

## High Technology High School

### FURY Technical Report



**Figure 1: Picture of "Fury"**

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## Abstract

The goal of the Fury Team of High Technology High School was to produce a remotely operated vehicle (ROV) capable of effectively and safely completing the two mission tasks of the Ranger Class division for the 2006 MATE ROV competition within 20 minutes. The first task, “Complete the Central Node”, requires the ROV to transport an electronics module from the surface, then position it inside a frame. The door of the frame is then opened to reveal two open ports. The ROV must retrieve a power and/or communications cable connector from the seafloor then insert it into the proper port. The second task, “Trigger a Malfunctioned Acoustic Release Transponder to Release an Instrument Package”, requires the ROV to remove a release loop that will free the instrument. In addition to completing these two tasks, the ROV must adhere to competition requirements. The maximum surface power may not exceed 13 volts or 25 amps. The ROV must withstand water pressure at a depth of up to 5 meters and be able to operate in chlorinated freshwater. Also, the mission team must be capable of transporting the ROV to the control shack, and the ROV must have an appropriately long tether cable. Finally, the ROV must be safe to operate, have a fuse on the electrical systems, and not release any materials into the environment.

## Photographs of Completed ROV



**Figure 2: Rear View of ROV**



**Figure 3: Angled View of ROV**



**Figure 4: Side View of ROV**



**Figure 5: Top View of ROV**

## Budget/Expense Sheet

Like any engineering project, funding is required to purchase the various hardware, software, and accessories necessary to construct a working ROV. ClassLink, a company focused on education technology, provided the funding for our project. When a part is needed, a team member orders it using their own money, then submits the receipt and is refunded using money in an account held by High Technology High School. This method gives the team flexibility and speed in purchasing power.

For Expense Sheet, see Appendix A, pages A1 and A2.

## Electrical Schematic

The electronic system on the ROV is divided into three distinct subsystems. The first is the surface control board, focused around a Microchip PIC18F4680 micro controller. This chip is responsible for capturing analog input from two joysticks, parsing the data and creating a transmission signal that is sent to the ROV's on board control system.



**Figure 6: Bob reviewing the programming**

The transmission subsystem, the second part of the electronics system, uses a pair of Maxim MAX3232e RS-232 transceivers; one on the surface and one on the ROV. The top side transceiver amplifies the signal generated by the PIC18F and encodes it in RS-232 format. The bottom side transceiver reverses this process and places the received data onto input pins of the two bottom side control chips. The process occurs at a speed of 9600 baud, which is dictated by the software on the PIC chips.

The third subsystem has two Microchip dsPIC30F3010 micro controllers that are programmed to accept the transmission from the top side chip and convert the received information into valid PWM signals. While each of the two chips receives the full signal, each only parses the portions of the signal which apply to the motors it controls. Each PWM signal (6 total, 3 on each chip) is mapped to a pair of pins and hooked up to an NMIH-0050 H-Bridge. The H-bridge acts as a floodgate for the 12V supply, using the 5V signal generated on the pins of PIC chip to adjust the flow of the 12V supply to the motors.



**Figure 7: Pat working on circuit board**

Each of the three micro controllers requires a clock and a 5V power source. A 16.384MHz ECS300C Oscillator on each chip provides clocking. Power is provided to the chips from the 12V supply through 5V regulators.

Safety is provided in two ways. First, there is an overall 25A fuse in place at the entrance point to the system. This prevents an overdraw by the motor system. Second, each motor is protected by a 5A diode, each camera by a 0.1A diode, and the voltage regulators by a 1A diode. This protects all vulnerable

devices in the event of an accidental polarity reversal.

For Schematic, see Appendix B, pages A3 through A5.

## Flow-Chart of Software in the ROV

See Appendix C, page A6 and A7.

## Design Rationale

### Frame

The robot's frame was constructed out of 0.64cm Steel Rod with weld joints. This material was chosen because it is strong, rigid and has a small surface area. 0.64cm rod is also inexpensive, easy to cut, and big enough to weld butt and cross joints. The frame consists of several structural members, made from parallel rods about 3.81cm apart. These provided a mounting surface for our actuators and motors. By compressing two plates onto either side of the parallel bars, we created moveable mounts. This allows our horizontal thrusters to move up and down, so that the thrust is along the center of lateral resistance.



**Figure 8: A Top-view of the Frame**

The welding of the frame was accomplished using a flux core MIG welder. The welder and safety equipment were provided by team mentor Mr. Bill Wetzel. Since none of the team members had

experience welding, three senior members received instruction from Mr. Wetzel. After the welding was completed, the rod was sanded and spray painted with Rustoleum black paint to prevent rust.

### Electronic Module System

Our four electronics module release actuators are attached to the frame so that they have two degrees of freedom, and can be adjusted to fit the competition's electronics module precisely. This adjustability is important because without a precise fit to the electronics module, the actuators may fail to release or catch on the U-bolts.

The two degrees of freedom are achieved by each pair of actuators (front and back) being mounted to a common set of parallel bars by two compressed plates, allowing lateral adjustment. Each of these assemblies is then mounted on each side to a set of parallel bars on the bottom of the robot, using the same method. This allows horizontal adjustment for each pair of actuators. This flexible mounting method allows for sizing errors of up to a few inches in either direction.

