from voltage drop introduced from the wire resistance when sending the signal as a current. They are also less sensitive to electromagnetic interference.

Some piezoresistive pressure transducers use only an unprotected silicon sensing element. Silicon is a brittle crystalline material, which can sometimes crack under severe cold transient environments. The MediaSensor™ pressure transducer uses an additional 316L stainless steel convoluted diaphragm with a protective non-silicone oil to protect the sensitive silicon sensing element from the harsh media and environmental conditions. The 316L stainless steel diaphragm not only provides for optimal water and chemical media isolation for the silicon crystal sensing element but can handle cold temperature transients without sustaining damage.

Under cold transient conditions and within our operating temperature range, the oil does not gel and acts as a buffer for the silicon sensing element from the extreme temperature transients found in certain applications such as refrigeration.

MediaSensor™ Compensations Features

All the compensation circuitry is internal to the MediaSensor™ pressure transducer. No external compensation modules are needed.

1) Zero balancing (Null Offset) Calibration

During manufacturing the Wheatstone Bridge resistive elements are closely matched and compensated, however an offset voltage (due to resistance differences) may still exist. SSI MediaSensor™ compensates for this offset over operating temperature range (refer to Table 1).

2) Span Calibration

The resistance of silicon gauges is temperature dependent. The span will shift with temperature to a final stabilized value as it warms up. SSI MediaSensor™ compensates for this span variation over operating temperature range.

AdaptNav™

Adaptive Sensor Fusion Algorithms

Description

Best-in-class AdaptNav™ and AdaptNav II™ adaptive algorithms for the Sparton GEDC-6 and AHRS-8 outperform traditional Kalman filter based approaches by providing real-time optimization of product performance when used in varying magnetic and dynamic operating environments. AdaptNav™ opens the door to optimized sensor system performance and a simplified approach to platform-specific customization.

Features

So what are AdaptNav™ and AdaptNav II™, and why are they extraordinary?

1. Sparton AdaptNav™ adaptive algorithms provide real-time (non-linear) sensor heading optimizations when used in varying magnetic and dynamic operating environments, offering unparalleled orientation accuracy under the most challenging conditions.
2. Our AdaptNav™ algorithms look at the system dynamics of the sensor environment in real-time and make adjustments based on optimal sensor reliability modeling.
3. AdaptNav™ improves on traditional Kalman filter based approaches by not requiring a dynamic profile to be preselected. There is no need to pre-select operational environment or use 'trial and error' parameter settings prior to deployment in the sensor application. This eliminates the guesswork often associated with many Kalman filter based implementations.
4. The AdaptNav II™ adaptive algorithm builds upon the AdaptNav™ feature functionality and provides revolutionary real-time noise characterizations used for drift compensation of heading, pitch and roll when in electrically and mechanically noisy environments (applicable to AHRS-8 only). 'Noisy' environments include magnetic materials in proximity of the inertial system, batteries, electric motors and high-current carrying wires as well as vibration, or vibratory rotation.
5. AdaptNav™ and AdaptNav II™ assures an exceptional out-of-box experience, facilitating ease of use in the selected application after completion of in-field calibration.



Please visit us at www.spartonnavex.com for additional information on the Sparton Navigation and Exploration line of inertial systems.

For more information and detailed specifications scan QR code. For support, please e-mail: productsupport@sparton.com

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De Leon Springs, FL 32130
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www.spartonnavex.com

AdaptNav.02



sparton
NAVIGATION AND EXPLORATION

Adaptive Sensor Fusion Algorithms

Product Data Sheet

GEDC-6

Gyro Enhanced Attitude & Heading System



Description

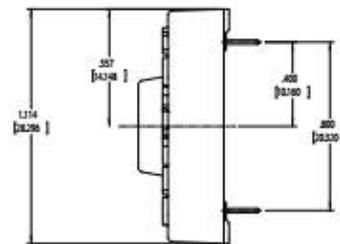
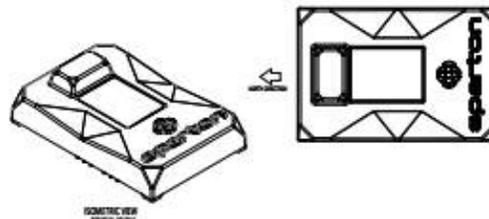
The Sparton GEDC-6 Attitude and Heading System provides best-in-class reliability and superior performance in challenging dynamic and magnetic environments by combining accurately calibrated tri-axial magnetometers and accelerometers with a set of tri-axial gyros. Proprietary state-of-the-art AdaptNav™ algorithms allow the GEDC-6 to provide accurate attitude and heading outputs, including full 360° tilt compensation, even when subject to highly dynamic operating environments and in the presence of transient magnetic interference. AdaptNav™ also includes enhanced adaptive in-field calibration algorithms to provide superior system performance, even in the presence of magnetic distortions due to ferrous objects positioned on the mounting platform. The GEDC-6 also incorporates the World Magnetic Model allowing it to provide a True North output at all locations around the globe.

Features

- Integrated AdaptNav™ adaptive algorithms provide real-time optimization of sensor performance when used in dynamic operating environments
- 2D and 3D adaptive in-field cal providing hard and soft magnetic interference compensation
- High dynamic heading accuracy enhanced by use of gyroscopes and fast sampling rate
- Simple 2-wire serial (UART) interface (3.3V logic level) with user-selectable baud rate
- Advanced sensing technology (3-axis magnetic, 3-axis MEMS acceleration, and 3-axis MEMS gyro)
- Built-in World Magnetic Model for accurate True North
- Rugged (epoxy encapsulated) construction and small physical size
- Magnetic and True North heading (yaw), pitch, and roll measurement
- Low power consumption and power management (Sleep Mode) functionality
- Powerful user programmable sensor customizations via NorthTek™ Forth interpreter
- Supports multiple communication protocols
- Full 360° rollover capability

Typical Applications

- Pan and Tilt, Mapping
- Platform stabilization, positioning and antenna pointing
- Weather, data, and ocean surveillance
- Electro-optical target designation systems
- Accurate vehicle attitude position and orientation sensing
- Precision autonomous unmanned vehicle guidance



GEDC-6.04



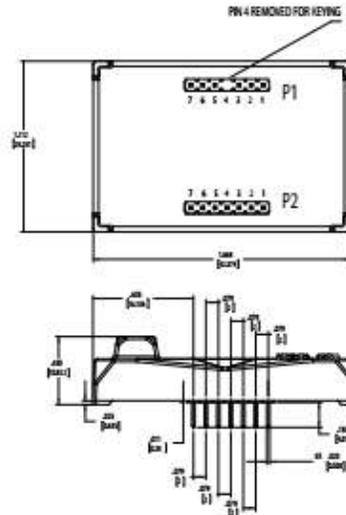
Product Data Sheet

GEDC-6

Specifications

Dynamic Heading Accuracy	1.0° RMS ¹
Static Heading Accuracy	0.3° RMS
Heading Repeatability	0.1° RMS
Dynamic Pitch/Roll Accuracy	1.0° RMS ¹
Static Pitch/Roll Accuracy	0.2° RMS
Pitch/Roll Repeatability	0.1° RMS
Pitch/Roll Range	± 90°, ± 180°
Accelerometer Range (Selectable) ²	+/- 4g (+/- 1g) ²
Accelerometer Noise Density	126 µg/√Hz
Accelerometer Bias Stability	0.023 mg
Accelerometer Velocity Random Walk (VRW)	0.063 m/s
Gyro Dynamic Range (Selectable)	± 480°/sec (± 300°/sec) ²
Gyro Noise Density	0.03 dps/√Hz
Gyro Bias Stability	10.8°/Hr
Gyro Angular Random Walk (ARW)	1.5 deg/Sqrt[Hr]
Magnetic Range	±1.2 Gauss (±900 MGauss) ²
Maximum Magnetic Inclination (Dip)	± 80°
Update Rate (Samples/Sec)	100
Baud Rate	0.3, 1.2, 2.4, 4.8, 9.6; 19.2; 38.4; 57.6; 115.2 kbaud
Dimensions L x W x H	42 x 28 x 11 mm (1.66 x 1.11 x 0.43 inches)
Mass	16g
Encapsulated or Enclosure	Yes
Storage Temperature	-40° to +85° C
Operating Temperature	-40° to +85° C
Humidity Resistance	95%, 70° C, 240 hrs Meets MIL-STD-202G Method 103A, Test Condition A
Shock Resistance	1500g, 1ms Pulse, Half-Sine Wave Meets MIL-STD-202G Method – 213B, Test Condition F
Vibration Resistance	.06 dB Power Spectral Density, 9.26 G RMS Meets MIL-STD-202G – Method 214A, Test Condition MC
Power Supply Input (Unregulated Voltage)	+4 to +10V DC
Input Power, Operating Mode (Typical @ 4v)	320 mW
Input Power, Sleep Mode (Typical @ 4v)	12 mW
3.3V Logic UART Interface	Yes
2D and 3D In-Field Calibration	Yes
Able To Maintain Function When Inverted	Yes
Quaternion/Rotation Matrix Output	Yes
True North Heading Output	Yes
NorthTek™ User Programmable Customizations	Yes
Pin Connectivity Gold Plating	Meets MIL-G-45204 Type III Class 4
Includes World Magnetic Model	Yes
RoHS Compliant	Yes

Pin #	Pin Name	I/O	Function
P1-1	V_TEST	O	3.3V regulator output for test purposes (factory use only)
P1-2	DEBUG_RXD	I	3.3V logic RXD Input to Debug Port (factory use only)
P1-3	DEBUG_TXD	O	3.3V logic TXD Output from Debug Port (factory use only)
P1-4		N/A	Pin removed for keying
P1-5	#WP_EEPROM	I	3.3V logic, active-low EEPROM write protect (the pin has 10kΩ pull-down)
P1-6	Factory Use	I	Do not connect (factory use only)
P1-7	GND	N/A	System Ground
P2-1	V+	I	+4 to +10V DC power supply input. Max load = 80mA
P2-2	USER_RXD	I	3.3V logic RXD input to User Com Port
P2-3	USER_TXD	O	3.3V logic TXD output from User Com Port
P2-4	#RESET	I	3.3V logic, active-low reset input (the pin has a weak pull-up)
P2-5	#BINT0	I	3.3V logic, active-low interrupt input (the pin has a weak pull-up). Used for programming purposes
P2-6	GND	N/A	System Ground
P2-7	GND	N/A	System Ground



¹ Dynamic heading accuracy derived from Seasby table set for 7 RPM, 30° of inclination.
² Specifications in parentheses represent current limits of calibration methodology.
 Specifications subject to change without notice.
 Performance data applies to 25° C, 0g Acceleration for Pitch/Roll unless otherwise specified.
 For more information and detailed specifications scan QR code.
 For support, please e-mail: productsupport@spartan.com

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GEDC-6.04





USB Weather Board V3

2011.6.15

Overview

Got weather? The USB Weather Board V3 can handle it. This board was designed to perform atmospheric measurements using a suite of onboard and external sensors, and consolidate that data into a serial data stream suitable for a datalogger or computer.

This versatile board features the following built-in sensors:

- Humidity (SHT15, COM-08227)
- Pressure (BMP085, COM-09603)
- Temperature (available from both humidity and pressure sensors)
- Light (TEMT6000, COM-08348)

You can optionally connect the board to SparkFun's Weather Meters (SEN-08942, not included), to add the following sensors:

- Wind speed
- Wind direction
- Rainfall

The board can send all this information to a host computer or datalogger via:

- Mini-USB cable (not included)
- Logic-level serial
- BlueSMiRF Bluetooth modem (not included)
- XBee radio module (not included)

The board can be powered via:

- Mini-USB cable (not included)
- An external DC power source from 3.7V to 12V (a JST connector is provided for a 3.7V Lithium-Polymer battery, not included).
- A regulated external 3.3V supply.

To top it all off, the board is Arduino compatible (3.3V, 8MHz, w/ ATmega 328) for easy reprogramming and customization.

Specifications

Power

- Voltage: 3.7V to 12V external supply, or 5V via mini-USB cable (not included). JST connector provided for 3.7V LiPoly battery.
- Current: 15mA average (no wireless), 60mA average with wireless module (1mW Xbee or class 1 Bluetooth)

The internal 3.3V regulator can supply 500mA peak to an XBee or additional hardware. The XBee socket is powered by the board's 3.3V regulator, while the BlueSMiRF socket is powered by USB 5V or raw external voltage.

Data

- 9600 baud 8N1 async serial (default)
- Numerous data output options available from configuration menu,

Sensors

- SHT15 humidity/temp sensor (COM-08227)
- BMP085 pressure/temp sensor (COM-09603)
- TEMT6000 ambient light sensor (COM-08348)
- Unpopulated headers provided for Weather Meters (SEN-08942, not included), which add sensors for wind direction, wind speed, and rainfall.

Wireless (optional)

The board can optionally accommodate either an XBee or BlueSMiRF radio module for wireless operation. Radio module and socket not included.

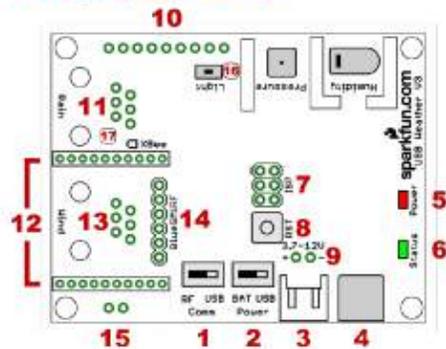
Dimensions

- Overall: 2.6" x 2" (1/16" board thickness)
- Bolt pattern: 2.4" x 1.8" (4-40)
- A socketed XBee module (optional) will extend 0.4" above the board
- A socketed BlueSMiRF module (optional) will extend 0.6" above the board
- RJ11 connectors for the Weather Meters (optional) extend 0.6" below the board

USB Weather Board V3

2011.6.15

Board layout (component side)



1. Comm switch (USB or RF)
2. Power switch (USB or battery/external)
3. JST battery connector (3.7V to 12V)
4. Mini-USB connector
5. Power LED (red)
6. Status LED (green)
7. ISP programming header (JP7)
8. Reset button
9. External power header (JP2, 3.7V to 12V)
10. Expansion header (JP7, see schematic)
11. WM rain gauge RJ11 header
12. XBee header
13. WM wind speed / direction RJ11 header
14. BlueSMiRF header
15. Regulated 3.3V in / out header (JP8)
16. SJ1, solder jumper for external light sensor
17. SJ2, solder jumper for BlueSMiRF reset (see "Hacking Tips" below)

TIP: Whenever you solder on the Weather Board, take care when cleaning up afterward. The pressure and humidity sensors are sensitive to contaminants, so don't get them wet or dirty if possible. See the sensor datasheets for more information.

Power connection

The board can be powered via USB cable, or a 3.7V LiPoly battery, or an external DC power source from 3.7V to 12V, or an external regulated 3.3V source.

The power switch lets you choose between USB and battery/external power. To turn the board on, move

the power switch towards the power source you're using, USB or BAT (BAT includes external power). The red power LED will illuminate and the green status LED will blink three times. To turn off the board, move the power switch to the other position.

Power via USB

To power the board from USB, connect it to a computer using a standard mini-B USB cable (such as SparkFun part number CAB-00598), and move the power switch to the USB position. The first time the board is plugged into a computer, you will need to load FTDI drivers to activate the serial port (see "Data via USB" below).

Power via battery or external supply

To power the board from a 3.7V Lithium Polymer battery (not included, see sparkfun.com for options), connect the battery to the white JST connector. To turn on the board, move the power switch to BAT.

To power the board from an external 3.7V to 12V source, you can connect a JST pigtail (SparkFun part number PRT-08670) to the JST connector, or solder wires directly to the 2-pin header behind the JST connector. Connect positive to the red wire on the pigtail, or the header labeled "+". Connect ground to the black wire on the pigtail, or the header labeled "-". *Note that the board is not reverse-polarity protected, so double check your polarity before providing power.*

You can also use an external, regulated 3.3V supply to run the board, by connecting it to header JP8. Note that the power switch will not operate in this case, and that an attached BlueSMiRF will not function (the BlueSMiRF requires 3.7V or above through the unregulated power input).

Data connection

There are several ways to get weather data out of the board. Note that you will only be able to use one data connection at a time. The Comm switch controls where the board will receive data from (USB or RF).

Data via USB

To power and communicate with the board via USB, connect it to a computer using a standard mini-B USB cable (SparkFun part number CAB-00598). Move the Power switch and Comm switch to USB.

