Virginia Tech Human Powered Submarine Team

ISR 12

Technical Report

June 24-28, 2013

I. Introduction

The following report details the conceptual design, development, fabrication and testing of Phantom 6, Virginia Tech Human Powered Submarine Team's (VTHPS) newest submarine. Research and development regarding the decision for the side-by-side two pilot configuration was vital, since such a design had never before been constructed. Each major system plays a vital role in achieving the goal of maximum speed, while also providing for pilot safety. Phantom 6 features two systems of extreme innovation. The dual linear drive system decreases the cross-sectional area of the submarine and allows the pilots to combine their outputs through the differential. The advanced electronics system provides the pilots with a heads-up display (HUD) while allowing for data acquisition. Phantom 6 is the most advanced submarine VTHPS has developed in its history, continuing the innovative spirit that has driven the team since its beginning.

II. Conceptual Design

Following the success of Phantom 5 and its innovative linear drive system, development began for Phantom 6. It became clear that the linear drive system had to be included as a major feature of the propulsion system. With this in mind, the team began to develop hull designs. It was decided that a two person concept was both challenging and provided room for innovation. The two hull forms that came out of the conceptual design phase were dubbed Orion and Typhoon.

The Orion hull form featured a long, slender hull that past submarine designs have utilized. This hull form features a small cross-sectional area to reduce drag. The design called for a pilot to control the submarine, and a propulsor, whose primary function would be to pedal. With the linear drive system, the sleek design of the Orion hull form could mimic that of Phantom 5. However, the overall length of the hull form was predicted to be difficult to handle and transport. In addition, the conceptual design showed that the safety system would be difficult to create. With this in mind, the Orion hull form was discarded in favor of the Typhoon.

The Typhoon hull form featured a much wider cross sectional area, while having a smaller length than the Orion hull. The major advantage that the Typhoon hull offered was the ability to couple two drive systems, one per pilot. While the cross sectional area is larger and increases the drag on the submarine, the power output allowed by a coupled drive system could overcome the increase, and allow for a two person submarine capable of achieving higher speeds than the others in its category.

III. Hull Fabrication

The process of taking a concept design from a computer to a practical submarine hull is a long and complex process. The process begins by creating a submarine design using Autodesk Inventor. Once the design meets the requirements that are set for the submarine, the design is sent out to a company that will take the design and create a foam mold of the hull. Foam is chosen for the mold as it is easy to shape into the proper hull form.

Once the foam mold is returned back to the team, the mold is covered in fiberglass to create a rigid hull form. The fiberglass is a substance that is easy to apply and very sturdy. The foam mold is completely covered with fiberglass to create a full rigid hull. The hull is then sanded with a low density filler to create smooth finish on the submarine hull. The hull is then coated with a layer of wax to ensure further smoothness of the hull.

After the hull is smoothed out, the glass, peel ply and vacuum bags and vacuum tape are cut to shape the submarine and remove the portions of the hull that are not needed. Once all this has been removed, lay ups are performed and the vacuums are run for one day to complete the first layer of fiber glassing. This process is repeated for an additional layer of fiberglass, with layers of foam in the top half of the submarine. In areas that are predicted to need more structural support, such as the areas of discontinuity near the hatches, the hull is also reinforced with carbon fiber.

IV. Systems

1. Propulsion

a) Drive Train

Phantom 6's drive train is one of the most innovative aspects of her design. With the success of the linear drive system from Phantom 5, the design called for a coupled system. This system would allow for both pilots to pedal simultaneously, and would potentially double the power output achieved by earlier subs. The gearbox from Phantom 5's drive system was adopted for Phantom 6, with changes only made to the gear configuration to allow input to the differential, discussed below. This familiar design allowed the team to easily fabricate the new gearboxes, and even use parts from Phantom 5 for a timely completion or for spares. Other minor changes to the gearbox were made to reduce weight, such as removing excess material from the bevel gears. The gearbox components were fabricated in the Virginia Tech Ware Lab by student team members, purchased online (in the case of the gears themselves) or professionally machined by the Department of Aerospace and Ocean machine shop.

The next, and arguably the most important aspect, of the entire power transmission system is the summing differential. This assembly allows for the power output from each gearbox to be combined and turn a common sprocket. Through use of a chain, this rotation is then translated to the aft section of the drive system, providing the same input into each propeller shaft. The differential therefore allows the pilots to pedal at different speeds, while maintaining an equal angular velocity, which prevents yaw problems that would exist should the system not be coupled through the differential. The drive system also forces the propeller shafts to counter-rotate, eliminating the roll moment produced by the torque reaction of a single shaft, which was a prevailing issue for Phantom 5.

