INTRODUCTION

Earth's environment is beautiful and unique. With the ability to produce and sustain life, it becomes one of its own kind in our Solar System, and possibly our Universe. In particular, Water, the substance of life, is becoming more and more inhabitable for aquatic life due to the multitude of garbage thrown by disinterested population. Among the trash, plastic can have a damaging impact on underwater life. Once digested, plastic can release toxic chemicals which are then passed through the food chain. These toxic chemicals, in high doses, could harm the health of wildlife .The potential impacts this could have for wildlife are far reaching: not only are the species that live in and around the river affected, but also those in seas that rivers feed into.

Surface trash cause Health Risk to Aquatic Life, play Role as a vector for Organic and Heavy Metal Pollution,

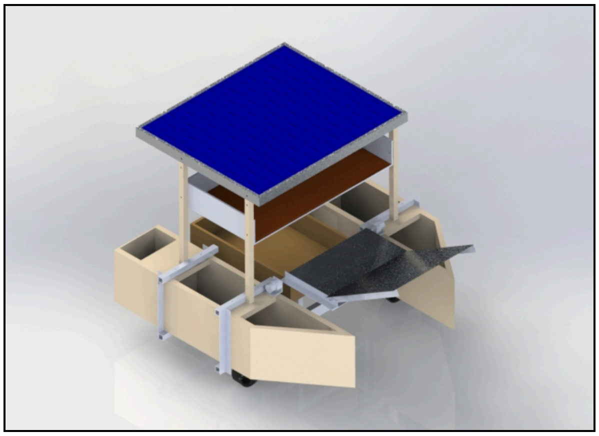
obstruct the natural flow of rivers and cause Damage to Tourism industry inflicting Navigational and Structural Hazard. Thus surface pollutants in water bodies impose serious threat to disrupt ecological balance.

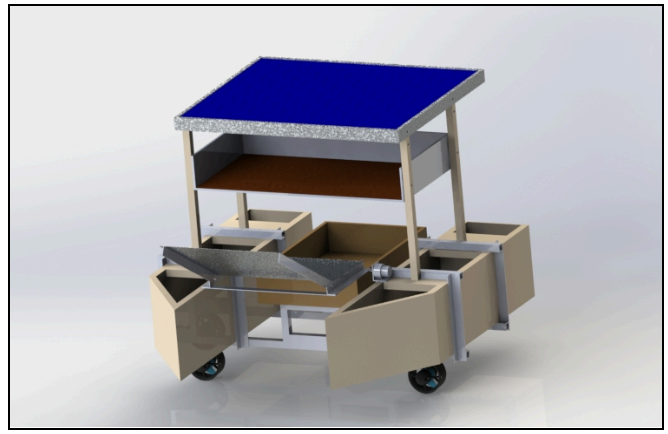
Human beings have come up with different technological measures to hamper the increasing pollution. Some of the technology which is in current practice has been tabulated below.

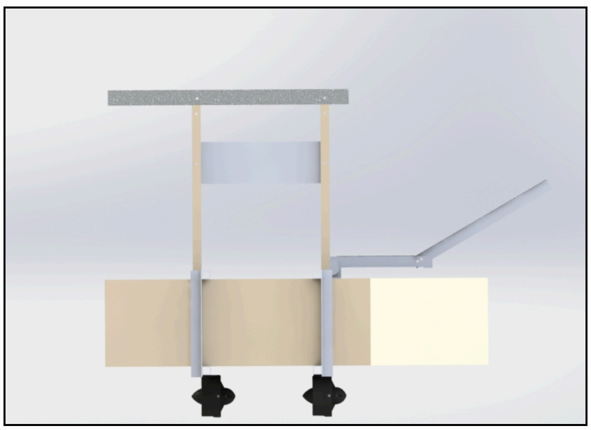
DESCRIPTION	MERITS	DE-MERITS	PHOTO
Conventional cleaning methods	Cheap	Large sized Manual only Slow Not a continuous process	
Cleaning Boats	Fast	Large sized Energy inefficient	

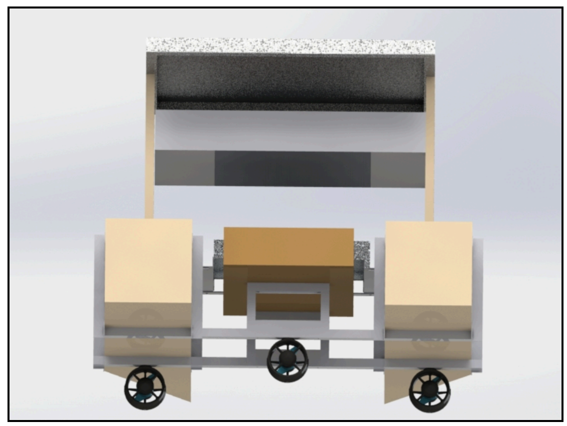
We are trying to solve the same by making a machine that is completely automated and simple to operate, thereby reducing human engagement. This model is an environment friendly as it uses solar energy to run itself and uses the image processing technique to detect the garbage afloat. These detected waste materials are collected on a mesh which is lifted by two motors that hold the frame of the mesh. The motors are attached to each hull. Hull keep the machine floating on water, provide stability. The entire chassis is made out of aluminum and the box that stores the garbage is made out of wood hence making the structure very light. The bot moves on water with the help of three thrusters attached below the body which are powered by batteries.

The different views of the model is shown below.

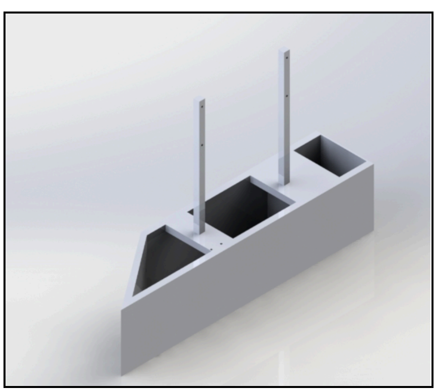








HULL DESIGN



A lot of elements can influence the speed and stability of the boat. One of the most important part of the boat is its hull. The shape of the boat has direct relation with the property of the boat. Different shape and size of hulls of the boat are applied in different areas and situation.
The objective here was to create a basic list of essential hull design elements.

The easiest boat to power through the water would be one with a fine, sharp entry with minimal frontal area that therefore produces minimal resistance. And you can also see that the boat that could carry the most people and cargo would be a box—a barge. So the obvious solution to traversing the water with maximum comfort and cargo is to combine the two shapes—a box-like body with a sharp bow.

The flat bottom hull form is the most efficient at getting up and staying on plane with the least amount of power. With flat-bottom boats' large bottom area, the boat is very stable in calm water. These boats are generally less expensive to build and have a shallow draft (the part of the boat that's under the water).

The multi-hull structure has greater stability because of its wide beam. The wide stance provides greater stability.

Displacement

Primary concerns is how many kilograms will the boat be expected to carry. The maximum weight of the gear plus the weight of the finished boat should be equal to or less than the intended design displacement of the boat.
Displacement is simply the amount of water expressed in kilograms that will be displaced by the boat when loaded.
At minimum, the boat must displace enough water to support the gears and its own weight in order to float.
Kilograms per cm of Immersion = 2 kg/cm

Beam Width

Beam is simply a measurement of the hull's width and is measured several ways. Beam at the waterline is the important measurement. The width or beam of the hull influences stability, volume and wetted surface. Generally, a wider hull is more stable especially in calm water. While the wide hull with a flat bottom will feel more stable in calm conditions.