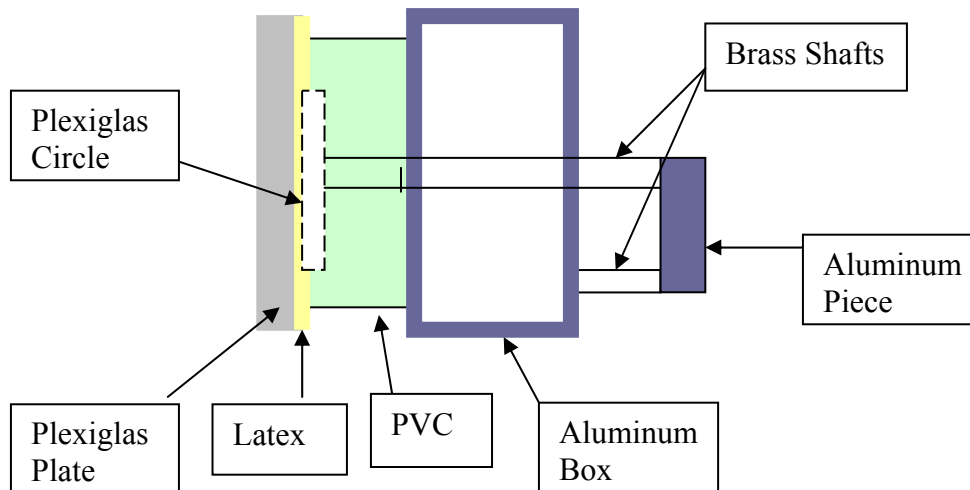
### Release Mechanism

Because of the underwater issues with motors, a hydraulic system was chosen for the release mechanism in the second task. The system uses bilge pump powered actuators that are attached to the bottom of the robot. Each actuator was built from a 10.16cm square of Plexiglas, a 10.16cm square of latex, a 7.62cm diameter 2.54 cm long



**Figure 9: A Disassembled Actuator**

piece of PVC pipe and a 10.16cm square aluminum box. Holes were drilled through the center of the Plexiglas square and the aluminum box. The outer hole on the aluminum block was tapped to 0.32cm and the hole in the Plexiglas was tapped to a 0.64cm pipe tap. The threaded end of a 0.79cm barb was screwed into the Plexiglas plate and connected to a piece of tubing that led to piping on the bilge pump.



The actuator was assembled using screws that passed through the Plexiglas plate and latex, around the PVC and through the back of the aluminum box. A 10.16cm brass shaft with a circle of Plexiglas on the end sat on top of the latex and passed through the aluminum box so that when the latex was expanded by the water coming from the bilge pump the shaft would push out. A piece of aluminum with another brass bar in it was then attached to the end of the 10.16cm shaft, serving as a hook, so that when the latex expanded it would release the box.

### Door Opener / Pin Puller (Second Challenge)

To open the door on the electronics module receptacle, the ROV uses a wire hook protruding from the front of the robot. The ROV will use the hook to open the door far enough to push it open the rest of the way by driving into it with the robot frame. The same hook will be used to pull the pin and release the instrument module in the second task. The hook is situated low enough on the robot to grab the pin, which is close to the bottom of the pool.

### Claw for Electronics Plug

On the front of the robot is a claw built from a hydraulic diaphragm identical to those used to hold the electronics module. Rather than having a hook to hold a u-bolt, the pin from the diaphragm pushes on a lever arm which closes a claw around the rear body of the plug. The claw is situated so its lowest point is on the same plane as the bottom of the hydraulic actuators that hold the electronics module. This way, the robot can be set down on the bottom of the pool



Figure 10: Claw

with the claw around the plug, the claw closed, and the robot lifted off the bottom again. The claw protrudes far enough off the front so the electronics module can settle completely into its receptacle without interference from the claw.

The claw is held open by default with a spring, and closed by pumping water into the diaphragm. It is run off the same hydraulic pump as the actuators which hold onto the electronics module. Since the two devices are not used at the same time, we chose not to install a separate pump and electrical controller for the claw.

### Buoyancy

Components of the robot were either weighed dry and their volume was used to calculate their underwater weight, or they were weighed in water. The main sources of positive buoyancy on the robot are PVC float tanks and our electronics box.

Piece	Material	Density (N/cm <sup>3</sup> )	Volume (cm <sup>3</sup> )	Dry Weight (N)	Wet Weight (N)	Buoyant Force
Frame	Steel	0.077	554.5844156	42.703	37.276	5.42683
Tanks	PVC	--	641	22.686	-79.961	102.647
Manifold	Brass	0.084	137.6785714	11.565	10.226	1.33876
Otterbox			190	20.462	-9.964	30.4258
Motors(6x)			24.72	33.362	29.403	3.95856
Claw			--	7.506	7.006	
Actuators(4x)			--	28.024	-3.505	
Total					-9.518	

Total Wet Weight in kg: -0.970

### Variable Buoyancy

Since the apparatus for the first task has a considerable weight, even under water, the team had trouble with a static buoyancy system. Either the robot would go down and then no longer be able to stay there after release, or it would not be able to make the trip down at all. This led the team to design a variable buoyancy system. The system utilizes a bladder inside a 10.16cm diameter tube. The bladder is attached through surgical tubing to a bike pump and release valve on the surface. This allows changes in the volume of air in the bladder, and thus changes in the buoyancy, to be made during the operation.

### Thrusters

Once the motors and propellers were selected, the motors had to be waterproofed. To build motor casings we machined front pieces that were then soldered onto copper end caps. The machined front pieces had two holes to match up with the mounting holes on the face of the motor, and a larger hole to correspond to the diameter and depth of the radial shaft seals which would allow the shafts to turn. A 7.62cm length of copper pipe was cut, and another end cap with a wire pass hole was soldered onto one end. The motors were then screwed onto the pass holes in the front mount, and the wires passed through the copper pipe and through the connector.

The shafts were made from 0.64cm brass rod. A piece was cut, and one end was drilled at 0.62cm (to be pressed onto the existing motor shaft), and the other to 0.79cm and tapped out.