One concept newly implemented on Phantom 6 is the addition of a maintenance hatch. This hatch is attached via screws, and is located towards the stern of the submarine. While the hatch will never be opened during a race, it does allow for easy access to the entire propulsion system, and the aft section of the controls system for construction & maintenance purposes. This eliminates the need for two halves of the submarine to be completely separate, and allows team members to work easily and closely with the systems. This hatch also contains much of the added foam in the stern that is needed for buoyancy due to the weight of the gearboxes.

b) Propellers

The propellers for Phantom 6 integrate a variable pitch system that is controllable by the copilot while the sub is moving. The copilot progressively releases a lever inside the cockpit to add more pitch. A cable running from the lever though the hollow propeller shafts actuates two pairs of cams in the propeller hubs. The final shape of the propeller hubs accommodates the spacing requirements for these cams while maintaining the smallest possible size and weight. The small size of the hubs and their interior slots for the propeller blade cams posed significant challenges for fabrication. The best choice for structural integrity, surface finish, and cost effectiveness was to have the propeller hubs sintered by ExOne using a blend of 316 steel and bronze.

The propeller blades themselves proved to be difficult to produce. Their twisted shape would have required that they be milled on a 4 axis mill, which for a set of 4 blades would have cost an estimated $4000. To reduce cost and lead time, we developed a working relationship with the Kroehling Advanced Materials Foundry in Blacksburg, Virginia, to have the propeller blades cast. This foundry is a new addition to the Virginia Tech campus. Students from the team made bonded sand molds on site, using an FDM pattern. Eight blades were successfully cast from aluminum 390, with 7 percent silicon added for increased stiffness. Overall weight per blade is 0.13-lb., and each measures 8.5 x 1.8 inches. Maximum thickness is 0.2 inches.

2. Dive Safety

The diver safety system of Phantom 6 is an integrated system consisting of the buoy, release switches, hatch releases, harnesses, and the associated cables. The buoys, one for each pilot, are comprised of shaped insulation foam. This foam is very buoyant, allowing for quick ascension to the surface. The foam is covered in a layer of fiberglass, which adds structural stability so that the strobe light and latch could be attached. The latch is taken from a common doorknob assembly, which reduced construction time and cost. The “bolt” that secures the buoy in its place is made from lightweight plastic. This lightweight plastic, known as starboard, replaces metal for various components throughout the submarine in an effort to reduce weight without sacrificing structural rigidity. The housing for the bolt is constructed from the same plastic as well as aluminum. This provides a cheap, simple, and lightweight solution to a previous design that used the complex bolt and lock mechanism from the doorknob assembly.

The buoys are deployed by the pilots as they release a “dead man’s switch”. When released, the cable attached to the switch removes the bolt from the latch, and the buoys ascend to the surface, tethered to the submarine with high visibility string. This string can be easily re-spooled by use of a mechanism designed and built by the team that was inspired by a fishing reel. The dead man’s switch provides two distinct advantages. First, it is a form of passive safety, in that if the pilot should become unconscious underwater, their grip on the switch is released and support divers alerted. Second, each pilot has their own switch, enabling each to make a decision should either become uncomfortable or alert divers if one pilot is incapacitated without the knowledge of the other.

Accompanying the dead man’s switches are both internal and external hatch releases. The external release is clearly marked on the top of the submarine, and is activated by twisting the handle. The hatches that enclose the pilots are positively buoyant, and will clear the submarine so that the pilots can eject without interference. The internal hatch release sits forward of the pilot’s heads, and can be activated by either in case of an emergency.

Finally, the integrated harness system was designed to save space inside the submarine. Moving the tank directly underneath the pilots created more space underneath their legs, which in turn allowed for a more comfortable leg motion while pedaling. The other advantage of moving the tanks forward is the reduction of required hose length for regulators. This reduces the likelihood of snags on other aspects of the submarine or the pilots becoming tangled. The life support system also features large windows near the bow, ensuring that pilots can see clearly, but also to facilitate support divers to maintain situational awareness.

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3. Controls

The control systems on Phantom 6 contain multiple engineering achievements that help to provide the pilot and copilot with as much freedom as possible. The primary control system is comprised of the four sets of stabilizer fins and control fins attached to the aft of the submarine, two sets on the port and starboard sides as well as two dorsal sets. These fins were designed by shaping wooden molds into appropriate airfoil shapes and then pouring performance plastic into the molds. While solidifying in the molds, metal rods were placed in to attach the fins to the hull. After hardening, the fins were removed and sanded down to a smoother texture.