USB Weather Board V3 2011.6.15

Once the switches are correctly set and the board is plugged into a computer, the correct drivers should be loaded automatically. If there is a problem, you can manually download and install the drivers from <http://www.ftdichip.com/Drivers/VCP.htm>. Once the drivers are working, a virtual COM port will be created in your computer that links to the Weather Board's FTDI chip. The COM port number should be listed in your computer's Device Manager and the Arduino IDE or terminal software you use to communicate with the board (see "Using the board" below).

Data via logic-level (3.3V) serial

To connect the board to a 3.3V microcontroller serial port (UART), you will need to solder wires to the BlueSMiRF connector. You'll need 3 wires; TXO (data transmitted out of the board), RXI (data received into the board), and GND. Move the Comm switch to RF.

Note that these are 3.3V logic-level signals, and should not be connected to a true RS-232 (+/-10V) port without translating hardware (not included). However, you *may* connect these signals to a 5V system as the BlueSMiRF header contains clipping circuitry to lower incoming voltages to 3.3V (the outgoing voltage will still be 3.3V, which most 5V systems can successfully read).

Data via wireless module

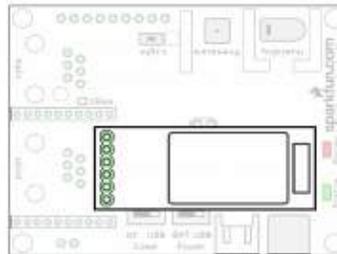
The Weather Board has provisions to transmit data via wireless radio module, either a BlueSMiRF Bluetooth modem, or XBee. Note that no radio systems are included with the weather board, and as the connectors overlap, you can only install one radio system (Bluetooth or XBee) at a time.

Data via Bluetooth modem

You can use a SparkFun BlueSMiRF modem (part no. WRL-00582 and others) to allow the board to transmit data wirelessly. You will also need a Bluetooth receiver, such as those built into many laptops, to receive the data.

The header on the Weather Board is configured for the BlueSMiRF pinout, and will accommodate any of the BlueSMiRF products sold by SparkFun. (You may be able to adapt other radio systems to the Weather Board, but it will require manually wiring the header to your radio inputs and outputs.)

You could solder a BlueSMiRF module directly to the Weather Board using M-M headers (SparkFun part no. PRT-00116), but we recommend using male and female headers (PRT-00115) to allow the BlueSMiRF to be removed if necessary. Ensure that you plug the BlueSMiRF module into the Weather Board in the correct orientation (the BlueSMiRF should "point" back towards the USB socket):



To configure your BlueSMiRF module, set up your computer to find nearby Bluetooth devices, and power up the Weather Board + BlueSMiRF. Your computer should see the BlueSMiRF module listed as "FireFly" followed by four hexadecimal digits. Connect to the module, entering the PIN code "1234" when asked. A new virtual COM port will be created, and the solid green LED on the BlueSMiRF will light up. Connect to the new COM port using your terminal program of choice (Hyperterm, Tera-Term, etc.) at 115200 baud, 8 bits, 1 stop bit, no parity.

At this point, you'll want to configure the BlueSMiRF module to work with the Weather Board. The first step is to configure the BlueSMiRF module's serial port for 9600 baud (the Weather Board's default baud rate). *Within the first 60 seconds after the BlueSMiRF has been powered on, connect to it with your terminal program, and type "\$\$\$".* The BlueSMiRF will respond with "CMD". Type the following commands, pressing enter after each one:

```
+
SU,96
ST,255
---
```

The "+" turns on local echo so you can see what you're typing. The "SU,96" sets the BlueSMiRF's baud rate to 9600 baud. (Note that you should *not* change

USB Weather Board V3

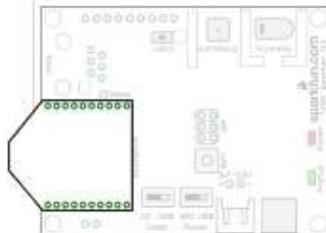
2011.6.15

your terminal program settings to 9600 baud; leave them at 115200. This 9600 baud rate is only between the BlueSMiRF and the Weather Board.) The "ST,255" turns off the 60-second remote configuration timer, which will allow you to remotely configure the BlueSMiRF at any time. Finally the "--" exits command mode and returns you to the serial connection. You will need to power-cycle the Weather Board / BlueSMiRF to cause these commands to take effect; once you do and reconnect to the module, you should see weather data being transmitted to your computer. See the BlueSMiRF documentation for more information.

Data via XBee radio

You can use an optional XBee module to connect to the Weather Board. You will need two matching XBee modules, one for the Weather Board, and one for the receiving end. (If the receiving end is a PC, you may want to use an adapter such as SparkFun part no. WRL-08687 to connect the XBee module to your computer's USB port.) You will also need two 2mm 10-pin XBee sockets (part no. PRT-08272) to connect one of the XBee modules to the Weather Board.

Solder the XBee sockets to the Weather Board. Note that these sockets attach to the top of the board, in the long white rectangles. Note also that XBee sockets tend to wick solder, so use the smallest amount possible.



Your XBee modules may need to be configured to connect to each other. Series 1 modules do not need any configuration, they'll talk to each other at 9600 baud out of the box. Series 2 and above modules may need to be configured. See the XBee tutorials at www.sparkfun.com/tutorials for instructions on how to accomplish this. Be sure to set the baud rate of both XBee modules to 9600 to match the Weather Board's

default baud rate (or the rate you've set using the configuration menu).

Once the sockets are soldered to the board and your XBee modules are properly configured, ensure that the "Comm" switch is set to "RF", plug in your XBees and power up. If everything is working, the XBees should link up and weather data should appear at the computer-side XBee.

Connecting to the Weather Meters

You can optionally connect the Weather Board to SparkFun's Weather Meters (SEN-08942), giving you three additional outdoor sensors: wind speed, wind direction, and rainfall. To do this, you will need to solder two RJ11 telephone-style connectors (PRT-00132, not included) to the Weather Board.

TIP: If you're ever going to connect the Weather Board to an XBee module, it's easiest to solder the XBee sockets to the board *before* you attach the RJ11 connectors.

IMPORTANT: The RJ11 connectors attach to the *bottom* of the board (the side without components), inside the white rectangular outlines. Fit each connector to the bottom of the board, ensuring that all six pins go into their respective holes. Once the pins are all in the holes, press the posts on the connector into the holes on the Weather Board until the connector snaps into place. Once the connector is snapped onto the board, carefully solder the six pins. Be especially careful when soldering near the surface-mount components on the top side of the board.

The Weather Meters come with preattached 10' cables that click into the connectors you just attached to the Weather Board (remember to connect the anemometer + wind direction cable to the Weather Board connector labeled "Wind", and the rain gauge cable to the connector labeled "Rain"). If you need to locate the Weather Meters further away from the Weather Board, you can use RJ11 extension cables, which are commonly used for wired telephones and available wherever telephone accessories are sold. Be sure you get four-conductor telephone cables, not two-conductor handset cables.

TIP: After you've installed the extension cables, use silicone sealant on the outdoor connections to prevent water from getting into them.

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Crucial M500 120GB 2.5-inch Internal SSD



Part Number: CT120M500SSD1

- Transformative performance: dramatically faster than a hard drive
- Nearly instant boot times
- Three-year limited warranty



\$109.99

QTY:

Currency Converter

Reviews Articles Discussion Installation Product Details

Transform your system's performance.

Dramatically faster than a hard drive, the Crucial M500 SSD isn't just a storage upgrade - it's a complete system transformation. Designed to keep your system up to speed with today's multitasking demands that often require instant and simultaneous use of apps, websites, downloads, work files and more, the Crucial M500 delivers nearly instant boot times, powerful data transfer speeds, increased multitasking capability, and rock-solid reliability - all at an affordable price. The Crucial M500 also includes top-level encryption technology to keep your data safe and is available in capacities up to terabyte-class. Built on proven quality, the Crucial M500 SSD has passed hundreds of SSD quality tests and over a thousand hours of pre-release validation testing. Don't settle for anything less.

Product Highlights

- Ample storage: available in capacities of 120GB, 240GB, 480GB, and 960GB†
- Includes top-level hardware encryption technology
- Advanced controller technology and Micron custom firmware
- Extensive quality and reliability testing built into every drive
- Compatible with PC and Mac® systems

†1 GB = 1 billion bytes. Actual usable capacity may vary.



MICRON® QUALITY

Micron® Quality - As a brand of Micron, one of the largest NAND manufacturers in the world, Crucial SSDs are designed and developed in-house with the latest technology. This means four things: hundreds of SSD qualification tests, over a thousand hours of pre-release validation testing, 1.5 billion dollars invested in R&D, and more than 30 years of industry expertise.



HARDWARE DATA ENCRYPTION

Adaptive Thermal Protection - Greater thermal management enables the Crucial M500 to work with the host computer to dynamically adjust power consumption based on usage demands, which helps address the cooling challenges of ultra-small, thermally constrained systems.



ADAPTIVE THERMAL PROTECTION



THREE YEAR LIMITED WARRANTY

Hardware Data Encryption - The Crucial M500 SSD offers top-level hardware-based encryption, enabling enhanced data security. Our AES 256-bit hardware encryption engine

and TCG Opal 2.0 compliant firmware allow the drive to operate at full speed without the performance loss that's typically found in drives that use software-based encryption technology.

Three Year Limited Warranty - From pre-release validation testing to ensure that our SSDs work with the broadest range of chipsets, motherboards, and operating systems to more than a thousand hours of endurance testing, our drives are tested for reliability from start to finish. We proudly offer a three-year limited warranty and award-winning tech support.

Capacity (Unformatted): 120GB
 Interface: SATA 6Gb/s (SATA 3Gb/s compatible)
 Sustained Sequential Read up to (128k transfer): 500MB/s
 Sustained Sequential Write up to (128k transfer): 130MB/s
 Random Read up to (4k transfer): 62,000 IOPS
 Random Write up to (4k transfer): 35,000 IOPS
 Form Factor: 2.5-inch, mSATA, and M.2
 NAND: 20nm Micron MLC NND
 Life Expectancy: 1.2 million hours mean time to failure (MTTF)
 Endurance: 72TB total bytes written (TBW), equal to 40GB per day for 5 years
 Operating Temperature: 0°C to 70°C
 Compliance: RoHS, CE, FCC, UL, BSMI, C-TICK, KCC RRL, W.E.E.E., TUV VCCI IC
 Firmware: Field upgradable firmware

TECHNICAL MANUAL

Of

Intel HM67 Express Chipset

Based Mini-ITX M/B

No: G03-NC9B-F

Revision: 2.0

Release date: September 19, 2012

Trademark:

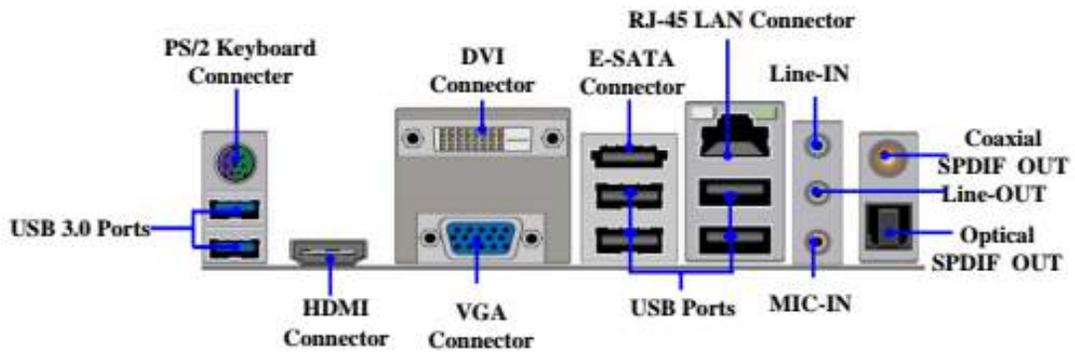
- * Specifications and Information contained in this documentation are furnished for information use only, and are subject to change at any time without notice, and should not be construed as a commitment by manufacturer.

