FAMU-FSU College of Engineering
Department of Electrical and Computer Engineering

DETAILED DESIGN REVIEW

EEL4911C – ECE Senior Design Project I

Project title: **Autonomous Water Quality Sampler**

Team #: 8

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Project Executive Summary

This detailed design review is in response to :

Contract: Project #8

AWQuSam Engineering will be providing a turn-key autonomous water quality sampler that will be utilized for acquiring hydrographic and water quality data by the Florida State University Department of Oceanography. As requested in the solicitation, the system will be designed and implemented to support the gathering of water quality and hydrographic data along Florida's coastal environment. The AWQuSam will be a propeller-driven kayak capable of driving itself across a bay, at least 5km, navigating with GPS, recording key oceanographic parameters, and relaying samples of data to a base station.

To accomplish these tasks, the AWQuSam will employ means that facilitate acquisition of useful scientific data, such as temperature and salinity, in the shallow environments of the Florida shelf. Signal processing will be performed via a PIC microcontroller aboard the AWQuSam. All acquired data will be logged onto an SD memory card for analysis by researchers.

A GPS system will be incorporated into the AWQuSam for use by the navigation, guidance and recovery systems. In addition to the AWQuSam, a base station will be developed in order to receive streamed data from the AWQuSam.

The primary objective of the AWQuSam is to remain autonomous, navigating and performing the aforementioned tasks, for the duration of the trip.

Presently, there is no such autonomous system for effectively collecting hydrographic data in shallow environments. The team believes their creative and potentially transformative design concepts can revolutionize oceanographic research by advancing discovery in this area.

The team of engineers is confident the data reflected in this document represents innovative test and evaluation techniques. Attention has been paid to detail, and the team holds a firm commitment to completing this task in an efficient and accurate manner.

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1 Introduction

1.1 Acknowledgements

AWQuSam Engineering would like to thank the FAMU / FSU College of Engineering and the Florida State University Department of Oceanography for monetary contributions toward the development of the Autonomous Water Quality Sampler, hereafter referred to as the AWQuSam. Thanks, also, to researchers within the Florida State University Department of Oceanography for contributing oceanographic expertise and equipment necessary for developing the AWQuSam.

1.2 Problem Statement

There is a need for water quality and hydrographic data from the coastal environment in order to understand the processes that mix and transport nutrients, carbon, pollutants, and other material entering the ocean from sources on land.

Ship-based measurements are expensive because of the operating cost for a sea-going vessel and crew. New platforms for sampling the ocean at high resolution are being used now in many coastal regions around the United States. These platforms, called gliders, are roughly torpedo shaped and, like gliders in the atmosphere, have a relatively large glide ratio in order to translate vertical motion into horizontal distance.

In the shallow environment of the Florida shelf, there is no room for large vertical excursions to provide for the buoyant force to drive the horizontal motion and gliders are not practical.

A new kind of platform is needed that moves across shallow bays and estuaries and measures key water quality parameters like temperature and salinity.

The AWQuSam is a fully autonomous surface vehicle designed to navigate the shallow waters along the Florida coast. Routes can be programmed into the AWQuSam prior to excursion, and the AWQuSam will navigate the route, collecting key oceanographic data along the way. A GPS system will be incorporated into the AWQuSam for use by the navigation, guidance and recovery systems.

The AWQuSam will process scientific information, such as temperature and salinity, from sensors located in the water. Signal processing will be performed via a PIC microntroller aboard the AWQuSam. All acquired data will be logged onto a SD memory card for analysis by researchers. Samples of data will be streamed via license-free channel to a receiver for real-time analysis. A base station will be developed in order to receive streamed data from the

AWQuSam.

1.3 Operating Environment

The AWQuSam will be operated in the shallow environment of the Florida coastal shelf. It will be operated and/or stored in a salt-air atmosphere with humidity levels potentially reaching 100%. While operating, the AWQuSam may experience extended exposure to sunlight. During the summer months, the AWQuSam may be stored in temperatures of up to +70°C and while operating, may be exposed to temperatures of up to +55°C. In addition, the AWQuSam may experience winter storage temperatures as low as -20°C and operating temperatures of -5°C. The AWQuSam may experience crashing waves of up to 1m in height, winds of 40knots, and driving rainfall.

1.4 Intended Use(s) and Intended User(s)

The AWQuSam is intended to be used by oceanographic researchers. It will primarily be deployed by users with at least a Bachelor's degree and knowledge of the system. However, the AWQuSam may be deployed by individuals with no knowledge of the system, and it shall be designed to allow such a user to deploy the system with the aid of user documentation which will be provided among project deliverables (See Section 1.6). Untrained personnel will be able to program a new mission path into the AWQuSam with only the aide of instructional documentation which will be provided by the project team. Once deployed, the AWQuSam will be fully autonomous. Collected data will be analyzed by oceanographic researchers.

The AWQuSam will be used to collect precise hydrographic and water quality parameters near the surface of the Apalachicola bay area and other shallow water environments. It will record water temperature and conductivity information. The AWQuSam will be used to collect this oceanographic data in an environment where there is presently no effective method for collecting such data. It is not intended to collect data on land or in deep ocean environments.

1.5 Assumptions and Limitations

The AwQuSam shall measure and record water temperature to a precision of 0.01ºC at a rate of 8 samples per second. It shall measure and record water conductivity to 0.01 S/m at a rate of 8 samples per second. Most recently acquired temperature, conductivity, and position will be transmitted to a base station receiver every 5 minutes. The AWQuSam will not be deployed for missions longer than 12 hours. The system is to be used only for surface water applications, and is not to be deployed in areas with ocean currents in excess of 5 knots or with waves greater than 2m in height. The end user will program paths into the AWQuSam using GPS coordinates.

The end product shall be no larger than 2m in length, 0.8m in width, and 0.5m in height (excluding antennas) to facilitate easy transport in the back of a van to and from a launch site. It shall weigh no more than 40kg to allow for deployment by one to two persons. An AWQuSam prototype shall be designed and delivered by April 13, 2011 with expenditures not to exceed $2000.

1.6 Expected End Product and Other Deliverables

One (1) Autonomous Water Quality Sampler prototype will be delivered to facilitate the gathering of oceanographic data in shallow coastal waters. Its path will be programmable by the end-user. Once programmed, the AWQuSam shall propel itself across the surface of bays and estuaries recording water temperature and conductivity.

The AWQuSam will be delivered with documentation detailing instructions for programming new paths. Data formats found in the data log and transmissions will be documented to facilitate analysis by researchers. Documentation will also be provided with instructions for performing maintenance and for servicing the system or components. Prototype and documentation shall be delivered by April 13, 2012.

2 System Design

2.1 Overview of the System

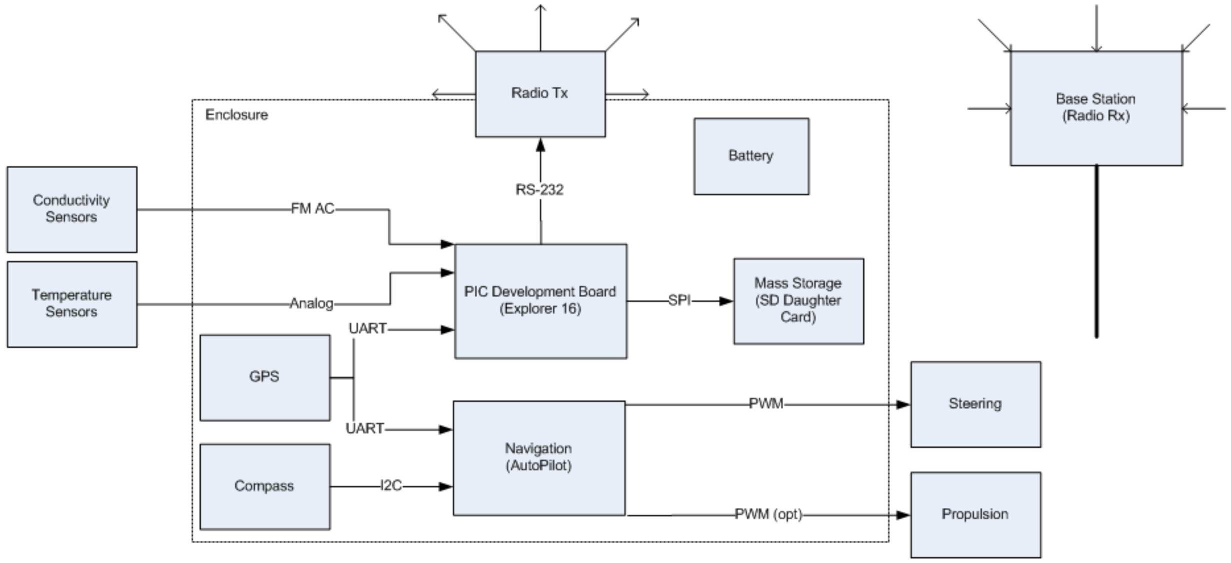


Figure 2.1.1: Top-level architecture of AWQuSam

The AWQuSam's design revolves around the Explorer16 PIC development board. This is a microcontroller based board. It will receive inputs from conductivity and temperature sensors. This information will be logged to an SD card. A separate navigation subsystem will receive inputs from a compass and GPS module that will be used to drive the steering and propulsion systems.

2.2 Major Components of the System

2.2.1 Explorer16 Development Board

The design revolves around the Explorer16 PIC development board. This is a low cost, efficient microcontroller based development board. It includes the dsPIC33FJ256GP710 microcontroller, which features up to 85 I/O pins. It also has a 12-bit A/D converter, two UART interfaces, two SPI interfaces, and two I2C peripheral interfaces. In addition, this microcontroller offers input capture, compare, and pulse width modulation peripheral functionality that will be utilized in the design.

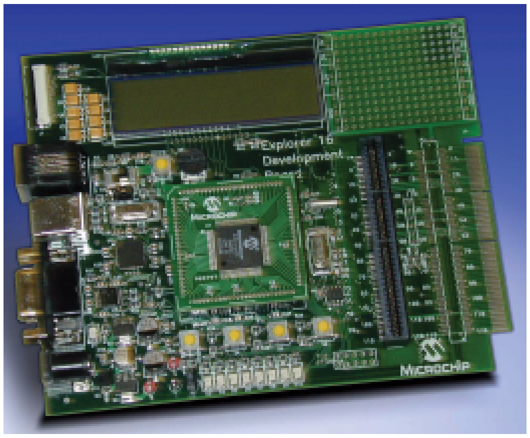


Figure2.2.1.1: Explorer16 Development Board

The Explorer16 offers expansion capabilities in the form of daughter cards and plug-in-modules. This easy integration feature will be utilized in the design of the AWQuSam. The development board also features pushbuttons, a 16x2 LCD display, and LED indicators that will be useful for debugging and programming. The development board, when powered from 9V supply, draws about 250mA of current.

2.2.2 Conductivity Sensors

A number of vendors were consulted in order to determine the conductivity sensor best suited for this design. The most practical option from YSI is their 600R model conductivity/temperature sensor. This series can sample at 10Hz. However, the sensor costs $2062 per unit, plus $85 for each pigtail connector for integration with the development board

Forston Labs offered a conductivity sensor for $125 per unit, but they only resolve to 0.02 parts per thousand (ppt). In addition, the response time of this conductivity sensor is too slow for this application.

PME offered a rapid-response conductivity sensor, as well. However, this option is not very stable. Engineers at PME advised the team that their sensors are not well suited for twelve hours of unattended operation. These sensors do not resist fouling and are quite fragile.

Figure 2.2.2.1: SBE-4 Conductivity Sensor

The SBE-4, by Seabird Electronics, will be used to gather water conductivity data. This sensor provides a precise, rapid response that satisfies the design requirements. Seabird Electronics is a premier manufacturer of marine instruments and sensors. This sensor outputs a variable frequency square wave signal (from 2.5kHz to 7.5kHz) corresponding to the conductivity (from 0S/m to 7S/m). When powered by a 12V source, these sensors draw about 12mA of current each.

2.2.3 Temperature Sensors

A variety of temperature sensors are available. Thermocouples offer a fast, almost immediate, response to temperature changes. However, they are best suited for extremely high temperature. RTDs are stable temperature sensing devices. However, because they are best suited for a wide temperature range, detailed precision is not guaranteed.

This application requires measuring a relatively limited temperature range. However, accuracy and sensitivity to small changes is important over this range. A fast-response thermistor is the best solution.

Figure 2.2.3.1: OL-710 Thermistor

The design will utilize such a thermistor for acquiring temperature data. In particular, the design will use the OL-710 device by Omega Engineering. This instrument is design for immersion in fluids, and it offers a level of precision in the range of temperatures experienced in the Apalachicola river and bay system.

2.2.4 GPS

Figure 2.2.4.1: D2523T GPS Module

The D2523T complete GPS module will be used in the design of the AWQuSam. This module revolves around the UBX-G501chipset, and itt features a 26dB helical Sarantel active antenna.

2.2.5 SD Daughter Card

Data acquired by the conductivity sensors, temperature sensors, and GPS will be recorded to an SD card. Microchip offers a board for interfacing the Explorer16 with SD cards (AC164122).

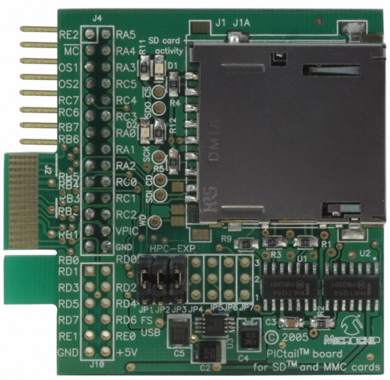


Figure2.2.5.1: SD Daughter Card for Data Logging

2.2.6 UDB4 PIC Unmanned Aerial Vehicle Development Board

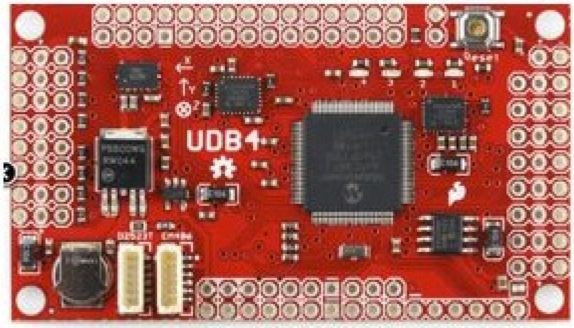


Figure 2.2.6.1: UDB4 PIC UAV Development Board

The UDB4 will be modified to fit the automonous navigation requirements for the AWQuSam. The UDB4 is equip with a dsPIC33FJ256 CPU, an 3-axis accelerometer, a 2-axis gyro for movement in the xy-plane, and an 1-axis gyro for movement in the z-plane. The D2523T GPS receiver is also compatible with the UDB4 board. The board consists of 8 input and and 8 output pulse width modulated points. The points will be used to attach the board to the speed and steering servo. The UDB4 will be used to control the speed and steering servo, perform navigation calculations for autonomity, and intialize D2523T gps receiver which will be connected to both the UDB4 and Explorer16.

2.3 Performance Assessment

The system shall be designed to satisfy the requirements of the specification as discussed with the customer. It will measure and record eight samples each second of water conductivity, water temperature, and position for the duration of the mission. During each conductivity and temperature sample, a measurement will be recorded at the surface of the water and at a level six inches below the surface of the water.

The AWQuSam will allow for programmable mission paths in the form of GPS waypoints. It will autonomously propel itself across the surface of the water to each waypoint before reaching its final destination.

The AWQuSam will also wirelessly transmit a sample of recorded data to a base station receiver every five minutes. This will provide researchers a real-time glimpse of what is being recorded and where the AWQuSam is presently located.

2.4 Design Decisions

2.4.1 Obstacle Avoidance

The prototype design for the AWQuSam will **not** include an active obstacle avoidance system. It is the responsibility of the waypoint programmers to configure paths that will avoid known oyster beds and other potential hazards in the bay area.

A future obstacle avoidance system could include a sonar system fixed to the front of the kayak. Such a system could feed back to the navigation system if an obstacle is detected. In the event an obstacle is detected, the navigation system would have to respond by intelligently choosing a new course and/or shutting off the motor. Such a system would be able to detect non-permanent obstacles such as boats.

2.5 Overall Risk Assessment

Technical Risks

ID	Risk Item	Probability	Impact	Mitigation Plan
1	Writing to SD card may affect the ability to process data at 8 samples/second.	Medium	Low	Efficient data encoding techniques (see 3.7 Data Handling) may be used to reduce the amount of data to be written to SD Card. If this is the case, data on the SD card will have to be decoded so it is human readable.
2	While periodic real-time transmission is live, data cannot be recorded.	High	Low	Data transmissions will be encoded to ensure minimal downtime.
3	Much of code for data acquisition has been tested on PIC24FJ128GA010, which satisfies all requirements except A/D resolution. This poses a risk in achieving .01ºC temperature precision	High	Medium	Team will move forward with designing on PIC24FJ128GA010 µC. Time permitting, the design will be ported to the more desirable dsPIC33FJ256GP710. Team may also explore utilizing voltage to frequency converter. *See Technical Risk 4 *See Scheduling Risk 2
4	The 12-bit A/D converter on dsPIC33FJ256GP710 may not be able to utilize such a narrow window of reference voltages to achieve .01ºC temperature precision.	Medium	Medium	This risk applies if time permits porting the design to the dsPIC33FJ256GP710 MCU.

5	Explorer16 only has one PICtail expansion slot. Two cards needed (One to pull out all pins of MCU, one to interface with SD Card)	High	Low	Team will have to carefully hardwire SD Daughter card to Prototyping Board. Must minimize interference to avoid flipped bits.

Scheduling Risks

ID	Risk Item	Probability	Impact	Mitigation Plan
1	Personnel Leave - Illness or absence of any engineer would require over-allocating other resources	Medium	Medium	Some flexibility has been built into schedule. Many subsystems have multiple engineers assigned. One engineer can divide time to cover responsibilities of absent engineer.
2	Design is moving forward with PIC24FJ128GA010. Time may not permit porting the design to the more desirable dsPIC33FJ256GP710.	High	Medium	Customer would prefer a functional prototype that does not have precision than risk delaying the prototype.

Budget Risks

ID	Risk Item	Probability	Impact	Mitigation Plan
1	Increase Product Expenses - Price estimates in the original proposal could possibly be lower than what the team actually pays	Low	Moderate	To make sure that this never occurs, the team makes budget talks a priority at every meeting
2	Unforeseen Expenses - As the team continues moving forward in the design and development of the AWQuSam, there may be devices or products that the team was initially unaware of, that are a necessity to the completion of this product	Moderate	High	If an engineer can identify a component that may be needed in the future early in the process, it becomes much less expensive to solve compared to the final stages of the design

3 Design of Major Components

3.1 Mechanical Housing

3.1.1 Hull

The prototype design for the AWQuSam shall use a Riot Trickster Kayak. Some of the benefits of a kayak is that they are very durable, light weight, easily transported, cheap, and fairly streamlined. Purchasing a kayak makes the most economical sense for the purpose of the AWQuSam prototype. This route saves time, money, and labor cost. The kayak would need to be refitted to accommodate the needs of the AWQuSam. These accommodations include: (1) internal support for propulsion and electronic components; (2) structural support for sensors, and (3) a stabilizing structure below the hull. The idea is that with this design, other kayaks could be retrofitted into an AWQuSam so special consideration is put into the versatility of the design.