The next step was to mix low density filler (LDF) with epoxy. This LDF mixture, the same mixture that was used later on to cover the entire hull, was then spread over the fins and sanded down multiple times to provide a smooth outer layer to the fins. From here, the stabilizer fins, which were designed not to move, were ready to be attached to the hull. To do so, metal hard-points were epoxied to the hull with hollow metal rods. The stabilizer fins were then able to simply slide into place and are locked down with pins or set screws, depending on their location.

To attach the control fins, which are designed to move based on the control stick held by the pilot, a system needed to be implemented such that the pitch and the yaw of the submarine would be equal from both sets of fins. Since Phantom 6 is such a large submarine with a large beam-to-height ratio, she has passive roll stability, meaning active roll control was deemed unnecessary. This means that the control fins need only be responsible for pitch and yaw. To provide pitch control, the port and starboard control fins are attached to a single hollow rod that runs across the entire beam at the aft of the sub. The fins are then set screwed in order to prevent independent movement. To attach the control fins to the control stick, metal bike cables are run down the length of the submarine and attached to two moment arms on the rod. When the control stick is pushed forward or pulled backward, it pulls on one of these bike cables, which rotate the rod using moment arms, thereby rotating the control fins to a positive or negative angle of attack, as necessary. To control the yaw, a similar system was used, but a rod could not be simply run directly through the height of the sub as it would intersect with the horizontal control rod. Therefore, a custom-designed C-piece is attached to both control fins that allows the fins to stay in place, but move the vertical rod around the horizontal rod. This C-piece also serves as the moment arm needed for the bike cables to move the vertical control fins.

The other control system that is unique to Phantom 6 is the active variable pitch control system. This system is designed to provide a similar experience to gears on a bike. To provide the most thrust possible at lower speeds, the propellers are at a lower pitch, which provides less thrust, but also less resistance, thereby allowing the pilot and copilot to begin pedaling much faster. Once the propellers reach their optimal thrust, pedaling faster means more energy is wasted by the pilot and copilot. Therefore, the copilot has a lever which is attached to a bike cable, similar to the control system. This cable runs approximately two-thirds of the length of the sub, where it then attaches to a ring. This ring is connected to two bike cables that run to each propeller hub. As the lever is released, this then increases the pitch of the propellers. The ring is designed such that the single bike cable is able to change the pitch on both propellers equally. By changing the propeller pitch, the props begin to create more thrust. At this point, the pilot and copilot have already built up enough momentum to overcome the initial resistance. This means that the propellers are constantly providing the optimal thrust at each stage of the run.

Initially, it was thought that the pilot would be responsible for both control systems, but this was changed for two primary reasons. The first was to prevent the pilot from being overloaded with information. If the pilot were responsible for the variable pitch of the props and control of the sub's attitude while simultaneously pedaling as hard as possible, it would be too much for the pilot to handle, especially if the copilot's only responsibility would be to pedal. It also became apparent that it would be challenging to the variable pitch control into the dead-man switch. The only other options would then be to either place both systems in the same control stick, which would only add to the confusion of the pilot, or to provide two different control sticks for the pilot. This would mean the pilot would have to move back and forth from each system and not be capable of using both simultaneously. Again, this was found to be counter-intuitive if the copilot was only pedaling. Therefore, the final decision was for the pilot's left hand to hold the dead-man switch for the diver safety system and the pilot uses their right hand to move the control stick for the control fins. The copilot then uses their left hand to move the variable pitch control stick while their right hand holds the copilot dead-man switch.

4. Electronics

The electronics team's responsibility is to provide real-time sensor data for the pilots as well as store the data for system performance analysis. The following electronics section breaks down the design of the hardware and software system, and analyzes the performance of the current implemented system. The pilots developed the requirements for the electronics system since the system was created in order to provide them with accurate data about the vehicle and its environment.

- The vehicle must provide the pilot with roll, pitch, and yaw angles.
- The vehicle must provide the pilot with the depth in feet and vehicle speed using a static and dynamic pressure reading.
- Measure the RPM of each propeller.
- The pilots must provide input with a waterproof button.
- Log sensor data to microSD card.
- Display sensor data with an onboard LCD and 7-segment displays.

Software System:

- **Languages**: C++
- **Compiler**: MPIDE
- **External Storage:** Sparkfun Logomatic - 2 GB microSD card

- **Microcontroller:** Digilent chipKIT Max32 Microchip® PIC32MX795F512 (Arduino Compatible)

The electrical system is shown in Figure 4.1.

