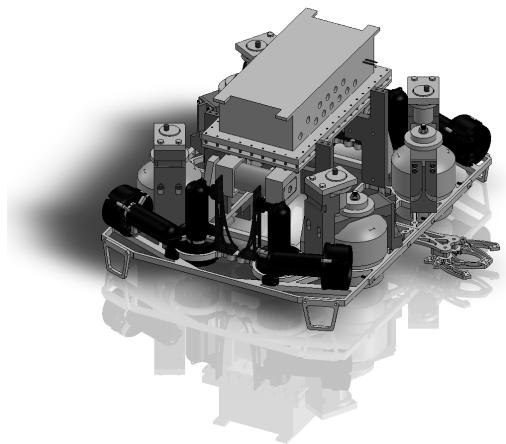




2013 Technical Report

Purdue University
IEEE ROV Team
West Lafayette, IN

Technical Report: ROV *Model M*



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2013 Technical Report

Abstract

Edison Submersibles, formerly Aperture Aquatics, designed and constructed ROV *Model N* to meet and exceed the requirements set forth by the 2013 MATE International ROV Competition. This includes installing the Scientific Interface Assembly and replacement Acoustic Doppler Current Profiler, leveling the secondary node, and deploying a transmissometer to measure ocean turbidity. At 71 cm long, 69 cm wide, and 51 cm tall, ROV *Model N* is capable of performing all these tasks with peerless speed and maneuverability.

Designed with reliability, stability, and speed in mind, ROV *Model N* is capable of maneuvering with six degrees of freedom. It has four thrusters for horizontal movement and four thrusters for vertical movement. The payload tools have been designed specifically for the mission and include a main gripper, turning motor leveling system, and spring-loaded measuring tool. All of the electronic hardware responsible for power management, vehicle movement, and sensor data collection, has been designed and fabricated from the ground up. The on-board and base station software was designed and developed by the company. Although it was a significant challenge to custom design electronic hardware, ROV *Model N* is fully functional.

The remainder of this document covers the design process and specifications of Edison Submersibles' ROV *Model N*. Also included are an expense report and a reflection on the issues that arose in the design process.



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2013 Technical Report ii

Table of Contents

Abstract	i
Mission Summary	1
Task 1	1
Task 2	1
Task 3	1
Task 4	1
Design Rational	2
Shape and Frame	2
Thrusters	3
Cameras	3
Electronics Enclosures	4
Buoyancy & Ballast	5
Manipulator	5
Turning Motors	6
Measuring Tool	6
Tether	7
Pneumatic System	7
Transmissometer	8
Electronics	8
Software	9
Reflections	
Challenges	14
Troubleshooting Techniques	15
Lessons Learned and Skills Gained	15
Future Improvements	16
Group Reflection	17
Team Safety	17
Outreach	18
Expense Report	19
Acknowledgements	20
Appendix A - Electrical System Block Diagrams	I
Appendix B - Software Flowcharts	II
Appendix C - Pneumatic System Diagram	III

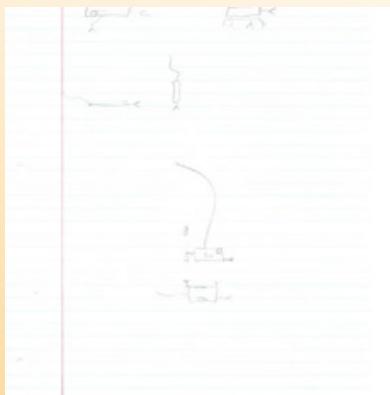


Fig. 1 - The very first design sketch of ROV Model N.

Mission Summary

Task 1: Complete Primary Node and Install Secondary Node

The Scientific Interface Assembly (SIA) is carried down in ROV *Model N*'s manipulator, and the pilot lowers it into position on the Backbone Interface Assembly (BIA). Using the hook on the top of the manipulator, the pilot may grab the Cable Termination Assembly (CTA) from the seafloor, hold it in an upright orientation with a hook on the top side of the manipulator, and insert it into the bulkhead connector on the BIA. With these steps complete, ROV *Model N* may remove the pin anchoring the secondary node to the elevator with the manipulator and retrieve the secondary node. By fixing the end of the string to the red pipe at the base of the BIA, the pilot may move the ROV in the direction of the deployment site and read the distance on the base station from the gray code encoder on the spring-loaded measuring tool. Once the secondary node is in the correct deployment site, the ROV will land on top of it such that each of the turning motors aligns with the four handles on the legs of the instrument. By using accelerometer data, a software script will be run that auto-levels the secondary node with manual adjusts following under the direction of the co-pilot. The pilot then moves ROV *Model N* off the secondary node to open the BIA door, retrieve the secondary node cable connector using the manipulator and attached hook, and insert it into the appropriate bulkhead connector.

Task 2: Construct and Install Transmissometer

ROV *Model N* takes the transmissometer down from the surface in the manipulator. The ROV rests the transmissometer on the simulated ocean vent using the guideposts to achieve alignment of the transmitter and receiver through the medium. Continuously gathering data from the internal lock-in amplifier, the transmissometer will sit in that position for the duration of the mission run. Using a Vernier voltage probe, relative opacity is plotted against time on the company's custom GUI.

Task 3: Replace Acoustic Doppler Current Profiler (ADCP)

Power will be disconnected from the suspended mooring platform by using the manipulator to remove the platform connector from the



2013 Technical Report 2

bulkhead connector. The fast-acting pneumatic manipulator is next used to turn the handle in order to unlock the hatch before opening the hatch itself. The ROV removes the ADCP from its cradle and returns it to the surface. The mission crew exchanges the old ADCP for a new one. The ROV then returns to the mooring platform to install the new ADCP. The incredible power-to-weight ratio of the ROV allows a two-way trip to the surface in a short amount of time. The pilot uses the manipulator to close the hatch and relock it using the handle. By grabbing the platform connector using the hook on the manipulator, the connector may be re-inserted into the bulkhead connector with the proper orientation in short order.

Task 4: Remove Biofouling

During the completion of the other tasks, the ROV may return video showing biofouling on the seafloor equipment and instruments. The pilot may position the ROV directly in front of its forward thrusters and activate “tornado mode.” The “tornado mode” is a programmed vector thrust configuration that does not displace the ROV, but spins the forward motors quickly. The turbulence from the front thrusters will safely detach the biofouling organisms without requiring the pilot to release any object in the manipulator. Once all mission tasks are complete and all biofouling is removed from the equipment, the ROV may return to the surface.

Design Rationale

Shape and Frame

The shape of ROV *Model N* was controlled by the mission requirements. In order to have the leveling system for the secondary node require only a single docking, the turning motors were spaced so as to mount over the legs of the secondary node. In order to clear the center of the secondary node, the electronics box was mounted atop four posts so that it could have a clear view of the leveling bubble on the instrument. The next decision was to have the manipulator centered at the front of the vehicle at the extreme lower end to minimize difficulties that could arise when picking up objects from the seafloor. The measuring tool was mounted on the side of the vehicle to prevent interference with the manipulator and turning motors. Wanting to keep the length and width of the vehicle as compact as possible, the thrusters and accumulators filled the

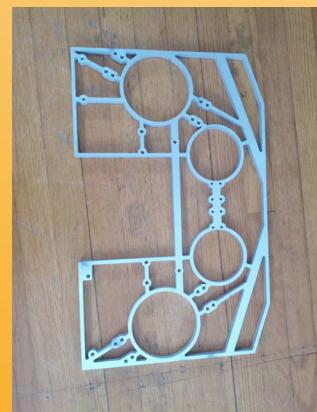


Fig. 2 - One frame half immediately after machining.

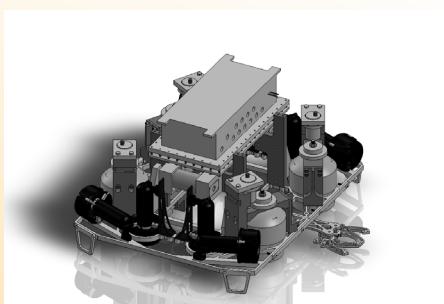


Fig. 3 - Frame assembly.

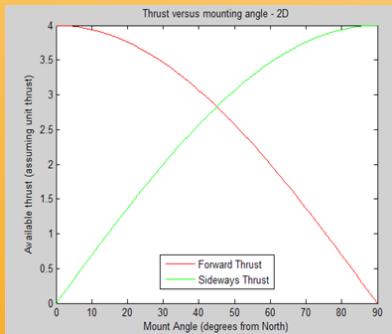
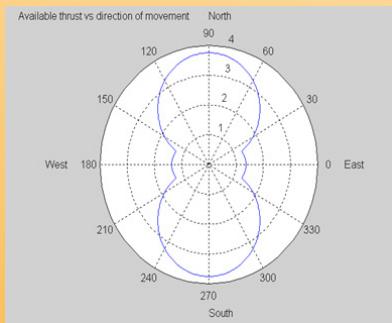


Fig. 4 - Thrust directional analysis.

remaining space by taking advantage of the vertical space available.