The end with the 0.79cm hole was keyed on the milling machine by cutting material off from both sides. A slot was cut into the “front” of the propellers that corresponded to the width of the key in the shaft. With this design, the propeller was supported by the key in the shaft, and would not loosen itself when run in reverse. A screw was passed through the propeller, holding it to the shaft. The purpose of the screw was to hold the propeller onto the end of the shaft. The 0.32 cm end of the brass shaft was passed through the radial shaft seal and pressed onto the existing motor shaft. The motor casing was then closed and sealed using epoxy.

### **Tether**

Two separate wires make up the tether (a power cable and a signal cable). The power cable is a 4 conductor 12 AWG SJ cable, 18.29m in length. Using two conductors for power and two conductors for ground, only 1 volt will be lost across the entire line at a peak current of 25A. The SJ cord has heavy insulation and is flexible enough for our needs. The signal cable is a standard Category 5 cable made with stranded wire for greater flexibility. The Cat 5 cable contains 4 twisted pairs in a common outer insulation, which is durable enough for our needs. Two of the twisted pairs are used to send the analog video signals from each camera to the surface. The third twisted pair is used for the above water PIC to send an RS232 signal to the underwater PICs. The fourth is used for the underwater PICs to send an RS232 signal to the above water PIC, but is only used for debugging purposes. The tether wires are bound together at two foot intervals with electrical tape, and are made neutrally buoyant by foam ‘draft stopper’ stripping attached as necessary.

### **Electronics Box**

The electronics box is an Otter Box (model no. 3000, discontinued), bought directly from the Otter Box Company. It contains the underwater PIC microcontrollers, motor controllers, and power distribution. The cable entries are sealed in several ways.

Because of the large diameter of the power carrying cable in the tether, a large cable seal was purchased at West Marine. The Cat 5 cable used in the tether for communication is connected to the case with a waterproof Ethernet connector donated by Belden. The connector includes a receptacle which seals around a hole in the side of our otter box, and a terminator for the end of the cable which plugs into the receptacle and seals with a gasket.

The motor wires and camera cables enter the case through waterproof electrical conduit seals available at hardware stores. Since the cables do not meet the rubber in the seal perfectly, automotive silicone sealant is used liberally in this joint to prevent water from seeping in through the spaces between the wires. Two of these seals accommodate all of the motor and camera cables.



**Figure 11: Close-up of electronics box**

## Visual Systems

The visual system of the ROV required a camera that fit specific criteria. The camera should fit within a standard 3.81cm pipe fitting, the predetermined camera casing. At least 400 lines of resolution and color images allow the pilot better depth perception. With these criteria in mind, the ideal camera, CWC1011ST, was procured from Security Cameras Direct, a company that specializes in visual systems for security applications. This is a PCB camera with 470 lines of color resolution. The camera is 3.18cm long by 3.18cm wide, requires 9 to 15 DC volts, and draws 110mA of current.

## Description of Challenges

A challenge for our team was the selection of an optimal thruster/propeller combination to propel the ROV, a combination found through extensive testing.

### Selecting the Motor

The motor testing method used was called Prony brake testing. It is a way of determining the force output of motors at varied power inputs. In order to do this, a motor is attached to a rod and a metal spool that has a strap over it. The strap is attached to a force transducer on one side and a known weight on the other side. By seeing the difference between the known weight and the reading in the force transducer, it is possible to determine the force output at a power input. The other end of the rod was attached to a rotational velocity sensor, which measured the rpm. The testing allowed us to optimize force for the amperage permitted. We chose the middle sized motor.

### Selecting the Propeller

The next step once we had selected our motor was to choose a propeller. In order to do this, we utilized bollard pull testing. In this type of test, the motor was sealed and then the propeller is attached to it. This is then attached to our bollard pull testing rig which translated the push or pull of the propeller to the force transducer, which registered the force from the propeller. We tried an assortment of propellers, but the best by far was the smallest, a 35mm diameter propeller. Our Prony brake testing showed that the motor worked the best when it was running at high speeds, and the small propeller allowed the motor to run at a more optimal point than the larger ones.

## Explanation of Troubleshooting Techniques

While testing the final circuit boards, the team had to go through a troubleshooting process. The PIC microcontrollers were setup, programmed, and tested on breadboards; for the final boards, copies had to be constructed by soldering chip sockets and wires onto smaller 'protoboards.' Because the wires would be soldered, detailed diagrams were made of the wire connections prior to construction. However, when the testing began, the PIC18f became very hot. Power was shut off and after it cooled, the PIC removed. After checking for shorts, the team consulted the wiring



**Figure 12: Close up of thruster**

diagram and traced power wires on the board to check for construction errors. Since the board matched the diagram, power was reapplied with the chips removed from the sockets, which were checked with a voltmeter against the diagrams. Finally, Bob Sherbert opened the manufacturer's datasheet on the PIC18f and compared it to the team's diagram. The diagram was wrong: the chip's second power pin had been labeled ground on the diagram, which meant power from the supply would short straight through the chip, drawing currents that the internal circuitry is not designed to handle. The solution was simple: the ground wire was moved over one pin to the chip's actual ground.

## Description of Skill Gained

The visual systems of the ROV required an underwater camera. However, the camera the team chose was designed for security applications, not underwater environments. So, our team needed to make the cameras waterproof, while retaining their compact size.

The team selected PVC piping as the major component of the casing because it comes in standard sizes and can be made watertight easily. Also, there is a variety of adhesives in the market that will bond PVC. A 3.81cm PVC pipe fitting was selected with pipe joint on one end and a screw-in plug on the other. For the remaining components of the casing, clear 0.32cm Plexiglas was used because it is clear, easy to cut, and abundant.

The camera was mounted onto a circular piece of Plexiglas, 3.81cm in diameter, held in place by size 4-40 screws. A section was removed in the middle to accommodate the lens of the camera which protruded through the piece of Plexiglas. Standoffs were placed in to stop the nuts on the screws from coming into contact with the circuit board of the camera.