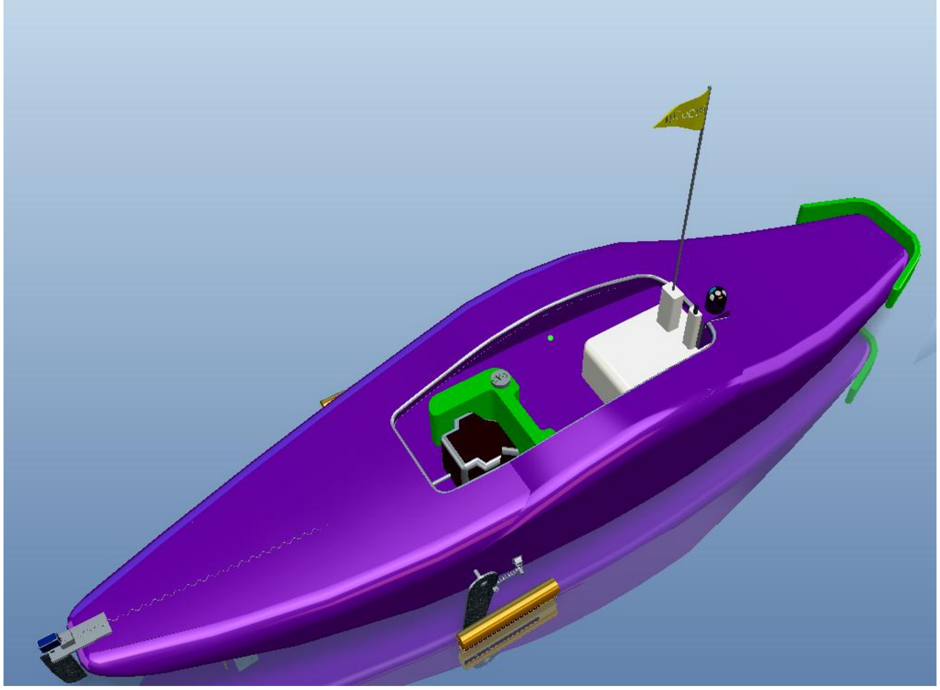


Figure 3.1.1.1: Hull Top View

The kayak hull will enclose all the electronic and mechanical components but shall allow for easy access. It will displace more volume of water than the entire weight of the craft in order to achieve maximum buoyancy in order to cruise effectively in shallow waters. The design needs to be water tight to avoid damaging electronic and propulsion components if it capsizes or rains. It also needs to be light enough so that the craft is able to be carried by two using handles at each end of the hull. The dimensions of the Riot Kayak Trickster can be seen in the image below. The kayak weighs 33 lbs.

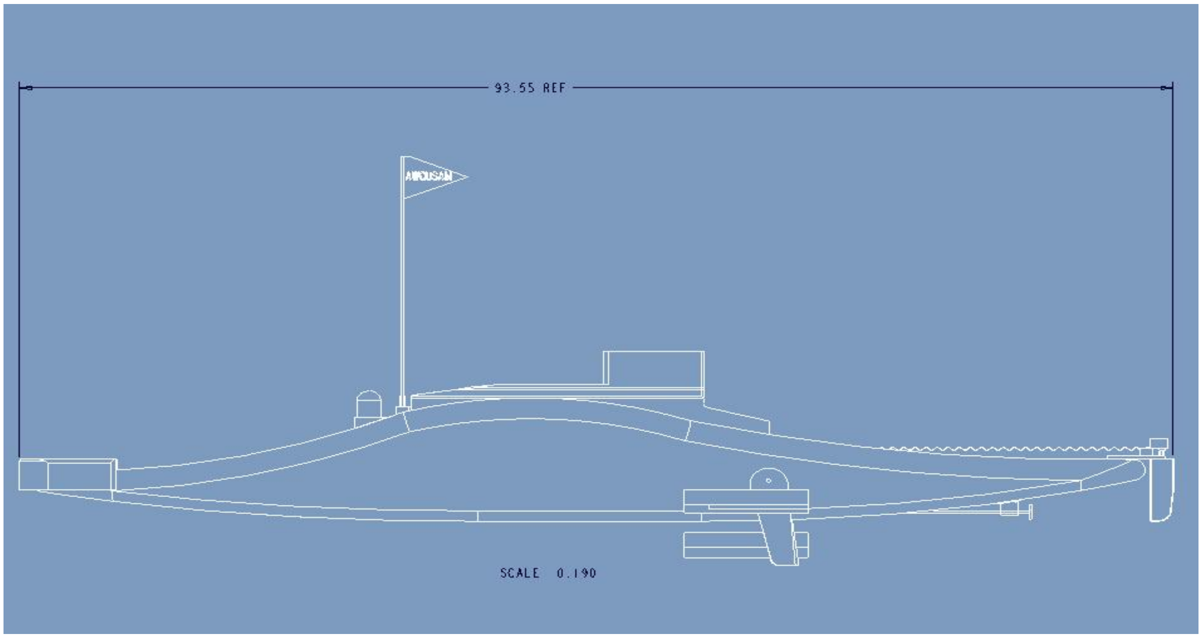


Figure 3.1.1.2: Wire Frame Side View with Dimension (93.55 inches)

The kayak hull satisfies the posing environmental challenges. The AWQuSam will not suffer any degradation of performance when operated in and when stored in a salt fog atmosphere. It will not suffer damage from exposure to sunlight. The AWQuSam will be operable in a hot, humid environment with a diurnal cycle peak of 100% humidity. The AWQuSam will be fully operable at a continuous, ambient temperature of +55°C, and will suffer neither damage nor degradation due to storage at a temperature of +70°C. The AWQuSAm will be fully operable at a continuous ambient temperature of -5°C, and will not suffer neither damage nor degradation due to storage at a temperature of -20°C. The AWQuSam shall operate and remain functional during driving rain. The kayak will protect all instrumentation from suffering any damage from waves up to 1m in height or collision.

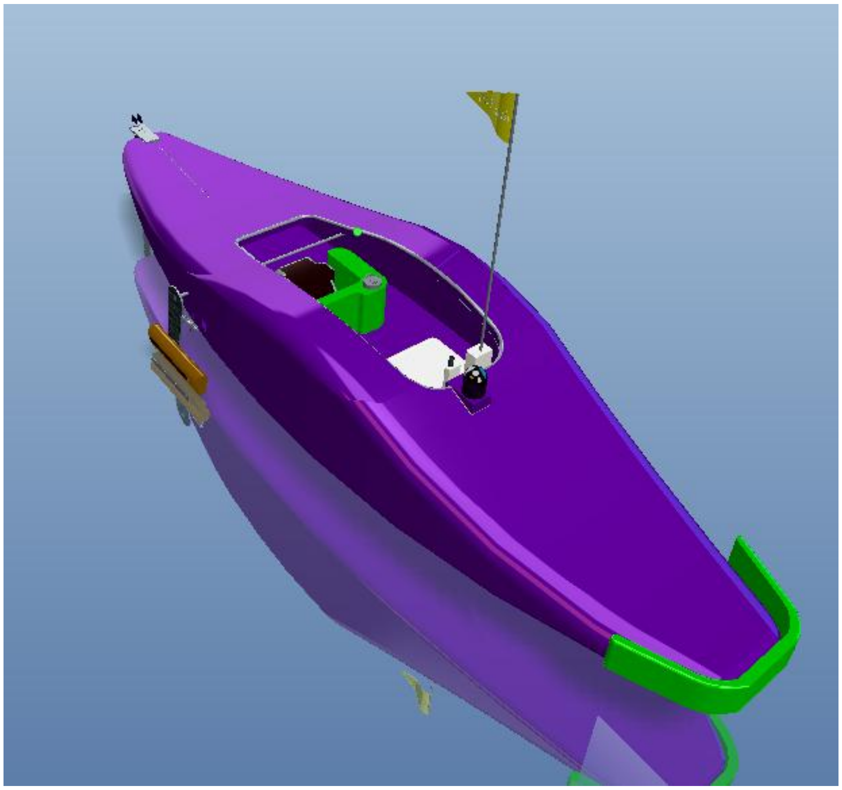


Figure 3.1.1.3: Hull Front View

The Riot Kayak Trickster is normally used in river rapids however it is no stranger to salt water. The kayak is normally used for tricks, so it slides easily. Therefore two stabilizing keels are to be implemented and used both as a structural elements as well as a hydrodynamic elements. The keels will also house the sensors of the AWQuSam. These keels will ensure the AWQuSam moves in a straight line while also protecting the sensors from impact with any external object. The keels will be attached externally to the hull. In order to hold the keels two structures will be bolted to the side of the kayak. The keels will be held in place by a rotating about-an-axis-joint so that if it impacts on shallow ground it has some freedom to rotate and come back into position after impact. The springs will force the keels to rotate back into its rightful place. The design for this mechanism can be seen below.

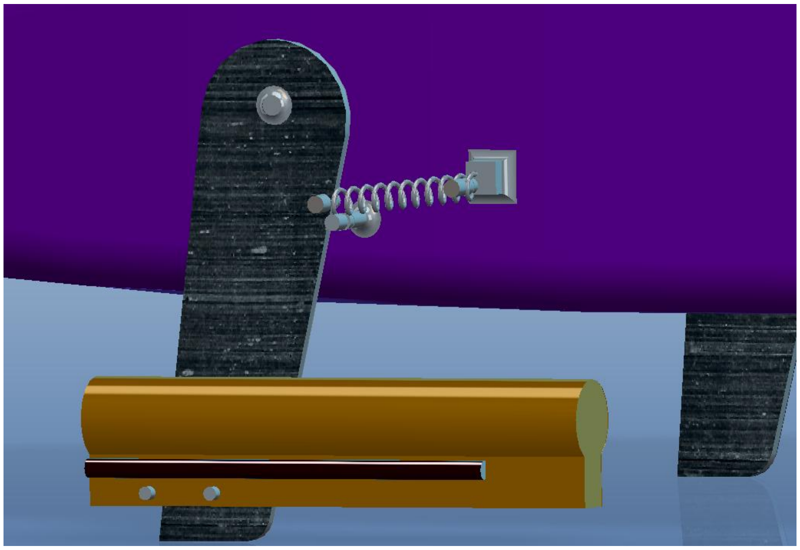


Figure 3.1.1.4: Side Keels and Sensors

The internal structure put in place in the main compartment of the hull will hold the engine and the shaft in place. The engine and the shaft shall be placed in an angle coming out of the bottom of the back of the kayak as seen in this concept picture. The electronics box will be fixed into the bottom of the hull by 3M Velcro.

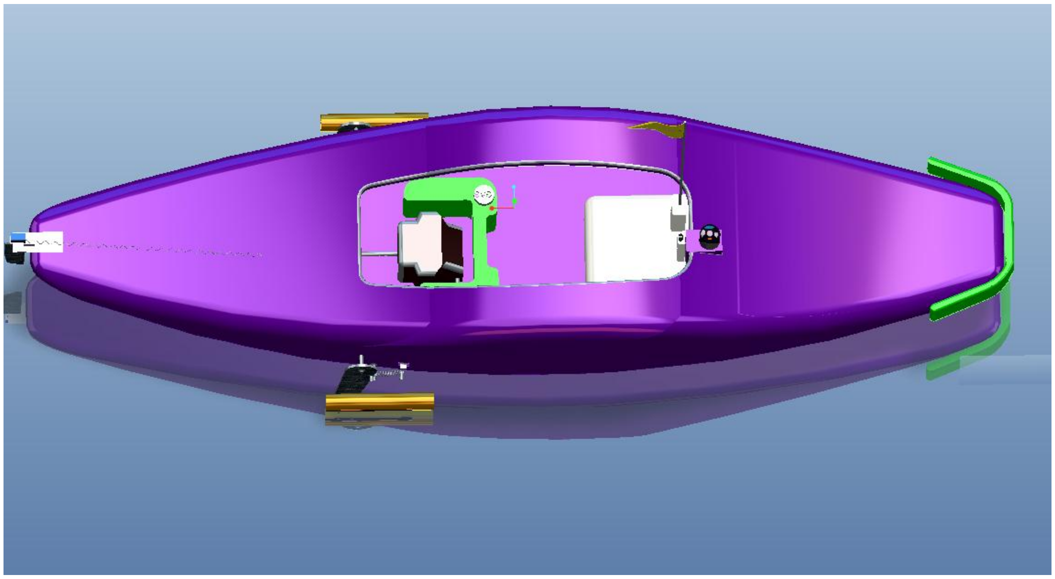


Figure 3.1.1.5: Hull Top View

Finally the top covering on the hull of the AWQuSam will be provided by a fire-retardant cloth that fits snugly on the Riot Kayak Trickster. It has an opening on top that allows the engine to exhaust and extract air. A depiction of the cloth can be seen on the image below.

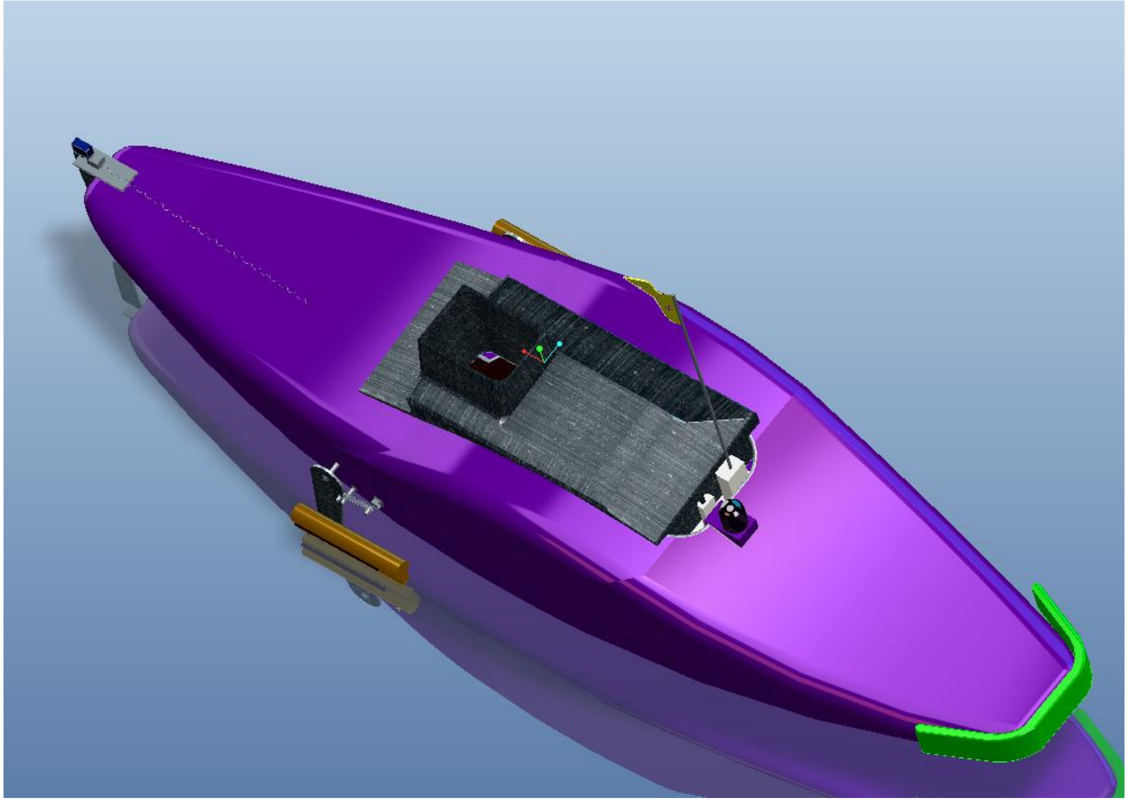


Figure 3.1.1.6: Hull with Top Covering

3.1.2 Electronic Housing

The electronics housing will be placed safely inside the hull and will enclose all electronic components. It shall be easily accessible when out of the water; however, when in operation all seals shall be water tight indefinitely. The main challenge is to seal tight all electronic components during operation but prevent components from overheating.

The electronic housing can be seen in the images below. It will enclose the compass, GPS, mass storage card, battery, development board, communication system, in addition to all the wires. All wires will be sealed in plastic tubing, as shown in Figure3.1.2.2. The tubing will be sealed with all entrance/exit points (w/ box, kayak, etc) with RTV. The connections and assembly components can be seen in the images below.

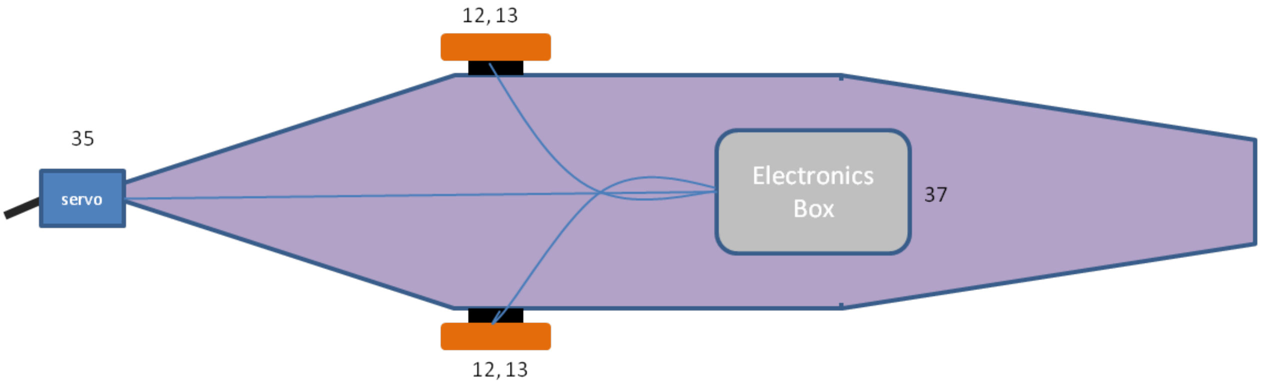


Figure 3.1.2.1: Wire Assembly

Figure 3.1.2.2: Wire Covers

A big box will be fixed to the AWQuSam using 3M Velcro to reduce the amount of protrusions done on the hull. The box will be closed by a rubber water tight seal on the edges with all the electronic components fixed safely inside. Two small towers will come out of the box housing the GPS and transmission antennas. This is necessary for optimum signal transmission. These towers, essentially boxes, will also be water tight and permanently fixed to the main box.