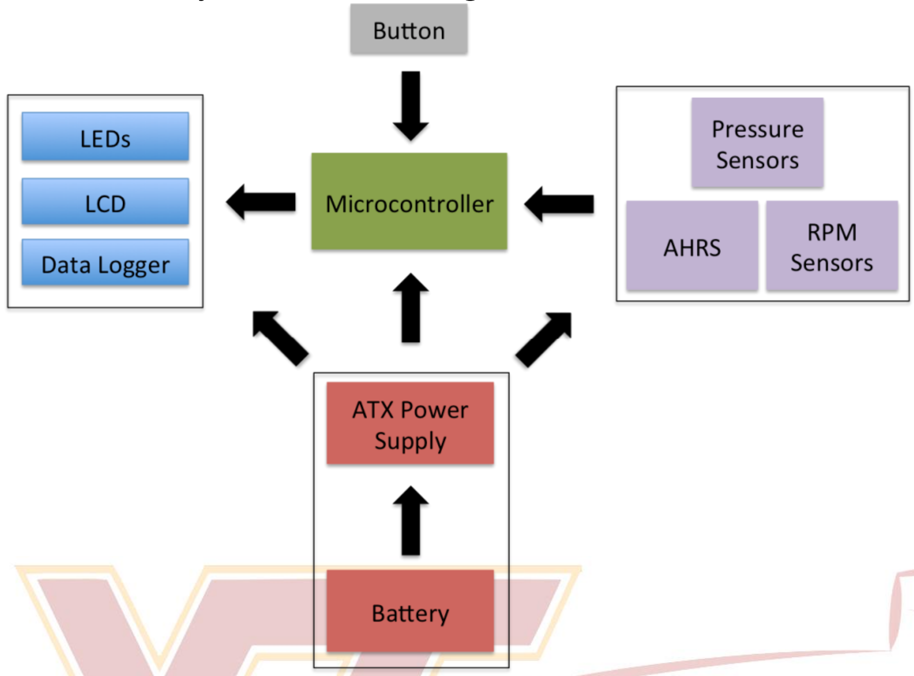

Fig. 4.1 Electrical Integration Diagram

The red boxes that say “Battery” and “ATX Power Supply” depict the power system for the vehicle. The ATX Power supply is a DC to DC converter which takes the input battery voltage and converts it into a voltage that the sensors, displays, and microcontroller can utilize.

The purple boxes that say “AHRS”, “RPM Sensors”, and “Pressure Sensors” represent the various onboard sensors. AHRS stands for Attitude and Heading Reference System and is used to obtain the roll, pitch, and yaw of the vehicle. The RPM sensors are used to determine the RPM of each propeller. The pressure sensors are used to determine the vehicles depth and speed.

The green box is the microcontroller, which is the chipKIT Max32. The microcontroller receives data from sensors and displays it for the pilots.

The gray box is the button that allows the pilots to interface with the onboard displays.

The blue boxes represent the onboard displays and data logger.
The spreadsheet below shows the power budget for each component and was used when selecting a battery and power supply.

Quantity	**Device Name**	**Current (mA)**	**Voltage (Volts)**	**Power (mW)**
1	Data Logger	90	5	0.45
1	chipKIT Max32	90	5	0.45

2	Pressure Sensors	600	12	7.20
2	Hall Effect sensors	18	3.3	0.06
2	7-Segment Display (LED)	1200	9	10.80
1	Crystalfontz Display (LCD)	600	5	3.00
1	CHR6DM (AHRS)	400	5	2.00
10	**Total:**	**2998**		**23.96**

Since the vehicle needed to run for at least an hour on one charge, the battery that was chosen to power the onboard electronics was the NiMH 16.8V Battery Pack with 4.2Ah (55Wh).

$$\frac{4.2Ah}{2.998A} = 1.4\ hours$$

This means that the battery can supply the proper power to each device for over an hour. In order to supply the proper DC voltages to each device we chose to use a 12-25V input pico ATX power supply. This power supply contains 3.3V, 5V, and 12V rails, which were essential for the onboard devices.

Data Logger

The Logomatic Serial SD Datalogger was used to store sensor data on a 2 GB micro SD card. The data is stored in a text file which is imported into excel for analyzing. Once the microcontroller collects the data from each sensor, the data is sent to the Logomatic using the microcontroller's serial port. The sensor data that is being collected is the vehicle's roll, pitch, yaw, battery voltage, dynamic pressure, static pressure, depth, speed, and propeller RPM.

Fig. 2.2 Logomatic Serial SD Datalogger

Digilent chipKIT Max32 Development Board

When choosing which microcontroller to use it was between a BeagleBone and a chipKIT Max32. The microcontroller needed to collect, store, and display sensor data with I/O pins and serial ports. The decision matrix in Figure 2.3 was created to compare the features of the chipKIT Max32 and the BeagleBone.