Depth

The primary measures of depth are at the bow, center and stern. Increased depth especially at the center translates to increased volume and capacity given the same length and width.
Increased depth helps to minimize taking on water from the effects of waves and spray.

Center of Buoyancy

The center of buoyancy is an imaginary focus of all vertical forces that keep the boat afloat.

If the boat is to float on her designed waterline, the center of gravity (CG) must be in line vertically with the CB, both fore and aft and athwart ship. If the two centers are not in line the boat will change trim, and so change her underwater shape, until the new CB lines up with the CG. The centre of buoyancy is at the geometric centre of boat.

Solidworks

Solidworks was a primary tool for both analysis and construction. Then, section properties such as moment of inertia and center of gravity could be determined. In addition, cross-sections were also printed from Solidworks to be used as templates when cutting wood during hull fabrication.

WATERPROOFING

Water proofing is done on Hull bodies which is made up of wood (which is hygroscopic) using Aluminium sheet of thickness 2 mm and elastic acrylic sealant.

Wood - Woods are easily available, cheap, lightweight and can be easily modelled into hull.

Aluminum sheet -
- Lightness: Its specific weight is 2.7 g/cm3, which is one-third that of steel
- Strength: Provide strength to the hull body
- Impermeable and odorless: Releasing no taste or toxins, so water body will be unaffected.

Elastic acrylic sealant has optimum weather resistance and weatherproofing properties also it's economical.

Araldite epoxy adhesive provides great adhesiveness between Aluminum and wood it is also economical.

Cleaning Mechanism:

The purpose of this project is to design and develop a lifting and dumping mechanism for an autonomous boat embedded with Image processing that can collect garbage from water surface and dump it in collector by itself. This boat is programmed to move towards garbage against a green background. The boat base is integrated with a lifting mechanism and a collector is situated above the water level in which garbage will be dumbed. Solar Panel is attached at the top of chassis to lessen use of conventional energy. Thrusters are attached to the body to provide locomotion accordingly.

Lifting Mechanism: The lifting mechanism consists of aluminum arms, two motors of RPM 15 revolution/min, mesh (extended between two aluminum arms in which water will be filter down).

Motors are attached on the top of hull body through which two arms are connected. Rotation of these arms provide mesh to rotate in such a way that it will collect floating substance by filtering the water out.

Dumping Mechanism: Collected substances will be dump into a collector situated at the level of top of the hull body having maximum capacity of 2 KG.

Locomotion: 3 thrusters are attached to hull body to provide the locomotion accordingly

THRUSTER (T100)

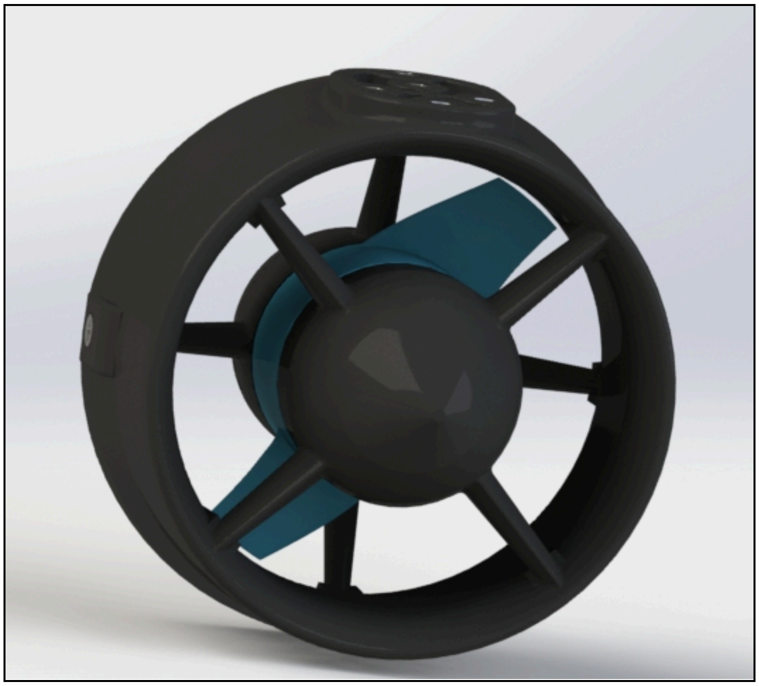
The **T100 Thruster** is a patent-pending underwater thruster designed specifically for marine robotics. It's high performing with over **5 pounds of thrust** and durable enough for use at great depths.

The T100 is basically a brushless electric motor. Its **compact design** fits in any project. The T100 is made of **high-strength, UV resistant** polycarbonate injection molded plastic. The core of the motor is sealed and protected with an epoxy coating and it uses **high-performance plastic bearings** in place of steel bearings that rust in saltwater. Everything that isn't plastic is either aluminum or high-quality stainless steel that **doesn't corrode.**

A specially designed propeller and nozzle provides **efficient, powerful** thrust while active water-cooling helps cool the motor. Water flows freely through all parts of the motor while it's running and can handle **extreme pressures.**

The thruster is **easy to use:** just connect the three motor wires to any brushless electronic speed controller (ESC) and we can control it with an RC radio or a microcontroller. It's usable with Arduino, ArduPilot, Raspberry Pi, Beagle Bone, and many other embedded platforms.

The T100 can operate in both **clockwise and counter-clockwise propellers** to counter torque.