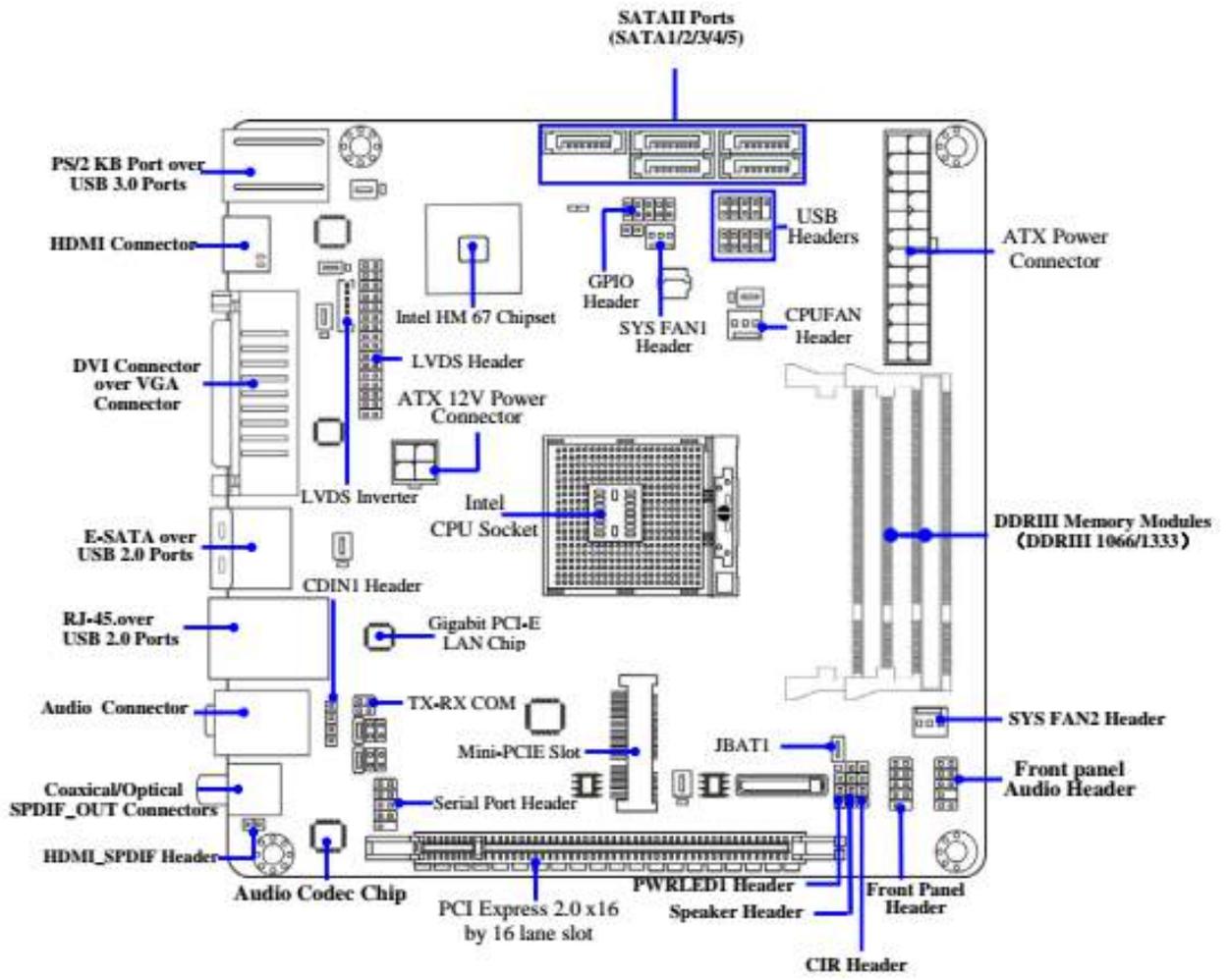
1-2 Specification

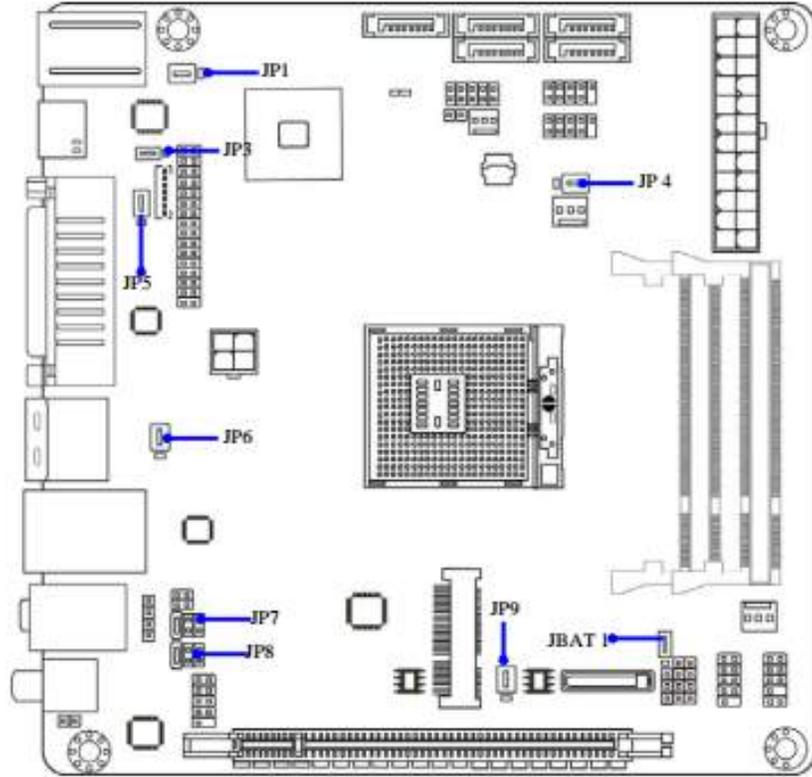
Spec	Description
Design	<ul style="list-style-type: none"> ● Mini-ITX form factor 6 layers ; PCB size: 17.0x17.0cm
Chipset	<ul style="list-style-type: none"> ● Intel HM67 Express Chipset
CPU Socket	<ul style="list-style-type: none"> ● Intel socket G (rPGA 988B) ● Support up to Intel Core™ i3, i5, i7 Mobile Processors
Memory Socket	<ul style="list-style-type: none"> ● 2 * SODIMMs Sockets ● Support two DDRIII 1333/1066 MHz SODIMMs expandable to 16 GB ● Support dual channel function
Expansion Slot	<ul style="list-style-type: none"> ● PCIE 2.0 by 16 lane slot x1 ● Mini-PCIE slot x1
LAN Chip	<ul style="list-style-type: none"> ● Integrated Intel 82579LM Gigabit Ethernet LAN chip that supports Fast Ethernet LAN function of providing 10Mb/100Mb/1000Mb Ethernet data transfer rate ● Intel 82579LM Gigabit Ethernet LAN chip supports Intel Active Management Technology 7.0
Audio Chip	<ul style="list-style-type: none"> ● VIA VT 1705 6-channel HD Audio Codec integrated ● Audio driver and utility included
BIOS	<ul style="list-style-type: none"> ● 32MB SMT Flash ROM
Multi I/O	<ul style="list-style-type: none"> ● PS/2 keyboard connector x1 ● HDMI connector x 1 ● DVI connector x1 (HDMI Connector and DVI Connector can not be used at the same time) ● VGA port connector x1 ● USB 2.0 port x4 and USB 2.0 header x2 ● USB 3.0 port x2 ● E-SATA connector x1 ● RJ-45 LAN connector x1 ● Audio connector x1 (Line-in, Line-out, MIC) ● Coaxial S/PDIF Connector x1

	<ul style="list-style-type: none"> ● Optical S/SPDIF Connector x1 ● Front panel audio header x1 ● SATAIII Connector x2 ● SATAII Connector x3 ● CDIN header x1 ● LVDS header x1 ● LVDS Inverter x1 ● HDMI_SPDIF header x1 ● Serial port header x1 ● RS422/RS485 header x1 ● Front panel header x1 ● CIR header x1 ● GPIO header x1
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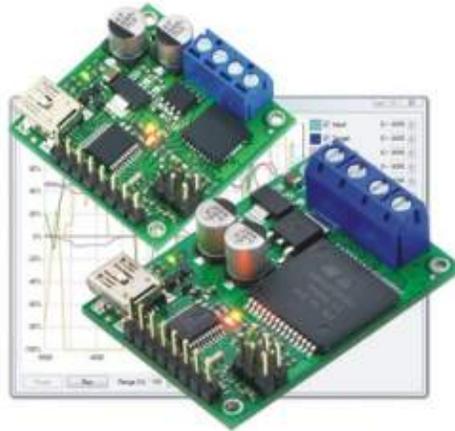
1-3 Layout Diagram







Pololu Jrk USB Motor Controller User's Guide



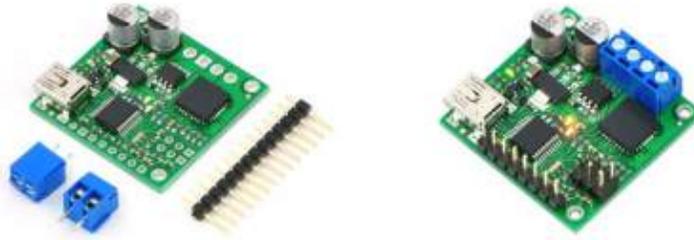
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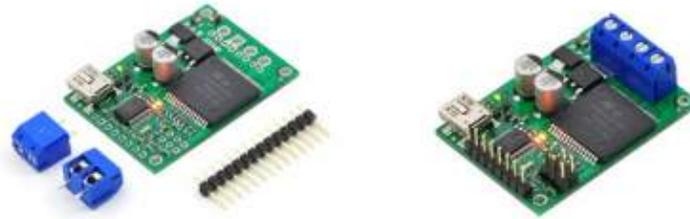
- Simple configuration and calibration over USB with free configuration program (Windows 8, Windows 7, Vista, Windows XP compatible).
- Configurable parameters include:
 - PID period and PID constants (feedback tuning parameters).
 - Maximum current.
 - Maximum duty cycle.
 - Maximum acceleration.
 - Error response.
 - Input calibration (learning) for analog and RC control.
- Optional CRC error detection eliminates communication errors caused by noise or software faults.
- Reversed power protection.
- Field-upgradeable firmware.
- Optional feedback potentiometer disconnect detection.

Specifications

	Jrk 21v3	Jrk 12v12
Motor channels:	1	1
Operating voltage:	5 – 28 V	6 – 16 V
Continuous output current:	3 A	12 A
Peak output current:	5 A	30 A
Auto-detect baud rate range:	300 – 115,200 bps	300 – 115,200 bps
Available fixed baud rates:	300 – 115,200 bps	300 – 115,200 bps
Available PWM frequencies:	20 kHz, 5 kHz	20 kHz, 5 kHz
Reverse voltage protection?:	Yes	Yes
USB connector style:	USB Mini-B	USB Mini-B

Included Hardware





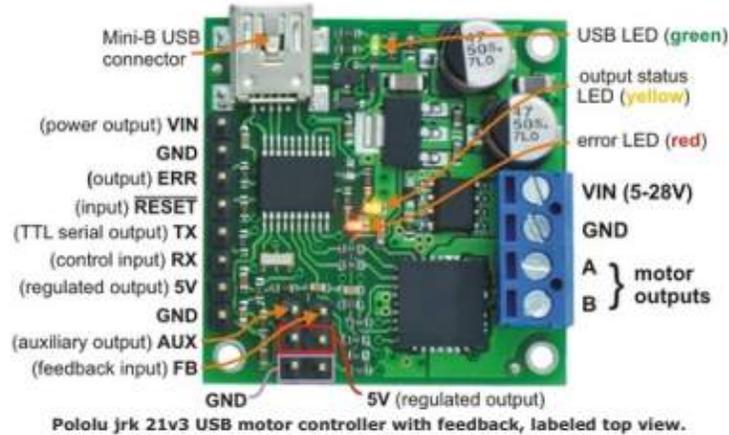
The jrk 21v3 ships with a 14×1 **straight 0.100" male header strip** [<http://www.pololu.com/catalog/product/965>] and two 3.5mm, 2-pin terminal blocks. The jrk 12v12 ships with a 14×1 **straight 0.100" male header strip** [<http://www.pololu.com/catalog/product/965>] and two **5mm, 2-pin terminal blocks** [<http://www.pololu.com/catalog/product/2440>]. To provide maximum flexibility, none of these parts are soldered to the board.

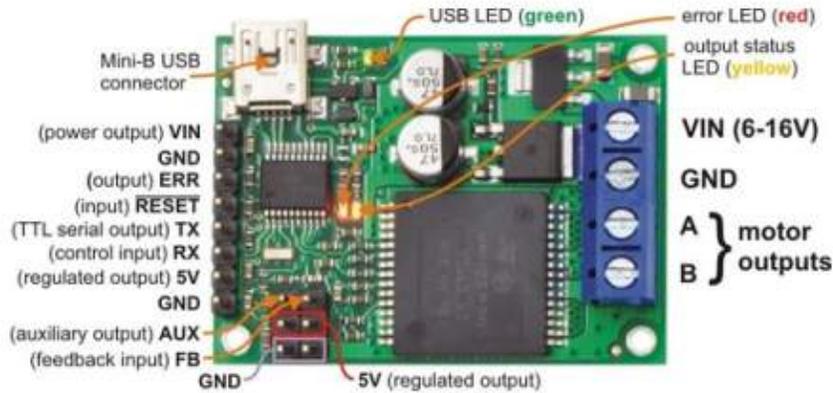
For the most compact installation, you can solder wires directly to the jrk pads themselves and skip using the included hardware. The included hardware allows you to make less permanent connections. You can break the 14×1 header strip into an 8×1 piece and two 3×1 pieces and solder these strips into the jrk's I/O pads.

The three mounting holes are intended for use with **#2 screws** [<http://www.pololu.com/catalog/category/101>] (not included).

Note: A **USB A to mini-B cable** [<http://www.pololu.com/catalog/product/130>] (not included) is required to connect this device to a computer.

1.a. Module Pinout and Components





Pololu jrkl2v12 USB motor controller with feedback, labeled top view.

The Pololu jrkl USB motor controller can connect to a computer's USB port via a **USB A to mini-B cable** [<http://www.pololu.com/catalog/product/130>] (not included). The USB connection is used to configure the motor controller. It can also be used to send commands to the motor controller, get information about the motor controller's current state, and send and receive TTL serial bytes on the TX and RX lines.

Power for the motor must be supplied to the jrkl on the **VIN** and **GND** lines pictured on the right side of the diagram above. Your power source must be capable of delivering the current your motor will draw. The jrkl has reverse power protection on the motor power input lines, so the board will not be damaged if the motor power inputs are accidentally switched. If the VIN supply is not present, the jrkl's microcontroller can be powered directly from USB and perform all of its functions except for driving the motor.

For the jrkl21v3, the input voltage should be 5–28 V (the recommended operating voltage is 8–28 V, but the jrkl21v3's motor driver has derated performance down to 5 V and transient protection to 40 V). The jrkl21v3's motor driver can supply a continuous 3 A with peaks up to 5 A.

For the jrkl12v12, the input voltage should be 6–16 V. The jrkl12v12's motor driver can supply a continuous 12 A with peaks up to 30 A.

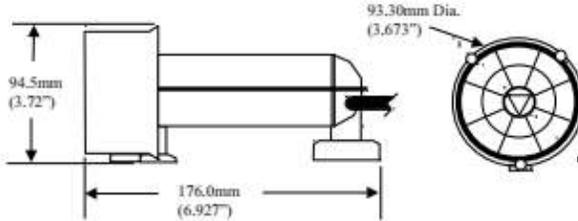
The jrkl has a linear voltage regulator that derives 5 V from the VIN supply. The 5 V supply is used as the internal logic supply for the jrkl and is also available at several pins for powering devices such as external microcontrollers and feedback sensors (such as potentiometers). Because the regulator must dissipate excess power as heat, the available output current is dependent on the input voltage: 50 mA is available for VIN up to 12 V; the available current drops off linearly from 50 mA at 12 V to zero at 30 V.

The jrkl has three indicator LEDs:

- The **green USB LED** indicates the USB status of the device. When the jrkl is not connected to a computer via the USB cable, the green LED will be off. When you connect the jrkl to USB, the green LED will start blinking slowly. The blinking continues until the jrkl receives a particular message from the computer indicating that the jrkl's USB drivers are installed correctly. After the jrkl gets this message, the green LED will be on, but it will flicker briefly when there is USB activity. The configuration utility constantly streams data from the jrkl, so when the configuration utility is running and connected to the jrkl, the green LED will flicker constantly.



BTD150 DATA SHEET

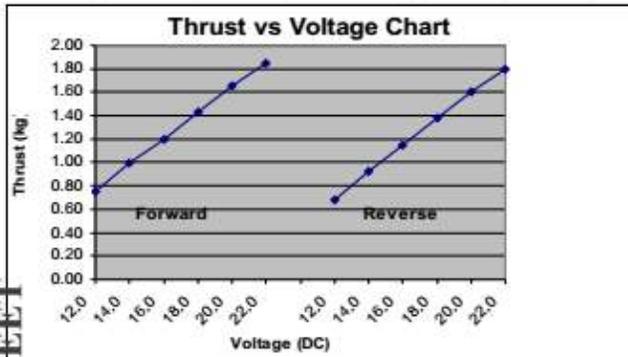


SPECIFICATIONS:

VOLTAGE NOMINAL..... 12VDC
 MAX CURRENT
 OF MOTOR WINDINGS..... *4.0AMPS
 (a current regulator is highly recommended)

WEIGHT:
 Dry..... 754grams
 Wet..... *124grams (in fresh water)

WIRING CONFIGURATION:
 White..... Positive
 Black..... Negative



Direction	Voltage(DC)	Current Draw (A)	Thrust (kg)
Forward	12.0	1.91	0.75
	14.0	2.45	1.00
	16.0	2.78	1.20
	18.0	3.32	1.43
	20.0	3.78	1.65
Reverse	12.0	1.92	0.68
	14.0	2.42	0.92
	16.0	2.89	1.15
	18.0	3.30	1.38
	20.0	3.75	1.60

* Higher currents (up to 6A) may be used, but will drastically shorten the life of the thruster if ran continuously in this mode. High current bursts of 1 minute or less can be performed as long as the running average current is kept at 4.0 Amps MAX to prevent the motor windings from building up excessive heat.

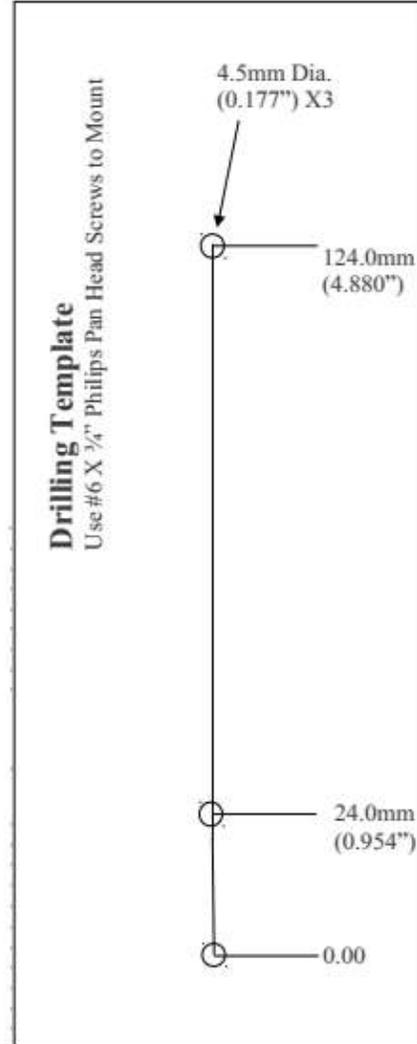
SEABOTIX, 1425 Russ Blvd, Suite T112D, San Diego, CA. 92101, USA