Decision Matrix: Microcontroller Interface				BeagleBone	chipKIT
CRITERIA	**Mandatory (Y=1/N=0)?**	**Weight**	**SCALE**		
Cost	0	10	3= Least Expensive 1= Most Expensive	3	2
Risk	0	10	3= Lowest 1=Highest	3	2
Power/Speed	0	10	3= Most Efficient 1=Least Efficient	2	3
I/O pins	0	20	3= Most Pins 1= Least Pins	2	3
Ease of Implementation	0	30	3= High 1=Low	2	3
Weight/Size	1	20	3= Smallest 1= Biggest	2	3
WEIGHTED TOTALS in %		**100%**	**3**	**73.30%**	**93.30%**

Fig. 2.3 Decision matrix for chipKIT versus BeagleBone

From the decision matrix in Figure 2.3, it can clearly be seen that the chipKIT Max32 outclassed the BeagleBone in almost every category. The chipKIT Max32 earned a score of 93.3% while the BeagleBone earned only a 73.3% based on our criteria. Thus, the chipKIT Max32 was used for Phantom 6.

The chipKIT Max32 is compatible with the Arduino development platform, therefore, this microcontroller has the same functionality as an Arduino. The Arduino development platform was considered because it is easy to implement for beginners, is small and compact, and has low power consumption with high processing speed.

The features of this device are listed below:

- PIC32MX795F512L processor
- 512K Flash, 128K RAM
- Up to 80MHz operating speed
- 83 available I/O lines
- USB or externally powered
- 5 External Interrupt pins

• 4 Serial ports

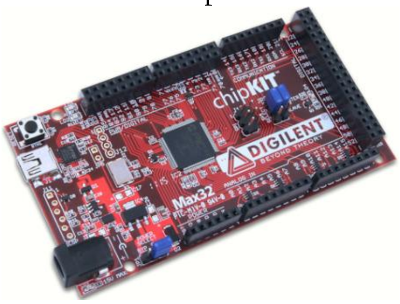

Fig. 2.4 chipKIT Max32

Calibrate Microcontroller's ADC:

The chipKIT Max32's ADC had to be calibrated because the voltage reading wasn't accurate when a known DC power supply was wired to the input of the ADC. This was a very important calibration because it would assure the microcontroller would read the various onboard sensors properly. Since the pressure sensors provide a change in output every inch in water, the ADC had to be very accurate or the depth reading would be skewed. To calibrate the chipKIT Max32, a known voltage from a DC power supply was used to compare it to the voltage that the chipKIT Max32 outputted. Using these data points, a trend line was created that would correct the chipKIT Max32's ADC error. The trend line plot can be seen below in Figure 2.5.