The frame of ROV *Model N* was cut by a water jet from a single piece of .635-cm thick Mic 6 aluminum. The material was chosen for its light weight and durability to avoid warping. The intricate shape was designed in Solidworks only after the position of all other attached items were finalized. This design paradigm allows the company to design each tool for its purpose in the mission rather than be forced to design to a pre-existing infrastructure. To reduce the complexity of the design when only a few payload tools are needed, a single-layer frame was implemented rather than a more costly dual-plane frame as used on Aperture Aquatics' 2012 vehicle, ROV *PotaTOS*.

To protect against corrosion, every stainless steel bolt that goes through the aluminum frame is covered in anti-corrosion Tef-Gel brand fastener lubricant. The head of the bolt is also spaced away from the frame by a washer. To further protect the vehicle, every aluminum piece on *Model N* is anodized. To protect the bottom of the frame and tools from the ground, the vehicle is raised on four skids that are 6.8 cm high. These feet are trapezoids with a flat bottom which allow *Model N* to move in any direction while on the floor.

Thrusters

ROV *Model N* uses eight new, custom-designed Seabotix SBT166 thrusters for propulsion. Each thruster is only 17-cm long and produces a maximum of 28.4 N of thrust. While the acquisition of new thrusters presented a significant expense to the company, this purchase was deemed necessary when the thrusters used over the past three years were deemed unreliable for another year of use. These custom-designed thrusters are made to run off 50 Vdc, which eliminated the need for expensive DC/DC conversion boards as used in past years. Because these thrusters communicate between their built-in motor drivers and the microcontroller using RS-485 serial communication, the team could remove their own motor driver boards and utilize a more straightforward communication protocol. Overall, the decision to use brand-new thrusters allowed for reduced electronics and software complexity without sacrificing motor performance.

The four horizontal thrusters are placed at a 20 degree offset to achieve the best balance between turn speed and forward thrust. This angle was determined by performing a thruster analysis at

many different angles until a desirable result was found. The vertical thrusters are placed at each corner of the vehicle. The use of four thrusters for movement along the z-axis not only gives the vehicle improved vertical thrust, but also allows for pitch and roll control. Pitch and roll control gives the pilot greater maneuverability which is needed for the fixed manipulator when picking up objects on the seafloor.

The output of each of the thrusters is determined by the base station software's thruster mixing algorithm, and is discussed in the software section of this report.

Cameras

There are three cameras on-board ROV *Model N*: the main front camera, the rear facing camera, and the down facing camera. The combination of these views allows for a composite image of most of the payload tools on the vehicle. The electronics system on ROV *PotaTOS* can transmit two of the three cameras at any given moment, with the front camera constantly sending video. Switching between the cameras is done by the pilot on the handheld controller. All three cameras use the same Super Circuits Wide Angle Board Cameras inside custom HDPE waterproof enclosures, with the exception of the down facing camera which is housed directly in the electronics box. Analog cameras were chosen for added reliability, lower cost, and simplicity. These particular cameras were chosen for their low weight, small size, and high quality.

The custom enclosures are made with a 3D printer from Taulman 618. This material was chosen after testing Delrin, Aluminum, and HDPE together in the past. Aluminum worked as a watertight material, but was too heavy. Delrin leaked through the side walls of the enclosure when at depths below approximately 35 m. HDPE was both watertight and lighter than either the Delrin or Aluminum. Taulman 618 was eventually chosen for its superior durability and water tightness. These camera enclosures are also used to hold the Transmissometer TX board and Transmissometer RX board.

Electronics Box

With the desire to implement the leveling system for the secondary node in only a single docking, the shape and placement of the electronics enclosure on ROV *Model N* needed to be completely

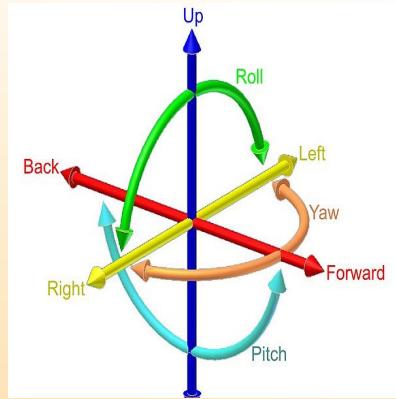


Fig. 5 - A visual representation of six axis movement.

(Image courtesy of Wikipedia.org)



Fig. 6 - Testing the O-ring seal on the camera enclosures.



Fig. 7 - Camera prototypes.

2013 Technical Report

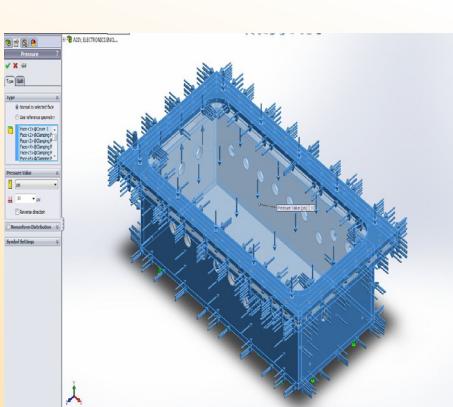


Fig. 8 - Pressure Test on Electronics Box at 208 kPa.



Fig. 9 - The electronics box being machined.

redesigned. After much deliberation, it was decided to create a rectangularly shaped electronics box made from 9.525 millimeter thick aluminum sheets with a transparent, 6.35 millimeter thick polycarbonate, downwards-facing lid. By raising the electronics box on thick stilts, the bulk of the secondary node could fit underneath the box while the handles on the secondary node legs fit under the turning motor shrouds. This design has the benefit of offering a large volume to fit all water-sensitive parts while protecting a camera that can be used to monitor the leveling bubble seafloor instrument during the deployment process.

Inside the volume provided by the box, the entire onboard electronics system lies protected by the forty-six bolts affixing the lid to the rest of the box. While accessing the electronics may prove more cumbersome than in years past, the simplicity of the overall design saves machining costs because welding the aluminum sheets is more cost-effective than milling carriers and designing round polycarbonate tubes as the company has done before. Twenty-four holes provide all the connections necessary for the electrical systems, pneumatic solenoids, and camera housed within the electronics box. In order to save these vulnerable components in the chance of a leak, water-detection systems will be employed using software.

Buoyancy and Ballast

Because ROV *Model N* was designed entirely in Solidworks, accurate volume and mass estimations were available to allow for buoyancy calculations. Because the electronics box is large, there is enough enclosed air to almost balance ROV *Model N*, though the vehicle will still sink slightly. In order to achieve a slightly positive buoyancy, a small amount of hydrostatic proof foam is cut to fit in the crevices of ROV *Model N* and painted for a proper seal and finish. This step will take place two weeks prior to traveling to the international competition to ensure that all modifications that might need to be made can be completed beforehand. The frame of *Model N* has a hole on each corner for .64 cm diameter bolts. These bolts can be laden with enough stainless steel washers to finely tune the vehicle to a neutral buoyancy. This method of ballast also offers an easy method of fine tuning balance to assure that the vehicle sits level in the water.

$$F_{\text{net}} = 0 = mg - \rho_f V_{\text{disp}} g$$

Manipulator

Model N has one fixed manipulator. Having multiple manipulators leads to extra cameras, extra weight and off-vehicle-center mounting of the gripper, which is more challenging for the pilot. This manipulator is used to transport the SIA and the tools to their receptacles. Instead of depending on a moving manipulator, the ROV's thruster layout enables the ROV to pitch up and down without much difficulty in controlling the vehicle. The *Model N*'s manipulator is coated with an ultra-soft polyurethane also known as Sorbothane. It is a nonporous material with a fluid-like consistency and is very durable and elastic in nature.

The manipulator was made from aluminum due to its strength and lightness. It is powered by dual pneumatic pistons. Initially during the design process a single piston manipulator was considered but then later ruled out, as having dual pneumatic pistons made the system more reliable. If one piston fails, the other piston still assures the functioning of the manipulator.

Turning Motors

The turning motor leveling system was dimensioned to fit over the legs of the secondary node, with the bulk of the instrument fitting under the electronics box. Built around a bilge pump, each turning motor consists of a plastic shroud, two tines, and a 3:1 drive gear system all attached to an ABS vertical mount. The two tines fit over the handles on the secondary node legs such that all four rest underneath the turning motor shrouds. The gearing increases the output torque enough to turn the handles. A software script may then be activated that automatically levels the vehicle according to accelerometer data. The copilot may then fine tune the secondary node using manual control over the four turning motors until the leveling bubble is in the correct location. Once the secondary node is level, the ROV may lift straight off the instrument, having deployed the device with only a single docking.