(619)239-5959

BTD150 Data Sheet Rev B 24Feb05.doc Rev B

Page 1 of 1

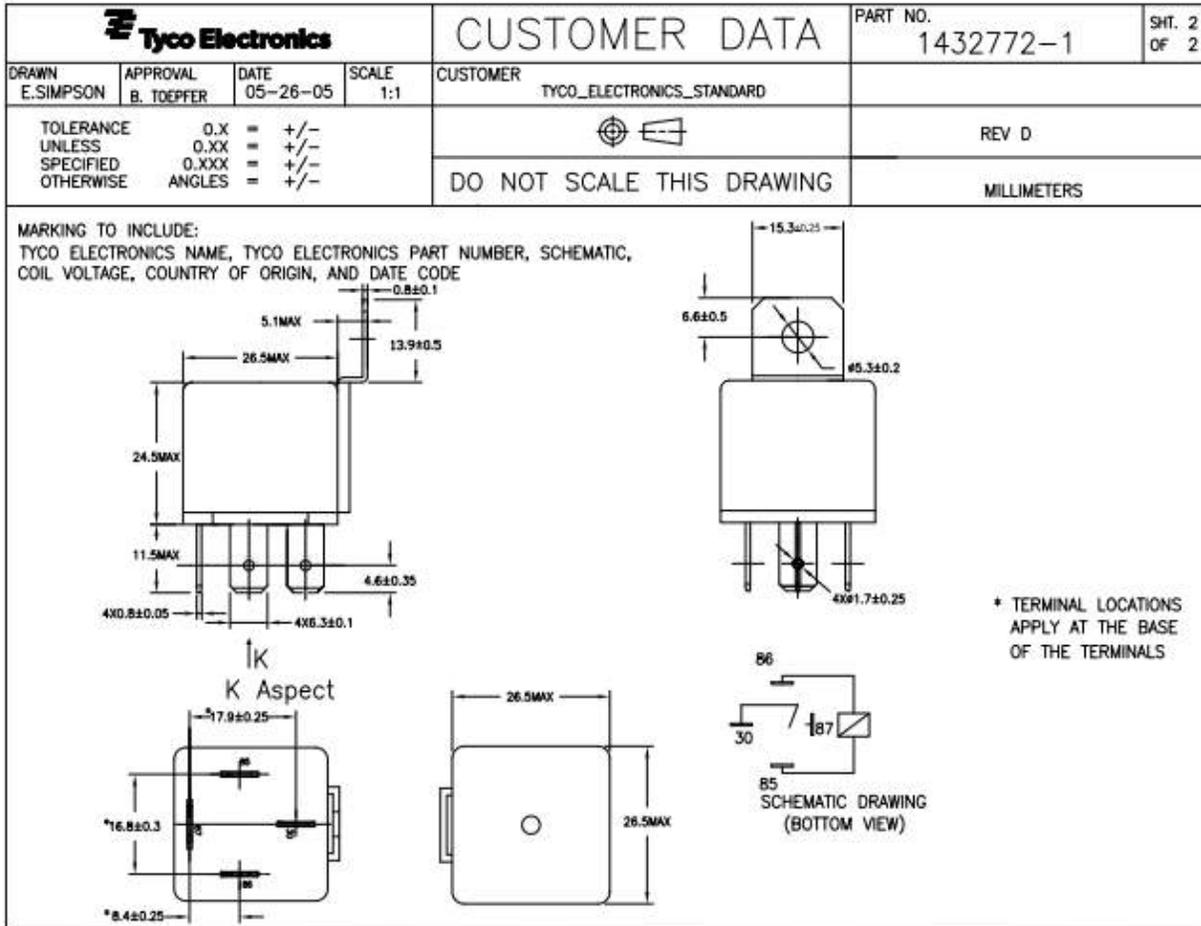
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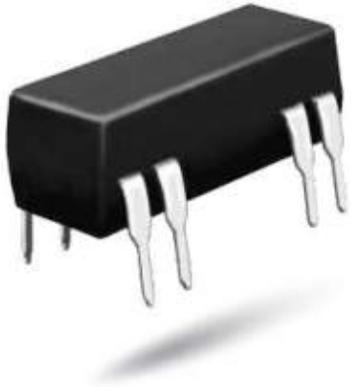
Drilling Template
 Use #6 X 1/4" Philips Pan Head Screws to Mount

SEABOTIX BTD150 DATA SHEET

				CUSTOMER DATA		PART NO. 1432772-1		SHT. 1 OF 2																													
DRAWN E.SIMPSON	APPROVAL B. TOEPFER	DATE 05-26-05	SCALE 1:1	CUSTOMER TYCO_ELECTRONICS_STANDARD																																	
TOLERANCE 0.X = +/- UNLESS 0.XX = +/- SPECIFIED 0.XXX = +/- OTHERWISE ANGLES = +/-						CHANGES																															
DO NOT SCALE THIS DRAWING						REV.	DATE	CO	APP.																												
						08-19-05	RELEASE	BT																													
						30APR2010	ECR-10-008018	BT																													
<p><u>ELECTRICAL CHARACTERISTICS:</u> (ALL DATA APPLIES @ 23°C UNLESS OTHERWISE SPECIFIED)</p> <p><u>COIL DATA:</u></p> <table> <tr><td>NOMINAL VOLTAGE:</td><td>12 VDC</td></tr> <tr><td>OPERATE VOLTAGE:</td><td>7.8 VDC MAXIMUM</td></tr> <tr><td>RELEASE VOLTAGE:</td><td>1.2 VDC MINIMUM</td></tr> <tr><td>COIL RESISTANCE:</td><td>90 OHMS +/- 10%</td></tr> <tr><td>OPERATE TIME:</td><td>8 mSEC. MAXIMUM EXCLUDING BOUNCE</td></tr> <tr><td>RELEASE TIME:</td><td>5 mSEC. MAXIMUM EXCLUDING BOUNCE</td></tr> <tr><td>TEMPERATURE RANGE:</td><td>OPERATING -40°C TO +85°C</td></tr> </table> <p><u>CONTACT DATA:</u></p> <table> <tr><td>CONTACT ARRANGEMENT:</td><td>1 FORM A (SPST)</td></tr> <tr><td>CONTACT MATERIAL:</td><td>AgSnO (SILVER TIN-OXIDE)</td></tr> <tr><td>CONTACT MILLIVOLT DROP:</td><td>200mv @ 35A (AFTER SWITCHING)</td></tr> <tr><td>MAXIMUM MAKE CURRENT:</td><td>90A (LAMP) @ 16 VDC</td></tr> <tr><td>MAXIMUM BREAK CURRENT:</td><td>40A @ 16 VDC RESISTIVE</td></tr> <tr><td>MAXIMUM CONTINUOUS CURRENT:</td><td>40A @ 23°C , 35A @ 85°C</td></tr> <tr><td>INITIAL BREAKDOWN CURRENT</td><td>500V RMS CONTACTS TO COIL</td></tr> </table> <p>EXPECTED LIFE: 100,000 OPERATIONS, 40 A, 14 VDC RESISTIVE</p> <p><u>MECHANICAL CHARACTERISTICS:</u></p> <p>EXPECTED LIFE: 10 MILLION OPERATIONS, NO CONTACT LOAD</p> <p>TERMINALS: BRASS, UNPLATED</p>										NOMINAL VOLTAGE:	12 VDC	OPERATE VOLTAGE:	7.8 VDC MAXIMUM	RELEASE VOLTAGE:	1.2 VDC MINIMUM	COIL RESISTANCE:	90 OHMS +/- 10%	OPERATE TIME:	8 mSEC. MAXIMUM EXCLUDING BOUNCE	RELEASE TIME:	5 mSEC. MAXIMUM EXCLUDING BOUNCE	TEMPERATURE RANGE:	OPERATING -40°C TO +85°C	CONTACT ARRANGEMENT:	1 FORM A (SPST)	CONTACT MATERIAL:	AgSnO (SILVER TIN-OXIDE)	CONTACT MILLIVOLT DROP:	200mv @ 35A (AFTER SWITCHING)	MAXIMUM MAKE CURRENT:	90A (LAMP) @ 16 VDC	MAXIMUM BREAK CURRENT:	40A @ 16 VDC RESISTIVE	MAXIMUM CONTINUOUS CURRENT:	40A @ 23°C , 35A @ 85°C	INITIAL BREAKDOWN CURRENT	500V RMS CONTACTS TO COIL
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8L SERIES/SPARTAN DIP REED RELAYS



8L Series Economy DIP Reed Relays

The Coto 8L Spartan Series relays combine Coto quality and economy in the industry standard 14 pin molded DIP package. This series will cross to all competitive DIP packages and is ideal for telecom, security, and other general purpose applications.

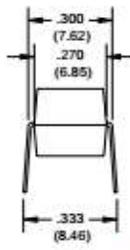
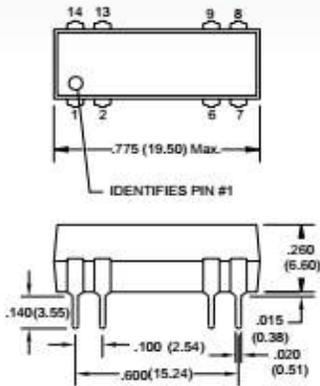
8L Series Features

- ▶ Drop-in low cost replacement for industry standard DIP packages
- ▶ Contact forms; 1A, 2A and 1C available
- ▶ Available coils in 5V, 12V and 24V
- ▶ Molded thermoset body on integral lead frame design
- ▶ Hermetically Sealed Contacts
- ▶ Optional Electrostatic Shield and Coil Suppression Diode
- ▶ UL File #E67117 - Contact factory for details
- ▶ RoHS compliant

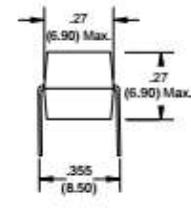
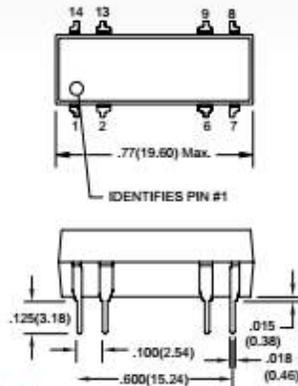
DIMENSIONS

in Inches (Millimeters)

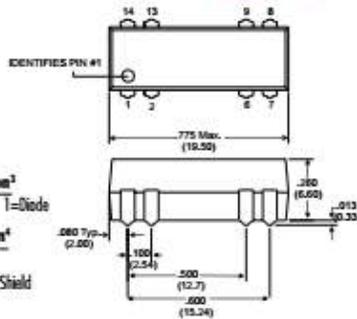
Model 8L01, 8L02 & 8L41



Alternate Package



Model 8L61



Ordering Information

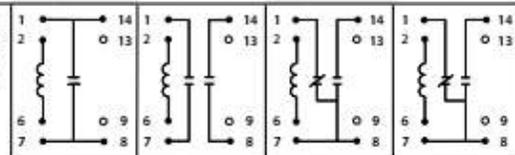
Part Number	8LXX-XX-XX1
Model Number	8L01 8L41 8L61
Coil Voltage	05=5 volts 12=12 volts 24=24 volts
Diode Option ²	0=No Diode 1=Diode
Shield Option ⁴	0=No Shield 1=Electrostatic Shield

Ordering Information

Part Number	8LXX-XX-XX
Model Number	8L02
Coil Voltage	05=5 volts 12=12 volts 24=24 volts
Diode Option ²	0=No Diode 1=Diode
Shield Option ⁴	0=No Shield 1=Electrostatic Shield

MODEL NUMBER			8L01 ^{2,3,4}			8L02 ^{2,3,4}			8L41 ^{2,3,4}			8L61 ^{2,3,4,5}	
Parameters	Test Conditions	Units	1 Form A		2 Form A		1 Form C		1 Form C				
COIL SPECS.													
Nom. Coil Voltage		VDC	5	12	24	5	12	24	5	12	24	5	12
Max. Coil Voltage		VDC	6.5	15	32	6.5	15	32	6.5	15	32	6.5	15
Coil Resistance	+/- 10%, 25° C	Ω	500	500	2150	200	500	2000	200	500	2000	200	500
Operate Voltage	Must Operate by	VDC - Max.	3.8	9.6	19.2	3.8	9.6	19.2	3.8	9.6	19.2	3.8	9.6
Release Voltage	Must Release by	VDC - Min.	0.5	1.0	2.0	0.5	1.0	2.0	0.5	1.0	2.0	0.5	1.0
CONTACT RATINGS													
Switching Voltage	Max DC/Peak AC Resist.	Volts	200		200		100		100				
Switching Current	Max DC/Peak AC Resist.	Amps	0.5		0.5		0.25		0.25				
Carry Current	Max DC/Peak AC Resist.	Amps	1.0		1.0		0.5		0.5				
Contact Rating	Max DC/Peak AC Resist.	Watts	10		10		3		3				
Life Expectancy-Typical ¹	Signal Level 1.0V, 10mA	x 10 ⁶ Ops.	500		500		100		100				
Static Contact Resistance (max. init.)	50mV, 10mA	Ω	0.150		0.150		0.200		0.200				
Dynamic Contact Resistance (max. init.)	50mV, 50mA at 100 Hz, 1.5 msec	Ω	N/A		N/A		N/A		N/A		0.25		
RELAY SPECIFICATIONS													
Insulation Resistance (minimum)	Between all Isolated Pins at 100V, 25°C, 40% RH	Ω	10 ⁹		10 ⁹		10 ⁹		10 ⁹				
Capacitance - Typical Across Open Contacts	No Shield	pF	0.5		0.5		1.5		1.5				
	Shield Floating	pF	1.0		0.5		1.5		1.5				
	Shield Guarding	pF	0.5		0.2		1.0		1.0				
Open Contact to Coil	No Shield	pF	1.5		1.5		1.5		1.5				
	Shield Floating	pF	2.0		2.0		2.0		2.0				
	Shield Guarding	pF	0.5		0.5		0.5		0.5				
Contact to Shield	No Shield	pF	2.0		1.5		2.0		2.0				
	Shield Floating	pF	2.0		1.5		2.0		2.0				
	Shield Guarding	pF	2.0		1.5		2.0		2.0				
Dielectric Strength (minimum)	Between Contacts	VDC/peak AC	250		250		200		200				
	Contacts to Shield	VDC/peak AC	1500		1500		1500		1500				
	Contacts/Shield to Coil	VDC/peak AC	1500		1500		1500		1500				
Operate Time - including bounce - Typical	At Nominal Coil Voltage, 30 Hz Square Wave	msec.	0.5		0.5		1.0		1.0				
Release Time - Typical	No Suppression	msec.	0.5		0.5		1.0		1.0				

Top View:
 Dot stamped on top of relay refers to pin #1 location
 Grid = .1"x.1" (2.54mm x 2.54mm)



Notes:

- ¹ Consult factory for life expectancy at other switching loads.
- ² Molded depression on top of relay refers to pin #1 location.
- ³ Optional coil suppression diode across pins 2(+) and 6(-).
- ⁴ Optional ES Shield is tied to pin 9.
- ⁵ Surface mount processing temperature: 260°C max for 1 minute dwell time. Temperature measured on lead where lead exits molded package.

Environmental Ratings:

Storage Temp: -35°C to +100°C; Operating Temp: -20°C to +85°C;
 Solder Temp: 270°C max; 10 sec. max
 All electrical parameters measured at 25°C unless otherwise specified.
 Vibration: 20 G's to 2000 Hz; Shock: 50 G's



Stock No. #86-764 In Stock: ✔

\$695.00

Quantity

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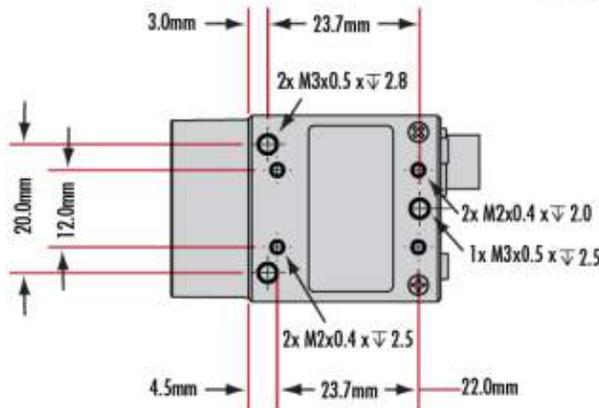


[Silver Series Telecentric Measuring Lenses](#)

Specifications	
Model Number	FL3-U3-13S2C-CS
Imaging Device	Progressive Scan
Camera Sensor Format	1/3"
Type of Sensor	Sony IMX035 CMOS
Pixels (H x V)	1328 x 1048
Pixel Size, H x V (µm)	3.63 x 3.63
Pixel Depth	8, 12, 16 and 24-bit digital data
Frame Rate (fps)	120
Type of Shutter	Rolling Shutter
Electronic Shutter	0.008ms - 1s
Image Format	Y8, Y16, Mono8, Mono12, Mono16, RGB, YUV411, YUV422, YUV444, Raw8, Raw12, Raw16
Transfer Speed (Gbit/s)	5
Synchronization	External or Via Software
Video Output	USB 3.0 interface with screw locks
Mount	CS-Mount w/C-Mount Adapter
Dimensions (mm)	29 x 29 x 30 (Excluding 1/4-20 Tripod Adapter and Lens Holder)
Operating Temperature (°C)	0 to +45
Storage Temperature (°C)	-30 to +60
Weight (g)	52
RoHS	Compliant

Technical Images

[View More 1 of 4](#)



M4-ATX

6-30V Intelligent ATX Power Supply

Installation Guide

Version 1.0e
P/N M4-ATX-01

Before you start...

Please take a moment and read this manual before you install the M4-ATX in your vehicle. Often times, rushing into installing the unit can result in serious damage to your M4-ATX board, computer and probably your car's electrical system. **Always double check the polarity** of your wires with a voltmeter.