PVC cement was applied onto the edge of the circular piece and the camera was placed into the pipe, lens away from the threads. To seal the unthreaded end of the pipe, a clear piece thick enough to withstand the pressure was needed. A 0.32cm circular piece of Plexiglas with a diameter of 5.72cm was cut to cover the unthreaded end of the pipe and attached using PVC cement.

A piece had to be selected to seal the back of the pipe and accommodate the camera wire. A standard PVC threaded plug was chose for this application: a hole was drilled through the center of the plug, and tapped to thread the hole. Finally, a 0.32cm NPT nipple was inserted 1.91cm into the hole, sealing the casing.



**Figure 13: Close-up of camera inside casing**



**Figure 14: Casing around camera**

A special type of caulk was used on the threads of the plug to ensure a watertight seal. The caulk is designed to be a poor adhesive, so the casing could be opened as needed. This same caulk was also applied to the threads of the nipple. Finally, a piece of heat shrink tubing, about 6.35cm long, was placed around the wire and pipe-fitting. The entire unit was then allowed to dry for a couple days. The endeavor was a success and the team had learned the valuable skill of waterproofing a camera.

## Discussion of Future Improvements

Several improvements can be made to the ROV. Waterproof plug connectors could be used for the motor wires, camera cables, and SJ power cords, allowing for easy removal of the electric box. More reliable, smaller motor controllers with a greater amperage tolerance would be better than our current motor controllers. Further, the frame should be constructed of stainless steel in the future to eliminate potential issues with the formation of rust. Also, brackets were custom fabricated by hand and by CNC milling machine for mounting on the ROV. The brackets had to be sanded and altered to fit properly. Commercial brackets or improved bracket design would be more exact and less time consuming. The waterproofing methods used on the camera can be improved, while a camera with an even wider field of view could be more beneficial in the future.

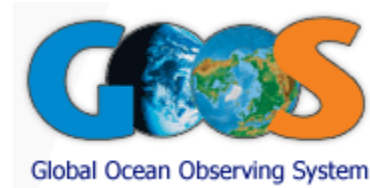
## Description of an Organization That Supports Ocean Observing Systems

The Global Ocean Observing System, or GOOS, is an international organization that collects valuable data from the oceans of the world. GOOS was created in 1991 through the combined efforts of the Technical Committee for Ocean Processes and Climate and the World Meteorological Organization. Part of GOOS is dedicated to weather and climate. The oceans have a profound impact upon the climate. By monitoring the ocean, predictions can be made in regards to the forecast in the regions along the coast and of islands. The second part of GOOS involves environmental protection. GOOS monitors and protects marine and coastal ecosystems. GOOS monitors aspects such as potentially harmful algae blooms, or fish populations in highly fished waters. GOOS also monitors for pollution in the ocean and other potential hazards.

GOOS's operates through the cooperation of regional organizations around the world that monitor their own coastal areas and international waters. Examples include U.S. GOOS, EuroGOOS, and Black Sea GOOS. U.S. GOOS, comprised of a global branch through Texan A&M University, and a coastal branch through the University of Maryland, monitors the US. In Europe, the EuroGOOS was founded in 1994 and now pools the efforts of 17 European countries and shares their information with the public through the internet database EDIOS, the European Directory of the Ocean Observing System. In the Black Sea Region, the Intergovernmental Oceanographic Committee established the Black Sea Regional Committee, BSRC, in 1995 to monitor the waters of the Black Sea Region. The BSRC would eventually develop into the Black Sea GOOS in 2001 which now includes Bulgaria, Georgia, Russia, Turkey, Ukraine, and Romania.

### Sources

<http://www.ioc-goos.org/>  
<http://www-ocean.tamu.edu/GOOS/goos.html>  
<http://www.eurogoos.org/>  
<http://www.edios.org/>  
[http://www.ims.metu.edu.tr/Black\\_Sea\\_GOOS/](http://www.ims.metu.edu.tr/Black_Sea_GOOS/)



**Figure 15: GOOS Logo**

### Acknowledgments

This project requires considerable time and effort from the members of the team in order to achieve success. However, the completion of a functional ROV would not be possible by team efforts alone. High Technology High School provides both the support and a workshop for the team. Our instructor, Mr. Dennis, devotes a large portion of his time to monitoring and aiding the course of our progress, building the mission props, relaying information from the Board of Education, and keeping the workshop available for our disposal. Our mentor, Mr. Wetzel, provides us with a wealth of technical information, advice on completing the project, and aid in the construction and testing of the various components of the ROV. Finally, ClassLink is a crucial component of the success of our project. Last year, ClassLink provided a sizeable donation to our team in our rookie year. This year, ClassLink continued to show support through another donation, which was used to purchase the components necessary to make our ROV. This project only meets success through the combination of team members, High Technology High School, Mr. Dennis, Mr. Wetzel, and ClassLink.

## 2006 MATE/MTS ROV Committee Student Competition

### Budget/Expense Sheet

Period:

**School Name:** High Technology High School

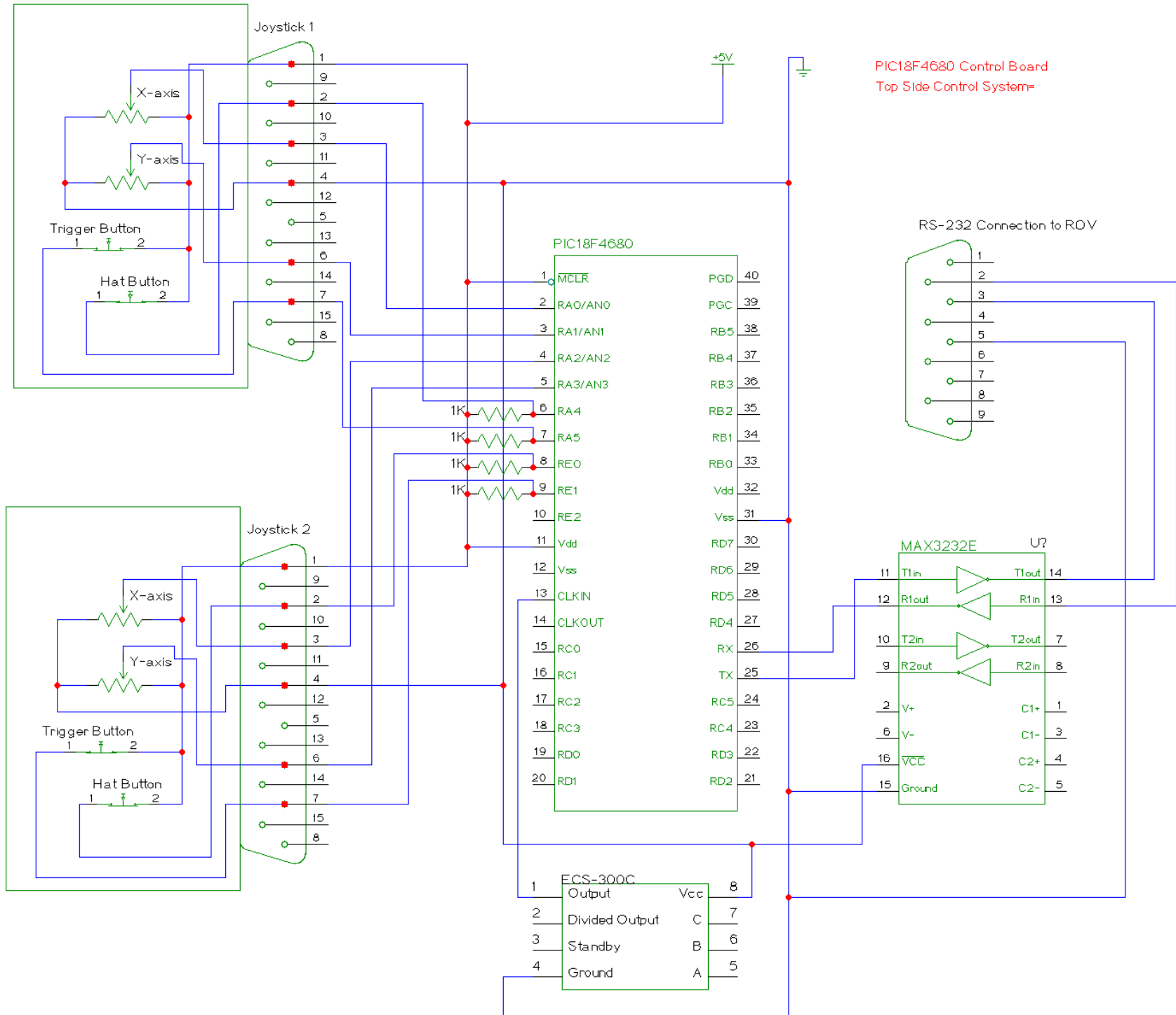
From:

**Instructor/Sponsor:** Mr. Robert Dennis and Mr. Bill Wetzel

To:

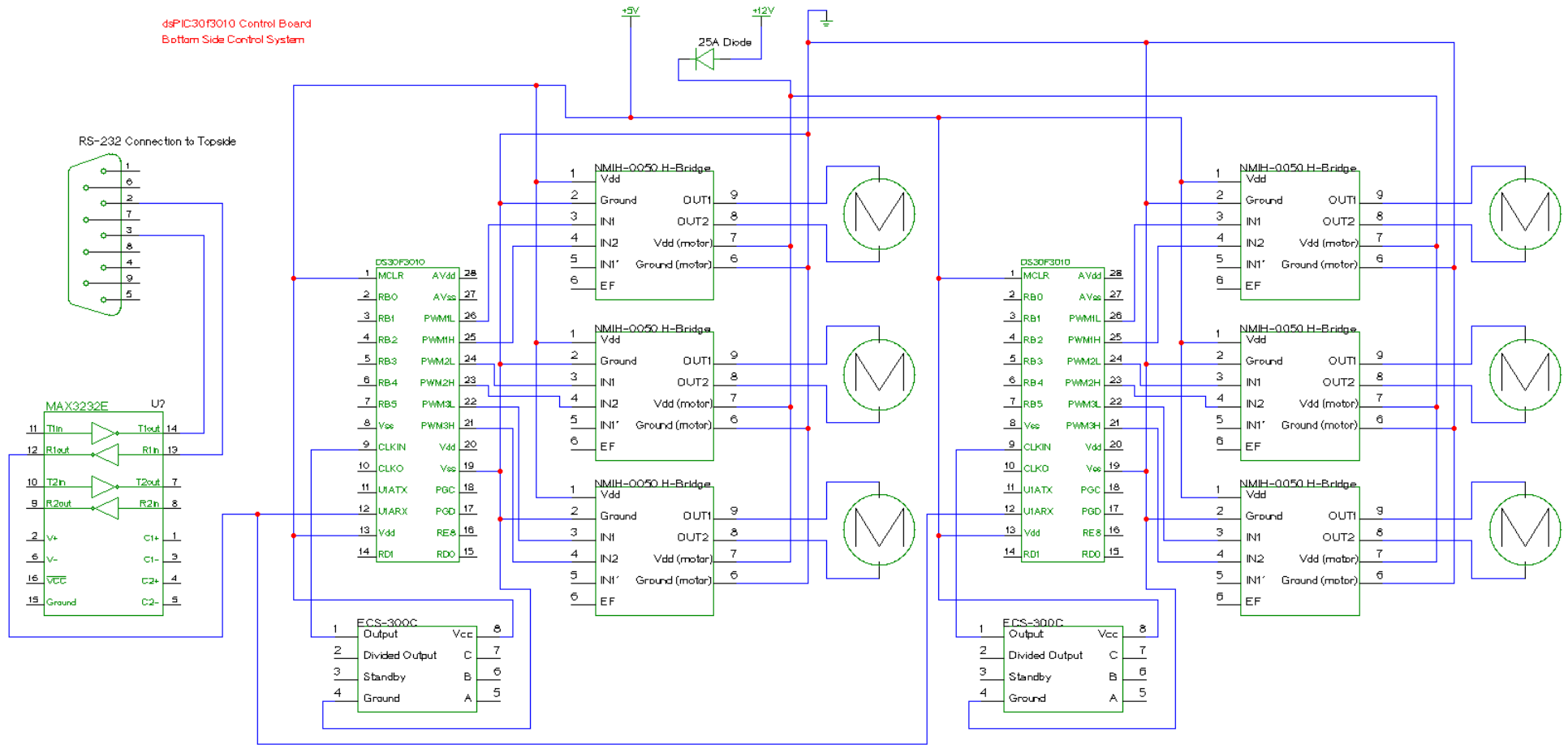
Funds					
Date	Deposit or Expense	Description	Notes	Amount	Balance
	Deposit	Donation By ClassLink Technologies		\$ 4,000.00	\$ 4,000.00
	Expense	1/4" Wing Nuts		\$ 3.48	\$ 3,996.52
	Expense	Clampst (1/8-3")		\$ 1.96	\$ 3,994.56
	Expense	4" Glove Worm Gear Clamp		\$ 1.96	\$ 3,992.60
	Expense	Clamps (31/16-4")		\$ 1.96	\$ 3,990.64
	Expense	Galvanized Carriage Bolt		\$ 1.92	\$ 3,988.72
	Expense	Galvanized Carriage Bolt		\$ 2.24	\$ 3,986.48
	Expense	1 1/2" Adapt F		\$ 1.34	\$ 3,985.14
	Expense	1 1/2" DVW Plug MIP		\$ 0.96	\$ 3,984.18
	Expense	2.8 OZ Silicon		\$ 3.28	\$ 3,980.90
	Expense	OSC CMOs Dual Output 16.384		\$ 21.40	\$ 3,959.50
	Expense	IC MCU Flash		\$ 27.56	\$ 3,931.94
	Expense	IC DSPIC MCU/DSP 24K		\$ 22.30	\$ 3,909.64
	Expense	3" PVC Cap		\$ 5.66	\$ 3,903.98
	Expense	Mason Line Nylon		\$ 5.36	\$ 3,898.62
	Expense	18" WH Stky Strips		\$ 2.97	\$ 3,895.65
	Expense	1" Cap SCH 40		\$ 0.64	\$ 3,895.01
	Expense	3/4" Tee SCH 40		\$ 0.27	\$ 3,894.74
	Expense	Modular Connector Socket		\$ 4.08	\$ 3,890.66
	Expense	MOLAB ICD2 Programmer/Debugger		\$ 159.99	\$ 3,730.67
	Expense	IC Hbridge 5.2A		\$ 60.60	\$ 3,670.07
	Expense	IC DSPIC MCU/DSP 24K		\$ 22.30	\$ 3,647.77
	Expense	PIC 18F4680		\$ 13.78	\$ 3,633.99
	Expense	PIC16F676		\$ 9.92	\$ 3,624.07
	Expense	4x12 VDC Hobby Motor		\$ 15.80	\$ 3,608.27
	Expense	12 VDC Hobby Motor		\$ 3.95	\$ 3,604.32
	Expense	12-Volt DC Hobby Motor		\$ 2.95	\$ 3,601.37
	Expense	12VDC Motor		\$ 5.95	\$ 3,595.42