Measuring Tool

ROV *Model N* is equipped with a measuring tool consisting of a 7.62-cm spool with a string wrapped around it. In the fully-wound state,

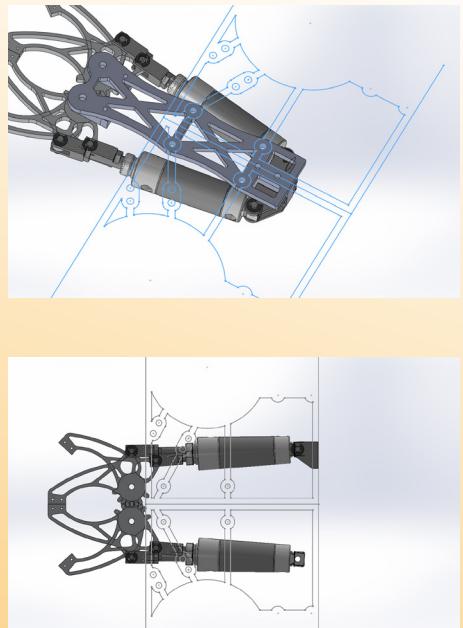


Fig. 10 - Manipulator MK2 with frame layout.

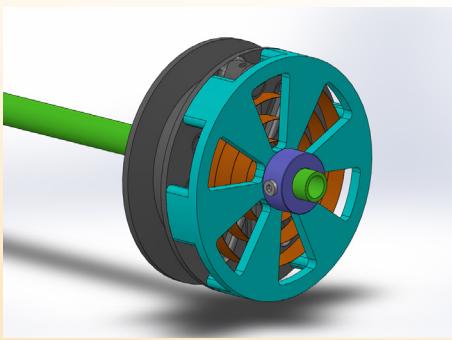


Fig. 11 - Spool assembly, 4 inch

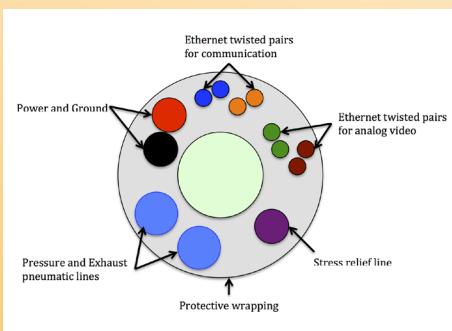


Fig. 12 - Diagram illustrating the innards of the Model N's tether.

a tab slightly protrudes from the vehicle such that it can easily latch onto the red pipe at the end of the Backbone Interface Assembly. As the vehicle moves towards the direction of the secondary node deployment site, the spring-loaded spool unwinds while keeping the string taut. A twelve-notch gray code encoder can measure the length of string in the water down to within 2 cm. With this information, the pilot may find the correct deployment site for the secondary node. With the toggling of a switch on the interface, the pilot may reverse the direction of the vehicle and still track the length of string unwound from the spool. By heaving the vehicle upwards, the pilot may then release the tab from the red pipe.

Tether

ROV *Model N* is equipped with a 23 m long neutrally buoyant tether for power, communication, and pneumatic air supply. For power, the tether has a twisted pair of 10 AWG wire. Communication is handled through an Ethernet wire, using two twisted pairs for analog video transmission and another two twisted pairs for serial communication. There are two pneumatic tubes in the tether: one to send pressurized air to the ROV and another to vent air used by the system to the atmosphere. To make the tether neutrally buoyant, there is a strip of foam along its length with a cross section of .92 cm x 1.3 cm. To protect the tether and make it easier to manage, there is a snake-skin like wrap on the tether.

Pneumatic System

The pneumatic system on ROV *Model N* is used to drive two of the vehicle's tools: the manipulator and the backup measuring system, which is a piston-driven pin release for a fixed-length measuring rod. A compressor is plugged directly in to the tether. The other end of the tether is plugged in to a pressure accumulator on the ROV. This accumulator assures that pressure supplied to the tools does not drop if both tools are actuated simultaneously due to the time it would take to send pressurized air over the length of the tether. This air then travels in to a pneumatic solenoid bank. This bank has a valve for each tool and is controlled by the ROV's electrical system (which takes in controls from the Xbox 360 controller). Air from these valves is then directed to appropriate pneumatic pistons to drive each tool. Once air is used, it is vented to another pressure accumulator. This accumulator serves the same purpose as the other, assuring a stable supply of pressure. The air then travels from this accumulator up the



2013 Technical Report 8

tether again to a venting silencer at the surface. This silencer quiets the pneumatic system without negatively impacting performance. The pneumatic system vents at the surface instead of at the ROV to increase the pressure differential since the pressure created by surrounding water at depth would reduce the effective pressure of the system.

Transmissometer

The company-designed transmissometer is an independent system from ROV *Model N* that receives 12 Vdc power from the surface. Its tether consists of a power line, ground line, and five lines of CAT5 ethernet cable. The body of the transmissometer consists of a rigid frame of ABS plastic made negatively buoyant by attached weights and held upright by sealed foam. The frame then rests against the alignment guides on the simulated ocean vent. Two of the company's camera boxes are positioned facing each other through the target area to house the sensing apparatus.

The transmissometer transmitter (TX) board is mounted inside one of the camera boxes on the frame. The TX board consists of three parallel infrared LED's that shine out of the box. The LED's are controlled by two signals at their positive and negative ends.

The transmissometer receiver (RX) board is mounted inside the other camera box. The RX board receives power from the surface and sends an output signal from a phototransistor. As the infrared light from the TX board is attenuated through the target medium, the phototransistor releases more electrons from the base-collector junction, increasing the current through the device. This increase in current lowers the voltage of the output signal due to the biasing of the phototransistor. The output signal is passed through a voltage follower to avoid degrading the signal.

The transmissometer surface board receives the signal from the RX board and compares it to a signal in-phase and at the same frequency as the pulse sent to toggle the LED's on the TX board. By passing the two signals through a lock-in amplifier, only a DC signal will remain that is associated with that specific frequency, even in a noisy environment with other signals of similar frequency. By passing the DC signal to a Vernier Voltage probe, the changes in this DC signal may be interpreted as relative ocean turbidity and graphed against time using custom software.

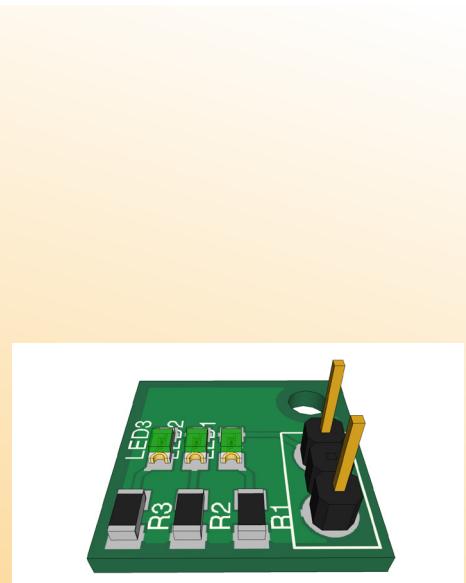


Fig. 13 - Transmissometer TX board.

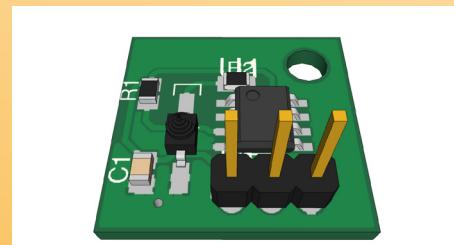


Fig. 14 - Transmissometer RX board.

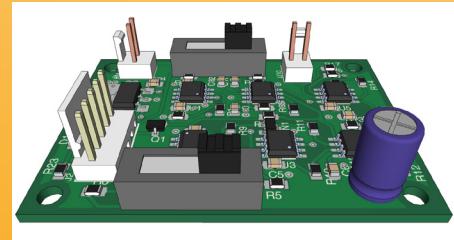


Fig. 15 - Transmissometer surface board.



Fig. 16 - The main board resting on the microcontroller adaptor board.

Electronics

The electronics system of the Edison Submersibles ROV *Model N* is designed to provide complete user control over all of the ROV subsystems, including thrusters, video cameras, pneumatic actuators, and leveling system. The electronics system includes the main microcontroller board, microcontroller adaptor board, application board, power board, and interface adaptor board.

The main microcontroller board is the central point of communication and control for the subsea electronics system. The board is a modified discovery board from STMicroelectronics. The processor used is a STM32-F4 that utilizes a Cortex M4 series ARM processor. This processor is responsible for sending and receiving data from the tether, parsing data from sensors, interpreting and calculating the necessary thruster commands, controlling the pneumatic actuators, managing the video multiplexing, and activating the turning motors with PWM. The tether communication protocol used is RS-485. It offers increased range over RS-232 and provides noise immunity due to the differential pairs used. The internal communications for subsystem to subsystem communication is I2C. The IMU and the magnetometer act as slave devices on the I2C bus, and will transmit the necessary sensor data when requested to by the main processor. This sensor data can include internal enclosure temperature, 24V bus voltage and current, and IMU positioning data from an accelerometer, gyroscope, and magnetometer. Thruster speeds and directions from the user input device (XBox 360 controller) are interpreted by the microcontroller and then are sent out on the motor bus.