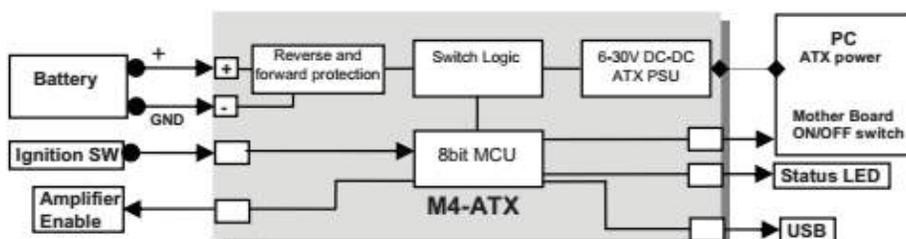
Avoid using the cigarette plug as a power source, often times the contacts are not capable of delivering high current to your PC.

Introduction

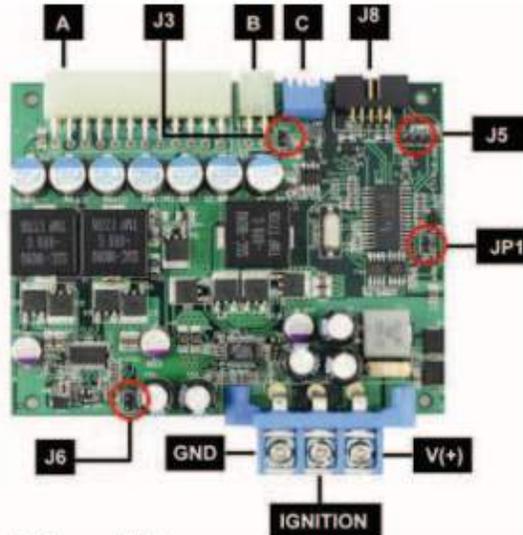
Thank you for purchasing the M4-ATX power sequencer / vehicle ATX power supply.

The M4-ATX was designed to work with a wide variety of main boards ranging from low power to fully fledged Intel, AMD or VIA motherboards.

M4-ATX Logic Diagram



1.2 M4-ATX Connection diagram



Power Input Connectors (bottom, right)

Left Battery negative (GND)

Center Ignition (To start connect to Battery +). **Do not use in the standard PSU mode (mode P0)**

Right Battery positive (+)

(A) ATX Power Output Connector 20/24 pin connector

(B) 12V-ATX power output connector 4 pin

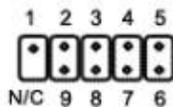
(C) Configuration dip switches

(J5) For internal use only (do not use)

(J6) Amplifier THUMP wire harness (connects to the M4-ATX pin header)

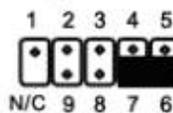
(J3) Fan Header. Positive pin is closest to "J3" marking.

(J8) USB, Motherboard ON/OFF and THUMP (Thump also available on J6)



- 1) GND
- 2) GND
- 3) USB D+
- 4) USB D-
- 5) Vcc

- 6) To Motherboard ON/OFF
- 7) To motherboard ON/OFF
- 8) Amplifier Thump
- 9) GND
- 19 N/C (key)



J8 shown with cable harness connected to the motherboard ON-OFF header (pin 7 and 6)

DIP Switch (ON=down)				Off-delay (All rails ON)	Hard-off (5VSB)
1	2	3	P		
OFF	OFF	OFF	P0	Standard PSU mode	
ON	OFF	OFF	P1	5sec + 1min AutoLatch*	1 min
OFF	ON	OFF	P2	1min + 1min AutoLatch*	NEVER
ON	ON	OFF	P3	1min + 1min AutoLatch*	1min
OFF	OFF	ON	P4	15min	1min
ON	OFF	ON	P5	15min	NEVER
OFF	ON	ON	P6	30min	1min
ON	ON	ON	P7	2hour	NEVER

IMPORTANT: Always use the "Hibernate" feature, never use "Standby" as it can severely discharge your battery over extended periods of time.

NEVER use "hard-off = NEVER" settings unless you understand the risks of battery depletion. Even with safety limits in place, your battery might be not be able to start your engine. "Hard-off=NEVER keeps your 5VSB rail on at all times"

***AutoLatch** is active during the first 60s of PC operation (and only during the first 60 seconds). For example, If Ignition is turned ON and then OFF right away, M4-ATX will latch Ignition in ON position for the next 60 seconds, **allowing your operating system to fully come up**. This will prevent disk drive corruption or systems that remain hung in the ON position. After the first 60 seconds of system operation, the AutoLatch feature will be removed and system will shut down at as governed by the "Off-delay" setting.

P0: In this mode, the M4-ATX behaves like a regular ATX power supply. If J6 is connected to the motherboard, M4-ATX will also send a gratuitous "ON pulse" to the motherboard right after power is first applied.

P1 (recommended): Sends ON pulse to motherboard when ignition is ON for more than 5 seconds, sends OFF pulse to motherboard **5 seconds** after ignition is turned off. Waits another **60 seconds** and then shuts down 5VSB to conserve battery. In this mode, the M4-ATX consumes less than 0.5mA. **This is our recommended setting.**

NOTE: Should you need to **reset to factory defaults** (in case changes were made via the USB uplink), simply power off the unit, connect a jumper to JP1 and then apply power back up for more than 2 seconds. The LED light will start to flash rapidly indicating that the factory defaults were loaded. **Don't forget to Remove jumper!** Disconnect M4-ATX from battery for at least few seconds. You are done!

Power challenges in a vehicle PC: One of most difficult tasks of operating a PC in a vehicle is power consumption while the computer is OFF. Even when your computer is OFF or in Suspend, it will still consume about 50-150mA on the 5VSB rail. *No matter how big your battery is, you will eventually drain it if proper actions are not taken.*

The M4-ATX is addressing these issues by cutting off the 5VSB rail after a pre-defined amount of time (see jumper chart, HARDOFF). During HARDOFF if the battery level drops below 11.2V for more than one minute, M4-ATX will shut down and re-activate only when the input voltage is above 12V.

Engine Cranks, under-voltage and over-voltage situations. Another difficult task is maintaining stable power to your PC. While car batteries are rated at 12V, they actually provide voltages in between 8-16V (engine cranks) or as high as 80 volts (load dump). Most times, your battery will stay at 13.5V but extra precautions need to take place in

order to prevent such situations. M4-ATX operates as low as 6V and as high as 30V while providing strict regulation as well as input voltage clamping and reverse protection.

Anti-Thump: If your PC is connected to your car amplifier, you will hear a loud pop when the computer is first started. The M4-ATX has an 'anti-thump' control that will keep your amp OFF while the PC starts. Simply connect the 2 pin wire to J6 harness to your amplifier remote control pins. The pin at the edge of the PCB is GND, inner pin is HOT.

Mode of operation explained

- 1) Ignition=OFF. Nothing happens. M4-ATX is waiting for ignition signals.
- 2) Ignition=ON. M4-ATX waits for few seconds then turns on the 5VSB rail. After another second M4-ATX sends an "ON" signal to the motherboard via the 2 wires connected to the motherboard's ON/OFF pins. The motherboard will turn ON and your system should start booting. The Ignition state will be latched for 60 more seconds so that the motherboard will have a change to come up in a clean manner.
- 3) Ignition=ON. Your computer will remain ON.
- 4) Ignition=OFF. M4-ATX waits for "OFFDELAY" in seconds (see jumper chart) and then it turns the motherboard OFF by sending a signal to the motherboard's ON/OFF switch. Your computer should turn off gracefully (shutdown procedure). After shutdown, 5VSB will still be provided for another "HARDOFF" seconds. In the event where the shutdown process is longer than "HARDOFF" (Operating System gets frozen, etc), power will be shut down hard, turning off all power rails. During the HARDOFF procedure, the battery levels will be constantly monitored to prevent deep discharge situations.
- 5) M4-ATX will go to step 1, if ignition is tuned ON again.

NOTE. When all dip switches are off, M4-ATX acts as a regular power supply. M4-ATX will also send a gratuitous "ON" pulse (to the ON/OFF motherboard pins, should you have a wire harness connected to it) when power is applied for the first time. Do not connect the on/off switch if you don't want your PC to be started automatically.

M4-ATX Characteristics

Minimum Input Operating voltage	6V
Maximum input Operating voltage	30V (hard clamping will occur at 34V)
Deep-Discharge shutdown threshold	11.2V
Input current limit (fuse protected)	Mini-blade 25A
Max Output Power	250 Watts / 300 watts peak
Deep Sleep Current Consumption.	< 1.6mA
Storage and operating temperature	-40 to +125 degrees Celsius (storage), -40 – 65C (operating)
MTBF	200,000 Hrs
Efficiency (Input 10-16V)	>95%, all rails combined, 50% load.
Input connectors	M4 screw terminal
Output Connector	ATX Power 24 pin (Molex P/N 39-01-2200)

*Unit shuts down when internal temperature sensor indicates > 85C. This value can be changed with software.

Maximum Power Characteristics

Output Rail	Current (Max)	Current Peak (<30 seconds)	Regulation
5V	15A	20A	1.5%
3.3V	15A	20A	1.5%
5VSB	1.5A	2A	1.5%
-12V	0.15A	0.2A	10%
12V	12A (see below)	16A (see below)	2%

When operating at <8V or >28V or extreme temperatures, de-rate by 25-50%, ventilation might be required. When operating at constant 160watts or more forced ventilation might be required.

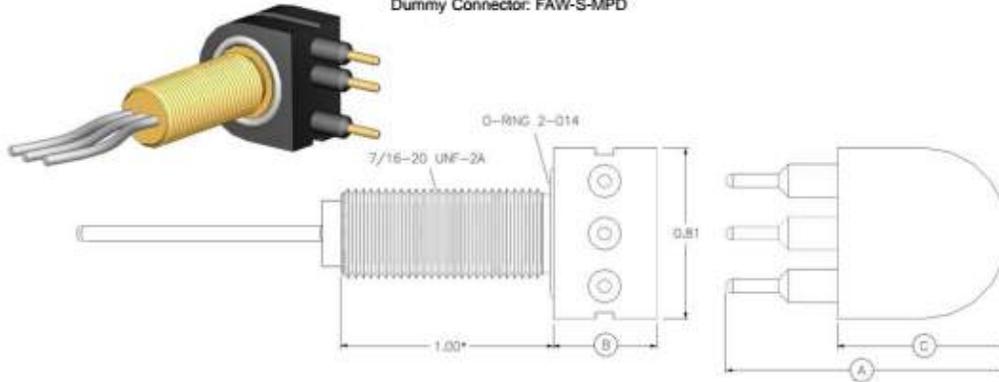
12V Rail Output Current (12V buck/boost converter)

Input (V)	12V out current	Input (V)	12V out current
6-8V	8A	11-16V	12A (16A peak)
8-11V	10A (12A peak)	16-30V	12A (14A peak)

Support and warranty: Standard Hardware Warranty 1Year / US, 2 Year EU.

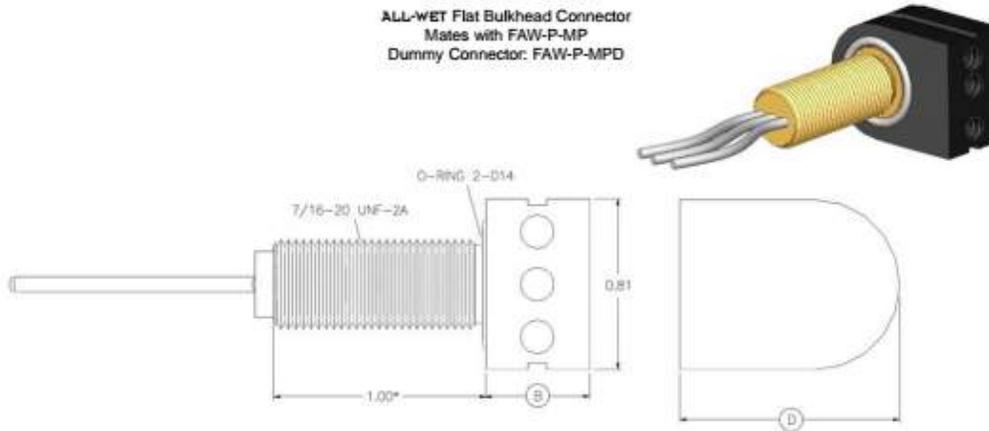
**ALL-WET SERIES
FAW-P-BC-R/A**

ALL-WET Flat Bulkhead Connector
Mates with FAW-S-MP
Dummy Connector: FAW-S-MPD



**ALL-WET SERIES
FAW-S-BC-R/A**

ALL-WET Flat Bulkhead Connector
Mates with FAW-P-MP
Dummy Connector: FAW-P-MPD



CONNECTOR	A - LENGTH (INCHES)	B - LENGTH (INCHES)	C - LENGTH (INCHES)	D - LENGTH (INCHES)
FAW-P-S-BC-R/A	1.34	0.50	0.81	1.05
FAW-S-P-S-BC-R/A	1.48	0.63	0.95	1.12

NOTES:

- Thread length is 1.00" standard. If shorter thread is required, specify as follows: FAW-P(or S)-BC-R/A (1/2" thread length).
- Available thread length: 1/2", 3/4" and 1".
- Bulkhead mounting torque: 40 inch pounds.
- Nuts and washer supplied.
- Connectors must be lubricated prior to mating.
- Connectors are designed for installation on one atmosphere vessels. Contact SEA CON® for recommendations if using compensated vessels.
- Dummy Connectors: Optional.
- Dummy Shorting Plug: Optional.

GENERAL INFORMATION

COMPONENT	MATERIAL
BULKHEAD BODY: STANDARD: OPTIONAL:	CA630 per QQ-C-485 Many materials including 316 Stainless Steel and 6A14V Titanium, Hard Anodized
CONNECTOR BODY: STANDARD: OPTIONAL:	Neoprene per BIA X5727 Hypalon per BIA X6830
CONTACTS	Copper Alloy Gold Plated per ASTM B488
O-RINGS	Nitrile (formerly known as Buna N)
IN-LINE CABLE:	
FAWL: FAWM 8: FAWM 10: MAW:	#18 AWG SO* #20 AWG SO* #22 AWG SO* IN2*
BULKHEAD NUT/WASHER	Brass
BULKHEAD PIGTAILS	Teflon® (registered trademark for DuPont) Type E Hook-up wire* FAWL #18 AWG* FAWM 8 #20 AWG* FAWM 10 #22 AWG* MAW IN2*

CATEGORY	VALUE
OPEN FACE PRESSURE #BULKHEADS	Up to 1,000 psi
MATED PRESSURE BULKHEADS	Up to 10,000 psi
MATED PRESSURE IN-LINES	Up to 10,000 psi
VOLTAGE	FAW: 600 VDC except FAWM-10*** MAW: 300 VDC
CURRENT	FAW: Up to 10 amps per contact** MAW: Up to 3 amps per contact**
CONTACT RESISTANCE	<0.01 ohms
INSULATION RESISTANCE	>500 megohms after wet mating
MATING CYCLES	>500 wet matings****

NOTES:

- * 18 inch standard length.
- ** Maximum current carrying capacity for contacts may be affected by cable selection.
- *** Rated to 300 VDC.
- **** Provided proper handling procedures are adhered to.

AMPACITY CHART FOR STANDARD PARTS

PART DESCRIPTION NUMBER OF CONTACTS	AMPACITY
FAWL - 2	7 amps
FAWL - 3	7 amps
FAWL - 4	5.6 amps

- Higher ampacities are available.