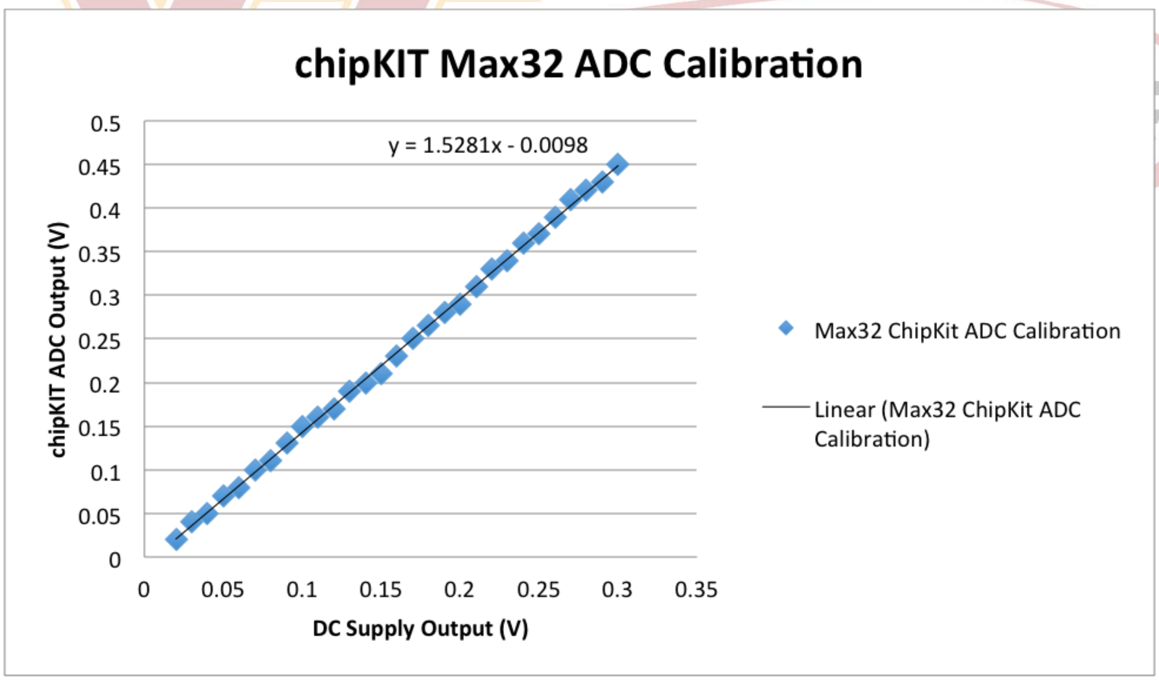

Fig. 2.5: Trend Line for chipKIT Maxk32 ADC

Pressure Sensor

The pressure sensors that were used to calculate depth and vehicle speed were the PRECISELINE models donated by Keller America. These sensors provide an analog voltage from 0 to 5V and were mounted to the vehicle using the threaded end of the sensor.

Fig. 2.6: Keller America Pressure Sensors

Two sensors were needed to calculate the vehicle speed. One pressure sensor was placed at the nose of the vehicle to obtain the dynamic pressure and another sensor was placed in the vehicle to obtain the static pressure. To obtain an accurate correlation between a voltage reading and the actual depth, the pressure sensors had to be calibrated.

Calibrating Pressure Sensors:

To make sure that the depth readings were accurate within an inch, the pressure sensor had to be calibrated. The depth sensor was originally calibrated at the manufacturer's location, which was at a different elevation, making the voltage output of the sensor different than the specified datasheet output. Because of all these factors, it was deemed necessary to recalibrate the sensor, as well as, reprogram them for different voltage ranges. In order to calibrate the depth sensor, the voltage at every inch was documented from the surface to the bottom of the pool. After collecting the appropriate data, a trend line was set that accurately converted voltage to depth in inches. The trend line plot can be seen below in Figure 2.7.

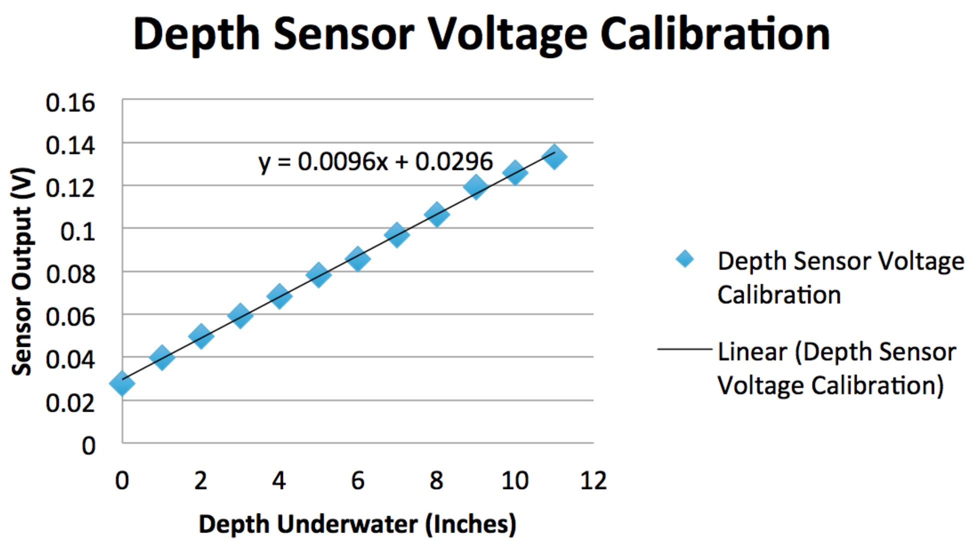

Fig. 2.7: Trend Line for Depth Voltage

Keller America provided the software and hardware to reprogram the pressure sensor in order to change the output voltage range. The pressure sensors were reprogrammed to output 0 to 5 volts at 0 to 26 feet, respectively. Figure 2.13 shows the calibration software which allows the user to set a desired pressure range and voltage output.