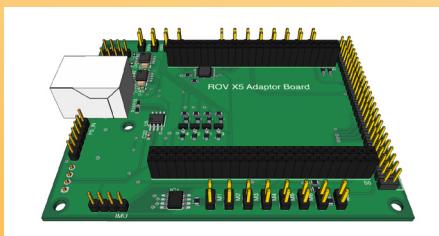
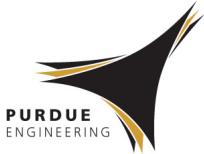


Fig. 17 - The microcontroller adaptor board.

The microcontroller adaptor board acts as a shield for the main board and a connection to the application board. The eight thrusters receive their instructions from this board. All input and output signals are routed to GPIO pins on the main board through the adaptor board. The RS-485 communication block resides here, and the two 2-to-1 video multiplexers are located here as well. Four Darlington pairs serve as water alert sensors that alert the pilot to water in the electronics box if there is an increase in conductivity between any of the sets of two leads positioned as suspect leaking points in the otherwise dry chamber.



2013 Technical Report 10

The application board contains system components pertinent only to this year's mission theme of Ocean Observing Systems. It receives 12 V for operating the turning motors and 3.3 V for logic from the power board. The application board receives the two motor select signals, direction signal, and PWM from the main board through a header connecting to the adaptor board. The select lines operate a 4-to-1 multiplexer that sends motor enable signals to each of the half-bridge motor drivers for the high-side voltage. A common low-side driver receives the PWM signal. The separation of the high-side and low-side voltage to the connected motors allows for direction control over PWM with just five half-bridge motor drivers.

The power breakout board helps to simplify the internal wiring and +48V power distribution to the main board and each of the DC/DC modules. This board has one input connector for the +48V wiring from the tether and fourteen individually fused outputs. Linear regulators create a +12V, +5V, and +3.3V output power line from the +48V provided over the tether, each of which is temperature-monitored. The connection to the microcontroller is voltage and current regulated. Each of the fast-blow fuses is connected to an alert signal that allows for rapid identification of any blown fuse on the power board. The first output of the device send power to the microcontroller adaptor board to power the thrusters. A second output is used for a +12V, +5V, and +3.3V connection for the main microcontroller board. A third output sends +12V to the solenoid bank, cameras, and IMU. Another output sends data about any alerts about voltage, current, temperature, or blown fuses that have been raised. The remaining three connectors are left open for debugging or future development. Each channel voltage also has a LED indicator to help to quickly determine the status of the fuse.

The interface adapter board acts as the topside interface between the RS-485 and video signals that come from the ROV and the computer and video monitors. It is responsible for converting the RS-485 data into USB, and it breaks out the multiplexed video lines with simple RCA video connectors.

Software

The control system of ROV *Model N* is meant to give the user an easy and intuitive way of controlling the vehicle. The control system has two distinct parts; the on-board software and the base station software. The base station is the brains of the operation. It takes user

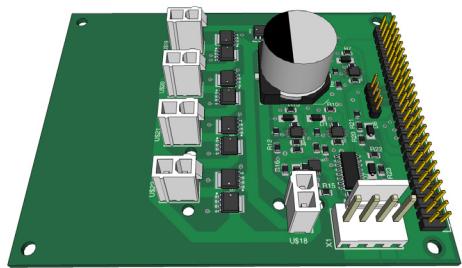


Fig. 18 - The application board.

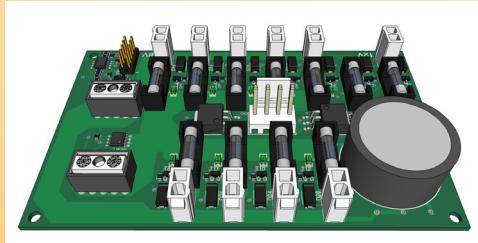


Fig. 19 - The power board.



Fig. 20 - Interface adapter board.

2013 Technical Report

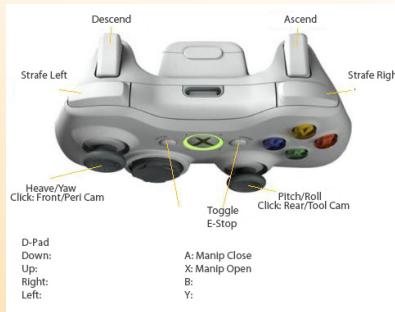


Fig. 21 - Xbox 360 controller mapping.

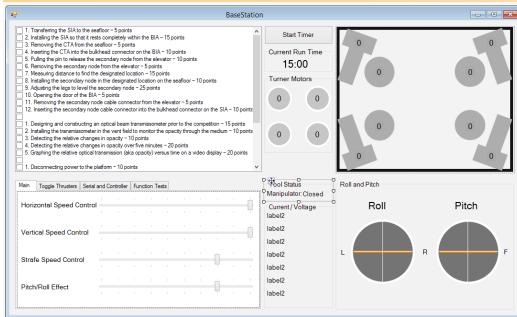
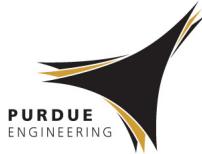


Fig. 22 - Graphical User Interface displaying relevant sensor data and thrust vectors.

input in the form of an Xbox 360 controller and computes thruster vectors for the vehicle's movement, as well as the position of the pneumatic systems and which video feeds are currently displayed. The base station was written in C++ and designed to communicate at a high baud rate to reduce lag in the movement of the vehicle. Using readily available libraries for the game pad controller, we were able to easily interface the controller with our software. It also displays relevant sensor data and thrust vectors to the pilot via a graphical user interface, as can be seen in the GUI screenshot. The base station software is responsible for core tasks such as communication with the vehicle processor, interpreting sensor data, controlling pneumatic actions and movement of the vehicle.

The on-board vehicle software is written in embedded C. The main ARM processor code is compiled using the EWARM libraries.

The main controller board talks to the integrated accelerometer allowing us to perform auto leveling actions as well as position holds. This allows much more fine grain control of the vehicle. Incorporated into our designs this year is a H2O sensing circuit. In the case of enclosure failure we can notify the pilot and perform an emergency shutdown of the system to prevent as much damage as possible. The main board utilizes the RS-485 serial protocol to communicate with the base station, receiving control values for the motors, pneumatics, and cameras on board the vehicle, as well as sending sensor data back up to the user. Any sensor data received is sent back to the base station and displayed on the graphical user interface, such as positional data and electrical voltages and currents. To control the solenoids, the processor takes the received instructions and assembles a byte of data to serve as a solenoid status byte. This byte is then output via the serial peripheral interface to the solenoid shift register, which then activates the appropriate solenoid. The motors are all controlled by a half duplex RS-485 bus. Each of the motors are individually assigned addresses and can be sent speed vectors and respond with information like motor temperature, current RPM and current power draw. The processor also uses general purpose digital outputs to create logical high and low switches to control which camera view is selected by the video switchers.



2013 Technical Report 12

Reflections

Challenges

In the interest of reducing manufacturing costs, the Purdue IEEE ROV Team decided that an alternative to the round polycarbonate electronics enclosures that the team has become well-known for over the past two years must be found. After investigating a few possibilities, the team decided that a welded aluminum electronics box with a polycarbonate lid would be the most effective solution for its cost and for the reduced size of the electrical systems. Even though it was decided to put the lid on the underside of the box to see the mission area and to minimize water damage in case of a breach, leaking was still a primary concern for the team. The team tested several different thicknesses of polycarbonate lids both in Solidworks and in a pool to achieve a manageable dimension that would allow several bolts to hold it in position without flexing under the pressure at extreme depths. Dual weld lines were made to provide extra protections to the electronics box at the sides. All bolts and connection holes were sealed with 2-hour dry Loctite brand marine epoxy, the only reliable sealant that the team has ever found for a pressurized seal.

Troubleshooting Techniques

After initial population of the Application PCB, the motor driver channels were not functional. Troubleshooting began with verification of expected signals from the microcontroller lines. The problem was then isolated to the driver ICs. Despite all of the expected input signals, the expected output was not being produced. The next step was to verify every single component in the circuit for build errors. No problems were identified.

However, it was then discovered that the circuit would intermittently operate correctly. It was determined that a bad solder joint was the root cause of the issue. Sometimes the driver was not being enabled due to a low voltage lockout condition or possibly the enable line itself. After reflowing the solder on the whole board, the problem has been resolved.

The bad solder joint was likely due to the very small size of the particular motor driver IC that was employed. The overall process could have been improved by avoiding chips that are small where

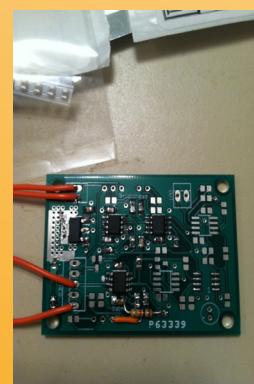


Fig. 23 - Electronics troubleshooting.



Fig. 24 - The team work-shop.

there are larger chips with acceptable functionality. Further, population of multiple boards could have helped to more quickly isolate a construction issue from a design issue.