PART DESCRIPTION NUMBER OF CONTACTS	AMPACITY
FAWL - 5	5.6 amps
FAWM - 8	4.9 amps
FAWM - 10	2.5 amps

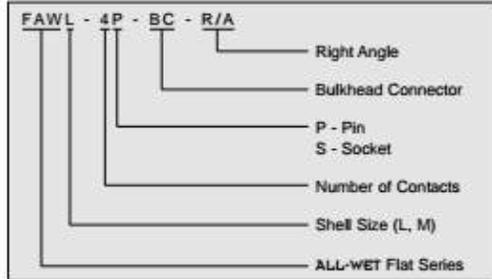
STANDARD IN-LINE WIRING COLOR CODE

CONTACT #	COLOR
1	WHITE
2	BLACK
3	GREEN
4	RED
5	ORANGE

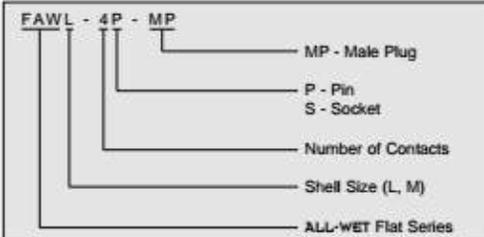
CONTACT #	COLOR
6	BLUE
7	WHITE/BLACK
8	RED/BLACK
9	GREEN/BLACK
10	ORANGE/BLACK

PART NUMBER SYSTEM - EXAMPLE

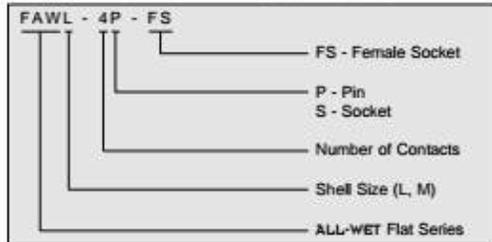
ALL-WET FLAT SERIES BULKHEAD CONNECTORS



ALL-WET FLAT SERIES IN-LINE MP CONNECTORS

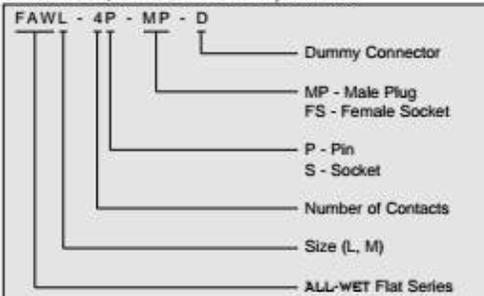


ALL-WET FLAT SERIES IN-LINE FS CONNECTORS



ALL-WET FLAT SERIES DUMMY CONNECTORS

Dummy connectors are available for all connectors in the ALL-WET Flat Series. To order, add the suffix-D after the part number.



Appendix E: Mechanical Calculations

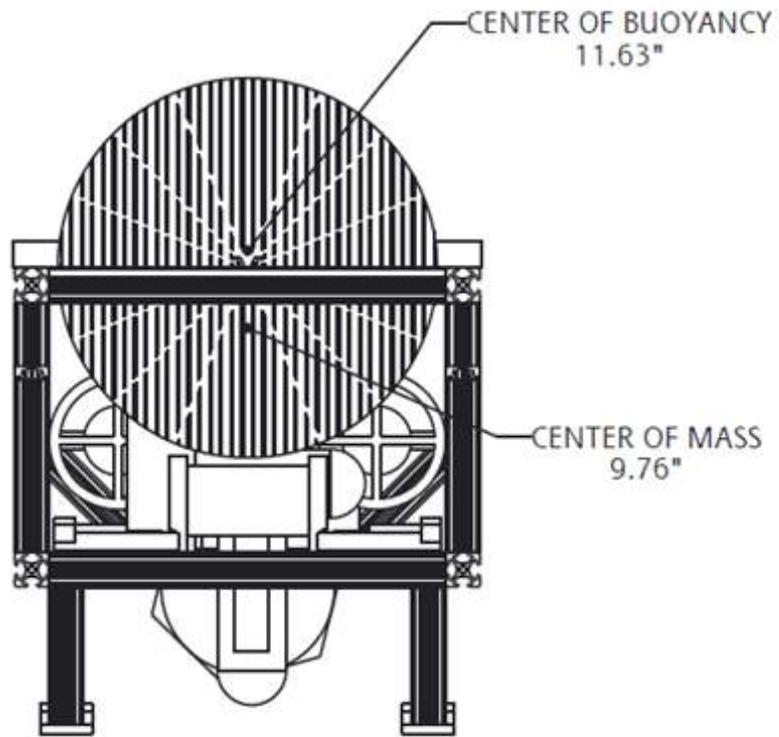


Figure 13: The center of buoyancy is a little less than 2 inches above the center of mass which will create a dynamically stable submarine. The calculations were completed using SolidWorks and showed that 3 lbs of force is available.

Robo-Sub Stability Calculations

$C.o.M := 9.82 \text{ in}$ Center of Mass

$C.o.BF := 11.70 \text{ in}$ Centroid of Buoyant Force

***Note that the centroid of the buoyant force is 1.88 inches above the centroid of mass. This allows for the submerged vessel to be dynamically stable.

$BuoyantForce := 54 \text{ lb}$ Buoyant force generated by Robo-Sub's water displacement

$\theta := 5 \text{ deg}$ Situation when sub experiences a 5 degree offset

$RestoringMoment := \sin(\theta) \cdot (C.o.BF - C.o.M) \cdot BuoyantForce = 8.848 \text{ lb} \cdot \text{in}$

Force Required to Tip Robo-Sub While Standing with Current Configuration

Guess Values
 $TippingForce := 10 \text{ lb}$ $\Sigma M_0 := 0 \text{ lb} \cdot \text{in}$

Constraints
 $\Sigma M_0 = -5.5 \text{ in} \cdot 49 \text{ lb} + 13.25 \text{ in} \cdot TippingForce = 0 \text{ lb} \cdot \text{in}$

Solver
 $\text{Find}(TippingForce) = 20.34 \text{ lb}$

This is the tipping force required if the sub is bumped from the highest point of contact possible.

Force Required to Slide Robo-Sub While Standing with Current Configuration

$\mu := 0.39$ Static coefficient of friction of hard rubber on wet tile

Solver
Constraints
Guess Values

$$SlideForce := 10 \text{ lb} \quad \Sigma F_x := 0 \text{ lb}$$

$$\Sigma F_x = \mu \cdot 49 \text{ lb} - SlideForce = 0 \text{ lb}$$

$$\text{Find}(SlideForce) = 19.11 \text{ lb}$$

The force to slide the sub across wet tile is lower than the force required to tip it.

Latching Force Required at Maximum Depth

$$W := 62.4 \frac{\text{lb}}{\text{ft}^3}$$

water weight

$$h := 38 \text{ ft}$$

max depth in competition pool.

$$A := \frac{\pi}{4} \cdot (10 \text{ in})^2 = 78.54 \text{ in}^2$$

area of endcap

$$\Delta P := W \cdot h = 16.467 \frac{\text{lb}}{\text{in}^2}$$

$$Force := \Delta P \cdot A = (1.293 \cdot 10^3) \text{ lb}$$

Proposed design requires four pull action toggle clamps with a clamping strength of 360 and 7,500 lbs

<http://www.mcmaster.com/#latching-clamps/=pfokg8>

$$MinimumClampingStrength := \frac{Force}{4} = 323.322 \text{ lb}$$

Bending Strength of Chassis Tube Attachement if Dropped from 4ft

$$m_{sub} := \frac{57.24 \cdot lb}{32.2 \frac{ft}{s^2}} \quad \Delta t := .05 \cdot s \quad h := 4 \text{ ft}$$

$$v_{drop} := \left(2 \cdot 32.2 \frac{ft}{s^2} (h) \right)^{0.5}$$

$$v_{drop} = 16.05 \frac{ft}{s} \quad \Delta Momentum := m_{sub} \cdot v_{drop}$$

$$F_{impulse} := \frac{\Delta Momentum}{\Delta t}$$

$$F_{impulse} = 570.62 \text{ lb}$$

$$Bending_{moment} := F_{impulse} \cdot 2.25 \text{ in}$$

$$b := 2 \cdot \text{in} \quad h := .75 \cdot \text{in}$$

$$I_x := \frac{b \cdot h^3}{12}$$

$$\sigma := \frac{Bending_{moment} \cdot \frac{h}{2}}{I_x}$$

$$\sigma = (6.847 \cdot 10^3) \frac{lb}{in^2}$$

$$\sigma_{slider} := \frac{\sigma}{4} = (1.712 \cdot 10^3) \frac{lb}{in^2}$$

Units- lenth=in, weight=lb

Initial Values(0 lb boiancy)

Weight

$$w_i := 17.251$$

Frame volume

$$v_{i1} := 232.573$$

Volume displaced by tube

$$v_{i2} := (4 - .125) \cdot \pi \cdot 18.38 = 867.039$$

Total Sub Volume

$$v_i := v_{i1} + v_{i2} = 1.1 \cdot 10^3$$

Density of water

$$\rho_{H2O} := .0361 \text{ lb/in}^2$$

weight of displaced water

$$w_{H2O} := v_i \cdot \rho_{H2O} = 39.696$$

Constant Values

Weight of Misc items

$$w_{misc} := w_{H2O} - w_i = 22.445$$

values from adding 10in to length

Weight

$$w_f := 19.484$$

Frame volume

$$v_{f1} := 272.321$$

Volume displaced by tube

$$v_{f2} := (4 - .125) \cdot \pi \cdot 28.38 = 1.339 \cdot 10^3$$

Total Sub Volume

$$v_f := v_{f1} + v_{f2} = 1.611 \cdot 10^3$$

Density of water lb/in²

$$\rho_{H2O} := .0361$$

weight of displaced water

$$w_{H2O} := v_f \cdot \rho_{H2O} = 58.16$$

buoyancy

$$w_B := w_{H2O} - w_f - w_{misc} = 16.231$$

As a function of unit length, x (inches)

$$x := 1 \quad v_i = 1.1 \cdot 10^3 \quad v_f = 1.611 \cdot 10^3 \quad w_i = 17.251 \quad w_f = 19.484$$

$$v_x := \frac{v_f - v_i}{10} \cdot x = 51.148$$

$$w_x := \frac{w_f - w_i}{10} \cdot x = 0.223$$

Buoyancy added to the sub.

$$B_x := v_x \cdot \rho_{H2O} - w_x = 1.623 \text{ lbs added for every inch added to sub.}$$

P1 - PLATE_THICKNESS	P2 - Directional Deformation Minimum	P3 - Safety Factor Minimum	P5 - Maximum Principal Stress Maximum	P4 - Maximum Principal Stress Minimum
	ft		psf	psf
1	-2.4773E-06	15	11135	-15395
0.75	-4.891E-06	15	19120	-20852
0.6	-8.4745E-06	15	29231	-26401
0.5	-1.3488E-05	15	41643	-34177
0.4	-2.4024E-05	15	68489	-43353
0.25	-8.6481E-05	15	2.0845E+05	-66784
0.2	-0.00016116	15	3.5411E+05	-71197
0.15	-0.00036848	9.0955	6.3735E+05	-83071
0.1	-0.0012011	4.0846	1.4197E+06	-1.0678E+05

Figure 14: FEA done using Ansys software preformed for end cap at depth.

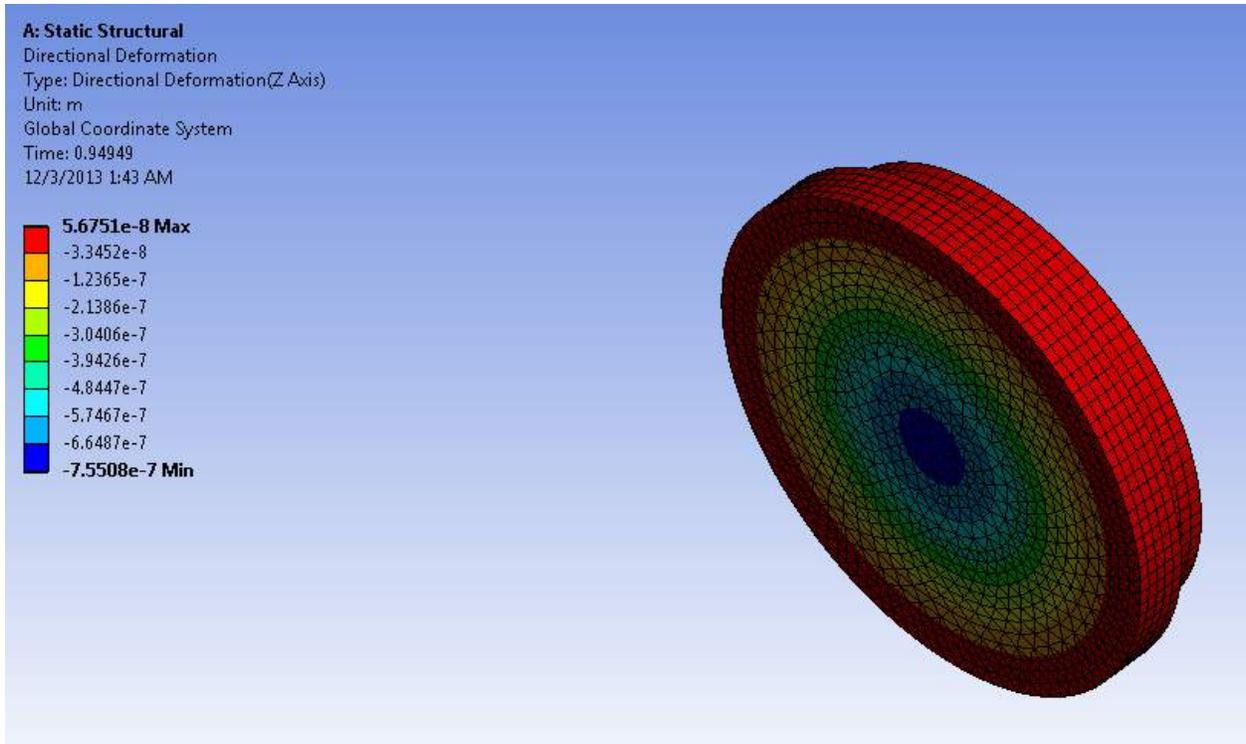


Figure 15: FEA done on the directional deformation experienced at maximum depth during competition.

Appendix E: Project Schedule

Project Schedule

Mechanical

Weeks 1 - 8: The mechanical side will have ordered some parts required for construction before the Christmas break, will order the rest upon arrival and will build the sub in the first six weeks of the semester.

Weeks 9-16: Troubleshoot all mechanical problems with Blue November by ample testing in the pool.

Electrical

Weeks 1 - 4: Order all electronic parts and begin assembly of the new electronic system along with interfacing with IMU team.

Weeks 5-16: Get mission software programmed and begin integration with the mechanical team. Test mission software with ample pool testing.

**Potentially start a MSU RoboSub Club and involve underclassmen in the testing, small designs, and projects. This will be to generate more interest in AUVSI at Montana State University so that the competition will be won be one day.

Appendix G: Changes Made During Construction

Electrical Changes

There were a couple of important changes made to the design that was created first semester. These changes affected the final fabrication and outcome of the Sub. The biggest change was the electrical wet connects. The original plan was to go with SeaCon wet connects but the company was taking too long to get back to us and it would have taken too long to get the wet connects and implement them. Another thing that was different from the original design were the desktop computer boards in the sub. The reason that these were not the same was because further research revealed better options. Another change were the arduino pin-outs that were used, but this was a simple change and can be found within the arduino programming. These, and a general overview of the sub and its components, will be discussed below.

The new sub has many things that should be noted that are different than the old sub and although they may be in the first semester design, their implementation is still helpful to describe. One of these things is the two separate electrical circuits that were implemented in the new design. The first circuit is powered by one of the batteries and powers all of the “brain” electronics in the sub. It basically powers the computer and all of the data boards. The second circuit is hooked up to four batteries and then is run through the motor controllers and to the batteries. These circuits are each on a separate kill switch. This allows for separate manual power control of the electronics and the engines. The other benefit to this is that if there is a power issue, which we experienced with the old sub, the problem can be further isolated to either the electronics or the motors. It should be noted that because there are two separate circuits, the one that goes to the motor controllers and then to the engines has a 12V voltage regulator on it because the batteries have an 18.5 nominal voltage but the motor controllers only run properly at twelve volts. The voltage regulator solves this issue.

Another implementation on the new sub was the end cap plugs for easy separation of the end cap from the rest of the sub. For these plugs we used M4-ATX extension cables. These are 24 pin plugs that connect all the throughputs on the end cap to their respective wiring to the internal electronics board. This allows the end cap to be easily disconnected from the electronics board. It should be mentioned that sometimes the wires fall out of the plug and need to be reinserted. This can cause issues with power and functioning of the sub but when they are pushed in so that the metal finger catches, they usually don't fall out again.

The clamshell design that was used was superbly successful. It allowed for the wiring to run through the middle of the electronics board so that all of the circuit boards are visible and easy to manage. It also allowed for easy troubleshooting of the electronics and most of the wiring. The wire to wire connections were also done differently than the previous sub. Instead of using crimping or crimp connectors, the connections were twisted together, soldered and then electrically taped. This is not necessarily aesthetically pleasing but it is dependable, works well and allows for fewer wiring issues.

The batteries that power the sub are now contained within the electrical tube. This allows for fewer internal to external connections and seems to work well. The downside of this design is that the electrical tube needs to be opened each time the batteries need to be charged or changed, however, the sub has a one hour plus run time which is sufficient for testing and working on the sub so this is not a big issue.