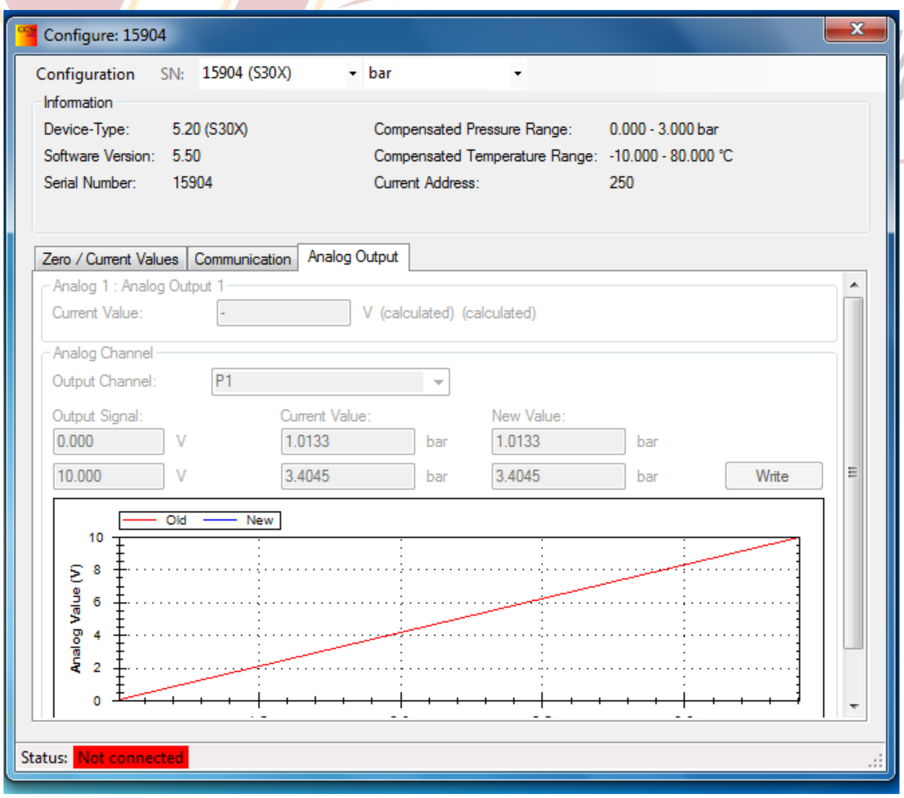

Fig. 2.8: Pressure Sensor Calibration Software

7-Segment Displays

Two SURE Electronics 1.8” Character Height 7-Segment LED Information Boards were used to display speed and depth to the pilots. The LED boards were secured in OtterBoxes directly in front of the pilots for easy viewing. The displays are supplied with 5V and communicate with the chipKIT Max32 via SPI protocol.

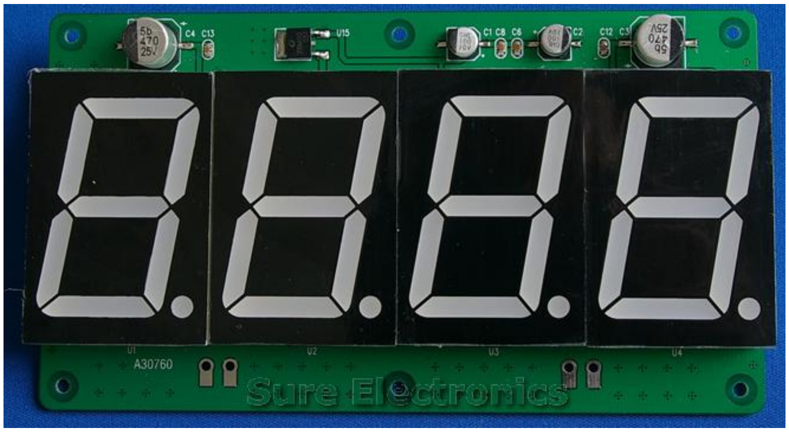

Fig. 2.9: 7-Segment LED Board

Attitude and Heading Reference System (AHRS)

To measure the roll, pitch, and yaw of the vehicle the CHR-6DM from CH Robotics was chosen. This Attitude and Heading Reference System combines three gyro axes, three accelerometer axes, three magnetic compass axes, and a 32-bit ARM Cortex. A Kalman Filter is applied onboard to combine the inputs from each sensor and calculate a roll, pitch, and yaw. The AHRS communicates the heading values through a serial interface at 300 samples per second. Figure 2.10 shows the CHR-6DM board.

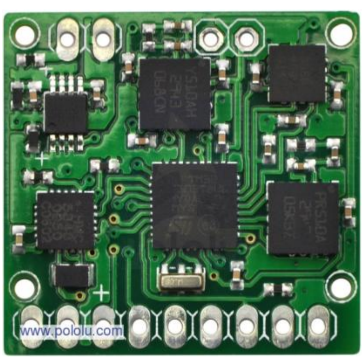

Fig. 2.10: CH Robotics CHR-6DM

20x4 Characters LCD

The LCD, which is located between both pilots, displays the current roll, pitch, yaw, battery voltage, speed, depth, and RPM. The display is powered with a 5V rail from the power supply and data is sent to the display through the chipKIT Max32’s serial port.