Lessons Learned and Skills Gained

The experience of building ROV *Model N* has taught both new and returning members many important skills. Most important of which is team work. No course can teach the ability for electrical and mechanical engineers to work together to make an end product that is up to professional standards. The Purdue team always treats its vehicles as test beds for learning. The electronics team learned how to code software with an ARM processor to control all of the vehicle's onboard systems.. There were a few new electrical members whose previous skill set ranged from designing some simple PCB's to never having done much soldering at all. The electronics team also refined its ability to design PCB's for professional printing, etching, and silk screening. The team struggled to design this year's vehicle with a shortage of mechanically focused team members. The team had to practice good project management skills to maintain forward progress among team members of vastly different skill levels. A returning challenge for the mechanical group this year was working with an outside machine shop. Because the team had enough funds to outsource some of its more complex pieces, an on-campus, University-affiliated machine shop was contracted. The mechanical group worked on refining its Solidworks designs to allow for cost-saving manufacturing. By working with a professional machinist to communicate clearly the engineers' intent, tolerances and other important criteria were reworked. The iterative and continuing nature of this process surprised everyone on the team because this year's team members had never gone through this process before.

Future Improvements

There are a few improvements to consider on ROV *Model N*. While the vehicle is more than capable of completing its mission tasks, there are a few luxuries that have been requested under this year's new pilot: depth holding, controllable pitch/roll stabilization, and faster vehicle response. The first two may be accomplished by software assistance. Better ROV responsiveness would be accomplished by reducing the weight of the vehicle, which may be accomplished by either reducing or replacing the heavy aluminum electronics box raised on thick stilts. Despite not having found a reliable, wide-angle digital camera



2013 Technical Report 14

that can be feasibly waterproofed, the team would enjoy being able to implement more digital signal processing to aid in the propulsion of the vehicle and manipulation of objects underwater. Despite the tantalizing nature of these changes, the team must seriously consider the benefit of these features against the cost and implementation time that they would require.

Group Reflection

This is the fifth year for the Purdue IEEE ROV team. The team began in 2009 with four team members, a \$500 budget, and a 5th place international finish. With the team size increasing to seven, nine, and seventeen and the budget increasing to \$6,000, \$14,700, and then \$24,000 in 2012; the team rose in its final placement at the International Competition to 4th, 2nd, and 2nd just last year. Dedicated to earning 1st place this year, the Purdue IEEE ROV Team returns in force with eleven members and a \$24,742 budget.

The team experienced its first transition of the captaincy and coped with changes in experience, management styles, and communication methods. With many of the past stalwarts of the team graduated and moved away, the team wrestled with its own inexperience designing and constructing ROV's. However, with the strong legacy of the team and mentoring from those past team members, the team came to terms with its abilities and still produced a superb ROV. The team has learned more collectively this year than any other year since its inception. With a year of growth, the returning members of the team next year are setting their sights higher and firmer.

Team Safety

The Purdue IEEE ROV team considered safety during both construction and operation of ROV *Model N*. Operation of all power tools required the use of OSHA approved glasses. The use of advanced tools owned by the team, such as a drill press and horizontal band saw, are safer than hand drills and hack saws when used properly because the work piece is not held by the user. Operation of the vehicle is made safe through many measures. Pneumatically, the ROV has a pressure regulator and an emergency quick release valve that can empty the system in a few seconds. Every part of the pneumatic system is rated to at least 689 kPa, well above the operating pressure of 270 kPa. Electronically, the ROV has a large array of onboard fuses and systems designed to not cause damage if communication is lost



Fig. 25 - The Celebrate Science Indiana IEEE Booth



Fig. 26 - ROV PotaTOS and materials at PSEF NEXT Day.

with the surface. There is also a main inline fuse on the tether at the surface. Electrical system activations on the vehicle are slightly staggered over approximately two seconds to reduce high inrush at vehicle start up. Mechanically, there are as few sharp edges as possible throughout the ROV. There are a couple points on the ROV's tools that team members know to be aware of when in operation, such as the gripper and measuring rod pin release. In the team's five years of operation, only a few minor scrapes and no serious injuries have occurred.

Outreach

The Purdue IEEE ROV Team believes that educating grade school students about the benefits of STEM (Science, Technology, Engineering, and Mathematics) and the Marine Engineering industry is important. The students the team reaches are often unaware of the multiple opportunities these fields could have for them and how to access these benefits for themselves. The team has utilized its 2012 ROV, *PotaTOS*, throughout the year as an ambassador for STEM learning at events such as Hobart High School EXPO and on campus grade school visits such as PSEF NEXT Day. These events put the vehicle and the team in front of thousands of young students from Indiana. This year, the Purdue team worked with the Eli Whitney School in Chicago in an advisory capacity as part of its long-term commitment to a mentoring partnership. While this was mainly limited to email exchanges, the team hopes that this partnership can continue to grow stronger in the coming years. Finally, the team has made an attempt to educate as many Purdue students as possible about the Marine Engineering Industry. Most students on campus have no knowledge of what opportunities are available to them and presenting the vehicle at many public events is helping to give the field necessary exposure in the absence of other outlets.



2013 Technical Report 16

Expense Report

Item	QTY If Applicable	Expense Cost USD / Unit	Donations Cost USD / Unit	Income Monetary
ROV Construction				
Waterjet Aluminum Frame		\$450.00		
Assorted Machining (from Local Machine Shop)		\$2,500.00		
Raw Aluminum, Stainless Steel, and Plastic Stock		\$1,920.00		
Stainless Steel Bolts & Washers		\$146.00		
Glues and Tef-Gel Corosion Protection		\$65.00		
Bearings		\$110.00		
Pneumatic Systems (Solenoids, Fittings, Tubing, Pistons)		\$207.40		
Electronics Box O-Rings	2	\$6.25		
Seabotix SBT166 Custom Thrusters (25% Discount)	8	\$1,103.15	\$365.51	
Board Cameras (from Supercircuits)	3	\$93.41	\$15.42	
Reused Tether Materials (Power Line, Ethernet, Pneumatic Tubes)		\$370.00		
Binder-USA Waterproof Connections		\$825.80		
Laptop to Drive ROV (Previously Owned)		\$1,000.00		
Reused Video Displays (televisions)	2	\$147.66		
Circuit Board Printing (from Advanced Circuits)		\$161.77	\$500.00	
Custom Electronics (Microcontroller, Fuses, Connectors, etc.)		\$532.47		
Transmissometer Probes (from Vernier)		\$84.00		
Turning Motors		\$248.65		
Other/Travel				
Flying to Seattle (8 people)		\$3,368.80		
Hotel in Seattle (5 Rooms)		\$2,203.00		
Rental Minivan		\$932.38		
SolidWorks	20		\$1,300.00	
Competition Fee			\$100.00	
Prototyping Costs (Electrical and Mechanical)		\$650.00		
Poster		\$150.00		
Presentation Materials		\$90.00		
Power Tools and Accessories				
Set of Mission Props for Practice		\$248.73		
Air Compressor		\$242.99		
Donations				
Purdue Office of the Provost				\$5,000.00
Indiana Space Grant Consortium				\$7,500.00
Purdue Engineering Student Council				\$4,800.00
Purdue IEEE Student Chapter				\$4,640.41
Northrop Grumman				\$1,000.00
Purdue College of Engineering				\$1,500.00
Purdue Student Government				\$301.65
Summary				
Please Note: Quantity is taken into account before values are summed				
ROV Construction		\$17,788.54	\$2,970.36	
Other/Travel		\$6,953.52	\$26,100.00	
Donations				\$24,742.06
TOTAL		\$24,742.06	\$29,070.36	\$24,742.06
Total Remaining Balance		\$0.00		



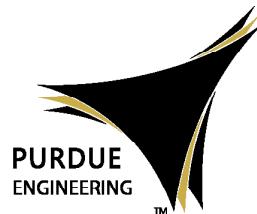
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Acknowledgements

Monetary Donations



NORTHROP GRUMMAN



PURDUE
OFFICE OF THE PROVOST

and
Purdue Student Government

Discounts or Non-Monetary Donations



Edison Submersibles would also like to thank:

All the volunteer judges of the MATE Competition
MATE Center for providing us with this opportunity
Shedd Aquarium for hosting the Midwest Regional

Veteran members Clayton Kleppinger, Clement Lan, and Rob Swanson for mentoring new electronics members

Lawrence Goldstein for mentoring our new mechanical members

Seth Baklor and Spencer Julian for aiding the new captain

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Dr. Mark Johnson for use of the Computer Engineering Senior Design Lab