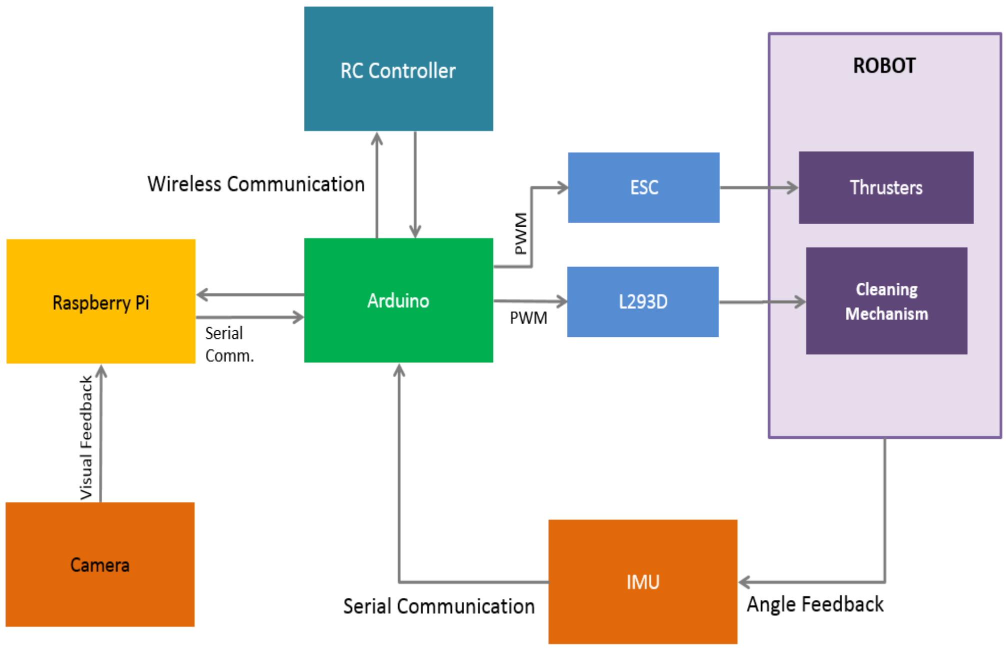


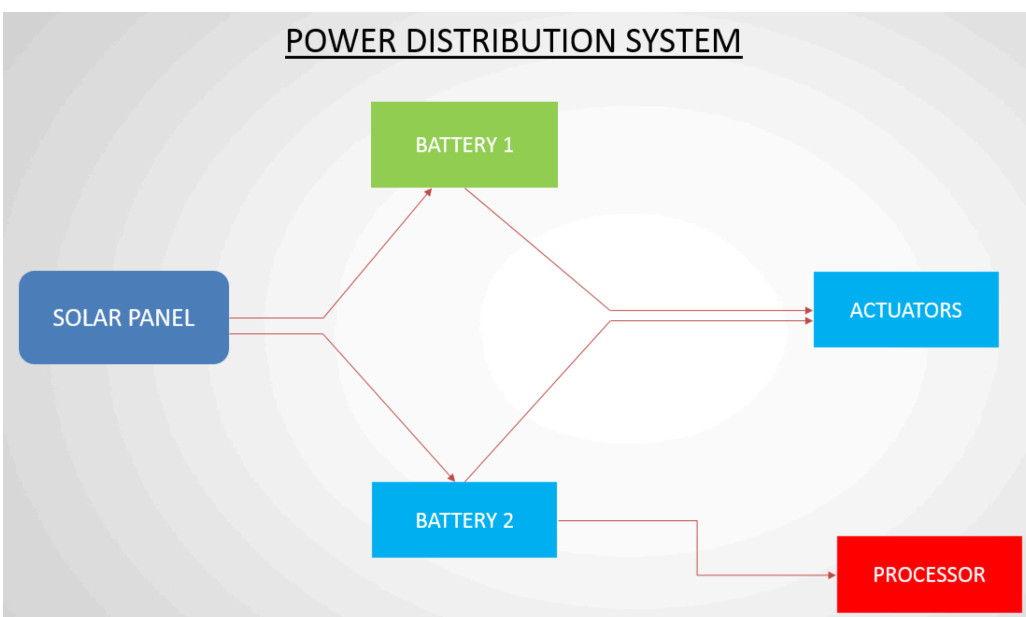
SPECIFICATIONS

	PARAMETER	
Max Thrust – Forward	5.2 lbf	2.36 kgf
Max Thrust – Reverse	4.0 lbf	1.82 kgf
Min Thrust	0.03 lbf	0.01 kgf
Rotational Speed	300-4200 rev/min	
Operating Voltage	12 Volts	
Max Current	11.5 Amps	
Max Power	130 Watts	
Length	4.0 in	102 mm
Diameter	3.7 in	94 mm
Cable Length	39 in	1.0 m

Mounting Hole Spacing	0.75 in	19 mm
Mounting Holes	M3x0.5 Screws	
Weight in Air (with 1m cable)	0.65 lb	295 g
Weight in Water (with 1m cable)	0.26 lb	120 g

BASIC FUNCTIONALITY





ELECTRONIC SYSTEM DESCRIPTION

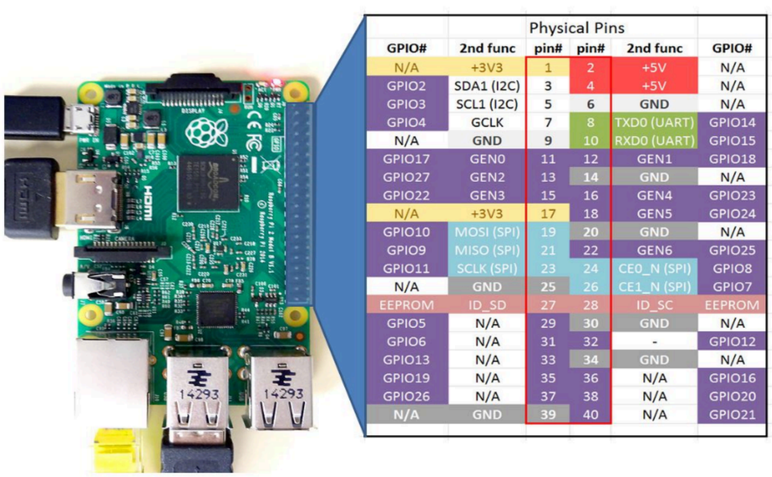
The developed system is broadly divided into the following modules

- Processor module
    1. Central processor(Raspberry pi)
    2. Low-level controller(Arduino Mega)
- Sensor Module (9 DOF IMU)
- Actuator Module (Several Actuators)
    1. Thrusters
    2. DC Motors
- Communication Module

PROCESSOR MODULE

We have designed hierarchical robot control architecture to facilitate modularization for a sustainable system. The idea of high-level control and low-level control is classification systematic goals. High-level is used to describe goals that are more abstract in nature, where the overall goals and features of the system are more concerned with the wider, macro system as a whole. Low-level control is more concerned with the specific modules of the system like, sensor and actuators. It deals with the communication interface with the various peripherals of the system. The access to the physical hardware layer is with this low-level controller.

In our case the high-level controller is the Raspberry Pi.



		Physical Pins			
GPIO#	2nd func	pin#	pin#	2nd func	GPIO#
N/A	+3V3	1	2	+5V	N/A
GPIO2	SDA1 (I2C)	3	4	+5V	N/A
GPIO3	SCL1 (I2C)	5	6	GND	N/A
GPIO4	GCLK	7	8	TXD0 (UART)	GPIO14
N/A	GND	9	10	RXD0 (UART)	GPIO15
GPIO17	GEN0	11	12	GEN1	GPIO18
GPIO27	GEN2	13	14	GND	N/A
GPIO22	GEN3	15	16	GEN4	GPIO23
N/A	+3V3	17	18	GEN5	GPIO24
GPIO10	MOSI (SPI)	19	20	GND	N/A
GPIO9	MISO (SPI)	21	22	GEN6	GPIO25
GPIO11	SCLK (SPI)	23	24	CE0_N (SPI)	GPIO8
N/A	GND	25	26	CE1_N (SPI)	GPIO7
EEPROM	ID_SD	27	28	ID_SC	EEPROM
GPIO5	N/A	29	30	GND	N/A
GPIO6	N/A	31	32	-	GPIO12
GPIO13	N/A	33	34	GND	N/A
GPIO19	N/A	35	36	N/A	GPIO16
GPIO26	N/A	37	38	N/A	GPIO20
N/A	GND	39	40	N/A	GPIO21

Here is the full list of specs for Raspberry Pi 2 Model B:

- SoC: Broadcom BCM2836 (CPU, GPU, DSP, SDRAM)
- CPU: 900 MHz quad-core ARM Cortex A7 (ARMv7 instruction set)

- GPU: Broadcom VideoCore IV @ 250 MHz
- More GPU info: OpenGL ES 2.0 (24 GFLOPS); 1080p30 MPEG-2 and VC-1 decoder (with license); 1080p30 h.264/MPEG-4 AVC high-profile decoder and encoder
- Memory: 1 GB (shared with GPU)
- USB ports: 4
- Video input: 15-pin MIPI camera interface (CSI) connector
- Video outputs: HDMI, composite video (PAL and NTSC) via 3.5 mm jack
- Audio input: I^2S
- Audio outputs: Analog via 3.5 mm jack; digital via HDMI and I^2S
- Storage: MicroSD
- Network: 10/100Mbps Ethernet
- Peripherals: 17 GPIO plus specific functions, and HAT ID bus
- Power rating: 800 mA (4.0 W)
- Power source: 5 V via MicroUSB or GPIO header
- Size: 85.60mm × 56.5mm
- Weight: 45g

The low level controller is Arduino Mega.