In order to turn the sub electronics on, there is a specific process that is described in the “Meaning of the LED Lights” document. In this document the LED indicator lights on the sub are also explained. There is also a parts list in this section that is useful to note because knowing the components in the sub is very important. Another thing to be noted is the engine wet connects; these have a restricted polarity through a key in the connection but this can be cut off with a knife to allow easy engine direction manipulation. This is useful because it is easier to switch a plug than it is to go into the programming and change the engine direction. This is most of the useful information about the new sub that was not elaborated on in the design document from the previous semester. The rest of the information can be found in the deliverables and troubleshooting documents added on in this appendix.

Meaning of the LED Lights

There are several lights on the electronics board that are not well labeled within the company documentation. These will be discussed here.

The first lights to be discussed are those that appear on each of the motor controllers. There are two LED lights on each motor controller. They need not be labeled as their colors give them away. The first light is a green light. This will be on and solid green when the USB is plugged both into the motor controller and into the motherboard. When the light is a solid green, there is a good data connection between the motor controller and the motherboard. Then the light will momentarily flicker when data is sent to it i.e. an input from the computer. The second LED light on the motor controller is either yellow or red. This light is red when there is not sufficient power going to the motor controller and solid yellow when there is sufficient power. This light will also blink yellow if there is another power issue, such as too much power is being supplied to the motor controller.

The second lights that will be discussed are the motherboard RAM memory lights. These can be customized to desired colors. When the lights are on, it means the motherboard has power, is on, and is accessing the RAM. When the computer is using more RAM, the lights will go through their sequence faster.

The third lights that will be discussed are on the M4 ATX power supply. There is one green LED located by J6 on the power board. This light has many different states. If the light is blinking slowly, or not at all, this means that there is insufficient power to the board. If the light is in a sequence of rapid beats, pause, rapid beats, pause etc, then the board is powering up and has sufficient power. A solid green light means the board has completed the power on sequence and is now on with sufficient power being output. These are the most important lights on the electronics board, the rest are pretty self-explanatory.

Electrical Purchases

Table 2: Electrical parts list for purchased parts during the second semester.

Name	Technical Name
Batteries	Tenergy Li-ion 18.5V 1100mAh Rechargeable Battery Pack
Voltage Controller Board	M4-ATX 6V-30V DC-DC Converter
Motherboard	ASRock B85M-ITX
Memory	Crucial Ballistix Tactical Tracer 8 GB 1600MHZ
Fan	Noctua NH-L9I
Hard Drive	crucial 2.5 inch solid state drive 128 Gb
CPU	Intel Core I3 4130T
External Pressure Sensor	SENSOR 50PSI 5/8" 7/16-20 UNF 5V
Capacitor	3 type 381 LX Capacitors 3300 micro farad each
7 port usb hub	2 plugable usb 2.0 4 port plugs
Micro controller board	Arduino Mega 2560
Motor Controllers	pololu jrj 12v12 usb motor controller
Motors and Thruster	Seabotix thrusters BTD150
Top Camera	Go Pro Hero 3 HD Camera
IMU + IMU board	GEDC-6 Starter Kit Plus (include GEDC-6 AHRS, NDS-1 Dev Kit &RM-1 Adapter Kit)

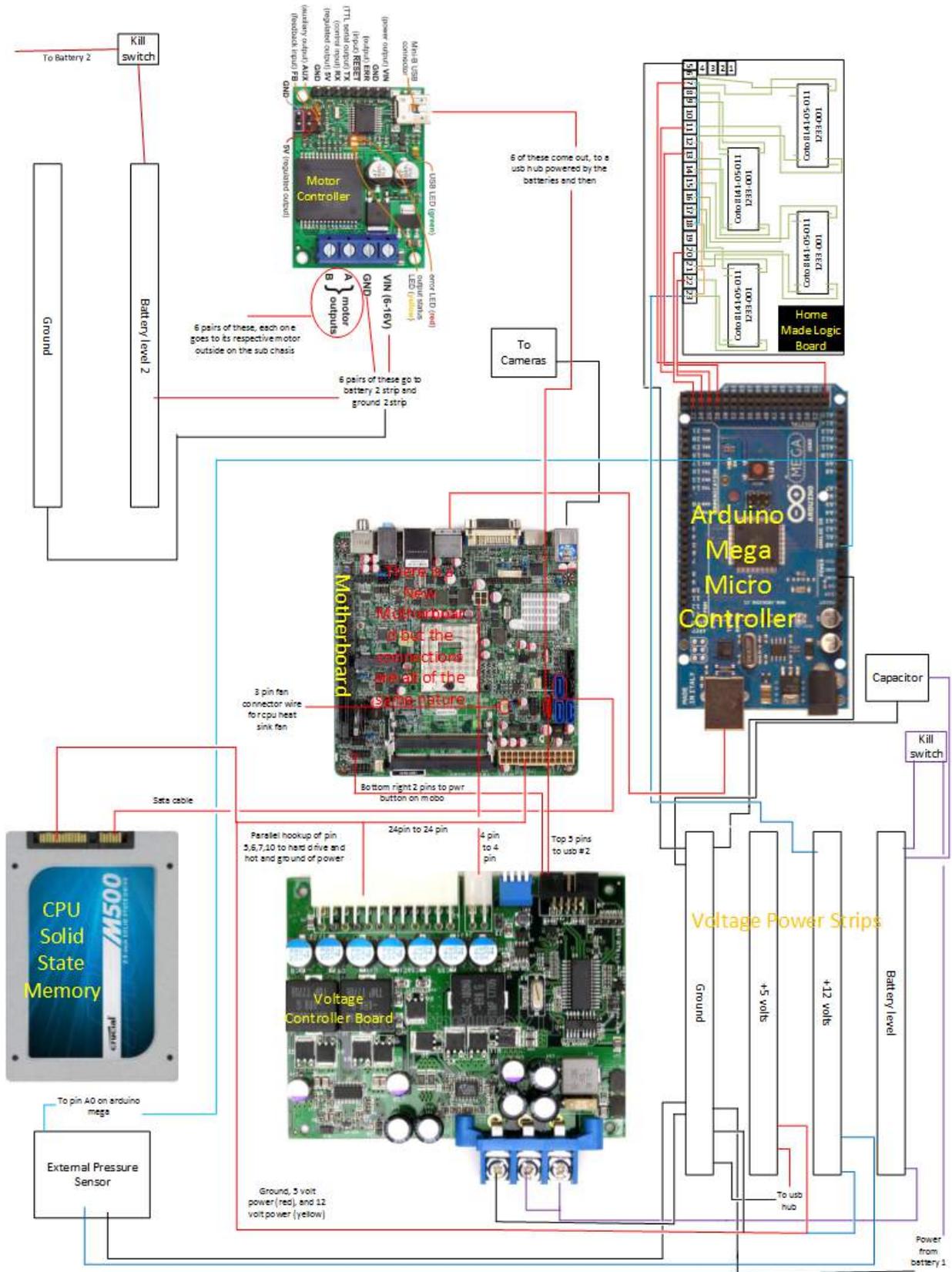


Figure 16: The above is a wiring diagram for the electrical board of the submarine.

Software Development

The three goals for this year's software development were to document the existing code, show status updates to the user, and to provide visual navigation. The existing code provided some basic manual control, but no autonomous behavior from the RoboSub. This functionality required thousands of lines of code that had been haphazardly commented with no diagrams or documentation explaining the design approach.

The major accomplishment for the previous year's team with their software was to have the RoboSub dive to a desired depth, maintain that depth consistently, and to then navigate forward in a straight line. The depth control is handled by a pressure sensor that sends data to the Arduino. The Arduino code then sends the data to the C# code. This information is then processed and the depth is maintained in a control loop that is independent of all other thruster control. This is a wonderfully elegant approach to navigation, as further navigation programming can concentrate upon movement in the horizontal plane, as long as the correct depth is being maintained.

The straight-forward navigation was accomplished using an Inertial Measurement Unit (IMU). A desired compass heading in degrees was chosen, from 0 - 359, and the RoboSub would move forward toward that heading. Unfortunately, due to the complexity of interfacing with the IMU, all IMU functions for the RoboSub were abandoned and a separate Capstone team was formed to develop IMU navigation software.

This year, after reviewing and commenting the existing code, we decided to base navigation on being able to track a brightly colored object in the water using the front camera. Any of the navigation code that would reference the IMU and interfere with the camera-based navigation was commented out, and left in the C# file for future integration.

In order for the camera to receive accurate coordinates of the location of the object on screen, we continued to use the third-party program RoboRealm. This program provides a host of visual filters that will reduce the incoming video stream from the cameras to single colored blobs, and then to a set of coordinates that are the location of the center of the principle blob on screen. The size of the blob, in pixels, is also sent to the C# code.

Once the coordinates have been passed into the C# code through the RoboRealm API, they were then used to decide whether the RoboSub needs to move left, right, up or down to center the coordinates in the middle of the field of view. Once relatively centered, the RoboSub moves forward, and the process begins again.

We conducted several successful tests of vision tracking with the Sanka RoboSub, adjusting the power and duration of the motors' thrust. As a result of these tests, we ended up deciding to make small, short movements, and let the inertia of the RoboSub carry it through the full movement. The processing then waits for one second, and corrects course again.

This approach leads to the RoboSub having a "lunging" behavior, as it will seek to aim itself directly at the object, then move forward in bursts to bump it. Upon reaching the object, it will fill the field of vision of the forward camera. The C# code then has the RoboSub back up, turn slightly, and move forward past the object in order to seek out the next task.

The navigation subroutine for the front camera object tracking was also copied and modified to be used with the bottom camera for line tracking. This functions well, but will require further modification in order to make the transition from tracking a line with the bottom camera to seeking the next task with the forward camera. Due to hardware issues with implementing two simultaneous WiFi connected cameras, this is not yet possible.

We were even able to change the color of the object being tracked on the fly during our tests in the pool by editing the color filter settings and taking a sample pixel from the screen in RoboRealm. Current software development is attempting to use the color data from RoboRealm to let the C# code know which color is being seen at each location on the screen. Being able to differentiate between colors will allow us to complete the buoy task with greater accuracy, rather than relying on a single color filter.

Continual status updates for the user are now shown in the console window, which is a significant improvement. Each action that the RoboSub is attempting is shown, along with the file that is attempting

that action. Error messages are now standardized to be color-coded red as well as indicate the file that is generating the error.

Mechanical Assembly

Epoxies

During machining and assembly of Blue November there were several epoxy types used to seal, connect and reinforce the sub. To seal the main chassis tube to the front end cap and the flange a casting urethane was used. The urethane was purchased from McMaster-Carr and was general purpose Medium Hard (60A) urethane. A small amount was poured into the front end cap and spread around the lip of the front end cap. The chassis tube was press fit into the front cap and more urethane was poured so that it would fill any cracks. To attach the flange to the main chassis tube a very similar process was used. The urethane was spread around the chassis tube and the flange was press fit around the tube. As a second check on the water tight seal a marine epoxy purchased at Ace Hardware was used as well. It was smoothed on the between the front cap and flange and can be seen as the white caulk on the edges.

The end cap with the wet connections....well. For the wet connects we used a combination of 1" PVC piping and more urethane. We cut three holes of just slightly over 1 inch and lathed down the outside diameter of the PVC piping until it was close to a pressure fit to put them through the three holes. We fit all the wet connections we were going to use through the piping and used more of the marine epoxy on the outside face. Once the marine epoxy had been smashed into the piping we poured a whole bunch of urethane to cover it all. **DON'T DO THIS.** A major design change for the next team to consider would be coming up with different wet connections. SeaCon should be approached. Reference the wet connections in the appendix. It would be really awesome if the wet connections could be sealed using nuts and small gaskets so that they could be put under compressive force to fight against the water pressure. During all sealing silicon is a nice way to double check the seal. Spreading a small amount of silicon on both the outside face and inside face should be used on all connections.

Steel Reinforcement Ring

The mechanical side decided to make an extremely thin back end cap. This was done to save weight and allow for easier heat dissipation through the cap. Analysis was done to calculate how thin the end cap could be and not deform dramatically under the water pressure. The bolting force on the end cap was not considered though. It was noticed after bolting and unbolting several times that the end cap was undergoing plastic deformation. To combat this, a stainless steel reinforcement ring was plasma cut and bolt holes drilled. This steel ring served two purposes. First, to stop the deformation of the end cap and second to distribute the pressure applied from the bolts evenly over the whole surface. This allowed for the flat end cap to put the flat gasket under good even pressure and create a nice water tight seal. The stainless steel was purchased from Pacific Steel.

Rotary Table

To machine the two end caps and the flange the largest rotary table was used. Due to the fact that the center of each part needed to be milled, it was necessary to keep the part mounted onto the rotary table until all processes of machining were completed. To mount the part, the rotary table was first mounted onto the mill with the largest amount of movement on the x- and y- axis. Next, a dead center was chucked into the mill and the x- and y- axis adjusted till the Dead center was directly centered over the center hole of the rotary table. Once this was accomplished, the DRO's where zeroed. This allowed all cuts to be based on polar and Cartesian coordinates. Once the first cut was made, the part was left clamped as much as possible. If a clamp needed to be relocated, a new clamp was placed before the old one was removed. When cutting the circular patterns, the feed speed is increased as the bit move closer to the axis of rotation.

Gaskets

Several gasket types were tried to create a seal. A range of durometers (a measure of the materials "squishiness") were tested. The final selection was purchased from McMaster-Carr and was a gum gasket. It had a durometer rating of 40A. However stiffer gaskets can also be used. Both gasket sheets and precut gaskets were purchased. To cut the sheet gasket to the appropriate shape and size scissors were used. A knife scissor combination was used to cut the holes required. A small amount of gasket grease was applied on both sides of the gaskets and occasionally reapplied as necessary.

Pneumatics

Several changes were done to the external pneumatic assembly. 4" sewer PVC piping was used to create another pressure vessel, external of the main pressure tube. The solid cap of the piping was sealed using the same method as the end cap and flange on the main pressure vessel, while the threaded end was sealed using pipe teflon tape. Five holes were drilled to allow for the pneumatic lines and two holes were drilled for the electric connections. Through wall push-to-connects were used for passing the pneumatic lines through the wall of the PVC. These were sealed using thread seal, epoxy putty, and marine silicone. The same method of sealing the wet connects on the main pressure vessel was used to pass the wiring through the PVC. A check valve was added to the pneumatics as well. It is a one way check valve to allow for internal pressure build up to be released in case a leak occurred in one of the pneumatic lines. This was to prevent a small bomb from forming on the bottom of our submarine. Teflon tape was used on all connections between solenoid valves which are rated to 100 psi. DO NOT pressurize system past 100 psi. Hard lines were used because originally it was feared that the pressure was not going to be easily regulated. In a future redesign these hard line connections could be replaced with pneumatic tubing to further cut down on weight. To paint the PVC piping a layer of RustFix primer and one layer of matte black were applied.

For the dropper system the pneumatic actuators do not have a spring to reset them. Each time the droppers are fired the pressure needs to be relieved so that they can be reset. To allow for this one way valves were placed in line to the pneumatic actuators. They can be unscrewed to relieve the pressure so that the dropper system can be reset.

Electronic Chassis

The electronic chassis was built out of two aluminum plates and static resistant UHMW plastic was used as supports and standoffs. Two hinges were used to allow for the chassis to open. The computer boards were charted out on the aluminum and holes subsequently drilled to pass the wiring through. Two small clamps were used on the opposite side of the hinges so that it could sealed shut.

Buoyancy and Balance

The sub buoyancy and balance were heavily regulated during the entire design, construction and assembly process. To keep within our weight limits reduction of material, wherever possible, should be done. For example the brackets that were constructed had as many holes drilled into them as possible without compromising structural integrity. The motor mounts were also drilled to remove as much material as possible.

In the end Blue November was two pounds positive buoyancy. To comply with competition rules of 0.5% we needed .3 lbs of positive buoyancy as Blue November weighs 61 lbs. To reach this objective small iron weights were placed on the t-slot aluminum frame and moved around until the sub was well balanced. To calculate total buoyancy of the sub a little trick was used. In SolidWorks all the material was changed to water. This allowed us to calculate the weight that would be displaced by all of the pieces of the sub. To find the center of buoyancy the center of mass was taken when all the parts were made of water.