Fig. 2.11: Crystalfontz LCD Screen

Hall Effect RPM Sensor

To measure the speed of each propeller, a hall effect sensor was mounted next to each propeller shaft. The hall effect sensor is powered with 3.3V and has an analog voltage output pin. Since the analog output pin goes high as individual grooves on a gear go past the sensor, a circular piece of starboard with four screws attached evenly around it was attached to the propeller shaft for the sensor to detect the speed of each propeller. The output pin of each hall effect sensor is attached to the chipKIT Max32's interrupt pins. Every time the hall effect sensor detects a screw passing, it interrupts the microcontroller to enter a subroutine that updates the current RPM value.

Fig. 2.11: Hall Effect Sensor

V. Testing and Training

While finishing up the electronics installation and the hull surface finish, only a limited amount of testing could be performed for Phantom 6. As a result, the testing team prioritized test objectives necessary for each system, as well as overall objectives for the submarine. All testing was performed either in air at the Virginia Tech Ware Lab, or in water at Virginia Tech's War Memorial Pool.

1. Dive Safety

The safety system is paramount for competition, to the point of disqualification should it not perform adequately. Therefore, it was necessary to closely analyze the testing of the system. The test was broken into two parts. The dead man's switch and buoy assembly was tested first.

Both pilot and copilot assemblies were released while the submarine was submerged at 16 feet. Both systems proved to be successful as the buoys ascended quickly to the surface, without interference.

The second part of the test involved the pilot hatch releases. The twisting motion of the external release proved simple to operate and both hatches released without issue. The positive buoyancy of both hatches was not as extreme as intended, but did provide a passive safety feature in that the hatches cleared the submarine and ascended to the surface, allowing for pilots to exit the submarine without interference. The internal hatch release was easily accessed from both pilot positions, and again the hatches ascended to the surface without issue.

2. Propulsion

The next system examined was the propulsion system. In order to verify that the system could provide adequate thrust, it was necessary to observe the system both in air and in water. While an overall assessment of the system was performed in each case, there were three areas that were closely monitored.

The first was the gearbox itself. Careful attention was paid to the frictional resistance of the pedal shafts and bevel gears, along with gear alignment. In both the air and water cases, the gearbox seemed to function as intended, with no major issues. Small gear alignment changes were necessary to get the system to its optimum level.

The second aspect of the propulsion system analyzed during testing was the differential. This assembly is essentially the heart of the propulsion system, allowing for the summation of the two pilot inputs. Gear alignment within the differential is vital, along with no slippage on the input shafts from each gearbox. The differential performed adequately in air and underwater, with only one issue (a loose shaft) that was quickly corrected.

The third test if the propulsion system was the propellers themselves. In contrast to the other two systems, this test did not produce successful results, although it did reveal issues that are to be examined at a later date. The most prevalent of these is the pitch of the propeller blades. There was much discussion on the correct orientation of the blades in the hubs to produce the most amount of thrust. While not tested on the submarine, a mock propeller hub was fabricated and various pitch angles could be tested through use of this hub, a small connecting shaft and an electric drill, to provide necessary rotation. After noting the optimum pitch on this mock hub, the blades on the submarine were changed accordingly.

3. Controls

Control testing was limited due to time constraints and the aforementioned problems with the propeller pitch. The team successfully demonstrated the response of the system both in air and in water by manipulating the joystick, but could not examine control authority in a dynamic environment. The variable pitch control could not be demonstrated due to issues with the propeller blades.

4. Electronics

Most of the electronics system testing was performed in air. These tests were mostly for functionality of the system, proving that sensors worked correctly and data was displayed in a readable form for the pilots. Waterproofing testing was conducted independently from the rest of the submarine, and was performed by leaving the containers at test depth (16ft) for a prolonged timeframe. Pressure testing was also performed by pressurizing a container with the electronics inside, to a local pressure of near 60 psi, well over the pressure limit that the system will encounter at competition.

VI. Conclusion

In conclusion, Phantom 6 is the most innovative submarine design that the Virginia Tech Human Powered Submarine Team has developed to date. Phantom 6 is a two pilot side-by-side design, which allows both pilots to input power into the dual linear drive system. This cutting-edge drivetrain allows each pilot to pedal individually while combining their power inputs. The combined power is transmitted down the drivetrain and outputted distributed equally to two counter rotating propeller shafts. The electronics system features a heads-up display that provides real time information to the pilots while during the race and allows for analysis later on. Although some aspects of the submarine remain untested and some areas could be improved, VTHPS believes that Phantom 6 will be successful in ISR12, and spawn ideas and concepts for the next submarine, Phantom 7.