Overview

The Mega 2560 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

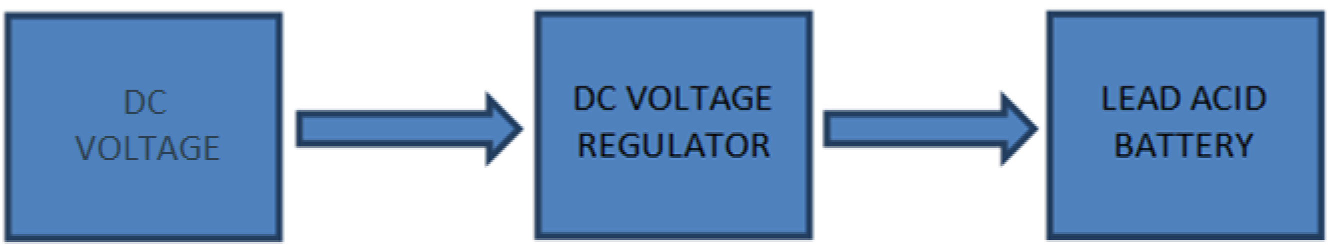
Technical specs

Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by boot loader
SRAM	8 KB

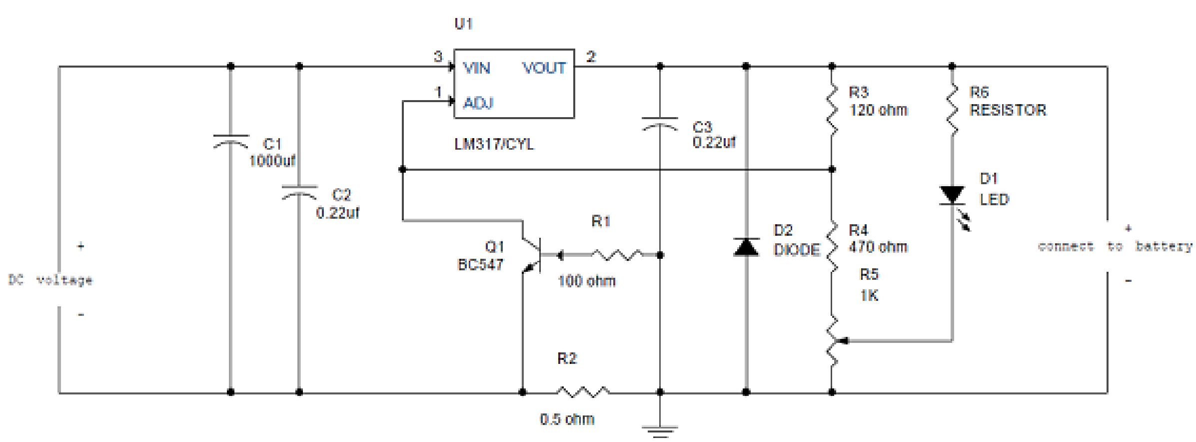
EEPROM	4 KB
Clock Speed	16 MHz
LED_BUILTIN	13
Length	101.52 mm
Width	53.3 mm

LEAD ACID BATTERY CHARGER CIRCUIT

To charge a battery from AC we need a step down transformer, rectifier, filtering circuit and regulator to maintain the constant voltage then we can give to the battery to charge it. Similarly for charging the lead acid battery with DC, we connect that DC voltage to a DC-DC voltage regulator and provide some extra circuitry before giving to the lead acid battery.



BLOCK DIAGRAM OF CHARGER FOR LEAD ACID BATTERY



Circuit Explanation:

- The DC voltage is connected to the Vin of the LM317 and the capacitors have been connected to remove any AC noise.
- The Vout of the LM317 is given to the battery which is to be charged. Adjustment pin of the LM317 is

connected to the transistor Q1. Resistors R1, R2 and R5 help in adjusting the regulator.

- The output of regulated voltage and current is controlled by the transistor Q1, resistor R1 and R2 and potentiometer R5, which is used to set the charging current. Resistor R2 will have more current when the battery is getting charged. This will help to conduct the transistor Q1. The conduction of Q1 will help to adjust the voltage of LM317.

- The LED indicates whether the battery is fully charged. The diode D2 protects the LM317 from the reverse current, so that when the battery is fully charged it will reduce the charge current. If the charge current reduces, the transistor will get into 'cutoff state' so that the adjustment pin of the LM317 receives no voltage and thus no charging occurs.

IMU (Inertial Measurement Unit)

In the system, we need two sensing elements. One is for determining the orientation of the robot and another for sensing the angular position of the motor.

For the orientation sensing, we made use of an IMU (Inertial Measurement Unit).

We purchased a 9 DOF IMU that would yield the yaw, pitch and the roll of the robot. IMU exhibits 9 degrees of freedom through a combination of Gyroscope, Accelerometer and a Magnetometer. The outputs from these sensors are processed by an onboard Atmega and the resulting parameters are outputted over a serial line. This parameters yaw, pitch and roll give us the orientation of the chip along all three geometrical axes. These values are encoded in double precision floating format and transmitted over the serial output pins. These Rx and Tx are pins are directly connected to one of the serial ports on Arduino and thus the communication takes place.

Since, we were never acquainted with this sort of sensor, we made some preliminary tests to understand and verify the functioning of this chip.

For testing, we made use of an FTDI chip that converts the serial data to USB format which could then be connected to our PC. A graphical interface had been developed using the software *Processing* that would facilitate the real time viewing of the chip orientation. We thus successfully tested the IMU and attached below is the snapshot.

Also from this test, we determined the geometrical conventions of the chip i.e., axial directions of roll, pitch and the yaw.

- **X axis pointing forward (towards the short edge with the connector holes)**
- **Y axis pointing to the right**
- **Z axis pointing down.**

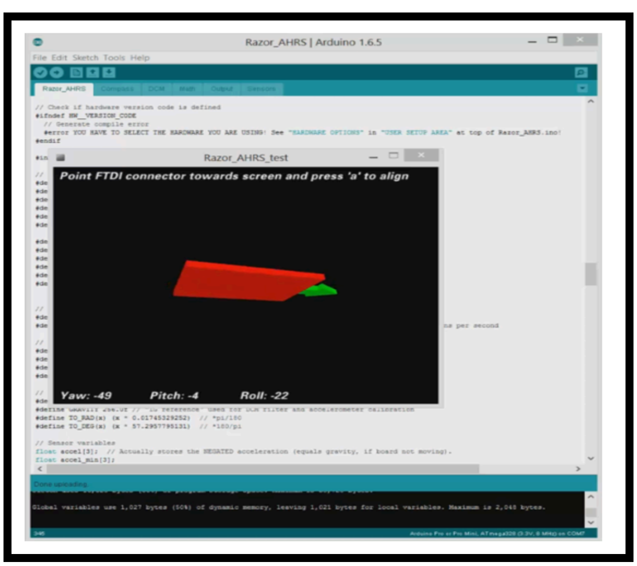
- **Positive yaw : clockwise**
- **Positive roll : right wing down**
- **Positive pitch : nose up**