Figure 3.1.2.3: View of Electronics Box, Antennas, and Siren

3.2 Propulsion System

The propulsion system for the AWQuSam will consist of 3 major parts: (1) the engine; (2) the connecting shaft assembly; and (3) the propeller.

The engine we chose is the Honda GX35. It is a small 4 stroke gasoline engine similar to those in many household *weedwhackers*. The chart below shows the specs of the engine. It has a pull-cord for cranking, so the battery need not be connected to the engine. One of the most attractive characteristics of this engine is that it is lightweight- only 3.33 kg. Also it has a very low fuel consumption. At the given rate of fuel consumption a 12 hour mission will consume about 2- 2.5 gallons of fuel. An external fuel tank of that size will have to be fitted to the smaller internal tank which is connected to the engine. The external gas tank will sit in front of the engine slightly elevated and fixed to the mounting frame. The elevation [in addition to the slight tilt created by forward motion] will allow for the gas to flow naturally from the external tank to the engine tank. A hole in the engine tank will be drilled to make this connection. Similar to the diagram below.

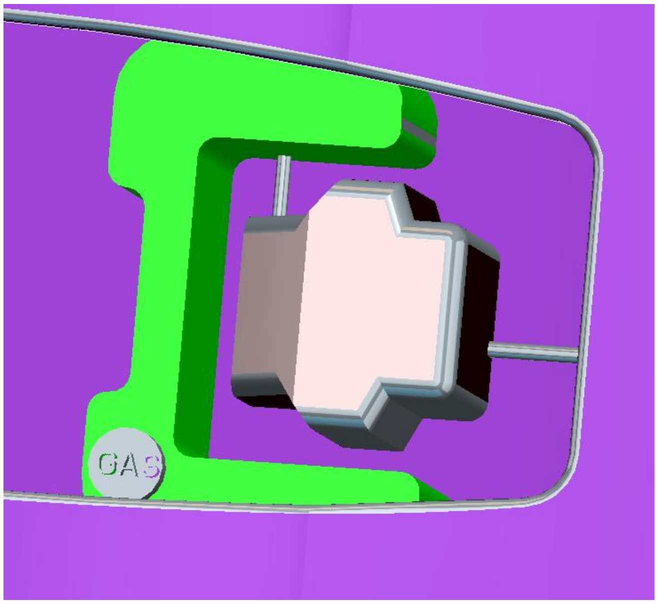
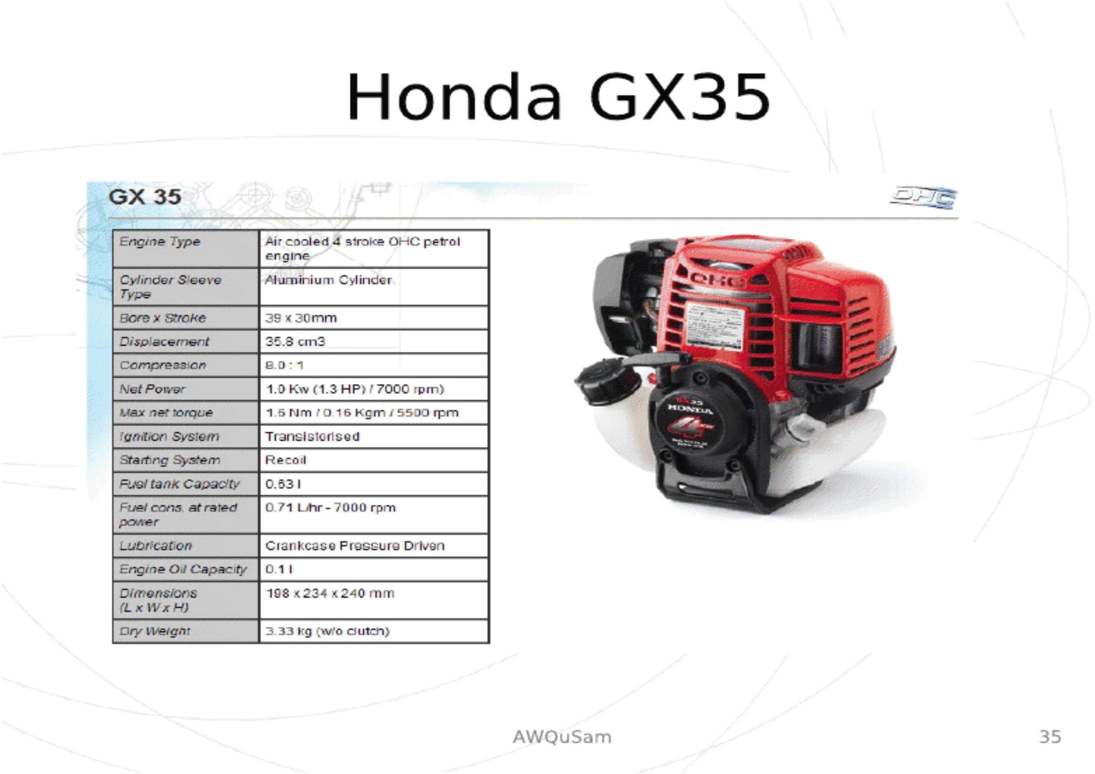


Figure 3.2.1: External Tank Connection

The engine has a high power to weight ratio and that is why a small internal combustion engine connected to a propeller was chosen over electric motors which would have had very heavy batteries to fulfill the 12 hour run.



Honda GX35

GX 35

Engine Type	Air cooled 4 stroke OHC petrol engine
Cylinder Sleeve Type	Aluminium Cylinder
Bore x Stroke	39 x 30mm
Displacement	35.8 cm3
Compression	8.0 : 1
Net Power	1.0 Kw (1.3 HP) / 7000 rpm)
Max net torque	1.6 Nm / 0.16 Kgm / 5500 rpm
Ignition System	Transistorised
Starting System	Recoil
Fuel tank Capacity	0.63 l
Fuel cons. at rated power	0.71 L/hr - 7000 rpm
Lubrication	Crankcase Pressure Driven
Engine Oil Capacity	0.1 l
Dimensions (L x W x H)	198 x 234 x 240 mm
Dry Weight	3.33 kg (w/o clutch)

AWQuSam 35

Figure 3.2.2: Honda GX35 Engine

The second part of the propulsion system is the connecting shaft assembly. This will allow the motor to transmit its torque through the shaft to the outside of the boat underwater and then to the propeller.

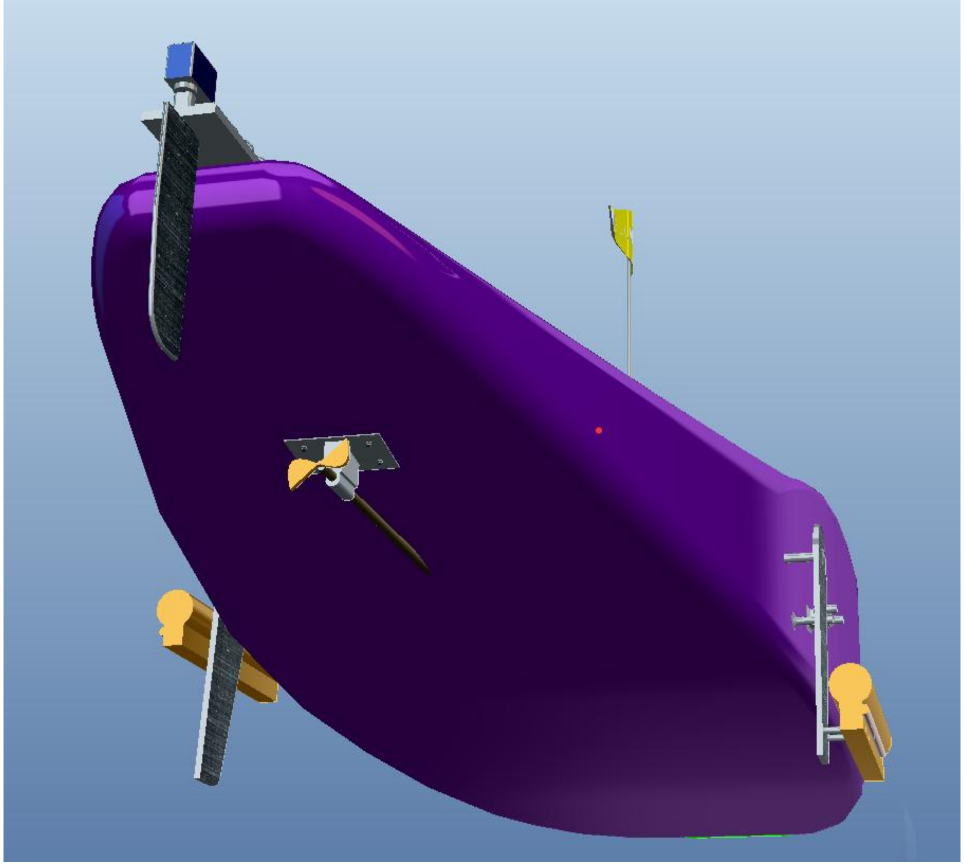


Figure 3.2.2: Shaft Assembly

The shaft assembly seen below consists of the aluminum strut which supports the shaft and attaches to the bottom of the boat. There is the the flexible dark metal shaft which transmits torque along its axis yet still allows for slight bends. It acts essentially like a universal joint. This dark metal shaft fits inside a very thin hollow Teflon tube (not shown below) to reduce friction and then that thin Teflon tube slides inside the hollow copper tube below. This configuration prevents water form draining in through the shaft hole in the boat. The rest of the hardware below, particularly in the bag, are nuts and bolts to attach the aluminum strut to the boat and to screw on the propeller at the end.


Figure 3.2.3: Connecting Shaft Assembly

The last component of the propulsion system is the propeller. the chosen prop is a Prather Racing Counterclockwise 3.10 inch diameter, 4.5 inch pitch and about 30-40 % mean area. Choosing the right prop to work best for a boat is no easy task. Dozens of variables have to be taken into account such as engine rpm range, engine horsepower, outputted torque, hull displacement, gearbox reduction if applicable, percentage of power loss due to bearings, speed length ratio, drag "C" value and more. After much research and analysis of a "*prop algorithm*" developed in the United Kingdom, the team found the appropriate prop size corresponding to the selected engine. A picture of the prop can be seen below.

Figure 3.2.4: Prather Racing Counterclockwise

3.3 Steering System

The steering for the AWQuSam is essential for its navigations. Its designed to keep the AWQuSam on track regardless of environmental conditions like currents or side winds. It will be mechanically tough so that it will not suffer any damage from choppy waves. It will allow for the nozzle to turn 30-40 degreess from the normal axis.

The steering will be achieved by having a waterproof high torque digital servo linked to a rudder. The servo is connected to the microcontroller board and will correct itself as a function of how far it deviates from the path. Pulse width modulated signals will control the servo. The rudder will be turned by the servo itself. The servo is connected to a shaft that goes through the rudder fixed.

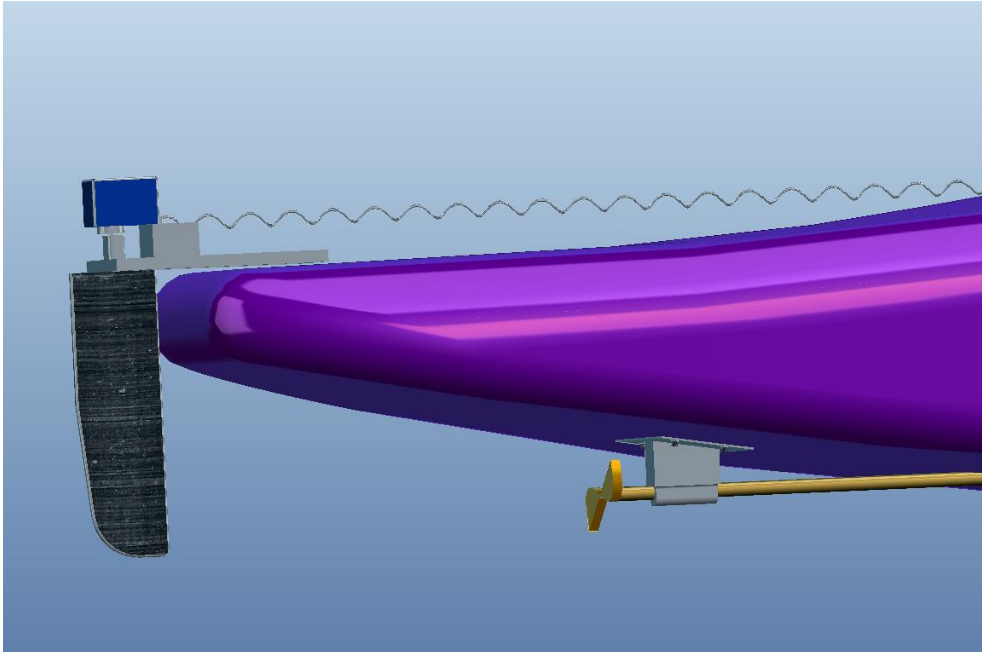


Figure 3.3.1: Steering Assembly

3.4 Navigation System

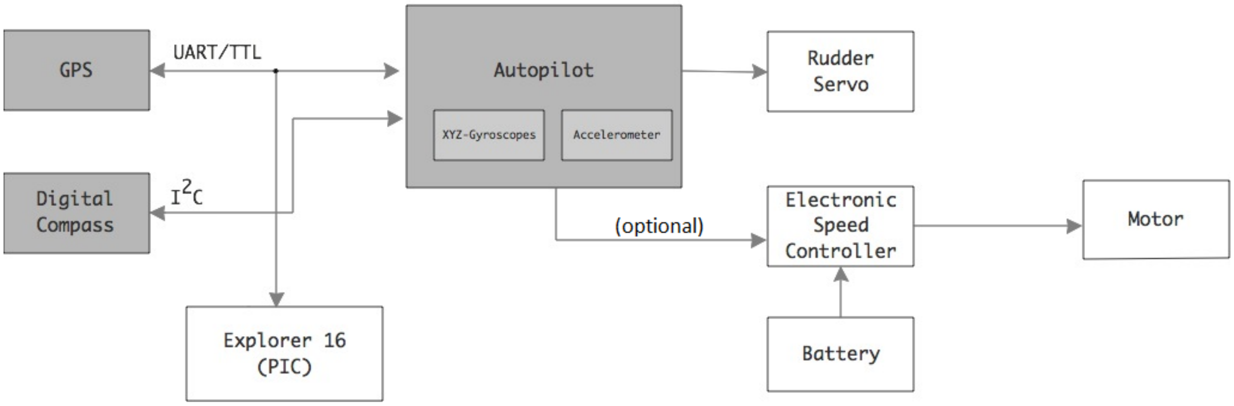


Figure 3.4.1 Top-level Architecture of Navigation System

As an autonomous vehicle, the AWQuSam must be able to maintain its path-planning strategies on-board during its mission. To satisfy this requirement, on on-board navigation system is being designed to undertake this task. This navigation system will use an Autopilot module equip with a dsPIC33FJ256 microcontroller, a set of gyroscopes that monitor the vehicles x, y, and z orientation, and an accelerometer. The Autopilot module is an off-the-shelf component with opensource software programming potential. The Autopilot will be provided with input data from the GPS module, and digital compass (magnetometer). It will process this data during the mission to determine its bearing, and distance from the current waypoint it is progressing towards. Once it calculates its bearing and distance to a waypoint, it will calculate the appropriate information to output to the rudder-servo and the electronic speed controller in the propulsion system.

For datalogging purposes, the TX ports for the GPS will be connected to an input pin on the Autopilot and Explorer 16 board.

GPS Smart Antenna Engine Board

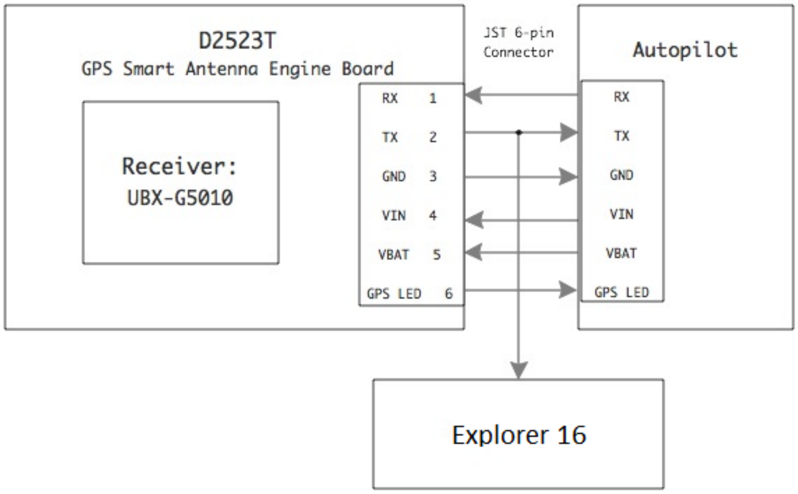


Figure 3.4.2 Interface between GPS Engine Board and Autopilot module

The GPS Smart Antenna Engine Board (GSAEB) has an factory integrated receiver chip, the UBX-G5010. It uses the GPS protocol format, NMEA, to output messages. There are 7 NMEA message strings which the GPS outputs contyinously. The only message strings of importance for the navigation system are the Global Positioning Recommended Minimum Specific [GPS/Transit data] (GPRMC) and the Global Positioning System Fix Data (GPGGA). The GSAEB will communiate with the Autopilot module thru a Universal Asynchronous Receiver / Transmitter and Transistor-Transistor Logic (UART/TTL) interface via a 6-pin JST connector.

Table 3.4.1 Pin Layout for D2523T GPS Smart Antenna Engine Board

Pin No.	Pin Name	I/O	Description	
1	RX	I	Data Input (TTL level)	
2	TX	O	Data Output (TTL)	
3	GND	GND	Ground	
4	VIN	I	Supply Voltage	3.3V +/- 10%
5	VBAT	I	Backup Battery Supply Voltage	
6	GPS LED	O	LED Indicator	

Once the GSAEB is connected to the Autopilot, its initialization procedure will determine the baud speed, the GPS NMEA headers to monitor from the output stream, and setup variables to compare its generated checksum against checksum received in the data stream. The Autopilot module will be designed to retrieve and store pertinent information from these two data streams.