Cameras

Two cameras were used, a front facing and down facing, for vision purposes on the sub. The front facing camera was a GoPro and came with its own water proof casing. It interfaced to the brain of the sub

using wi-fi connection. As wi-fi signal in water is greatly reduced it was required to place the camera as close as possible to the board. The signal was not strong enough to go through the aluminum end cap so a monacle was constructed to allow it to rest right above the wi-fi receiver. It was originally planned to use two GoPros both interacting via wi-fi. However it was discovered late in the semester that they shared the same IP address so it was not possible to stream images from both. A cheap webcam was purchased which needed to be hard wired into the sub was the replacement. To water seal the webcam two different epoxies were used. First the webcam was completely covered in a liquid marine epoxy purchased from Ace hardware. Once the first layer of epoxy had hardened a second coating was applied. The second coating was a putty marine epoxy which was also used on the external seam of the end cap and flange. Finally a small amount of silicon was applied on the wire. Two bolts were placed into the putty epoxy before it had hardened so that it could be attached to the frame.

Clamps

In the original design we had planned to use clamps to seal the rear end cap to the flange. It was planned to use JB weld to attach them to the flange. During testing however it was discovered that the clamp system had several problems. First, with the clamps that had been purchased the correct compressive force could not be applied. Instead a shear force was placed on the end cap. Second the JB weld attachment system was too weak. During testing the JB weld failed and the end clamp was broken off. In future redesign it would be very nice to have a functioning clamp system to attach the rear end cap to the flange.

Pressure Sensor

A hole was drilled into the end cap which closely matched the outer diameter of the pressure sensor. To seal it water tight a bolt and washer were used. A washer was placed on the outer face and the bolt was tightened. A small amount of silicon was placed on both the inside and outside of the pressure sensor connection to confirm seal.

Frame Assembly

After all of the t-slot aluminum had been cut to appropriate geometry and size assembly could begin. It is not easy. It is best to assembly this by not tightening any of the connections too much. Most likely a little finagling will be required to get all of the pieces to match up and be flush. Once everything is lined up then final tightening on all the connections can be done.

It will also be noticed that the large horizontal supports in our frame have been cut in half. This was a mistake. In our original design the frame pieces were going to anodized. Twenty6 has a size limit for the parts which can be colored. We cut them in half to allow for this. The t-slot aluminum we purchased from McMaster Carr was already anodized however so another coating could not be applied.

Anodization & Powder Coating

As was mentioned above the t-slot aluminum which was purchased was already anodized. We wanted the frame to be colored so to do so we had them powder coated. We brought all of our frame pieces to MidWest Industries. They did a wonderful job and were able to apply the powder coating into all the nooks and crannies. Twenty6 Products did all of the anodization for the submarine. Both of these companies are local and are very supportive of the AUVSI program. Their company logos have been placed on the sub to thank them for their work.

Appendix H: Getting Started Guide

Welcome to the MSU Blue November RoboSub!

Just the facts:

Password: R0bosub!

Power: 2 switches: The right switch is for the motors and flips up to power on the motors. The left switch is for the electronics, and is a bit fiddly to turn on. Flip the left switch up and look for the the blinking green LED on the power board. Flip the switch off and quickly back on once the LED is flashing rapidly (several times per second). This on/off flipping may need to be done more than once. The power is successfully on when the CPU fan and RAM LEDs turn on.

Getting started:

Locate these 4 major components:

The Blue November RoboSub
Ethernet cable spool
Laptop
Batteries and charging station

Also helpful would be the buoy, tools for removing the endcap, GoPro camera for documenting the pool test, multimeter,

Pre-Water Checklist:

Before dropping the RoboSub into the nearest pool, it is helpful to be sure that it is ready to go.

So before sealing the end cap check:

Can a Remote Desktop Connection be established? (is Ethernet working?)
Is every wet-connect on the end cap tightened down with dielectric grease inside?
Are the batteries fully charged (At least 8 hours)?

Then check:

Is the GoPro camera powered? This is done by pressing the forward facing button on the camera.
Is the GoPro WiFi on? This can be turned on by pressing the button facing down and checking that the GoPro display says "WiFi on"
Are all 8 of the nuts tightened?
Is the gasket squishing out from the cap by 1/2 a centimeter?

Manual control:

In order to control the RoboSub, you will be connecting an ethernet cable to the RoboSub. This cable has a standard ethernet jack on one end, and a wet connect on the other end. Start up the laptop, using the same password as for the RoboSub. Click on the Remote Desktop button in the taskbar to access the Blue November's computer.

On the RoboSub desktop, start the RoboRealm program by clicking on the icon of a checkerboard in the taskbar. Now click the icon of a gear in the taskbar, which is a shortcut that starts the RoboSub Program.

You will now have four windows open: RoboRealm, the dashboard, console window, and depth chart.

Locate the depth control on the dashboard.

With the RoboSub floating on the surface of the water, click the calibrate button on the dashboard to calibrate the depth sensor.

In the RoboRealm program, you can turn off image processing by unclicking the "Run" button near the top of the window, this will allow you to view the raw images from the camera.

You may now play around with the various manual controls, using the RoboRealm preview window of either camera to see where you are going.

If you want to use the keyboard for movement control, click the "Enable" button. The up, down, left, and right arrow keys control forward, backward, turn left, and turn right respectively. The comma and period keys are strafe left and right, respectively.

Connecting the GoPro camera via WiFi:

The GoPro requires two programs to stream video and appear as a webcam in RoboRealm.

First click the network icon in the lower right of the taskbar to check if the GoPro WiFi is recognized.

If it fails, click "troubleshoot" and Try repairs as administrator

open VLC media player

click the Media -> Stream menu

click network tab

paste the following URL <http://10.5.5.9:8080/live/amba.mp4>

click stream

click next

change file to HTTP in the dropdown box

click Add

enter "/go.mjpg" in the path box, make sure port is 8080

click next

change the profile to MJPEG

click next

click stream

make sure the play button is flashing between play and pause; if not, click on the repeat button.

open ManyCam

right-click on the main screen, click IP cameras -> gopro1

click the rotate button to turn the display right 90 degrees

Autonomous mode:

By selecting the "Wait and then Start" mission from the mission planner on the RoboSub dashboard, you will have 60s to disconnect the ethernet cable and place the sub in the water. Unfortunately, all this currently does is cause the sub to dive to 4ft and swim forward for a few seconds and then stop.

Selecting the "Buoy" mission, the Blue November will dive to 2.5 ft and then begin a spiral search pattern to find a bright red object. Once one is visible, the sub will move toward the object until it has bumped it, then back up 1 ft, turn slightly to the side, and then move forward beyond the buoy it bumped.

RoboRealm vision program:

This program allows us to obtain and filter data from the two cameras. The various filters being applied to the current camera are listed in the box below the video. They are listed in the order they are being applied, which can be critically important, as a blob filter should be applied after a color filter when looking for items of a single color.

Click the "**Camera**" button to view what RoboRealm sees in the large "Preview" window.

In order to view the unfiltered visuals from the camera, unclick the "**Run**" button near the top of the RoboRealm window. This will stop all filters from running and show the raw camera data.

To switch between the forward and down cameras, click the "**Options**" button near the "**Run**" button. Then select between the cameras using the drop down box. The "Webcam" is the down camera, "ManyCam" is the forward-facing GoPro.

Browser interface:

Since MRDS uses TCP socket number 50000 to communicate within the computer, it is possible to access information about the services while they are running via a web browser.

Open a browser and type "localhost:50000" into the URL bar. You will now see menus accessing each of the RoboSub's services and peripherals.

General Tips and Troubleshooting

Hardware Tips and Trouble Shooting.

There are three steps to hardware trouble shooting. They are as follows.

1. Power Check: Check the voltage levels at the component in question. Are they at the right level? If not, trace the lines back and see if there are any discontinuities. Make sure the component is getting the right power level and is grounded.
2. Data Check: Check any analog input output lines with the DMM and make sure that your signal is getting through. You should be able to see momentary voltage flickers and things of that nature on data lines.
3. Final Check: Check that all lines are continuous and that there are no breaks in the circuit anywhere, then check voltage levels on the actual board or component to see if the board or component has gone bad. Also, bad outputs from a board could mean a bad board or bad interface. Don't forget to check the programming output for abnormalities.

RoboSub Software Tips and Troubleshooting

The code for the RoboSub has been developed using code left from the previous year. Previously, all movement was based on setting IMU compass headings and then moving the sub forward while maintaining that heading. Due to problems obtaining data from the IMU, the IMU data analysis was spun off into a separate senior design team this year.

Thus, for this year's coding, references to the IMU heading system have been commented out wherever they interfered with the operation of the RoboSub. Instead,

our priority has been to develop the vision system so that navigation can be done solely with the cameras.

From a hardware standpoint, the previous year's Sanka sub cameras were woefully inadequate. Both housings developed persistent leaks that cause the lenses to fog over in the water, and attempts to reseal the housings did not succeed. The GoPro camera and its housing on the BlueNovember sub provides excellent clarity, especially underwater.

Unfortunately, due to IP address issues, only one GoPro can connect via WiFi at a time, so the down camera is a cheap webcam that was sealed in waterproof epoxy.

----- **Setting up a new RoboSub PC** -----

To install the software onto a new RoboSub, first install Windows, the motherboard drivers, ESPECIALLY the USB driver, then all of the Windows updates.

Next, install Visual Studio, and Microsoft Robotics Developer Studio 4. These programs are available to students for free via Microsoft Dreamspark. Now copy the entire "Microsoft Robotics Dev Studio 4" folder from an existing sub or backup. This will ensure that the necessary binary assembly files are included. Notice that the Arduino code and RoboRealm configuration files are included in the "Projects" subfolder.

Once installed and functional, it is only necessary to copy the "Projects" folder when backing up or transferring the RoboSub code.

Do not try simply cloning an existing RoboSub hard drive. This approach is not functional.

The Arduino software will need to be downloaded and installed. Remember to choose the appropriate board from the Board menu, otherwise the code will not upload properly.

RoboRealm will likely give you a free license to the software if you tell them that you are on the MSU RoboSub team. After installing RoboRealm, it will need to be set to act as a server to talk to the RoboSub code. Click "Options -> API Server" in RoboRealm, then check "Activate RoboRealm API server" and make sure that the port is 6060.

The RoboSub software shortcut will need to be copied to the new sub. This shortcut contains the TCP configuration parameters for running the C# software. You may need to right click on it in order to change the directory information in both the target and starting entries to match the names of directories on the new PC.

In order to have the existing code interface with new motor controllers, the serial numbers of the new motor controllers must be determined and inserted in the C# code. To do this, use the Pololu Jrk Configuration Utility. This can be downloaded from the manufacturer's website.

Once the utility is open on a PC connected to the new motor controllers, click the "Connected To" drop down box in the upper left corner of the window. This will show the

serial numbers of all connected motor controllers.

Now open the "Movement.Config.xml" file in Visual studio. It can be found in the "Projects/RDSroboSub/Main/Main/Config" folder.

Lines 29-59 will contain the motor driver serial numbers. Replace these with the new serial numbers.

For reference, the BlueNovember sub's motor controller serial numbers are:

#00071568

#00071575

#00071580

#00071566

#00071571

#00071573

Warning! Be sure to turn off the Windows Firewall on the new RoboSub PC, otherwise there will be an HTTP or FTP listening error when trying to run the RoboSub program. This error manifests by the program closing immediately after opening. The firewall isn't really necessary on a standalone computer anyway.

Warning! When using a version of Visual Studio earlier than the 2013 release, there was a large error that causes all of the RoboSub code to be corrupted if clicking Build -> Rebuild entire solution.

Warning! If the motherboard drivers are not installed as soon as possible when setting up a new PC, there may be connection errors later. This manifested for us when plugging in the Arduino and USB hubs; they were showing up as "Unknown Device" in the Windows printers and devices window. Our solution was to completely reinstall Windows 7.

A helpful link for addressing MRDS errors when getting started:

<http://msdn.microsoft.com/en-us/library/dd939179.aspx>

----- Movement -----

The search pattern for both the line on the floor of the pool and locating buoys with the forward camera is designed to be a spiral. By alternately moving forward and turning slightly, the idea is to cover the immediate area quickly, and if nothing is found, to spiral outward until a target can be obtained.

Left turns are accomplished by using the TurnRight() function with a negative power value.

The motor controllers will keep the motors moving at the last given power level, even if the PC shuts down or freezes. Starting the RoboSub program will cause all of

the horizontal thrusters to stop moving. In order to stop the vertical thrusters, enter a depth in the dashboard GUI and then click "Surface"

When using vision to accomplish a task, the code includes timeouts to slow the RoboSub to recalculate course corrections once per second. This was decided to be fast enough and not allow too much over-correction.

----- RoboRealm -----

The goal of the RoboRealm software is to take the incoming streaming video images and reduce them to a set of X,Y coordinates that are sent to the C# code. To do this, visual filters are applied, in a specific order, to only look for specific colors and then find the largest blob of that color. The coordinates are the Center Of Gravity of the blob.

If RoboRealm is generating any streaming errors, first check to be sure that the program has the most recent updates. Certain Windows updates may cause problems if RoboRealm is not also updated.

RoboRealm uses specific configuration files to determine which camera and filters to use when called upon by the C# code. These files can all be found in "Microsoft Robotics Dev Studio 4/ Projects/RDSRoboSub/RoboRealm"

Remember to save after changing any filter settings in RoboRealm, or they will not take effect when called upon by the C# code.

If RoboRealm is hanging or freezing and not allowing the editing of filter settings, this may be because the RoboSub software has been running. Quit both the RoboSub and RoboRealm programs and restart RoboRealm.

The cameras in the Sanka sub have a considerable amount of automatic image adjustment that cause a large amount of flickering and make it difficult for RoboRealm to lock onto a specific color. Setting the Color filter variation parameter in RoboRealm to a larger value helps to address this issue. Also, turning off as many of the automatic camera functions as possible in RoboRealm's "Options -> cameras" also helps.

Of the filters in RoboRealm, the Color filter has been most useful for identifying a specific color, and then setting a range around that color that will also be considered to be the same color.

Clicking on each filter while the "Run" button is depressed will allow you to see the cumulative effect of all preceding filters. This helps a lot with tweaking the filters so that a good set of Center Of Gravity coordinates are sent to the C# code.

----- The console window -----

The console window will provide valuable feedback that lets the user know what the RoboSub is trying to do. All comments appearing in the console window will be

preceded by the C# filename of the file that is generating that specific comment.

Error messages are colored red and are preceded by the string "!!! ERROR !!!" for maximum visibility.

----- **C# coding tips** -----

There is a physical copy of the Microsoft Robotics Development Studio manual in the lab, along with 2 flash drives that should contain all of the work from the previous 2 years. There is a PDF of the Head First C# book in these files that may also be helpful.

Also be sure to look at the software flowchart and watch the introduction video that we have provided. This should make the interactions between the different files more clear.

One of the most useful tools in Visual studio is right-clicking on a method in the code and clicking "go to definition". This will show you exactly where that variable or method is defined and show what it is supposed to do.

Another is simply using Ctrl-F to search, and then click "search entire solution" in the drop-down box. This will allow you to search for every occurrence of a variable, which is essential to understanding how that variable is instantiated and passed between various files in the code.

While each of the missions has their own separate C# file, the MissionPlanner.cs file contains state machines that control what mission will be selected next after any given mission is completed.

Since water is a fluid medium, a short burst of movement will cause the RoboSub to drift for quite a while. We've found that short bursts, update every second or so, allow for decent movement control. This means that when "stopped" no motors may be spinning, but due to inertia and currents in the pool the sub will never stay still!

The common movement methods are:

```
movement.Stop stop = new movement.Stop();           // for stopping
_movementServicePort.Post(stop);
```

```
_movementServicePort.MoveForward(.15, 300); // moving forward at 15% power for
300ms
```

```
_movementServicePort.TurnRight(.5, 200);           // turn right at 50% power for
200ms
```

```
_movementServicePort.TurnRight(-0.5, 200);        // turn left at 50% power for
200ms
```

```
_movementServicePort.SetTargetDepth(5);    // have sub hold depth at 5 ft. below  
surface
```

RoboRealm will send the coordinates of the Center of Gravity of a blob on the screen to the C# code. COG is a common abbreviation for the Center Of Gravity, and the COG is very useful, as this is how we determine where the object is relative to the RoboSub.

The following if statement checks to see if the first blob's COG Y coordinate is greater than 330. Since we reduce the camera resolution to 640x480 in RoboRealm, this will tell us if the object is at the top of the screen.

```
if (Blobs[0].Y > 330)
```

This can be modified to check other blobs (if more than one's data is sent to the C# code) and to check the X coordinate as well.

The latest challenge is to include multiple colors and multiple blobs, and send the COG coordinates and color of all blobs on