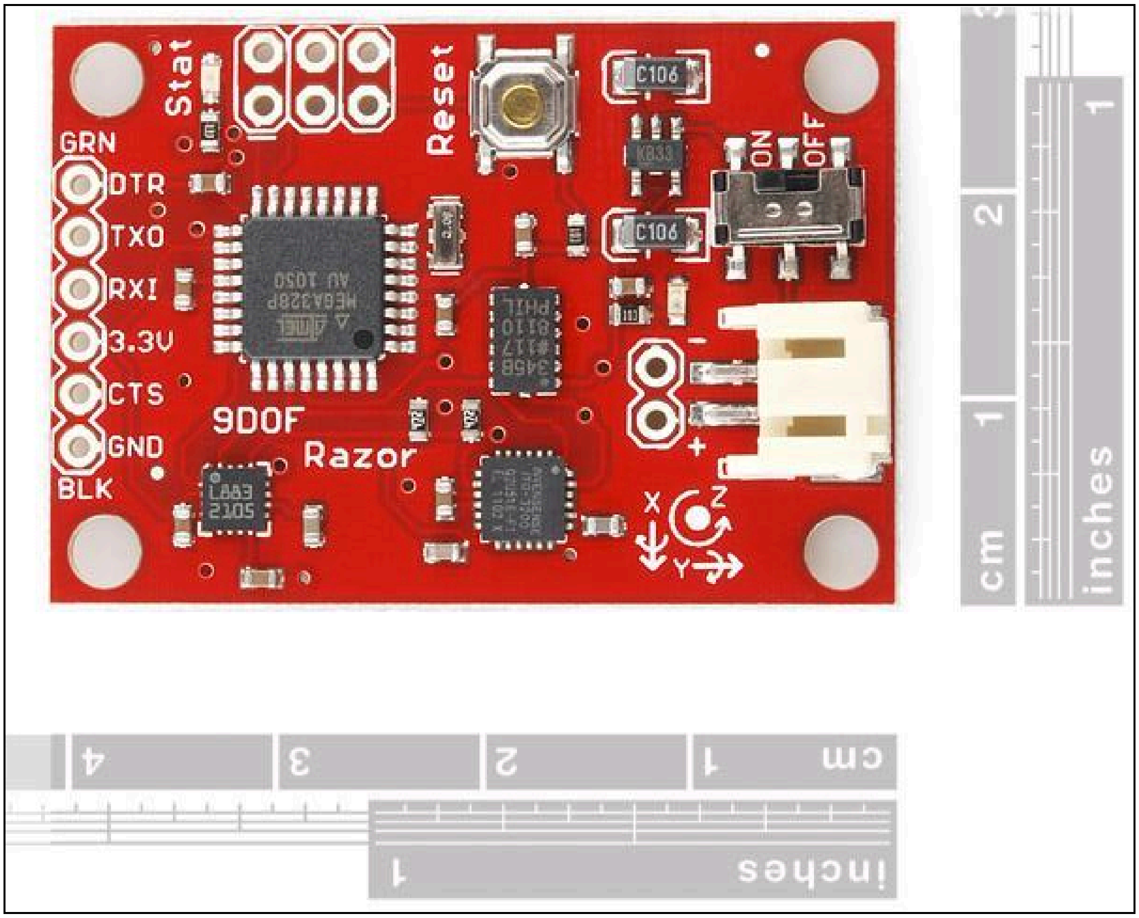
We then calibrated the IMU to improve the functioning of the sensor. This calibration improves the precision and responsiveness and prevents the effects like :

- **Drifts in yaw when roll is applied to the chip**
- **Pointing up does not really result in up attitude**.

Since the IMU consists of three different sensors, all three need to calibrated separately. The accelerometer was calibrated by moving the sensor slowly about all the three axes and noting the extreme values of the sensor readings along them (this accounts for the acceleration due to gravity). Gyroscope was calibrated by holding the sensor still for about 10 seconds. Magnetometer was calibrated by noting the maximum and minimum values of the earth's magnetic field along each axis.

The values thus obtained were incorporated into the **firmware code** of the onboard Atmega of the chip.





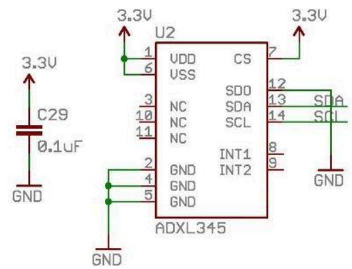
9 Degrees of Freedom - Razor IMU SEN-1073

Features:

- 9 Degrees of Freedom on a single, flat board:
  - ITG-3200 - triple-axis digital-output gyroscope
  - ADXL345 - 13-bit resolution, ±16g, triple-axis accelerometer
  - HMC5883L - triple-axis, digital magnetometer
- Outputs of all sensors processed by on-board ATmega328 and sent out via a serial stream
- Auto-run feature and help menu integrated into the example firmware.
- Output pins match up with FTDI Basic Breakout, Bluetooth Mate and XBee Explorer.
- 3.5-16VDC input.
- ON-OFF control switch and reset switch.

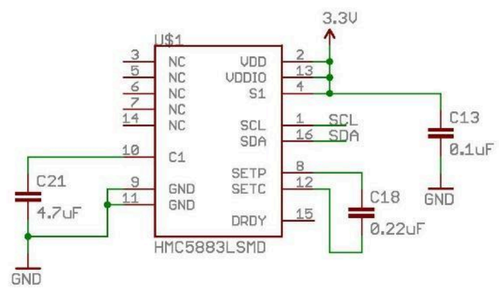
Dimensions: 1.1" x 1.6" (28 x 41mm)

ACCEL



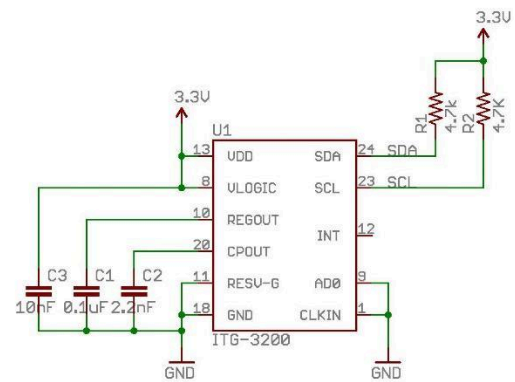
0xA6 for write, 0xA7 for read

MAG



Design by:

GYRO



0xD0 for write, 0xD1 for read

open hardware

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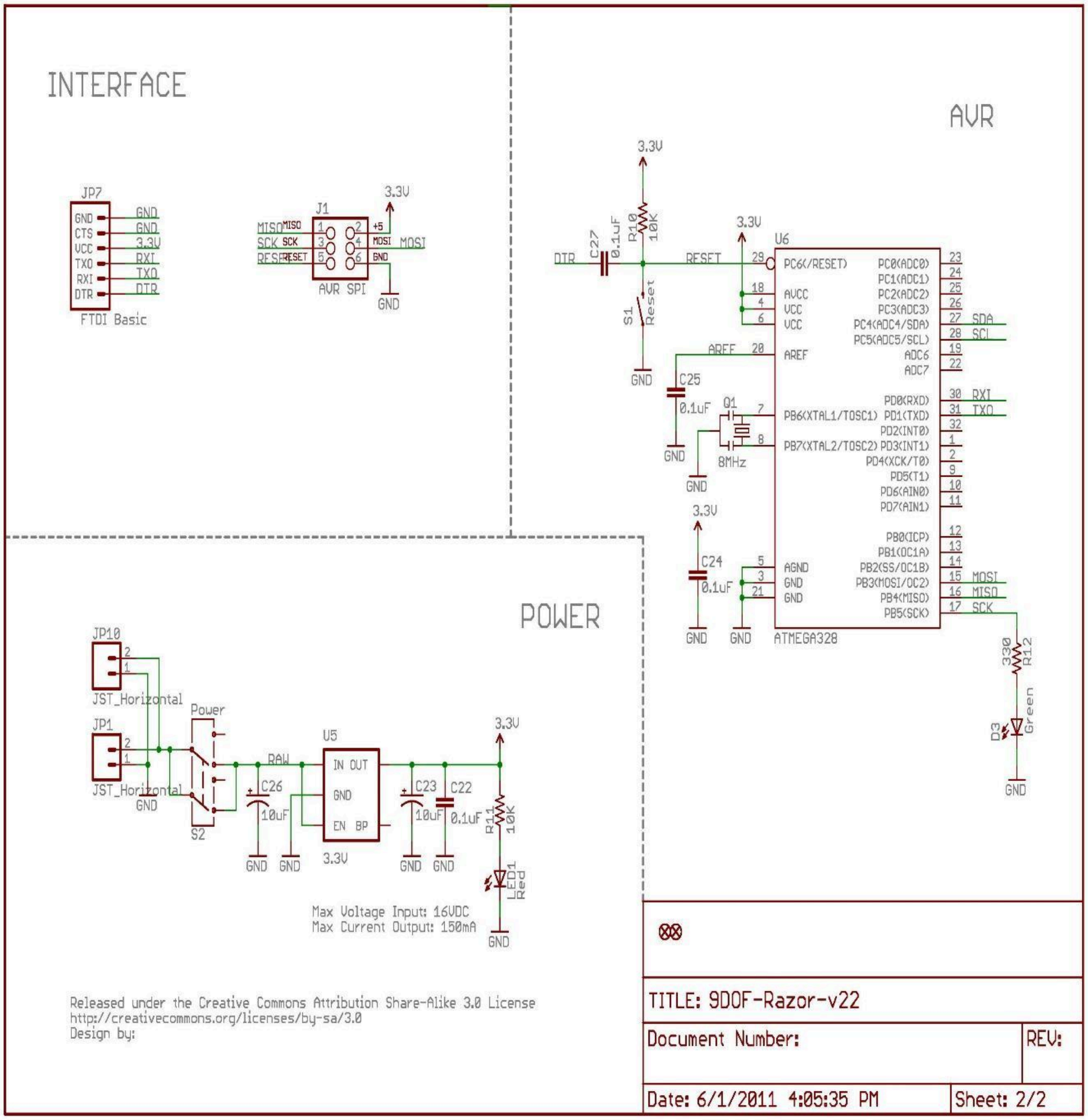


THRUSTERS

An **underwater thruster** is a configuration of marine propellers and hydraulic or electric motor built into, or mounted to an Underwater Robot as a propulsion device. These give the robot movement and maneuverability against sea water resistance. The main difference between underwater thrusters and marine thrusters is the ability to work under heavy water pressure, sometime up to full ocean depth.

There are lots of parameters that affect underwater thrusters considerably. It's very important to have the maximum efficiency. Motor driver, electric motor, shafting, sealing, propeller, nozzle and thruster outer geometry and surface all affect the efficiency.

1. Matching the propeller load with motor torque: One of the more difficult design problem of underwater thrusters is to match the propeller load line with the motor power line. If it does not happen the overall efficiency of the thruster will fall well below maximum or only a small

percentage of motor power will be used.

2. Using the right propeller: Propeller diameter, pitch ratio and type are very important to have the maximum performance.
3. Using low Total Harmonic Distortion (THD) motor and driver: PMSM motors have some efficiency problems with THD.
4. Streamlined Thruster Shell: Manufacturing of streamlined body and handle have a considerable effects on the efficiency, and manufacturing of the curves in this type of geometry is expensive.

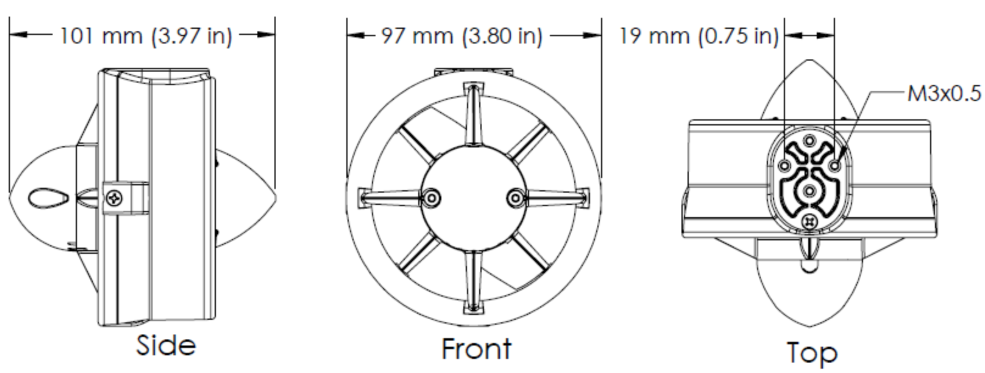
Based on these above 4 parameters, the thruster for our purpose is chosen.

WHAT WE USE?

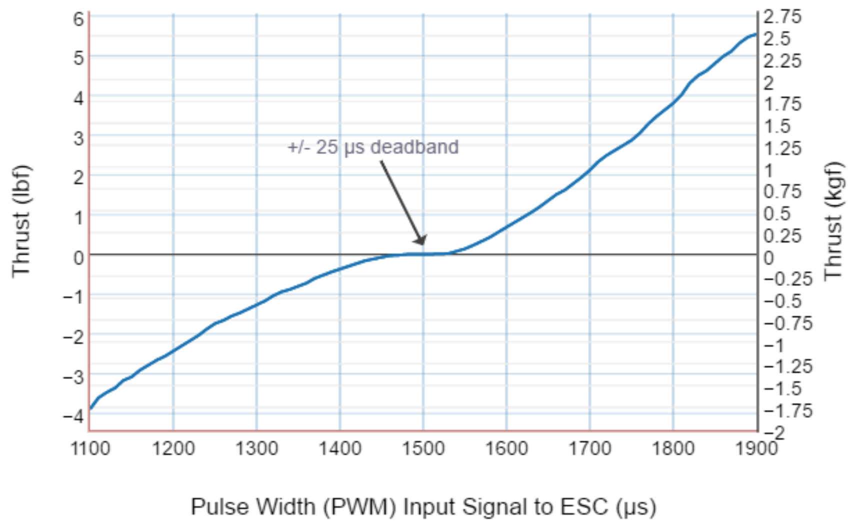
BlueRobotics T-100 Thruster

The **T100 Thruster** is a patent-pending underwater thruster designed specifically for marine robotics. It's high performing with over **5 pounds of thrust** and durable enough for use in the open ocean at great depths. A variety of mounting options, simple control, and a low price tag make it the perfect thruster to use on your marine robot.