GPS NMEA: $GPGGA

$GPGGA,hhmmss.ss,llll.ll,a,yyyyy.yy,a,x,xx,x.x,x.x,M,x.x,M,x.x,xxxx*hh

Table 3.4.2 GPS NMEA: $GPGGA Message Description

Name	Example Data	Description
Sentence Header	$GPGGA	Global Positioning System Fix Data
UTC of Position	hhmmss	Time Stamp
Latitude position	llll.ll	Degrees, decimal minutes
N or S	a	

Longitude	yyyyy.yy	Degrees, decimal minutes
E or W	a	
GPS Quality Indicator: - 0 = Invalid - 1 = GPS fix - 2 = DGPS fix	x	- 0 = Invalid - 1 = GPS fix - 2 = DGPS fix
Number of Satellites in Use	xx	
Horizontal Dilution of Precision (HDOP)	x.x	Relative accuracy of horizontal position
Altitude	x.x	Antenna altitude above mean-sea-level
Units of antenna altitude, meters	M	
Geoidal separation	x.x	
units of geoidal separation, meters	M	
Age of Differential GPS data (seconds)	x.x	Age in seconds since last update from diff. reference station
Diff. reference station ID#	xxxx	
Checksum	*hh	

GPS NMEA: $GPRMC

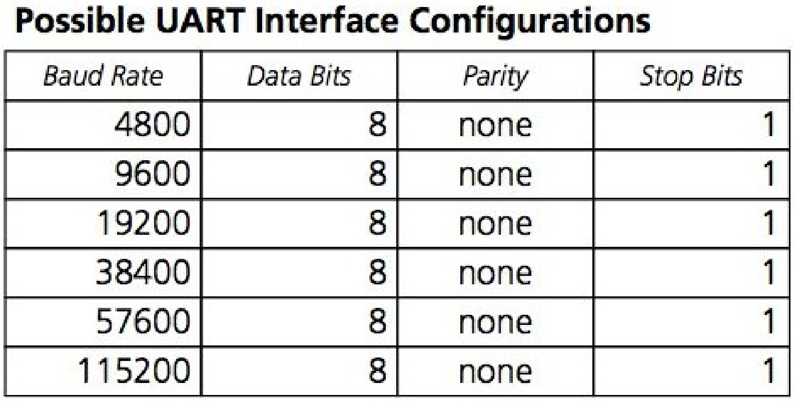
$GPRMC,hhmmss.ss,A,llll.ll,a,yyyyy.yy,a,x.x,x.x,ddmmyy,x.x,a*hh

Table 3.4.3 GPS NMEA: $GPGGA Message Description

Name	Example Data	Description
Sentence Header	$GPGGA	Global Positioning System Fix Data
UTC of Position	hhmmss	Time Stamp
Data Status	A	
Latitude position	llll.ll	Degrees, decimal minutes
N or S	a	
Longitude	yyyyy.yy	Degrees, decimal minutes
E or W	a	
Speed of Ground in Knots	x.x	
True Course	x.x	
UTC Date	ddmmyy	Date Stamp
Magnetic Variation Degrees	x.x	Easterly variation subtracts from true course
E or W	**a**	
Checksum	*hh	

The latitude and longitude coordinates extracted from the data stream will be used to calculate the true course between the current GPS coordinate and the current waypoint. It will also be used to calculate the distance between the current GPS coordinate and the current waypoint. The calculated information will be used to determine rudder control and navigation path during the mission.

The UBX-G5010 does not feature handshaking or hardware flow signals. The default baud rate is 9600 bps. The UDB4 was designed to be compatible with the D2523T GPS board. The Explorer 16, which will receive the GPS sentences directly will have a UART port configured to a baud rate of 9600 bps to ensure that its buffer space does not reach capacity as messages are being sent from the GPS. If the receiver senses that the buffer space has been exceeded it will deactivate its message delivery service. The autopilot will be configured as the master device, and the Explorer 16 will only receive signals from the GPS.



Possible UART Interface Configurations

Baud Rate	*Data Bits*	*Parity*	*Stop Bits*
4800	8	none	1
9600	8	none	1
19200	8	none	1
38400	8	none	1
57600	8	none	1
115200	8	none	1

Honeywell Digital Compass

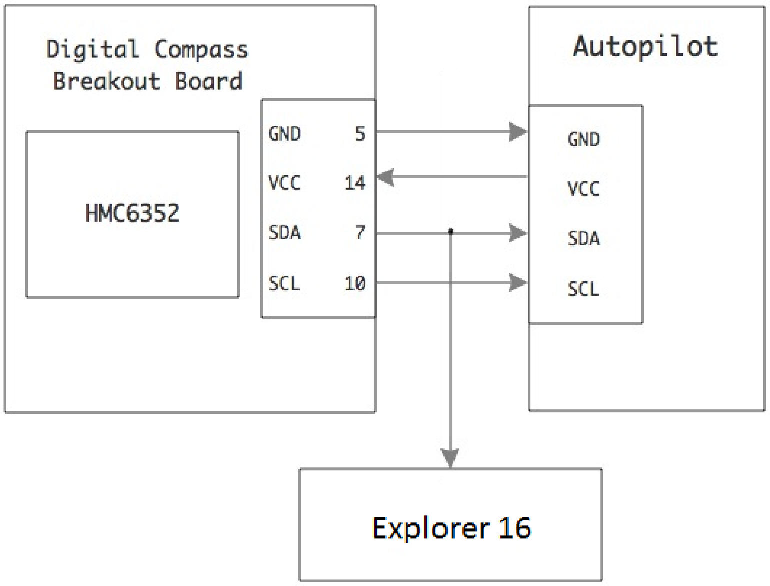
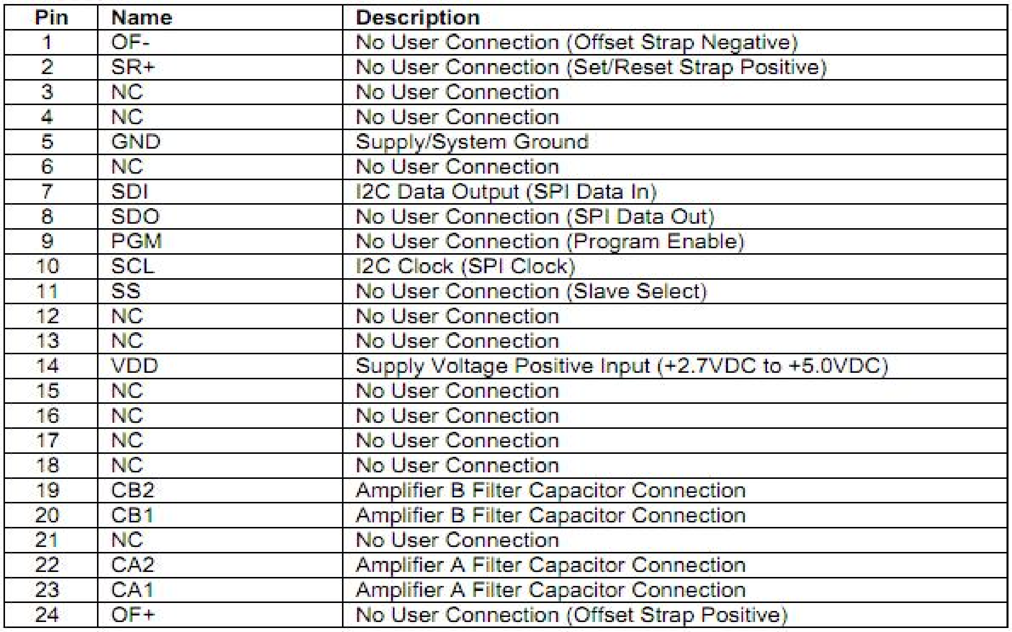


Figure 3.4.3 Interface between Digital Compass and Autopilot module

The Honeywell HMC6352 Digital Compass Breakout Board is equip with a 2-axis magnet-resistive sensors which supports algorithms for heading computation. Of the 24 pins provided by the HMC6352 chip, only 4 are needed to acquire heading computation from the device: GND (pin 5), SDI (pin 7), SCL (pin 10) and VCC (pin 14).

Table 3.4.4 Pin Layout for HMC6352 Digital Compass



Pin	Name	Description
1	OF-	No User Connection (Offset Strap Negative)
2	SR+	No User Connection (Set/Reset Strap Positive)
3	NC	No User Connection
4	NC	No User Connection
5	GND	Supply/System Ground
6	NC	No User Connection
7	SDI	I2C Data Output (SPI Data In)
8	SDO	No User Connection (SPI Data Out)
9	PGM	No User Connection (Program Enable)
10	SCL	I2C Clock (SPI Clock)
11	SS	No User Connection (Slave Select)
12	NC	No User Connection
13	NC	No User Connection
14	VDD	Supply Voltage Positive Input (+2.7VDC to +5.0VDC)
15	NC	No User Connection
16	NC	No User Connection
17	NC	No User Connection
18	NC	No User Connection
19	CB2	Amplifier B Filter Capacitor Connection
20	CB1	Amplifier B Filter Capacitor Connection
21	NC	No User Connection
22	CA2	Amplifier A Filter Capacitor Connection
23	CA1	Amplifier A Filter Capacitor Connection
24	OF+	No User Connection (Offset Strap Positive)

The breakout board will connect to the Autopilot and the Explorer 13 microcontroller I2C ports. Below is the method which will be used to initialize the digital compass upon startup.

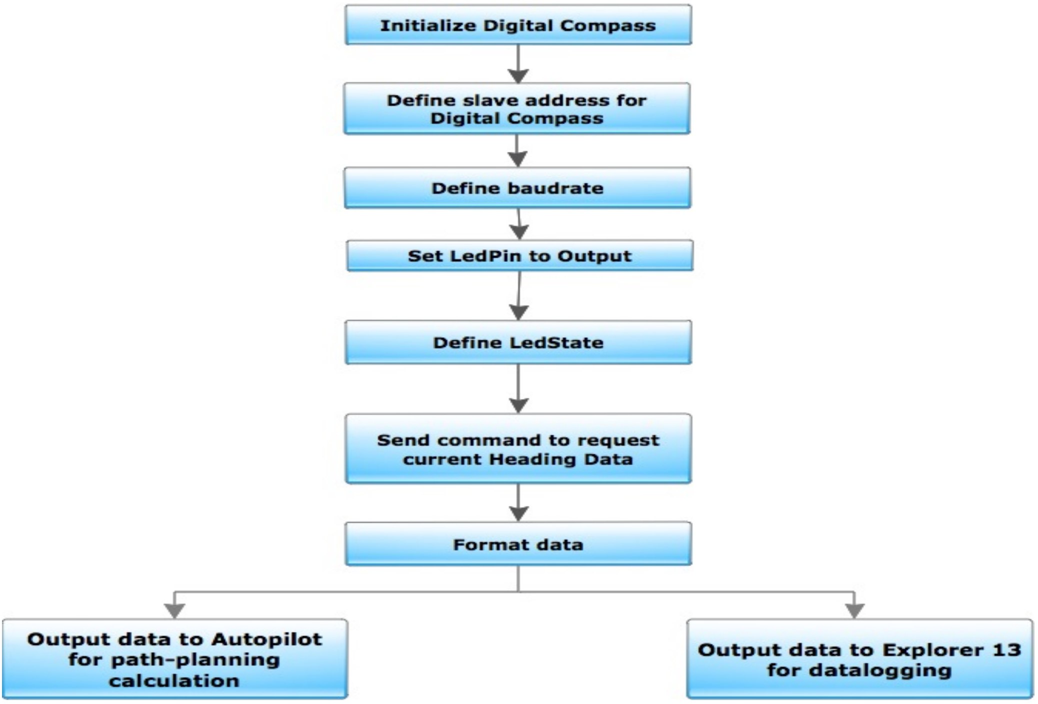


Figure 3.4.4 Digital Compass Operation Flowchart

Once the GPS and Digital Compass are initialized, the Autopilot will begin processing and performing calculations on the incoming data in order to set the rudder-servo and speed controller parameters periodically throughout the mission.

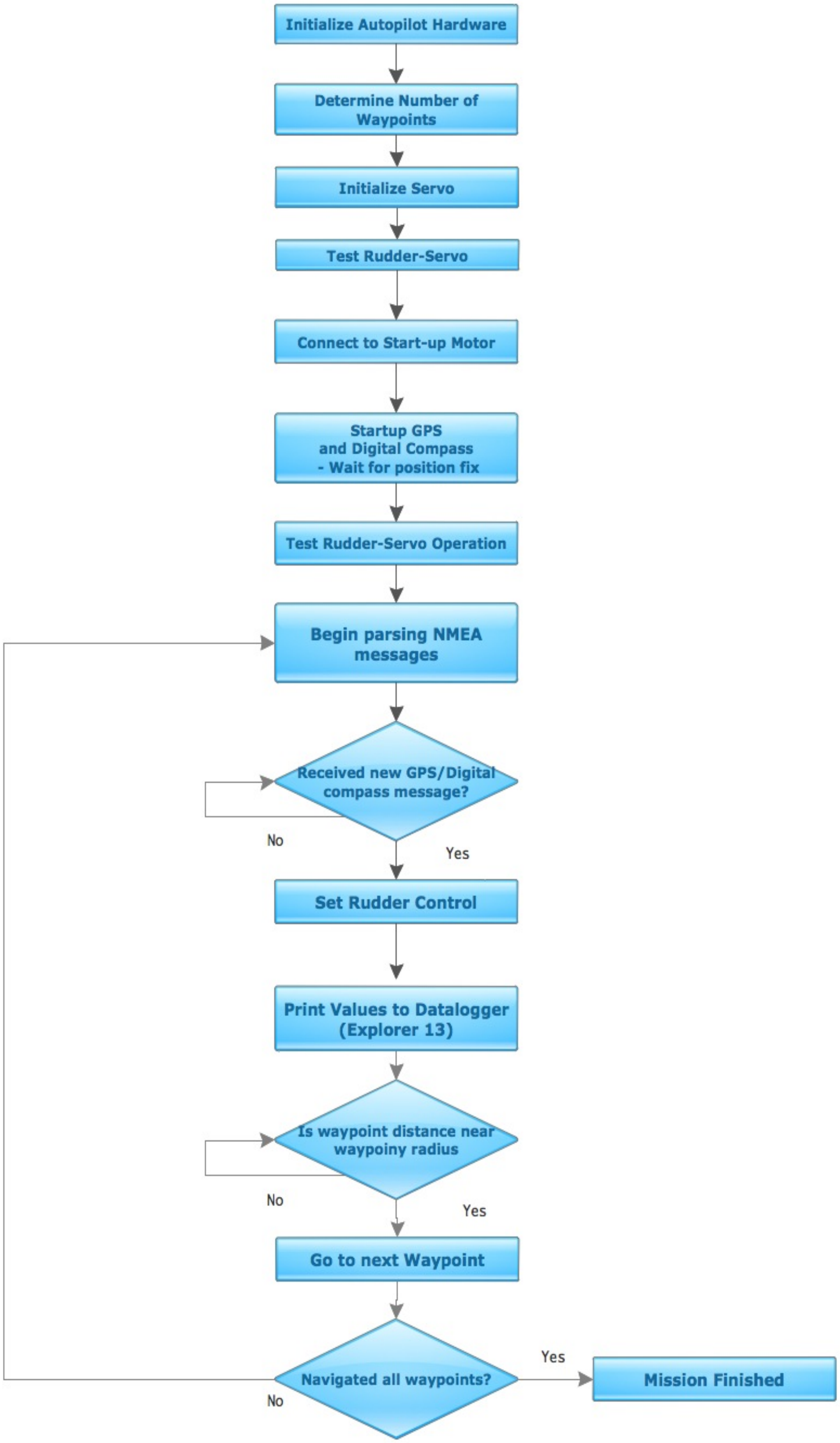
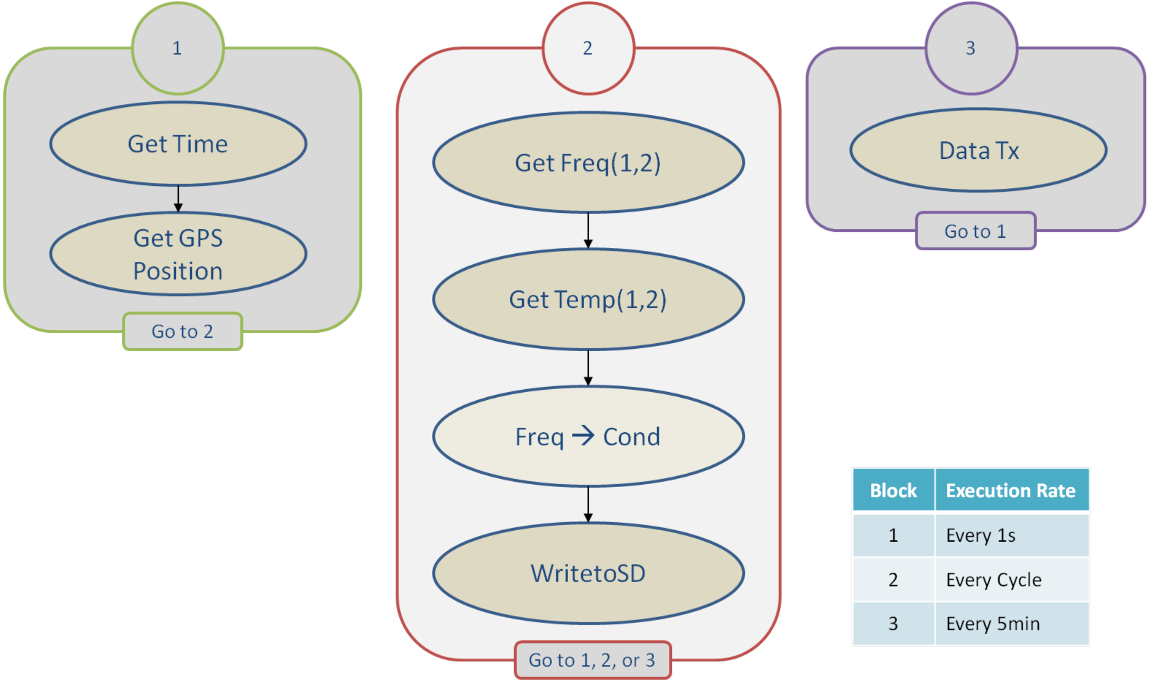


Figure 3.4.5 Navigation System Operation Flowchart

3.5 Data Acquisition System

The processing for the data acquisition subsystem will be implemented on the Explorer16 development board. This module has to interact with both the data logging and data transmission systems. A software flow diagram describing this interaction is shown in Figure3.5.1, below. Block 1 will be executed each second in response to an interrupt triggered by a change-of-state on the pin to which the GPS pulse signal is connected. For pin assignments, see Figure3.6.2.



Block	Execution Rate
1	Every 1s
2	Every Cycle
3	Every 5min

Figure3.5.1: Software Flow for dsPIC33FJ256GP710 microcontroller

3.5.1 Conductivity Acquisition

The SBE-4 conductivity sensor has a 3-pin connector, as shown in Figure3.5.1.1. The team will utilize a RMG-3FS to pigtail cable (SBE PN: 17029) to facilitate placement of the sensor some distance away from the development board.