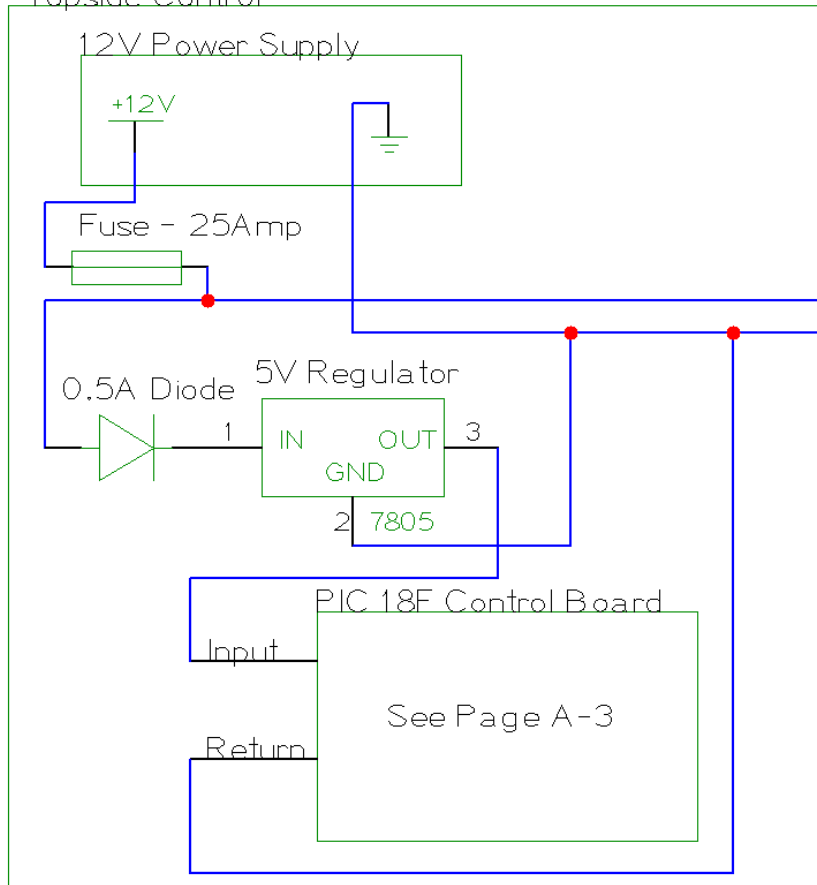


dsPIC30F3010 Control Board  
Bottom Side Control System

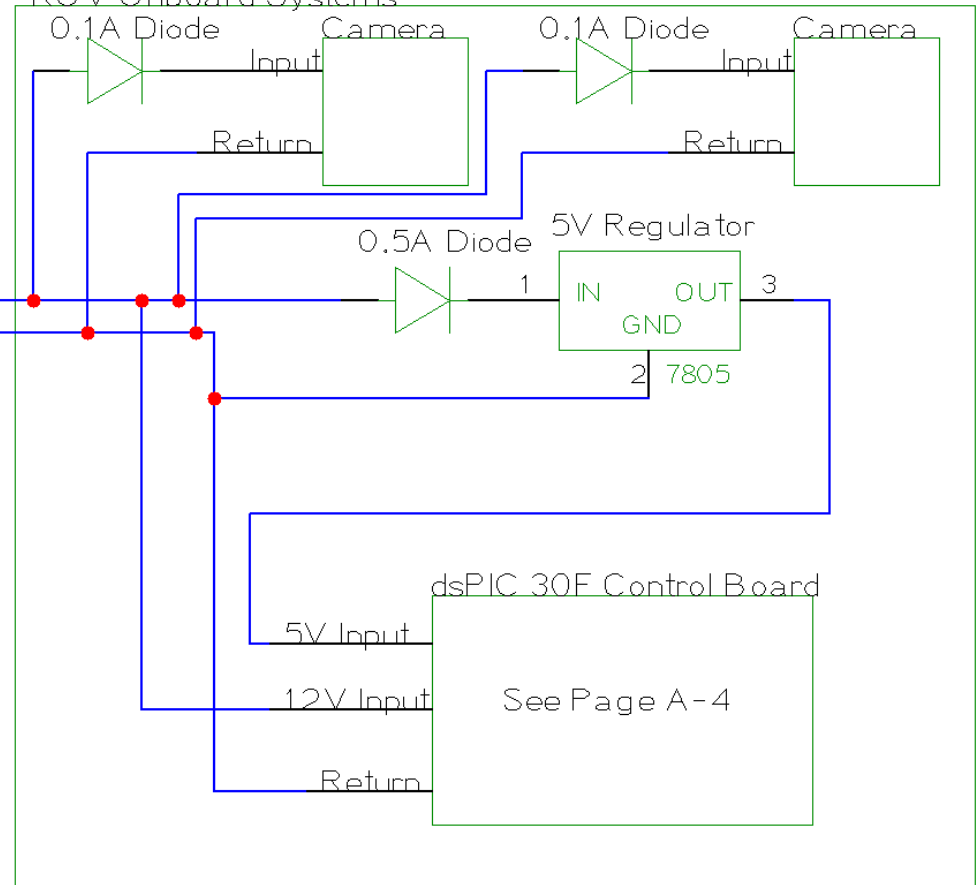


## Control System Overview

### Topside Control



### ROV Onboard Systems



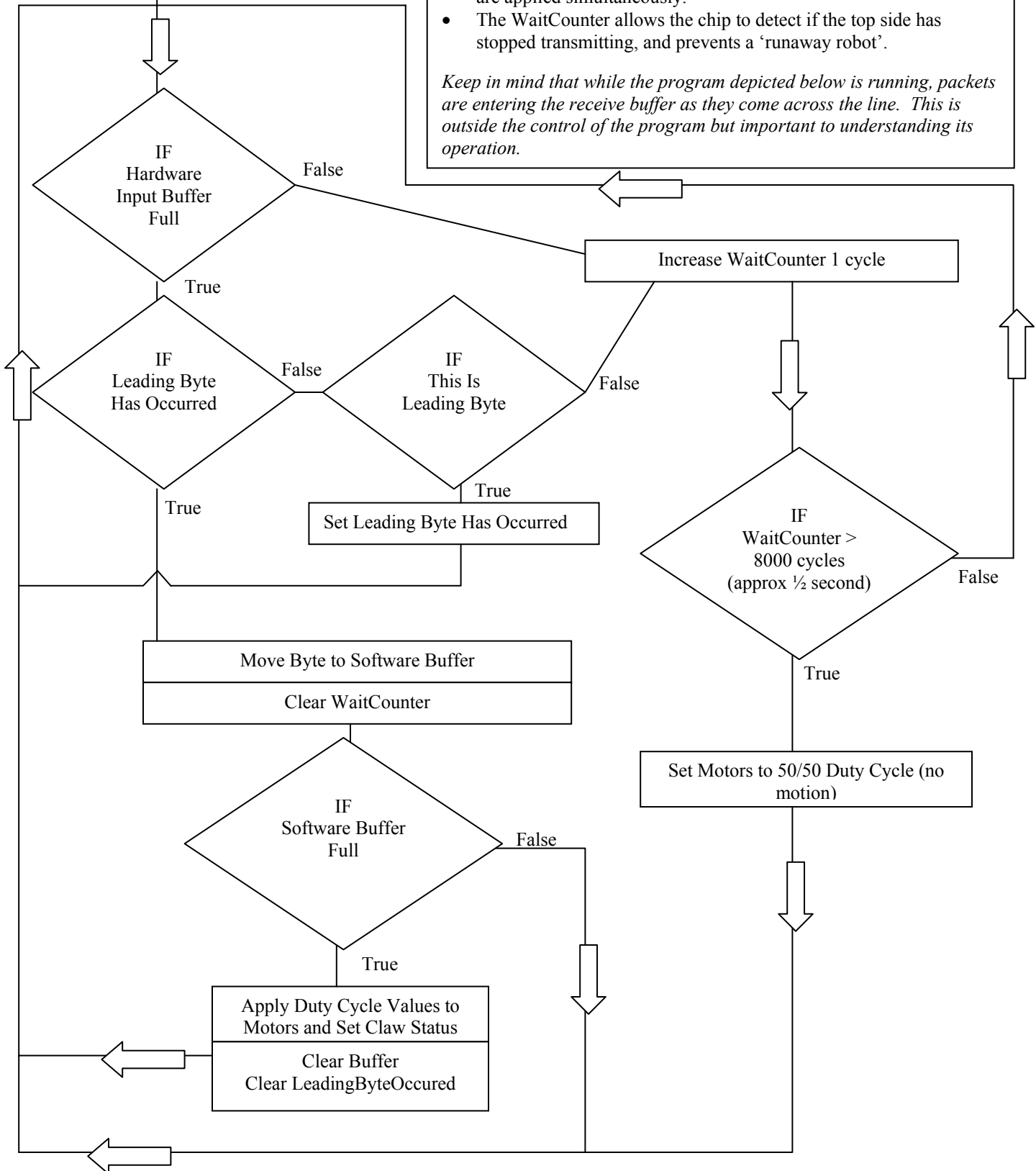
# dsPIC 30F3010 – Bottom Side Motor Control