Eta Kappa Nu, Beta Chapter for use of the HKN Lab

Ross Howard for his facilitation of purchases

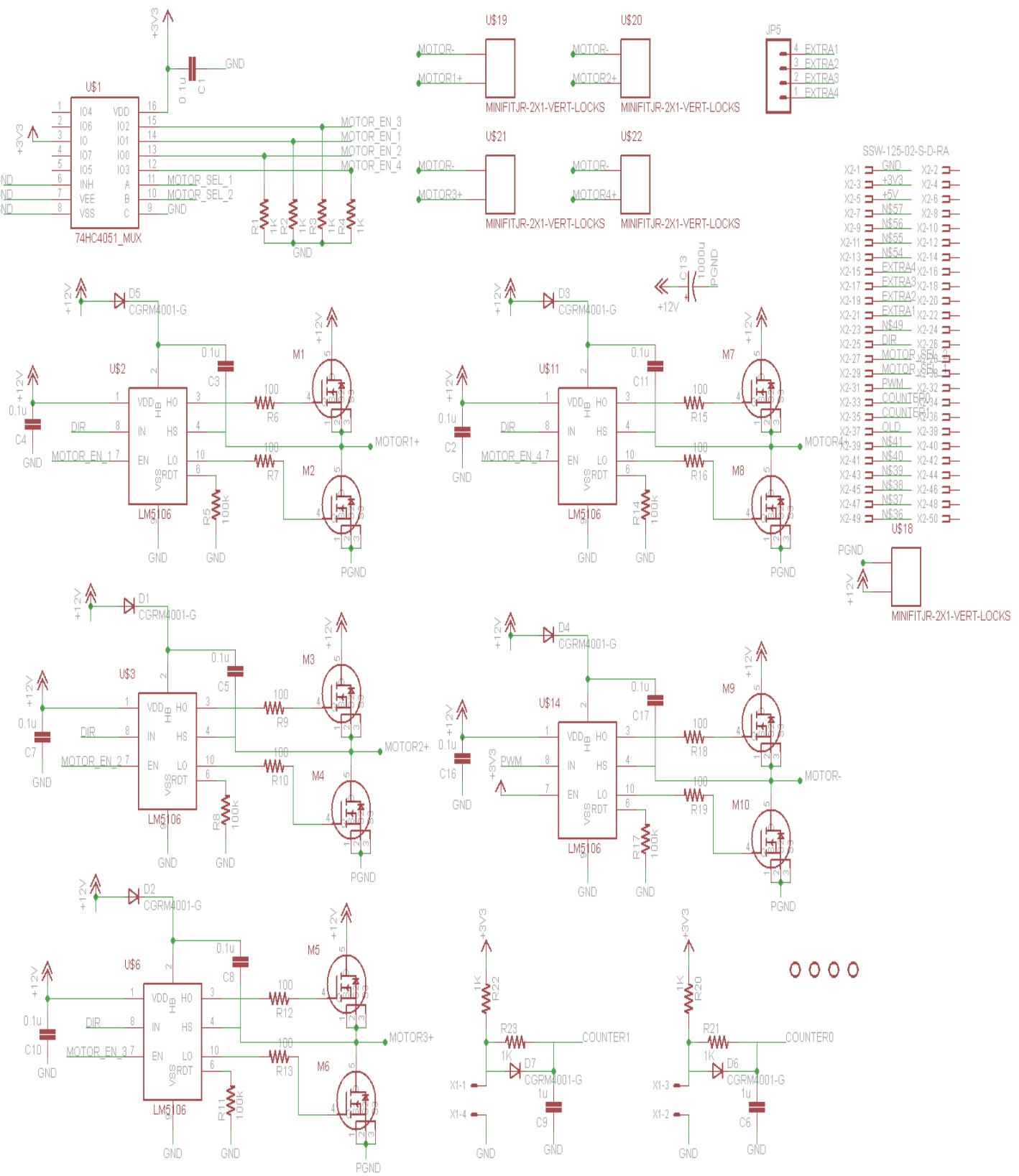
Friends and Family for putting up with us during the build season