Figure3.5.1.1: RMG-3FS Connector on SBE-4

The sensors outputs a variable frequency square wave signal (from 2.5kHz to 7.5kHz) corresponding to the conductivity (from 0S/m to 7S/m). The square wave is a ± 0.5V waveform. The design will implement a microcontroller based frequency counter. Consequently, the waveform must be conditioned to have 0-3.3V TTL logic levels so the microcontroller can effectively count the rising edges of the waveform, as shown in Figure3.5.1.2.

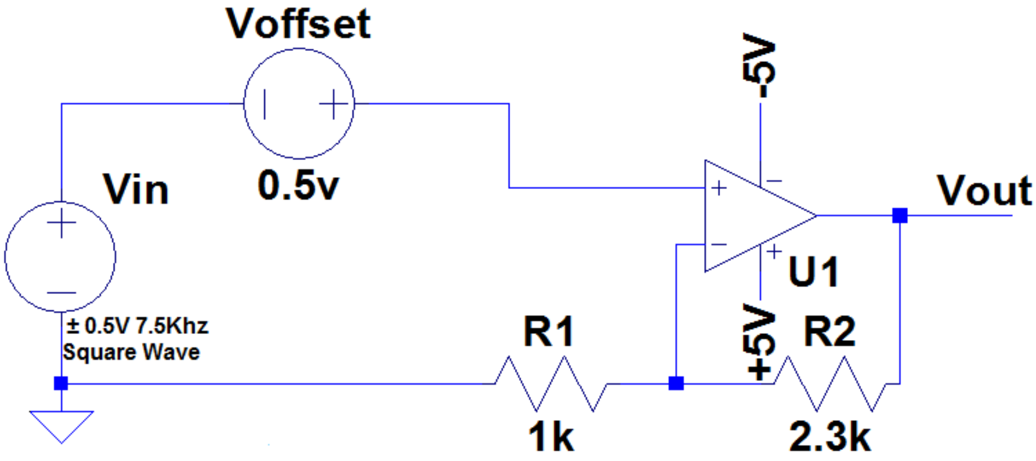


Figure3.5.1.2: Signal conditioning circuitry

A DC offset is introduced to the square wave before amplifying the signal. The gain of operational amplifier is given as:

$$\frac{V_{out}}{V_{in}} = 1 + \frac{R_2}{R_1}$$

$$\frac{V_{out}}{V_{in}} = 1 + \frac{2.3k\Omega}{1k\Omega} = 3.3$$

Figure3.5.1.3 shows the output waveform as well as the intermediary steps. Observe that the output waveform has the same frequency as the input, but now has TTL levels that can be processed by the microcontroller.

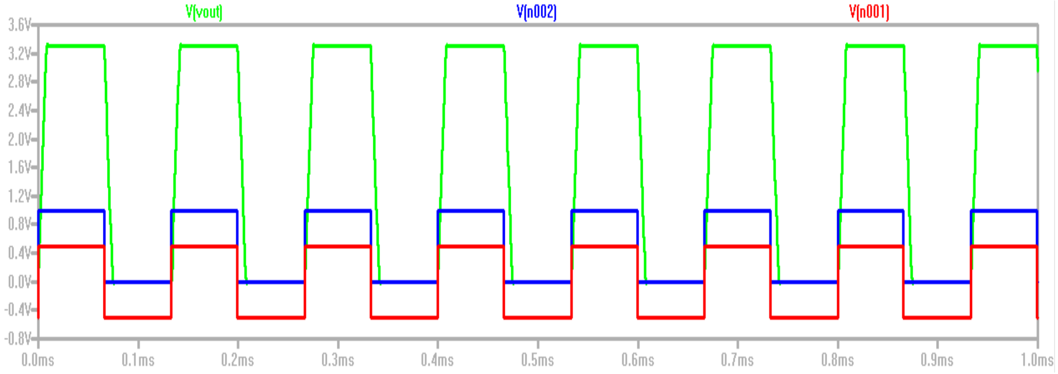


Figure3.5.1.3: Conditioned output of conductivity sensors

The design will utilize the input capture capability of the PIC microcontroller on the Explorer16 development board to determine the number of clock cycles between consecutive rising edges of the signal. From this information, the signal period can be determined, and subsequently the signal's frequency. One sensor will be tied to Input Capture1 (IC1, pin 68), and the other will tied to Input Capture2 (IC2, pin 69). Code for initializing the input capture and computing the frequency of a signal is provided in Appendix B.

The conductivity will then be computed from this frequency and the water temperature before relaying this information to the data handling and data logging routines. The conductivity calculation is also based on a number of other constants, including the thermal coefficient of expansion, bulk compressibility, and calibration data provided by the manufacturer. See the attached calibration sheets (Appendix C) for details regarding this transformation.

3.5.2 Temperature Acquisition

Figure3.5.2.1 provides an overview of the design for measuring temperature.

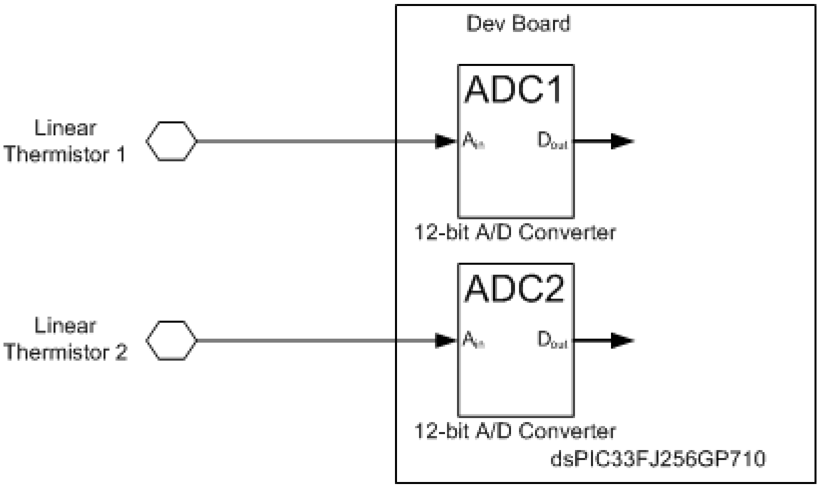


Figure3.5.2.1: Overview of Temperature Sensing Module

Because the relationship between a thermistor's voltage and the temperature is not innately linear, some design work must be performed. The OL-710 thermistor actually consists of two thermistors. When used with a particular resistor set, the output is linearized over a range of temperatures.

Each linear thermistor, as shown in Figure3.5.2.1, is actually represented by the circuit schematic shown in Figure3.5.2.2, below.

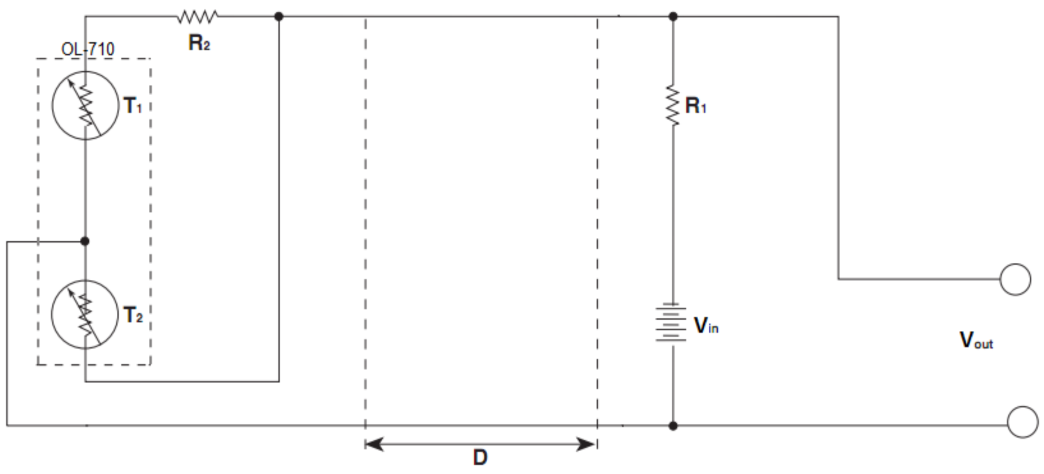


Figure3.5.2.2: Linear Thermistor Circuit Schematic

Resistor values of R_1=5700Ω and R_2=12kΩ can be selected to provide linear voltages across the range corresponding to -5ºC to 45ºC. With this resistor set, relationship between voltage and temperature is described as follows:

$$V_{out} = (-0.0056846 \cdot V_{in})T + 0.805858 \cdot V_{in}$$

The surface water temperature of the Apalachicola Bay is not known to fluctuate outside the range of 5ºC to 35ºC. The team will provide a system capable of accurately recording temperatures in the range of 0ºC to 40ºC. With a properly configured 12-bit analog to digital converter, this will allow for precision of 0.01ºC

Utilizing the equation above, with a 3.3V value for V_{in}, the A/D converter can expect voltages in the range of 1.9089642V to 2.6593314V corresponding to 40ºC and 0ºC, respectively. The A/D converter control register will be configured to use external reference voltages V_{ref+} and V_{ref-}. These voltages will be set to match this range of voltages. This allows the team to fully utilize the resolution of the analog to digital converter.

After passing through the analog to digital converter, a digital representation of the analog voltage will be obtained. With this, the voltage can be determined. Based on the voltage, the temperature can be computed. This temperature, in degrees Celsius (xx.yy), will be multiplied by one hundred (xxyy) and stored in a variable of 16-bits for the Data Handling and Data Logging routines. This process will be performed for both temperature sensors.

3.6 Data Logging System

The Explorer16 has only one expansion slot, and this slot will be used by a prototyping board that brings all the pins of the MCU out. Consequently, the SD daughter card referenced in Section 2.2.5 will interface with the Explorer16, via the protoboard, according to the schematic shown in Figure 3.6.2.

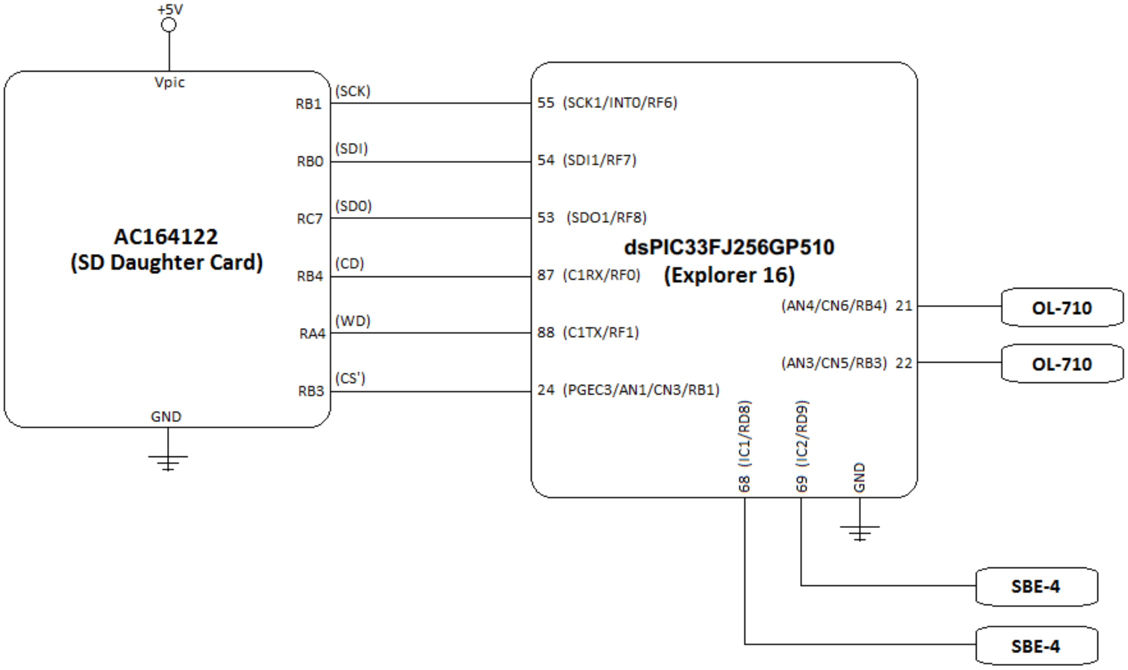


Figure3.6.2: Explorer16 Interface Diagram

File I/O will be implemented using Microchip's memory disk drive file system library. For more information regarding the specific functions of this library, please refer to Application Note AN1045 by Microchip. The SD must first be initialized and file created (or opened). A function will be called to write to the SD card and the parameters to be written will be passed to the function. A test application for writing to the SD card is shown in Appendix B.

Data will be logged according to the routine outlined in Figure3.5.1. The human readable log will have entries corresponding to the time, position, and data from each sensor. New sensor data will be received at least eight times per second. New GPS data (position and time) will be received one time per second. Interpolation of intermediary position reports will not be performed onboard the AWQuSam, but can easily be performed offline. Entries will be logged as comma separated values for easy importing into a spreadsheet application for analysis. Figure3.6.3 offers an overview of a sample of data that may be logged.

t=0s	Time, Latitude, Longitude, Conductivity1, Conductivity2, Temperature1, Temperature2
	, , , Conductivity1, Conductivity2, Temperature1, Temperature2
	, , , Conductivity1, Conductivity2, Temperature1, Temperature2
	, , , Conductivity1, Conductivity2, Temperature1, Temperature2
	, , , Conductivity1, Conductivity2, Temperature1, Temperature2
	, , , Conductivity1, Conductivity2, Temperature1, Temperature2
	, , , Conductivity1, Conductivity2, Temperature1, Temperature2
	, , , Conductivity1, Conductivity2, Temperature1, Temperature2
t=1s	Time, Latitude, Longitude, Conductivity1, Conductivity2, Temperature1, Temperature2
	, , , Conductivity1, Conductivity2, Temperature1, Temperature2

.
.
.

Figure3.6.3: Overview of sample data to be written to SD card

Since time is going to be stored as three separate integers in the form hh:mm:ss, one data slot will require 3 integers and 6 floats to be stored. Integers are stored in a 16 bit format, which makes a total of 48 bits per record allocated to integers (time). Floats are stored in single-precision IEEE-754 standard which means they use 32 bits, making a total of 192 bits per record allocated to floats. By adding this two figures, every record needs 240 bits (30 bytes). The number of samples needed are 345600. This number comes from the following calculation:

$$\frac{samples}{mission} = \frac{8\,samples}{second} * \frac{3600\,seconds}{hour} * \frac{12\,hours}{mission}$$

The 30 bytes needed per record time 345600 samples needed per mission give us a total of 10368000 bytes. Converting this number to Gigabytes yields a minimum required storage of 10.368 Gigabytes The team will utilize a 16GB SD daughter card.

3.7 Data Handling System

The purpose of this module is to convert the last line of the in the SD daughter card into a bit stream and send it to the transmitter. The total length of one transmission is going to be 109 bits.

To describe this implementation, it is necessary to have a clear knowledge of difference in ranges and precision between all the different measurements. The conductivity measurement ranges from 0 to 7 with a precision up to 0.01. Temperature which ranges from 0 to 40 with a precision up to 0.01 as well. Latitude ranges from -90 to 90 and longitude ranges from -180 to 180 with a precision up to 0.0001. Time is stored as a set of three integers; hours ranging from 0 to 23, and minutes and seconds ranging from 0 to 59 each.

For each data recorded, the subsystem will allocate a certain number of bits in the bit stream for the left side of the radix point and other amount of bits for the right side of the radix point. In the case of GPS coordinates there is another bit allocated for the sign.

The key part of this module is a function that converts to binary a decimal integer. This function receives two parameters. The first is the integer to be converted and the second is another integer that represents the number of bits needed to convert that integer. This function is called directly by the main function for the time values. It is also called by the function that transforms the floats which is called by the main routine.

The transmission length of 109 bits is divided as follows:

- Conductivity (10 bits * 2 sensors)
    - Left side of radix (0 - 7)
        - 3 bits
    - Rigth side of radix (0 - 99)
        - 7 bits
- Temperature (13 bits * 2 sensors)
    - Left side of radix (0 - 45)
        - 6 bits
    - Rigth side of radix (0 -99)
        - 7 bits
- GPS Coordinates (23 bits * 2 coordinates)
    - Sign (1 bit)
        - 0 for positive
        - 1 for negative
    - Left side of radix (0 -180)
        - 8 bits
    - Rigth side of radix (0 - 9999)
        - 14 bits
- Time (17 bits)
    - Hours (0 - 23)
        - 5 bits
    - Minutes (0 - 59)
        - 6 bits
    - Seconds (0 - 59)
        - 6 bits

3.8 Data Transmission System

Figure3.8.1 shows a block diagram of the data transmission system of the AWQuSam.