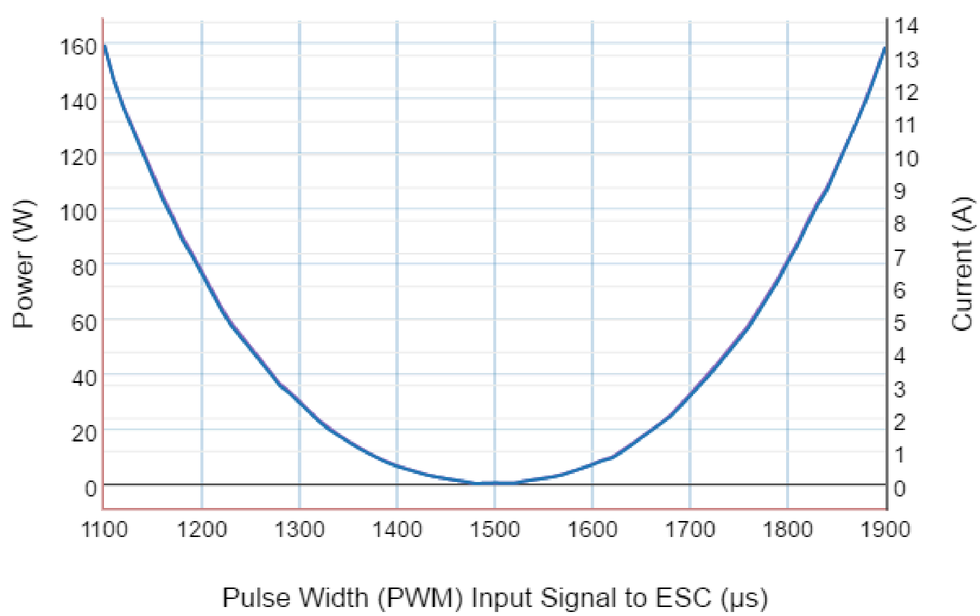
DIMENSIONS

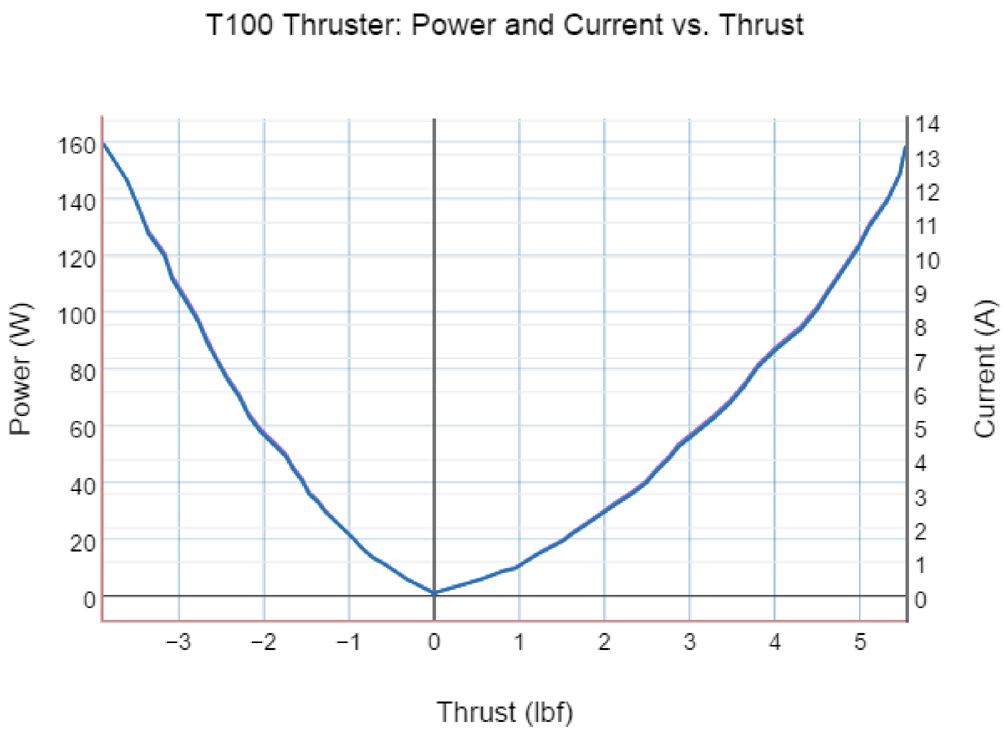


T100 Thruster: Thrust vs. PWM Input to ESC



Power and Current vs. PWM Input to ESC





SPECIFICATION TABLE

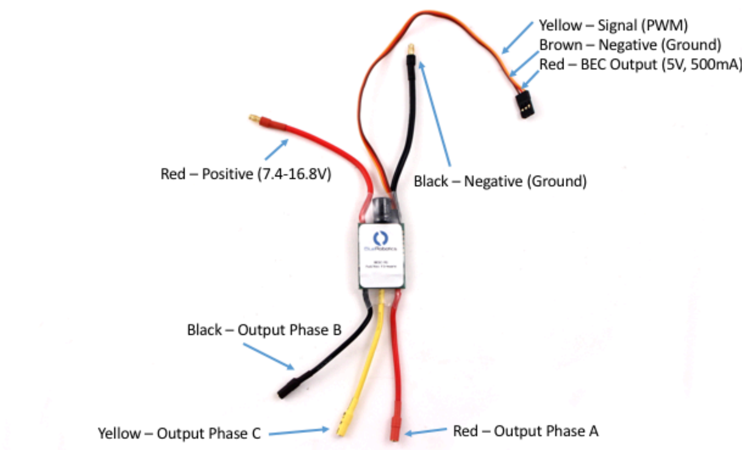
Performance		
Maximum Forward Thrust	2.36 kgf	5.2 lbf
Maximum Reverse Thrust	1.85 kgf	4.1 lbf
Minimum Thrust	0.01 kgf	0.02 lbf
Rotational Speed	300-4200 rev/min	
Electrical		
Operating Voltage	6-16 volts	
Max Current	12.5 amps	
Max Power	135 watts	
Phase Resistance	0.24 +/- 0.01 Ohms	
Phase Inductance (@ 1 kHz)	0.120 +/- 0.008 mH	
Physical		
Length	102 mm	
Diameter	100 mm	

ELECTRICAL CONNECTIONS

Connecting to an External ESC

The thruster has a cable containing three wires. These three wires must be connected to the three motor wires on the electronic speed controller (ESC). The order does not matter, but if the motor direction is the reverse of what is desired, switch two of the wires.

The three wires in the cable (green, white, blue) are always connected to the same motor phases, so connecting the colours in a consistent fashion will result in all motors rotating in the same direction.



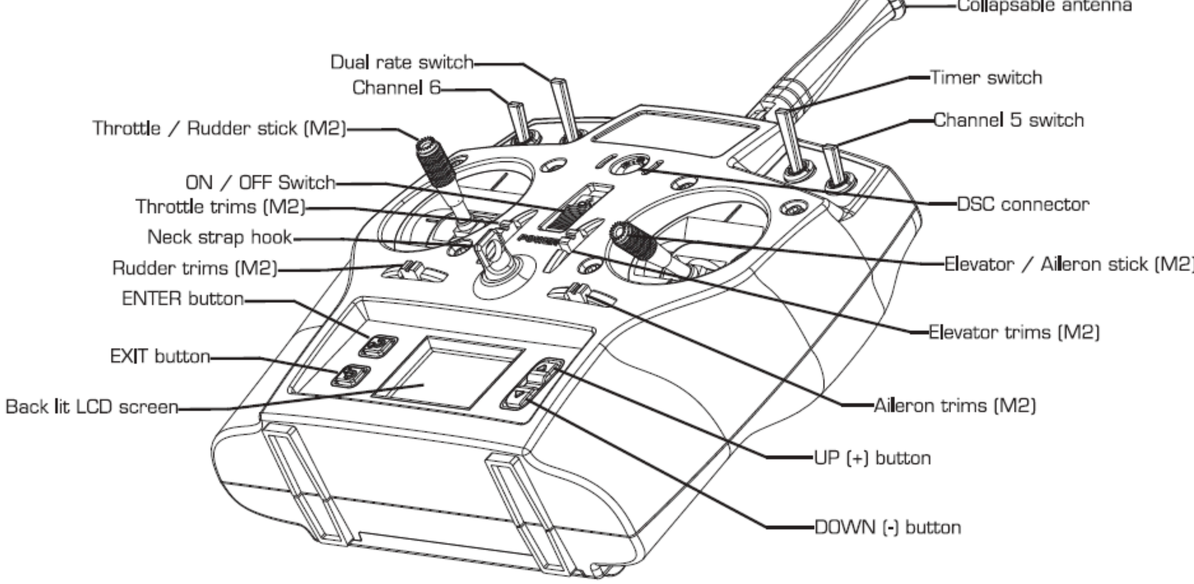
Pulse Width Signal	
Signal Voltage	3.3-5 volts
Stopped	1500 microseconds
Max forward	1900 microseconds
Max reverse	1100 microseconds
Electrical	
Voltage	6-16.8 volts
Max Current	30 amps
Physical	
Length	50 mm
Width	25 mm
Height	11 mm
Power Connectors	Male 3.5 mm bullet
Motor Connectors	Female 3.5 mm bullet
Signal Connector	3-pin servo connector (0.1” pitch) (ground, 5V, signal)