## Initialize Chip

- Set pins to the appropriate input/output states
- Initialize the PWM module and time base
- Initialize RS-232 receiver module

- A hardware buffer captures one byte of data at a time and passes it into a software buffer.
- The hardware buffer will not begin passing data into the software buffer until a special 'leading byte' character has been observed. This allows the chip to be sure that data sequence (which is used to determine which value is mapped to which motor) begins at the proper byte.
- The software buffer holds 7 bytes of data (6 motor duty cycle values and a single 1 byte value designating the position of the claw and release mechanism).
- When the software buffer is filled, the duty cycle and claw values are applied simultaneously.
- The WaitCounter allows the chip to detect if the top side has stopped transmitting, and prevents a 'runaway robot'.

*Keep in mind that while the program depicted below is running, packets are entering the receive buffer as they come across the line. This is outside the control of the program but important to understanding its operation.*

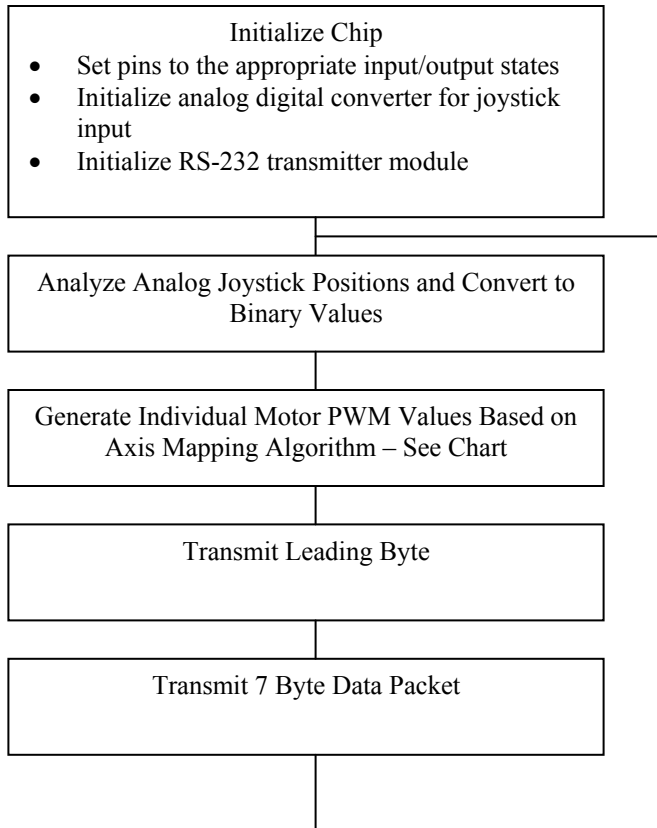


# Software Operations Flowchart

**Overall Notes:**

The software operations on the robot are split into two distinct halves. The halves are identified in this section by the chips they operate on. The first half is the top side half. It operates on a PIC 18F series microprocessor. Its function is to analyze joystick input and convert it into valid PWM (Pulse Width Modulation) duty cycle values. It then transmits those to the bottom side chips located on the robot itself. The bottom side code runs on two dsPIC 30F series microprocessors. These are responsible for taking those generated values and converting them into valid PWM signals to run the motors. This diagram only details one 30F program operation. The only difference between the programs on the two chips is a compile time instruction indicating to the chip which of the 6 motors and the claw/release it is responsible for. This makes no difference to the program at the level it is detailed here.

## PIC 18F4680 – Top Side Control



Because of the vectored approach taken in the physical robot design the robot must be controlled by two joysticks. The PWM duty cycle values for each motor are generated by adding and subtracting the different values gathered from the positions of each joystick's axis based on the chart below. The axis value is either added, subtracted, or not taken into account as indicated.

Motor Quadrant	X-axis Joystick 1	Y-axis Joystick 1	X-axis Joystick 2	Y-axis Joystick 2
<b>I</b>	-	+	-	0
<b>II</b>	+	+	+	0
<b>III</b>	-	+	+	0
<b>IV</b>	+	+	-	0
<b>Vertical I &amp; II</b>	0	0	0	+