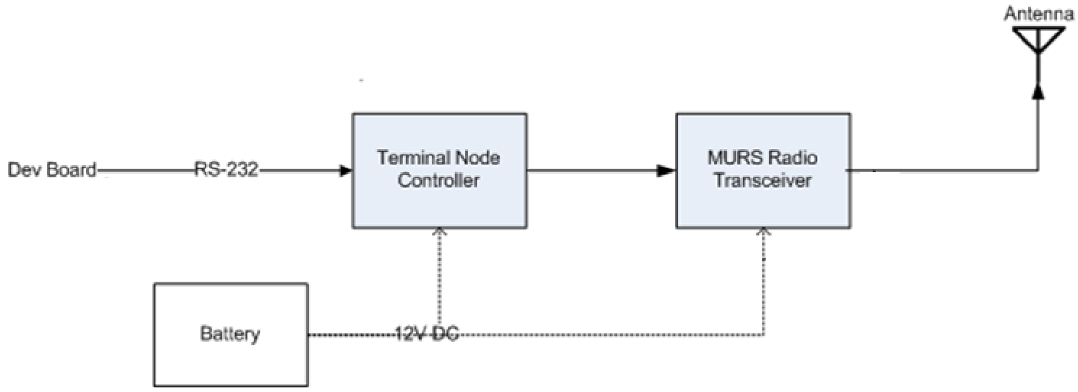
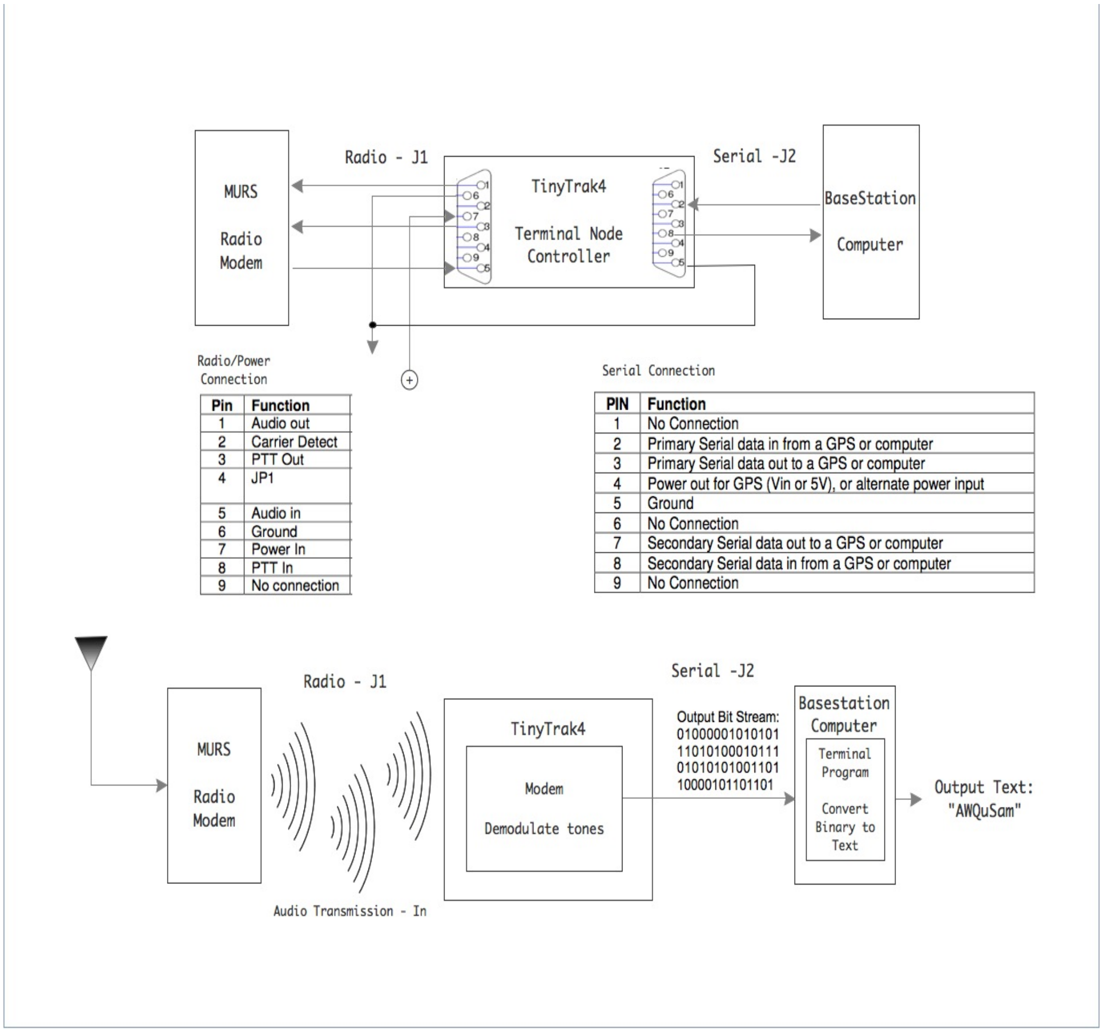


Figure3.8.1: Top-level block diagram of Data Transmission System



Radio/Power Connection

Pin	Function
1	Audio out
2	Carrier Detect
3	PTT Out
4	JP1
5	Audio in
6	Ground
7	Power In
8	PTT In
9	No connection

Serial Connection

PIN	Function
1	No Connection
2	Primary Serial data in from a GPS or computer
3	Primary Serial data out to a GPS or computer
4	Power out for GPS (Vin or 5V), or alternate power input
5	Ground
6	No Connection
7	Secondary Serial data out to a GPS or computer
8	Secondary Serial data in from a GPS or computer
9	No Connection

Figure3.8.2. TNC will receive serial bit stream from data handling routine

The MURS radio to be used in the design is the Dakota Alert MURS Base Station, model M538-BS. This model was selected because it is a low-cost, effective transmission system. It is only capable of transmitting and receiving on the MURS frequencies, hence it is FCC approved for unlicensed user.

Figure3.8.3: M538-BS Dakota Alert MURS Radio

The antenna to be used on the AWQuSam is MURS45 by Firestik. This is a 5/8 wave antenna with gain of 6dB over isotropic. A 5/8 wave antenna was selected over a 1/4 wave antenna because they tend to propagate better in the horizontal plane.

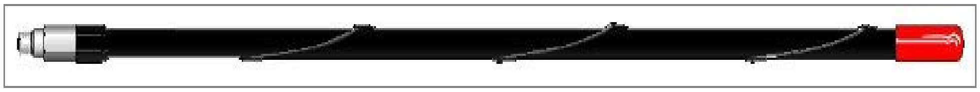


Figure3.8.4: Firestik MURS45 Antenna

The terminal node controller will output an audio signal that represents the serial bitstream sent by the AWQuSam. This audio signal will be passed to the M538-BS radio's microphone in port. Figure3.8.4 illustrates the scenario. The speaker audio line will be used at the base station receiver, and the mic audio line will be used at the AWQuSam transmitter.

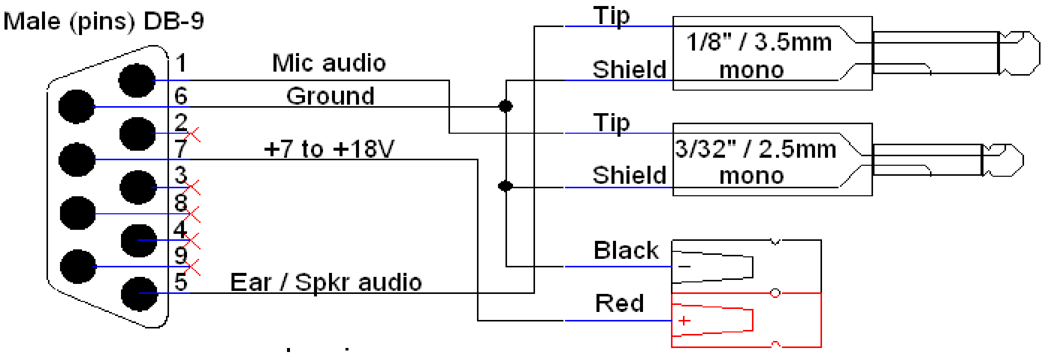


Figure3.8.5: Terminal Node Controller to M538-BS Interface

To interface with the terminal node controller, some modifications must be made to the radio. The push-to-talk button must be pressed while a transmission is active. Grounding the radios PTT line activates this function. While transmitting data, the microcontroller will pull the PTT line of the radio down. Figure3.8.5 below shows the internals of the M538-BS MURS radio.

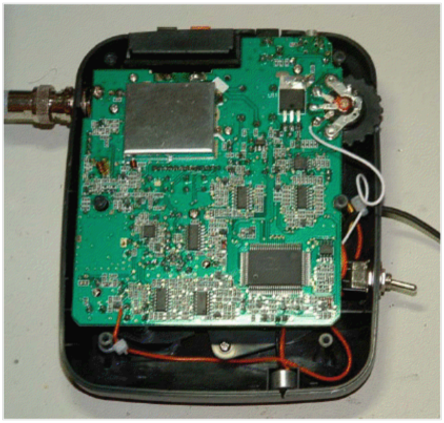


Figure3.8.6: M538-BS MUR Radio Open Box

3.9 Base Station Receiver

The Base Station Receiver functions in much the same way as the Data Transmission System (See Section 3.8) with data travelling in the opposite direction, as shown in Figure3.9.1.

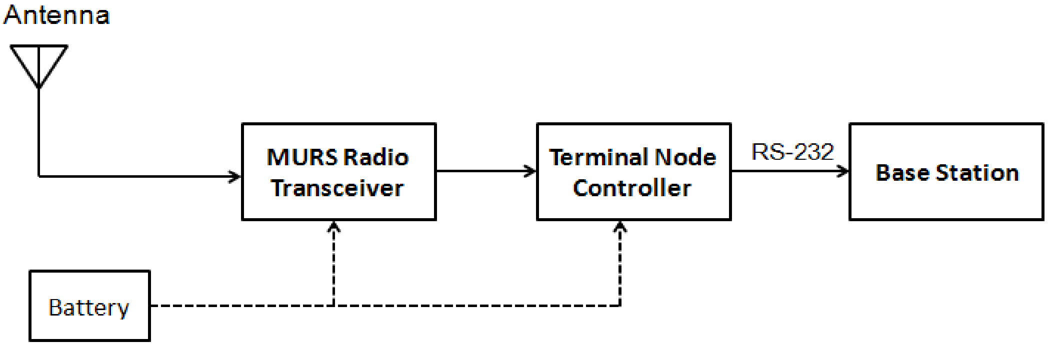


Figure3.9.1: Top-level Block Diagram of Base Station Receiver

To select a suitable radio transceiver, the team performed some quick calculations to determine the receive sensitivity required to achieve the desired transmission range (5km). From the Friis Transmission Equation:

$$P_r = P_t + G_t + G_r + 20\log\left(\frac{\lambda}{4\pi R}\right)$$

$$P_r = 27\text{dBm} + 6\text{dBi} + 6\text{dBi} + 20\log\left(\frac{1.96m}{4\pi 5000m}\right) = -51.12\text{dBm}$$

In the above equation, a transmission power of 2W was assumed over a maximum distance of 5km, with receive and transmit antenna gains of 6dB over isotropic. The wavelength, λ, based on a frequency in the 151-154MHz MURS band. It is apparent that the receiver must have a sensitivity of -45.12dBm to transmit over this range with these antennas.

The antenna used on the receiver is another model by Firestik, the MURS-BASE. It is also a 5/8 wave antenna with gain of 6dBi.

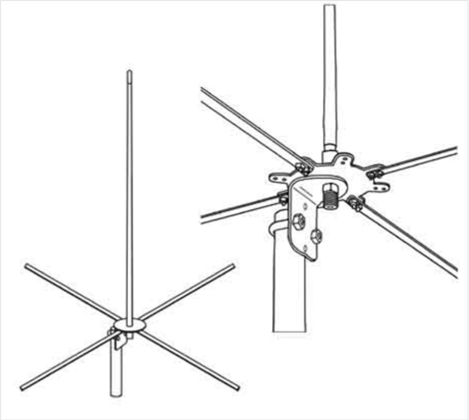


Figure3.9.2: MURS-BASE Antenna by Firestik

Refer to Figure3.8.5 for information regarding the interface between the terminal node controller and the MURS radio where the speaker audio line will be used at the base station receiver, and the mic audio line will be used at the AWQuSam transmitter.

The terminal node controller will demodulate the received audio signal into the serial bitstream that was transmitted by the AWQuSam. It performs error detection and correction before relaying the data to the TNC's output. This bit stream will be printed to a terminal on a PC furnished by the Florida State University Department of Oceanography.

3.10 Power System

The AWQuSam system will be powered by a 12V battery. Because of the duration of the mission, the battery's capacity must be no less than 36Ah. This already figures in a buffer of overhead, as it assumes almost continuous transmission from the MURS radio. The battery system will consist of four 10Ah batteries. This battery arrangement will weigh approximately twenty pounds. Figure3.10.1 illustrates the breakdown of the power system. The Explorer16 can operate via a 12V input (though 9V is recommended for thermal reasons). Internal voltage regulators on the Explorer16 are used to provide +5V and +3.3V to the board components. These internal regulators could be used to power some of the external components.

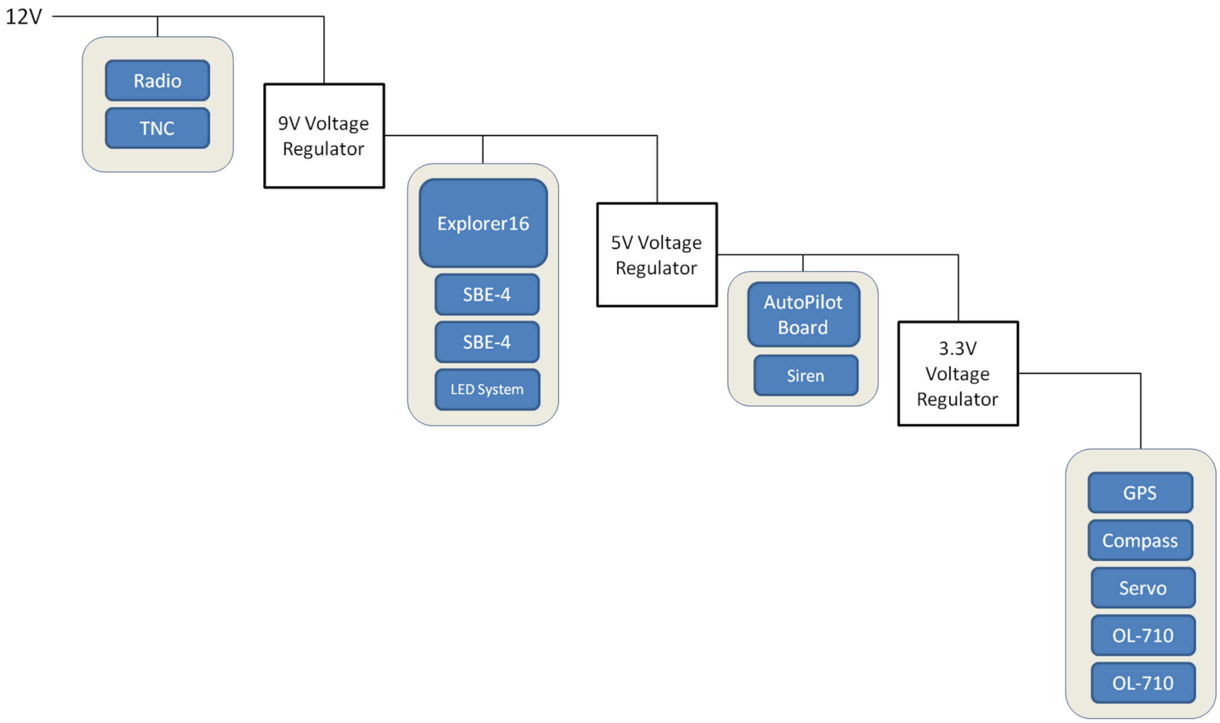


Figure3.10.1: Power System Architecture

Each voltage regulator will be a simple 780x type 3-terminal device. Using the configuration shown in Figure3.10.2 below, each regulator will provide a stable regulated voltage for the load.

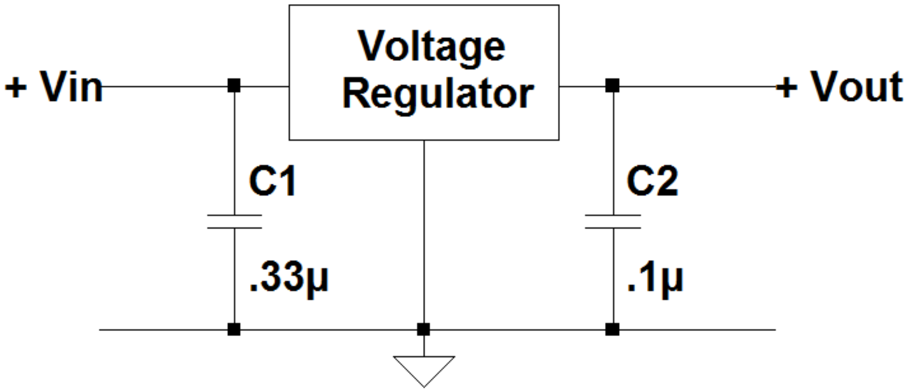


Figure3.10.2: Schematic for each voltage regulator

3.11 Safety System

The AWQuSam needs to be safe for the public and the environment. Apalachicola Bay is a busy area frequented by swimmers, fishermen, yachts, and boats in addition to animal life. In order for the vehicle to legally operate autonomously it needs to prove it is safe.

Safety specifications include that the vehicle needs to be easily detectable by all spectators. This means that it has to be visible from afar. It needs to be brightly colored. It needs to be detected even if it is not on any one's line of sight. It also includes a mechanism to prevent from damaging or physically hurting any one or anything it comes in contact with.

The safety system of the AWQuSam will include a LED system. This LED night time lighting system will serve as indication lights when operating at night. The LED lighting system will be integrated with the power system. A photoresistor may be used to ensure the lights are only turned on when it is dark outside. The kayak shall also be painted neon orange to make it easily visualized.

The AWQuSam may include a loud siren from a car alarm system with the ability of being turned off and on. This will provide unknown spectators with an indication that the AWQuSam is nearby. See image of siren on Figure 3.1.2.3.

A foam bumper is placed in the front of the vehicle to cushion any collisions and prevent the AWQuSam from damaging any of the boats around in case of a collision and protect all unknown spectators from a dangerous collision with the vehicle. The design of the bumper can be seen in Figure 3.1.1.3.

3.12 Cooling System

Two major components of the AWQuSam produce heat and need to be cooled. These are the engine and the electronics box. Both will be cooled using the air draft provided by the movement.

To enhance the cooling system freeze packets will be placed around the electronic box (not inside) providing low temperatures for the duration of the mission. The mass of freeze packets required will be determined experimentally. Again, the packets will be placed outside but fixed in contact with the box.