2013 Technical Report

Appendix A - Electrical System Block Diagrams

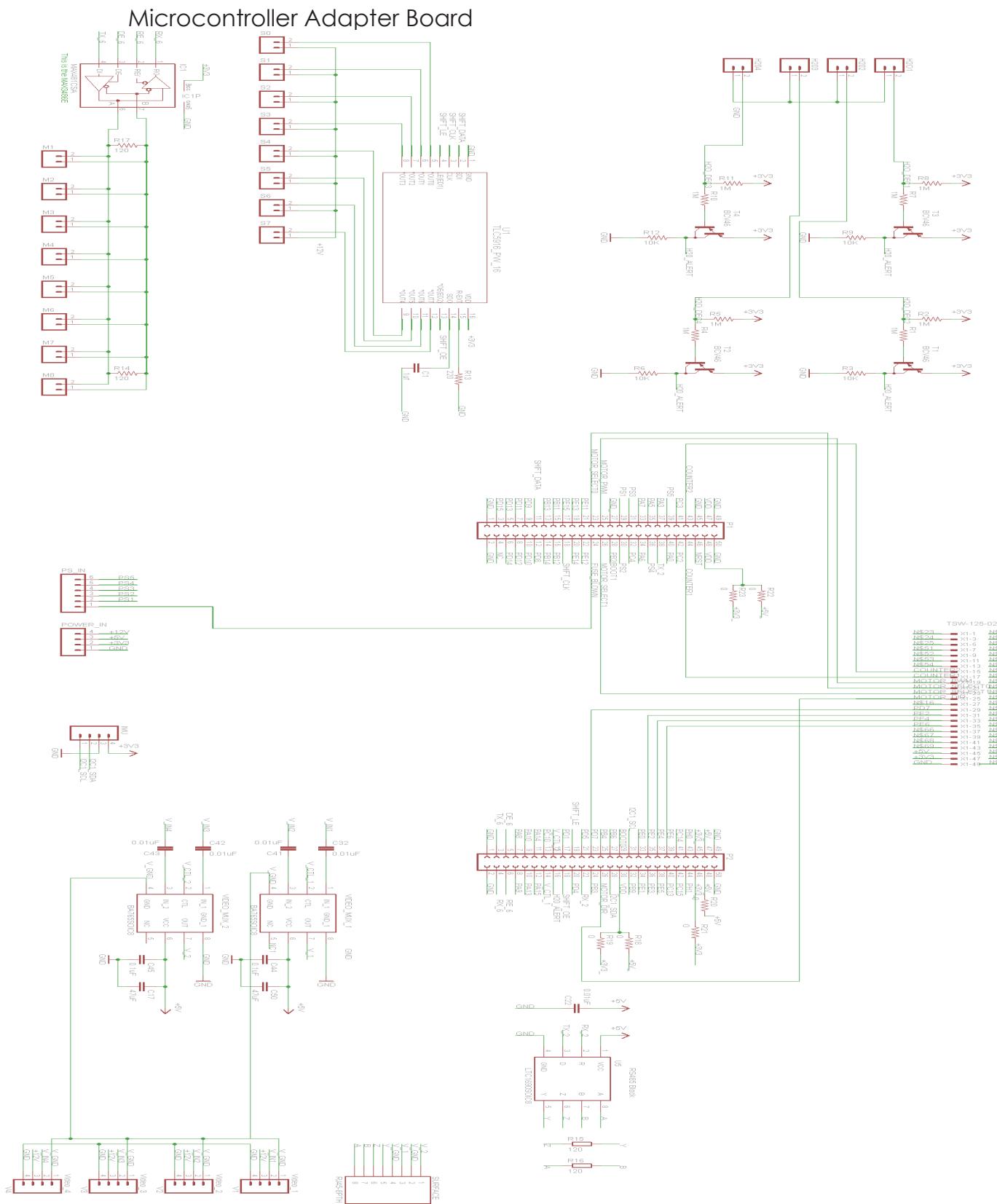
Application Board





2013 Technical Report

Appendix A - Electrical System Block Diagrams

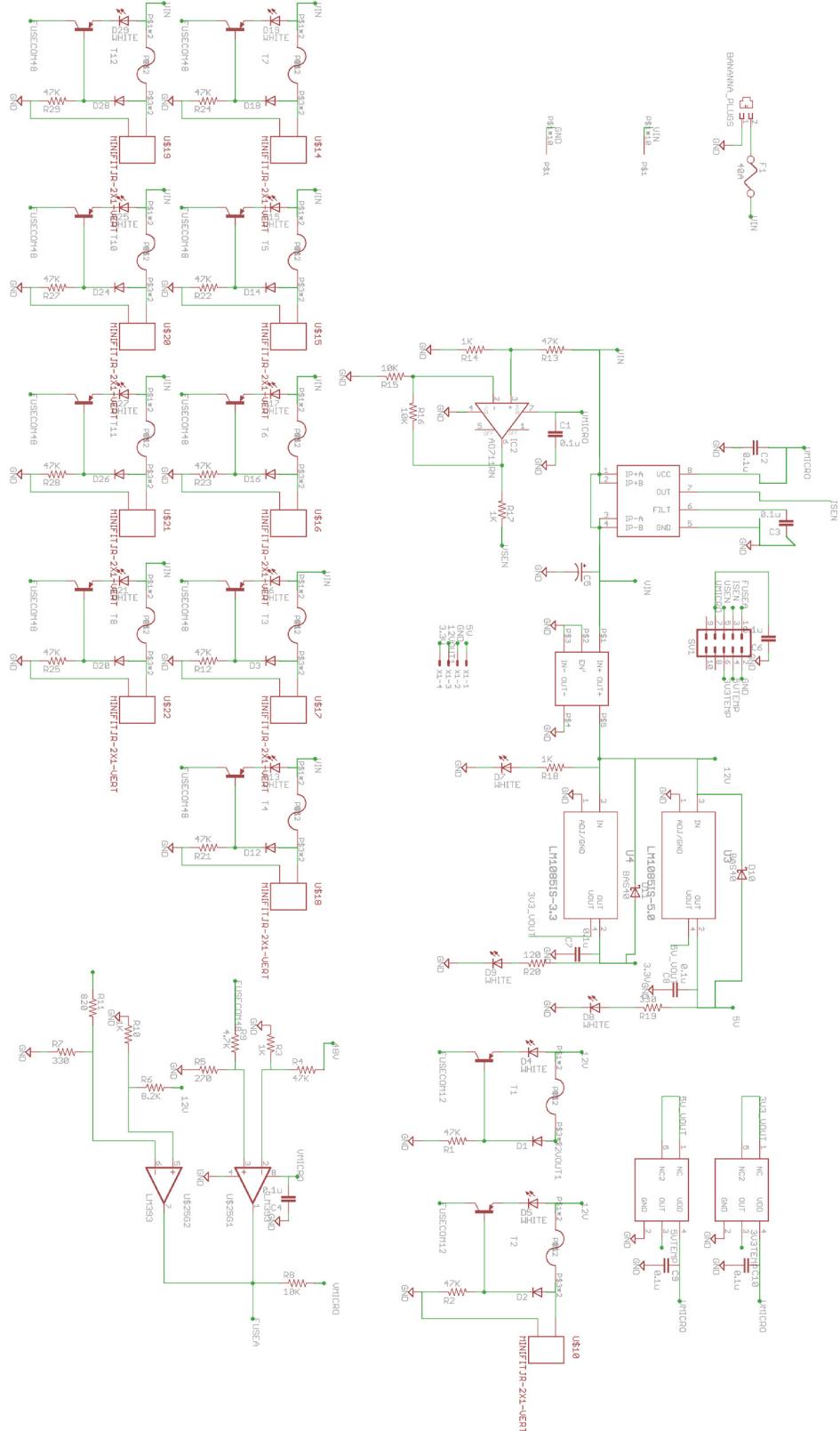




2013 Technical Report

Appendix A - Electrical System Block Diagrams

Power board

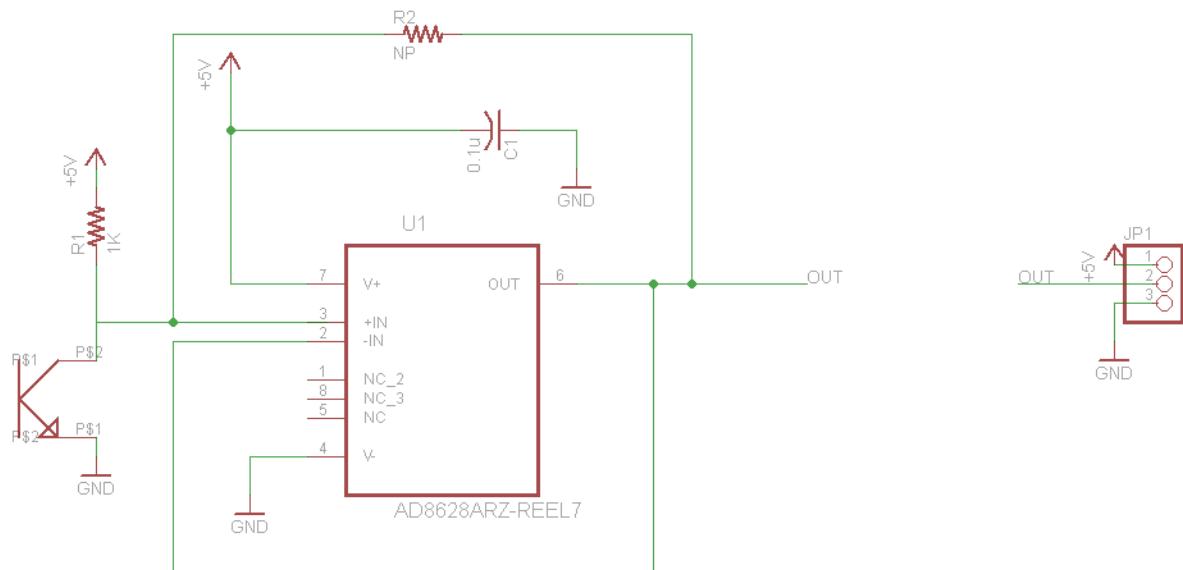




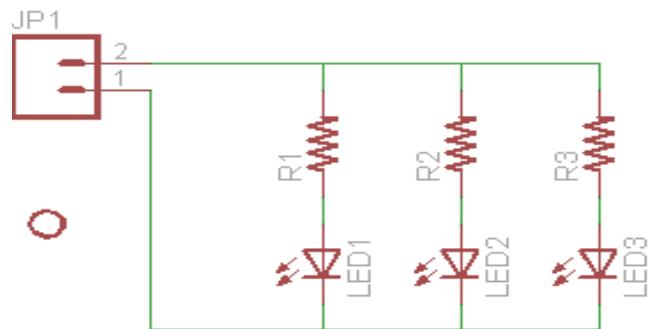
2013 Technical Report

Appendix A - Electrical System Block Diagrams