4 Test Procedure

4.1 Test Equipment

Table4.1: Module Test Equipment

Find Number	Component	Manufacturer	Description	Qty
1	Test Computer	(Any)	Windows computer used to facilitate module and system testing	1
2	USB A->B Cable	Microchip	Cable for interfacing Test Computer to Explorer16	1
3	RJ11 Cable	Microchip	Cable for interfacing ICD3 to Explorer16	1
4	Explorer16 Development Board	Microchip	Used to implement data acquisition and interface with data logging / data transmission subsystems	1
5	9V Wall Mount Power Supply	Microchip	Provides power to Explorer16 Development Board	1
6	dsPIC PIM (dsPIC33FJ256GP 710)	Microchip	Plug in programming module to perform tasks of Explorer16	1
7	Function Generator	(Any)	Simulates SBE-4 Conductivity Sensor	1
8	DC Power Supply	(Any)	DC Power Supply to provide external power to a number of modules	1
9	SD PICtail Daughter Card	Microchip	Interfaces with Explorer16 to facilitate data logging	1
10	Prototype PICtail Daughter Card	Microchip	Interfaces with Explorer16 to breakout all pins of PIM	1
11	SD Card	(Any)	SD card to which data will be written	1
12	SBE-4 Conductivity Sensor	Seabird	Outputs variable frequency signal to be analyzed by Explorer16	2
13	OL-710 Temperature Sensor	Omega	Linear thermistor set to be analyzed by Explorer16	2

14	In-Circuit Debugger	Microchip	Hardware debugger (ICD3) for programming Explorer16	1
15	MPLAB IDE	Microchip	Software, to run on Test computer, for developing on Explorer16	1
16	RS-232 DB-9	Byonics	Cable used for interfacing Test computer with TinyTrak4	2
17	TinyTrak4	Byonics	Terminal Node Controller for modulating and demodulating packets	2
18	MURS Radio	Dakota Alert	Radio Transceivers utilized in Data Transmission subsystem	2
19	MURS45 Antenna	Firestik	A ⅝ wave antenna to increase range of Data Transmission subsystem	2
20	TinyTrak4 - Alpha Config	Byonics	Computer programmer for TinyTrak4	1
21	Engine GX35	Honda	Air cooled 4 stroke petrol engine	1
22	Strut	PMB	Supports shaft in assembly	1
23	Shaft	PMB	Dark metal bendable shaft transmits torque	1
24	Teflon tube	PMB	Reduces friction and prevents water from draining in	1
25	Copper tube	PMB	Hollow copper tube fixes shaft	1
26	Bag of nuts and bolts	PMB	Attach the aluminum strut to the boat and screws propeller at end	-
27	Propeller	Prather	Racing counterclockwise prop, 3.10 in. diameter, 4.5 in. pitch	1
28	Kayak	Riot	Flat bottom kayak makes AWQuSam main hull	1
29	Voltage Regulators	-	Set of voltage regulators (see power system schematic)	-
30	SRM-24 12V Battery	Interstate	Battery used to power the AWQuSam	1
31	D2523T GPS Module	ADH Tech	GPS Module used for navigation system and for logging position	1

32	¼ inch thick 12x24 in. plexy glass sheet	-	Material would be cut in three pieces: one rudder and two keels	1
33	Assembly components for keels and rudder	-	Safely fixes both keels and rudder to kayak	-
34	EZ Pass Black Velcro	3M	Fixes electronics box to the bottom of the kayak	1
35	TRX2075-Digital Waterproof Steering Servo	Traxxas	Main component of the steering system. Moves the rudder.	1
36	Electronics box	TBD	Contains all electronics.	1
37	Autopilot	Sparkfun	UDB4 UAV Development Board for navigation system	1
38	In-Circuit Debugger	Microchip	PICkit 3 In-Circuit Debugger for interfacing with UDB4	1
39	Accelerometer	Sparkfun	MMA7361 3-axis Accelerometer	1
40	Gyro	Sparkfun	IDG500 2-axis gyro and ISZ500 1-axis gyro	1
41	Speed Servo	TBD	Optional component for controlling the speed of the motor	1

4.2 Test Configurations

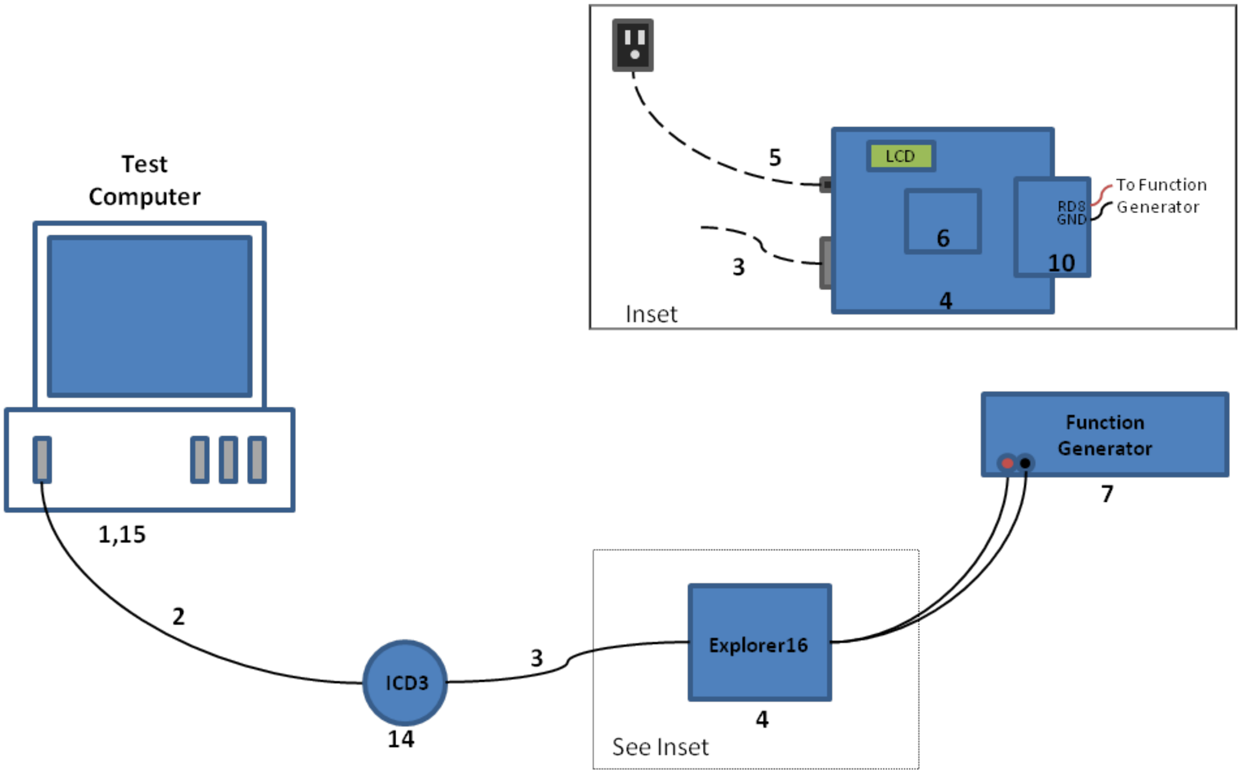


Figure 4.2.1: Test Configuration #1 for Data Acquisition, Conductivity Sensor Subsystem

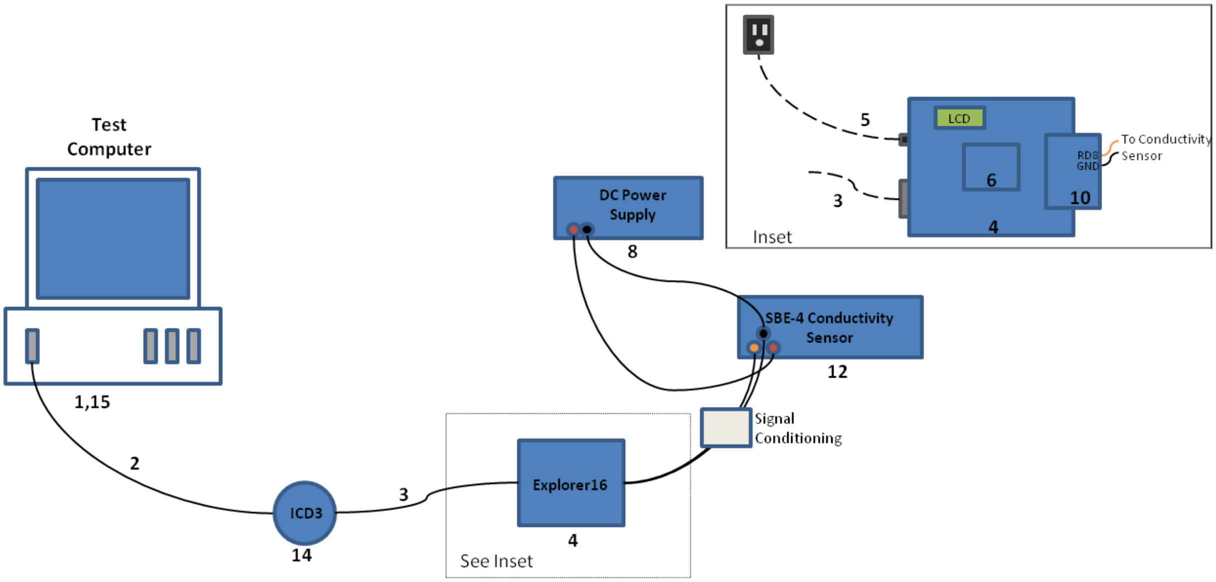


Figure 4.2.2: Test Configuration #2 for Data Acquisition, Conductivity Sensor Subsystem

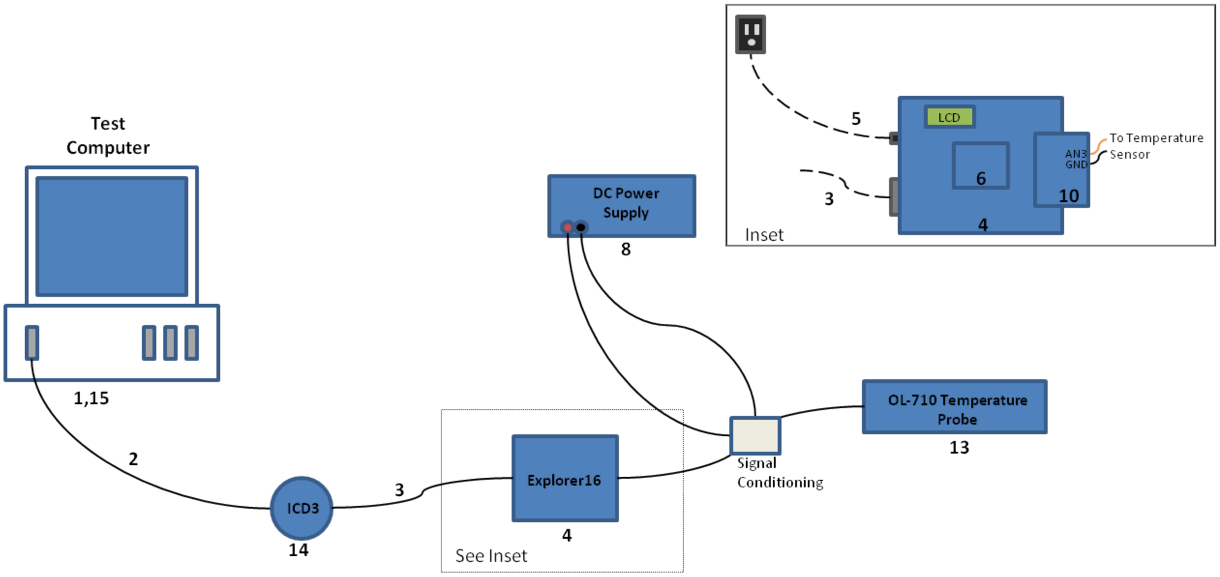


Figure 4.2.4: Test Configuration for Data Acquisition, Temperature Sensor

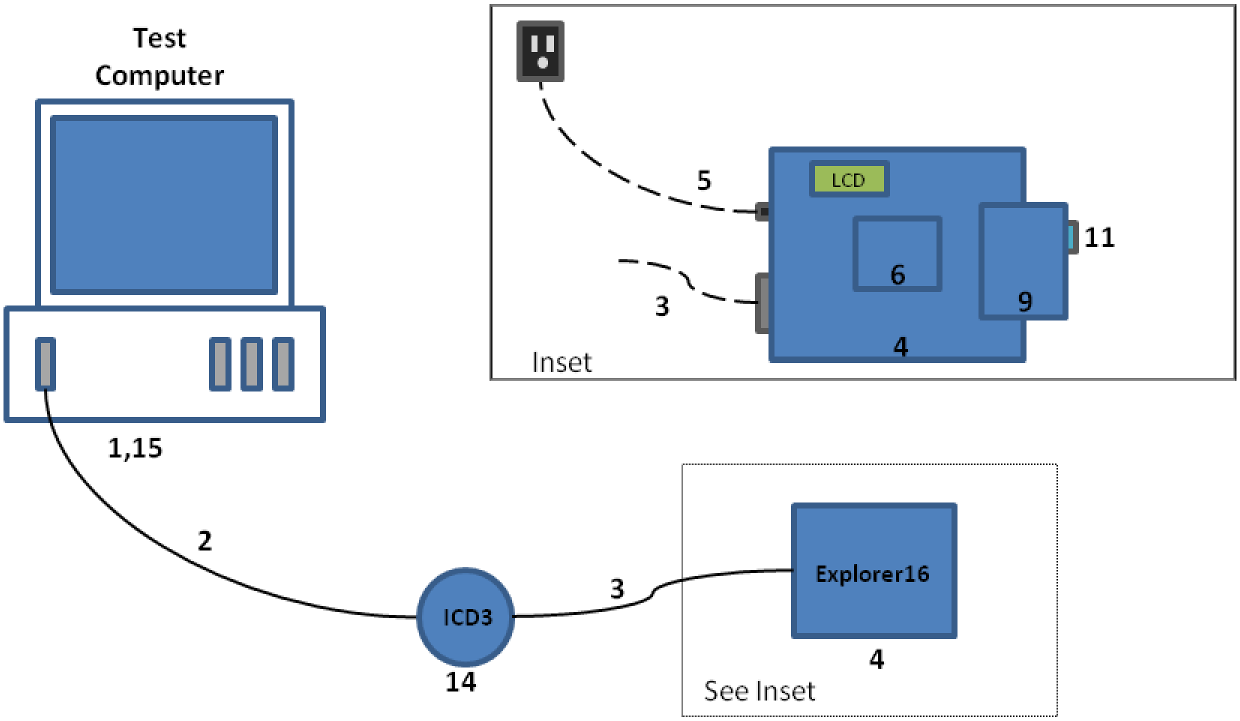


Figure4.2.4: Test Configuration for SD Data Logging Module

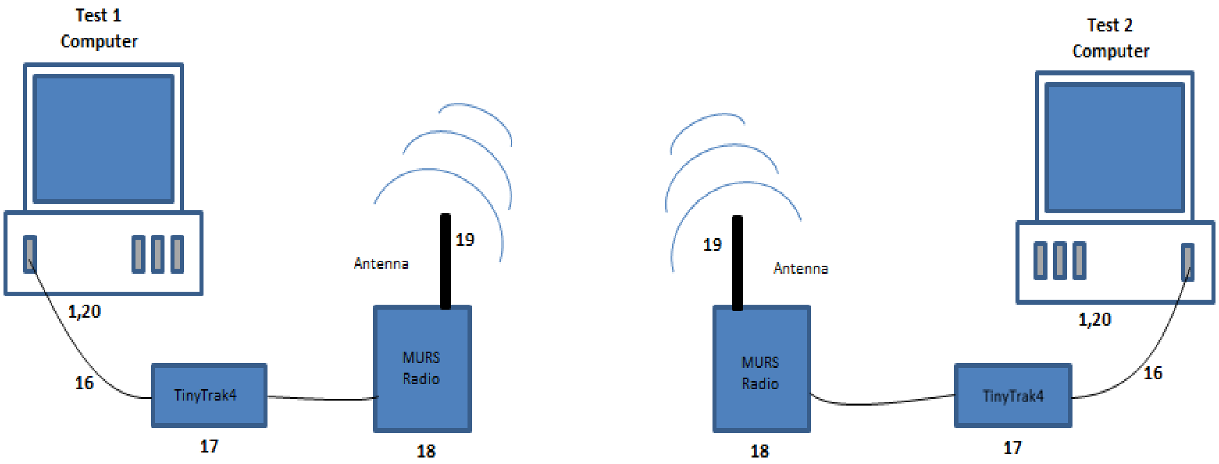


Figure 4.2.5: Test Configuration for Data Transmission

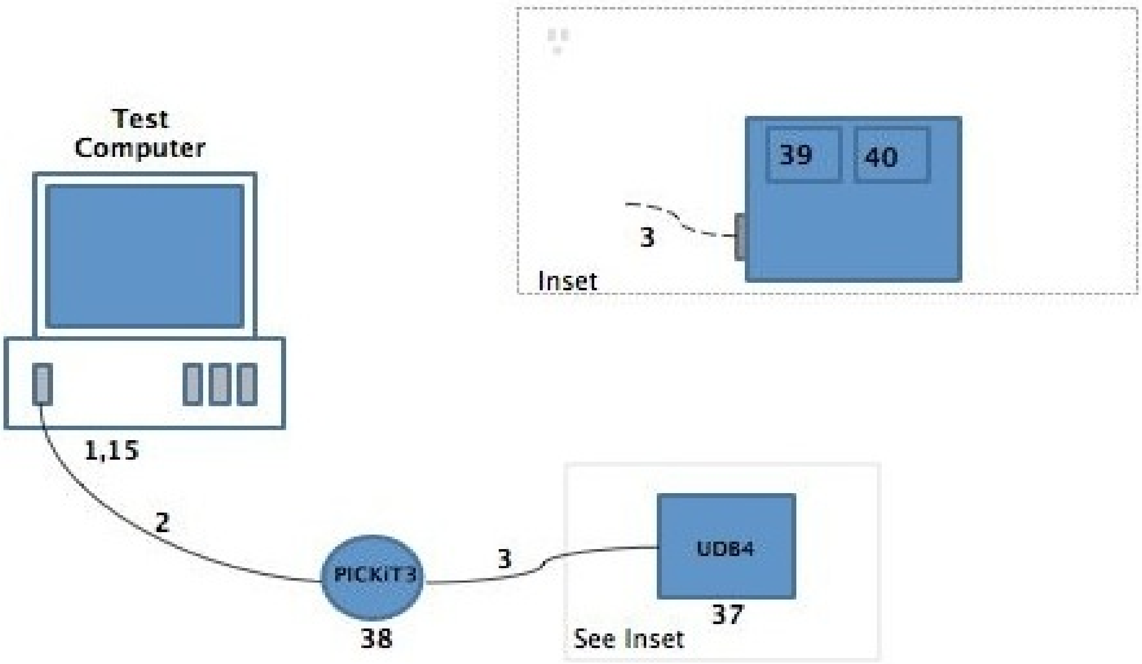


Figure 4.2.6: Test Configuration for Navigation system: UDB4

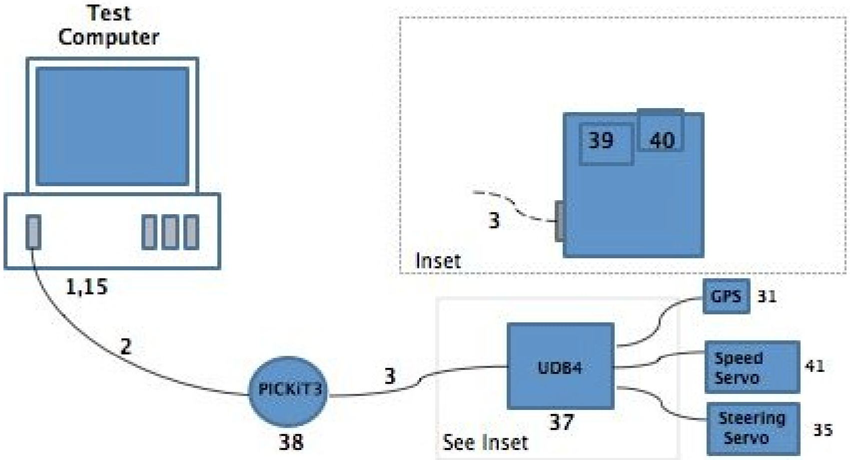


Figure 4.2.7: Test Configuration for Navigation System: UDB4, GPS, Speed and Steering Servo

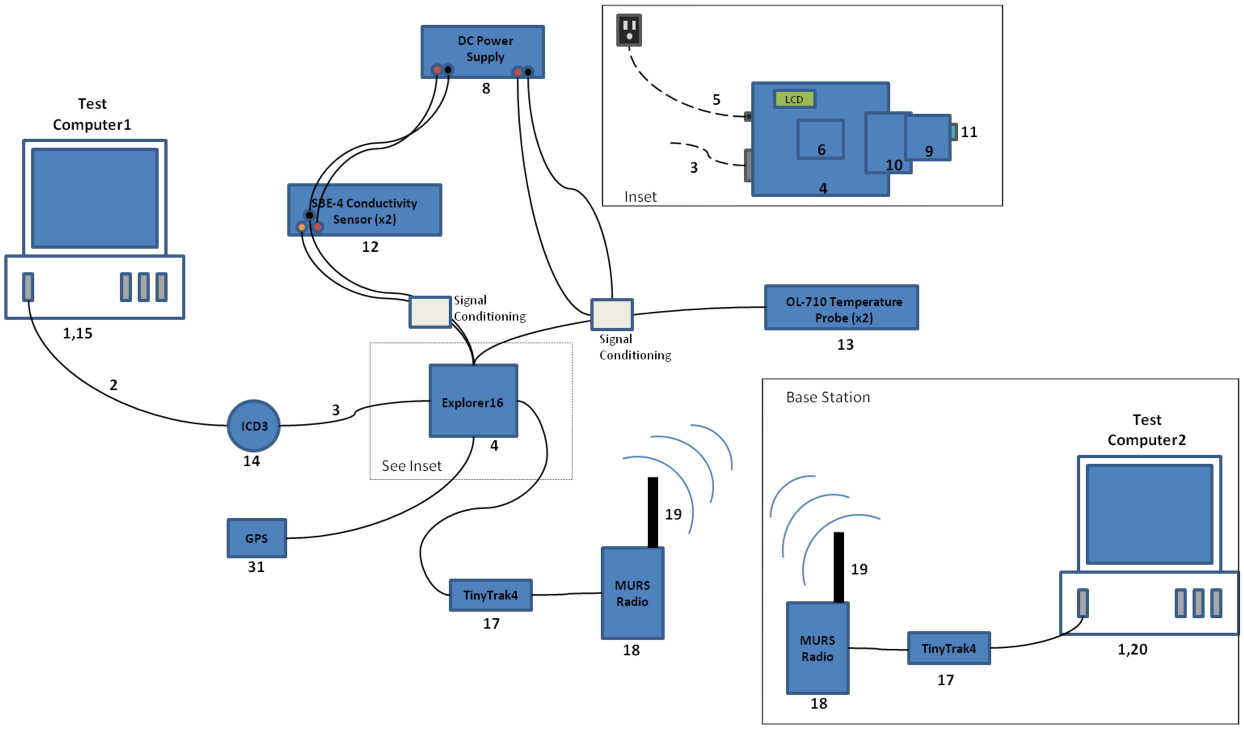


Figure4.2.8: Test Configuration for integrating Data Acquisition, Data Logging, Data Transmission

4.3 Test Plan for Major Components

4.3.1 Data Acquisition, Conductivity Sensor

Step #	Step Description	Expected Results	P/F N/A	Comments

1	Place the system in the configuration shown in Figure4.2.1		N/A	
2	Configure Function Generator to output a 3.3V square wave signal with frequency between 2.5kHz and 7.5kHz		N/A	
3	Execute Frequency Count test code block from MPLAB		N/A	
4	Verify the correct frequency is displayed on the LCD.	The microcontroller should determine the frequency of the signal using the input capture feature. The signal's frequency should be displayed on the Explorer16's LCD display	P	See Appendix D
5	Replace the Function Generator with the SBE-4 Conductivity Sensor (Refer to Figure4.2.2).		N/A	
6	Configure DC Power Supply to provide 12VDC to SBE-4.		N/A	
7	Immerse SBE-4 in a solution with known conductivity between 0 and 7 S/m.		N/A	
8	Verify output of signal conditioning is a 3.3V square wave signal.	Output of the SBE-4 conductivity sensor should be scaled to provide a 3.3V square wave signal to be analyzed by Explorer16.		
9	Execute Frequency Count test code block and Freq > Cond test code block.		N/A	

10	Verify LCD displays the appropriate frequency corresponding to the conductivity of the solution in which the sensor is immersed.	The function should determine the frequency of the signal and then convert this frequency to conductivity. The conductivity displayed on the LCD should match the known conductivity of the solution.		

4.3.2 Data Acquisition, Temperature Sensor

Step #	Step Description	Expected Results	P/F N/A	Comments
1	Place the system in the configuration shown in Figure4.2.3		N/A	
2	Apply 3.3V stimulus to OL-710 temperature probe		N/A	
3	Execute Get Temperature test code block from MPLAB		N/A	
4	Verify the correct temperature is displayed on the LCD.	The microcontroller should determine the voltage corresponding to the thermistor's temperature using the analog-to-digital converter feature. The temperature should then be computed and displayed on the Explorer16's LCD display		
5	Verify the temperature is correctly computed throughout the temperature range from 0ºC to 40ºC.	The 12-bit A/D converter should be configured to expect input voltages corresponding to temperatures 0ºC to 40ºC.		

6	Verify that temperatures in this range are displayed on the screen with a precision of .01ºC (or better)	The temperature computed should respond to variations of .01ºC. The computed temperature should resolve to .01ºC.		

4.3.3 SD Data Logging

Step #	Step Description	Expected Results	P/F N/A	Comments
1	Place the system in the configuration shown in Figure 4.2.4		N/A	
2	Execute Write To SD test code		N/A	
3	Remove SD Card and insert in test computer		N/A	
4	Verify data was accurately written to the SD Card.	The data should be written to the SD Card via the SPI1 serial interface of the microcontroller. The data written should be identical to the data sent over the serial interface.	P	See Appendix D

4.3.4 Data Transmission

Step #	Step Description	Expected Results	P/F N/A	Comments
1	Place the system in the configuration shown in Figure 4.2.5		N/A	
2	Create character string in terminal on Test Computer one		N/A	

3	Send string from terminal to TNC to begin data transmission across MURS radio		N/A	
4	Receive string from TNC on terminal of Test Computer two.		N/A	
5	Verify that data received on Test Computer two is identical to data sent from Test Computer one.	The data received should be identical to the data sent without any errors.		
6	Increase data size to match typical output sent from AWQuSam and verify that the data received is identical.	The data received should be identical to the data sent without any errors.		
7	Increase the distance between the MURS Radios to be 5km.		N/A	
8	Verify data is received at the base station receiver.	The data received should be identical to the data sent without any errors.		

4.3.5 Hull and Thrust Test

Step #	Step Description	Expected Results	P/F N/A	Comments
1	Measure the weight of the kayak.		N/A	Weight: 33lbs
2	Place kayak in body of water to estimate buoyancy and ensure there are no leaks.	Kayak floats smoothly on choppy waters.	P	

3	Attach kayak to rope and rope to an analog force sensor. Measure the speed of the kayak (with a GPS) as a function of the thrust experienced by the kayak. Thrust is applied a boat powered by a gas engine.	AWQuSam is able to move at speeds of at least 6 knots.	P	At 15 lbs of thrust kayak moves at 7 mph.
4	Repeat Step 3 but adding 45 lbs extra in water weight to act as placebo masses for other components of the boat.	AWQuSam is able to move at speeds of or more than 5 knots.	P	At 18 lbs of thrust kayak moves at 6.4 mph/

4.3.6 Propulsion System

Step #	Step Description	Expected Results	P/F N/A	Comments
1	Assemble propulsion system according to diagram in Figures 3.2.1 and 3.2.3			
2	Test the normal operations of the Honda GX35 engine with 2.5 gallons of fuel.	The engine runs smoothly for 12 hours without stopping		
3	Test engine in water AWQuSam. Measure variable speeds using placebo masses for other components	AWQuSam is able to move at speeds of or more than 5 knots.		
4	Measure the temperature of the engine after an hour run	Honda engine remains relatively cooled by draft		

4.3.7 Steering System

Step #	Step Description	Expected Results	P/F N/A	Comments
1	Assemble steering system according to diagram in Figure 3.3.1			
2	Test response of the servo motor on command in calm waters.	Servo motor is able to provide enough torque to move the rudder.		
3	Test effectiveness of system to steer the craft appropriately.	Steering will require some accommodations to achieve effective steering.		
4	Calibrate angle of the servo with steering intensity.	System will require some trial and error to achieve optimum steering		
5	Test vehicle performance to run on a 360 degree turn.	Step will show us system turning radius and will require more trial and error to achieve an appropiate turning radius of 5 meters maximum.		
6	Run the AWQuSam by remote control in rougher waters.	Mechanism proofs to be tough enough to handle itself in currents and waves.		

4.3.8 Mechanical Housing Stability, Bouyancy, and Safety features

Step #	Step Description	Expected Results	P/F N/A	Comments
1	Assemble hull structure and housing according to diagram in Figure 3.1.1.1, 3.1.1.3, 3.1.1.4, 3.1.1.5, 3.1.1.6, 3.1.2.1, 3.1.2.2, and 3.1.2.3			
2	Test the water tightness of the cover.	Cover successfully prevents water from entering the vehicle. Note that perfect tightness is impossible.		

3	Test attachment and that all components in the hull are fixed in position. This will be done simply by group members. Wave simulation will be involved.	All componets of the system remain in place safely attached. Bolts and screws don’t loosen.		
4	Place vehicle in water to determine the stability and bouyancy of the system.	Trial and error will be involved to achieve optimum balance and stability of the system. This step will also allow us to determine sensor (and other components) placement.		
5	Run the vehicle remotely control and maximum speed.	Step will allow us to determine the exact placement for sensors (at surface and 6 inches below surface).		
6	Test spring-keel mechanism.	Step will allow us to determine the size of spring required to bring keels back into position after coming in contact with an obstacle.		
7	Run the vehicle on shallow waters.	Step will allow us to identify the effectiveness of the stabilizing keels to rotate back when they come in contact with obstacles or ground. Trial and error will allow us to determine the appropriate type of spring that push keels back.		
8	Test effectiveness of LED navigation lights.	AWQuSam will be easily identifiable from a distance of no less than 50 meters.		
9	Test effectiveness of siren.	AWQuSam will be detected from a distance of no less than 50 meters.		
10	Test effectiveness of bumber. The test will involve various runs of the AWQuSam in collision with fixed surfaces and the impact will be analyzed by the group members.	Bumper proofs to be effective enough that it won’t damage any other vehicle or hurt any unknown spectators.		

4.3.9 Cooling System

Step #	Step Description	Expected Results	P/F N/A	Comments
1	Measure the temperature dissipated by the electronics inside the electronics box.	TBD	N/A	
2	Test the amount of time the packets will stay above the measured temperature (from Step 1) outside but covered from the sun rays.	TBD	N/A	
3	Test the effectiveness of the packets in maintaining the temperature of the electronics below thresh hold. Note that in this test operating conditions must be met (i.e. air draft and motion)	Packets are able to maintain the electronics at a safe temperature for the duration of the mission.		

4.3.10 Navigation System

Step #	Step Description	Expected Results	P/F N/A	Comments
1	Place the system in the configuration shown in Figure 4.2.6 and confgure PICKit 3 to provide UDB4 with 3.3 V		N/A	
2	Configure D2523T GPS to output update at a 4 Hz rate.		N/A	
3	Configure D2523T GPS to output GPGGA and GPRMC satellite data at a set update rate		N/A	
4	Configure pulse width modulation ports on UDB4		N/A	

5	Configure A/D ports on UDB4			
6	Configure UDB4 Accelerometer		N/A	
7	Configure UDB4 Gyro		N/A	
8	Travel with UDB4 at a set speed		N/A	
9	Verify accelerometers readings	Accelerometer readings should be constant and match known traveling speed		
10	Using protractor, tilt UDB4 to various positions (i.e. 0, 30, 60,90, 180 deg) in the x-,y-,z- plane		N/A	
11	Verify position output of UDB4 gyro	Gyro readings should match the known angles		
12	While GPS is updating data, travel a planned route with significant waypoints		N/A	
13	Verify GPS outputs GPGGA and GPRMC string	GPS should output only two GPS strings each beginning with the appropriate string header (i.e. $GPGGA, $GPRMC)		
14	Verify the GPS points which were recieved	The GPS coordinates obtained should match or vary slightly from known coordinates along traveled path		

15	Verify UDB4's ability to change speed output on speed servo when commanded	(Optional: For future expansion) Speed servo should increase or decrease speed on command		
16	Verify UDB4's ability to change direction of steering servo on command	Steering servo should rotate clockwise and counter-clockwise on command		

4.4 System and Integration Test Plan

4.4.1 Data Acquisition, Data Logging

Step #	Step Description	Expected Results	P/F N/A	Comments
1	Place the system in the configuration shown in Figure4.2.8		N/A	
2	Configure Function Generator to output two 3.3V square wave signals, each with varying frequency between 2.5kHz and 7.5kHz		N/A	

3	In MPLAB, configure Explorer16 (in loop) to: 1. Call *GPS* test code 2. Call *Frequency Count* test code for each input 3. Call *Get Temperature* test code for each probe 4. Call Freq > Cond routine (optional) 5. Write all acquired values to SD card		N/A	
4	Verify all values are written to SD Card	The microcontroller should accurately determine the frequency of each signal using input capture. The microcontroller should determine the temperature of the probes using A/D Converter. Time (hh:mm:ss), Position (Lat+Lon), Conductivity (x2) and Temperature (x2) should be written to the SD card		
5	Verify the frequency and temperature are logged at a rate of no less than 8 samples per second	The microcontroller should measure and record data from each sensor at a rate of at least 8 samples per second.		

4.4.2 Data Acquisition - Data Transmission

6	In MPLAB, configure Explorer16 to repeat step 4 and add: 6. Write acquired data to TNC serial output		N/A	

7	Configure receiver terminal to monitor serial port (commX) to which TNC is connected		N/A	
8	Verify data received at receiver terminal matches data output by Explorer16	Bit stream written to the receiver terminal should match the bitstream written to the TNC serial output of the Explorer16.		

4.4.3 Power System Integration

Step #	Step Description	Expected Results	P/F N/A	Comments
1	Place the system in the configuration shown in Figure 3.10.1 where the 12V input is from a DC power supply (FN 8)		N/A	
2	Verify all components receive power and are functional	The 12V supply should be distributed and regulated to supply power (per specification) to each component of the system		
3	Replace DC power supply with 12V battery (FN 30)		N/A	
4	Verify all components receive power and are functional	The 12V battery supply should be distributed and regulated to supply power (per specification) to each component of the subsystem		
5	Verify the system remains powered for 12 continuous hours of operation	The 12V battery should have sufficient capacity to provide power to the system for 12 hours of continued operation		

4.4.4 Electronic Housing Integration

Step #	Step Description	Expected Results	P/F N/A	Comments
6	Recharge battery		N/A	
7	Place the system in the configuration shown in Figure 3.10.1 where the 12V input is from a 12V battery (FN 30)		N/A	
8	Place electronic components within electronic housing and place outside for 12 hours (typical hot,humid diurnal solar cycle)		N/A	
9	Following this test, verify the AWQuSam still operates functionally	The cooling system of the electronic housing should be sufficient to provide a safe operating temperature for the AWQuSam's electronic components.		
10	Recharge battery		N/A	
11	With electronic components still within electronic housing (and cables in operational configuration), verify all cable interfaces with housing are properly sealed. Expose housing to driving rain (or simulated rainfall)		N/A	
12	Verify there is no water intrusion into the electronic housing	The electronic housing should be resistant to water intrusion as a result of driving rainfall. No water should enter the electronic housing through cable interfaces with the housing. All components should remain fully functional during and after operation in driving rainfall.		

4.5 Summary of Test Plan Status

See Appendix D

5 Schedule

See Appendix A

6 Budget Estimate

Item	P/N	Manufacturer	Distributor	Qty	Projected Cost	Actual Cost
PIC Development Board w/ Programmer	DV164037	Microchip	Microchip	1	$225	$225.00
SD Daughter Card	AC164122	Microchip	Microchip	1	$28.50	$28.50
Conductivity Sensor	SBE-4	Seabird	In House (FSU Oceanography)	2	-	-
Temperature Sensor	OL-710	Omega	Omega	2	$200	$173.00
Compass Module	SEN-07915	Honeywell	Sparkfun	1	$34.95	$34.95
GPS	GPS-09566	ADH Technology Co. Ltd	Sparkfun	1	$79.95	$79.95
microSD 16GB Memory Card	COM-08163	A-Data	Sparkfun	1	$9.95	$9.95
USB to Serial Converter	USB-232-1	CommFront	CommFront	1	$30	$26.40
MURS Radio Modem	RV-M3-M	Raveon	Raveon	2	$260	$113.00
TNC	TinyTrak4	Byonics	Byonics	2	-	$202.00
Base Station Antenna	MURS-BASE	Firestik	TBD	1	$39.99	
4x4 Keypad	TBD	Grayhill	TBD	1	$20	-

Wiring and Accessories					$200	
Battery	SRM-24	Interstate Batteries	Amazon	2	113.95	
Servo Motor	High Torque Water Proof Servo	Traxxas	TBD	1	83.76	
Honda GX35 35cc Engine	#HEGX35NTT3	Honda	Bailey’s	1	399.99	$299.38
GX35 - Clutch	Clutch	Honda	Small Engine Warehouse	1	38.97	$80.95
Prather 280 BC Metal Prop	PRAB280	-	FunRcBoats	1	-	$21.99
Kayak	-	-	CraigsList	1	98.00	$140.00
Shaft	SF2	Surface Drive Hardware	PMB Model Boats	1	$52.15	$52.15
Engine Coupling	HF192A	Surface Drive Hardware	PMB Model Boats	1	$22.11	$22.11
Hoses	Discharge and Suction Hoses with couplings	TBD	TBD	1	40.00	
Mounting Hardware	Sealants and Bolts	TBD	TBD	N/A	40.00	
SubTotal:					$2017.27	
Total Proposed Expenditures:					$2000.83	$1509.33

Table5.1: Product Prototyping Budget

7 Conclusion

Design and development of the Autonomous Water Quality Sampler is progressing as expected. The detailed design of the major subsystems are included in this design review. Navigation, data acquisition, data logging, propulsion, and steering are all critical subsystems of the design. Many of these subsystems have been completed and tested. These must be integrated with one another and fitted to the mechanical hull, as designed. A vision for the project’s future has been laid out, with implementation and system integration as the next phases of the project. The project schedule and risk registers are monitored weekly in order to ensure that the project is completed on schedule. AWQuSam Engineering’s primary business objective is to meet the customer’s requirements by providing quality service and designing with integrity. The quality of the team’s service is a direct consequence of the team’s commitment to continual excellence.

8 References

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Appendix A. Project Schedule

Appendix B. Project Code

Appendix C: Calibration Sheets

Appendix D: Test Results