Transmissometer RX Board



Transmissometer TX Board

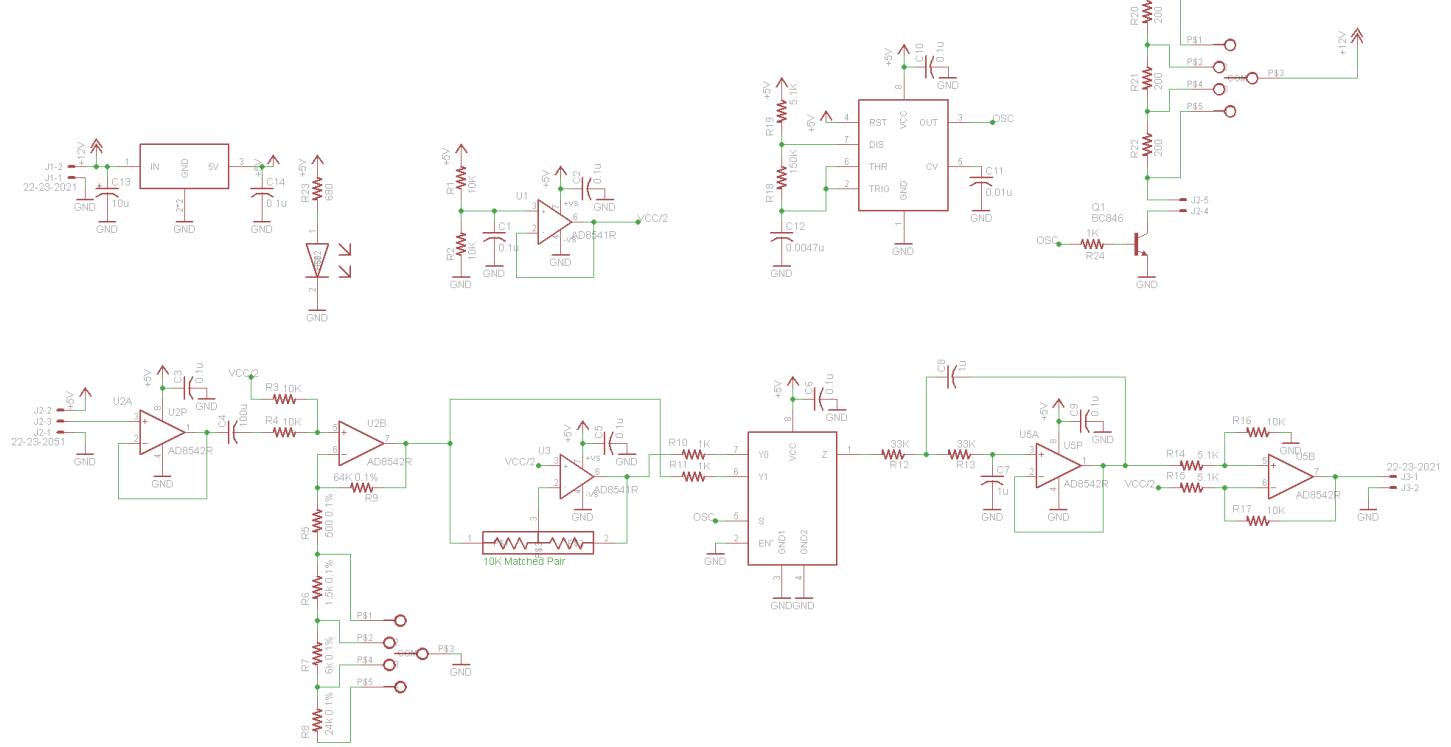




2013 Technical Report

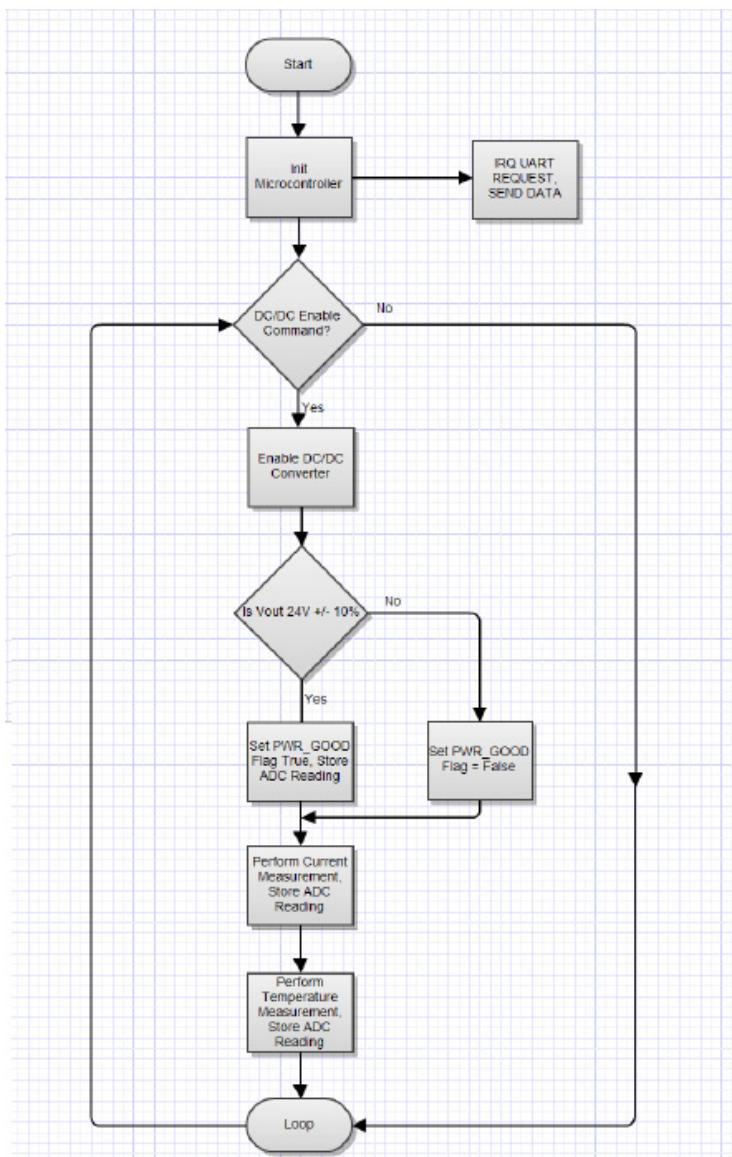
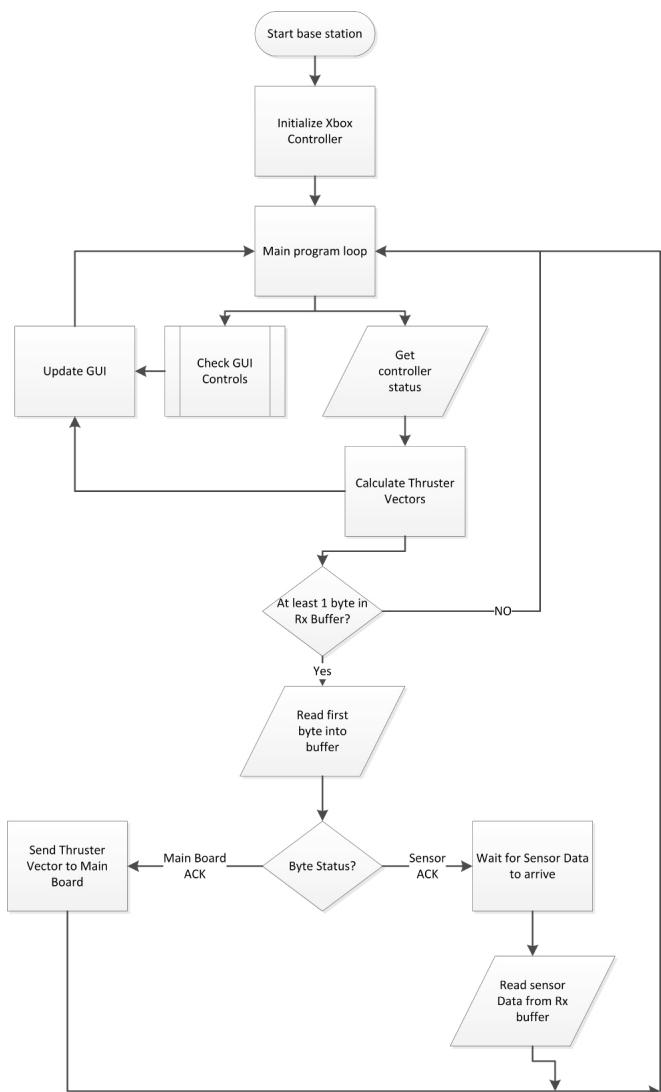
Appendix A - Electrical System Block Diagrams

Transmissometer Surface Board



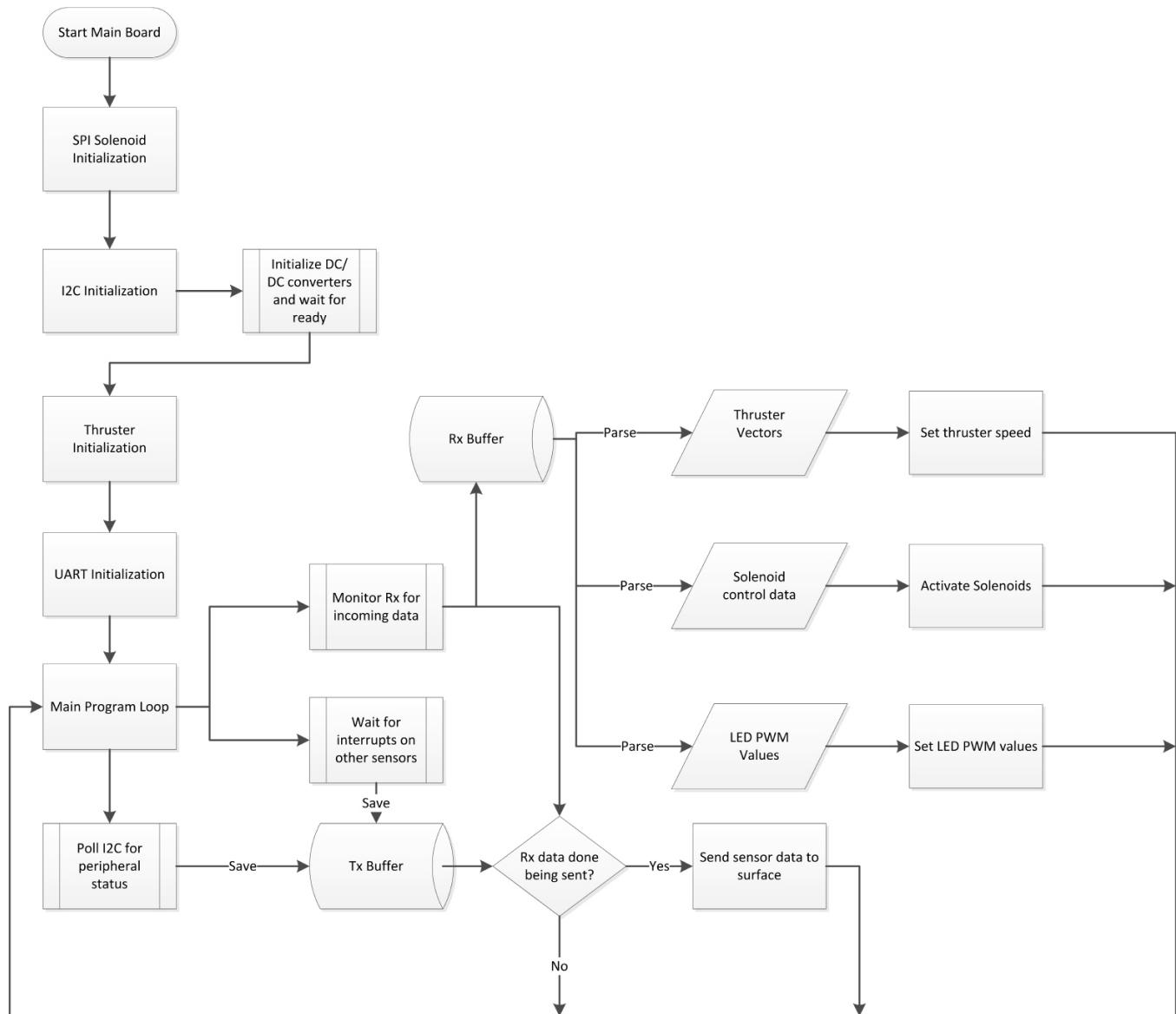
Appendix B - Software Flowcharts

Basestation & DC/DC



Appendix B - Software Flowcharts

Main Board





2013 Technical Report

Appendix C - Pneumatic System Diagram

Pneumatic System