MANUAL CONTROL BY AVIONIC RCB6I

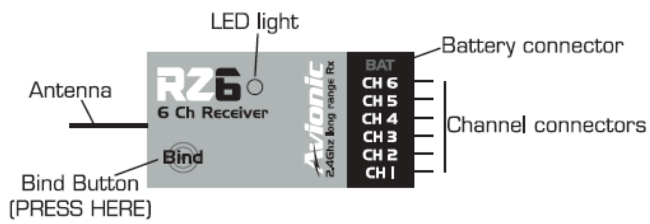
The Avionic RC86i consists of :

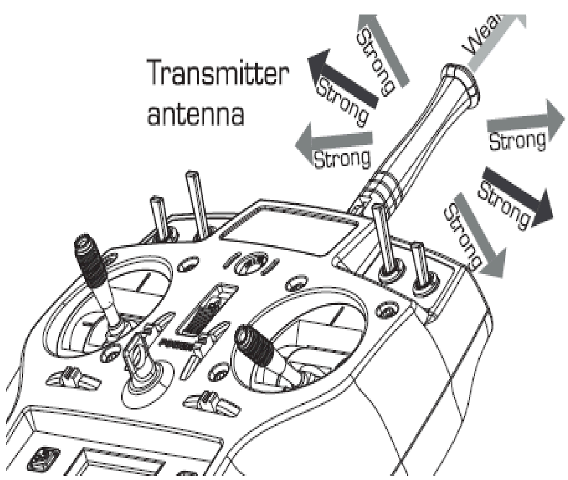
- Digitally Programmable transmitter with 6-channels
- Uses alkaline AA Batteries for powering the transmitter
- 2.4GHz FHSS Technology for a highly secure connection, optimum responsiveness and safety
- RZ6, a 6-channel receiver is easily powered by 3.6-6 V supply and is easily integrable into any system.
- Each of the six channels in the receiver, receives digital pulses, whose pulse timings give the information from the transmitter. Thus by monitoring the pulse widths using the Arduino, we are easily able to decipher the transmitted data.

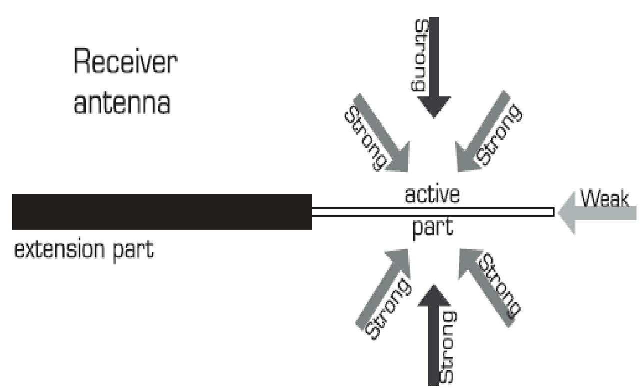
AVIONIC RCB6i transmitter



RZ6 receiver







TRANSMITTER

PARAMETERS	VALUE
Dimensions	185X185X80mm
Weight	About 600gms
Emitting range	2.4GHz (2400 to 2483 MHz)
Emitting type	FHSS
Emitting power	≤100 mW
Number of channels (functions)	6 (with 4 proportional channels)
Power supply	3.7V to 8.4V (integrated 4.8V 800mAh NiMH)
Battery type conpatibility	NiCd, NiMH, LiPo
Amp draw	<100 ma
Model memories	8
Simulator	3.5mm DSC commector
Trims	4 Digital
Display	Backlit LCD & automatic light shut down
Neutral value	1500 µs (1000 to 2000 µs)

RECEIVER

PARAMETERS	VALUE
Dimensions	185X185X80mm
Weight	About 600gms
Emitting range	2.4GHz (2400 to 2483 MHz)
Emitting type	FHSS
Emitting power	≤100 mW
Number of channels (functions)	6 (with 4 proportional channels)
Power supply	3.7V to 8.4V (integrated 4.8V 800mAh NiMH)
Battery type conpatibility	NiCd, NiMH, LiPo
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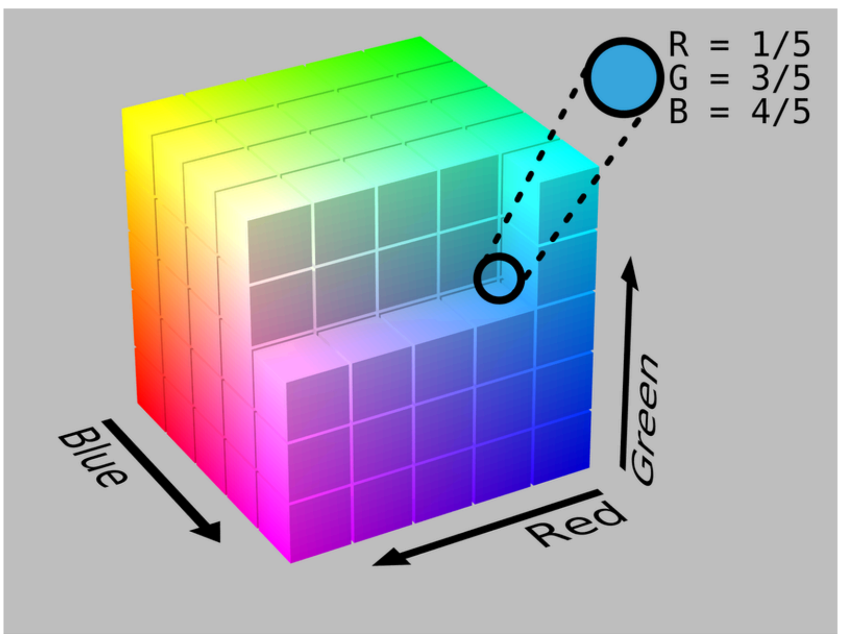
AUTONOMOUS: IMAGE PROCESSING

In imaging science, **image processing** is processing of images using mathematical operations by using any form of signal processing for which the input is an image, a series of images, or a video, such as a photograph or video frame; the output of image processing may be either an image or a set of characteristics or parameters related to the image. Most image-processing techniques involve treating the image as a two-dimensional signal and applying standard signal-processing techniques to it. Images are also processed as three-dimensional signals with the third-dimension being time or the z-axis.

RGB TO HSV COLOR SPACE CONVERSION

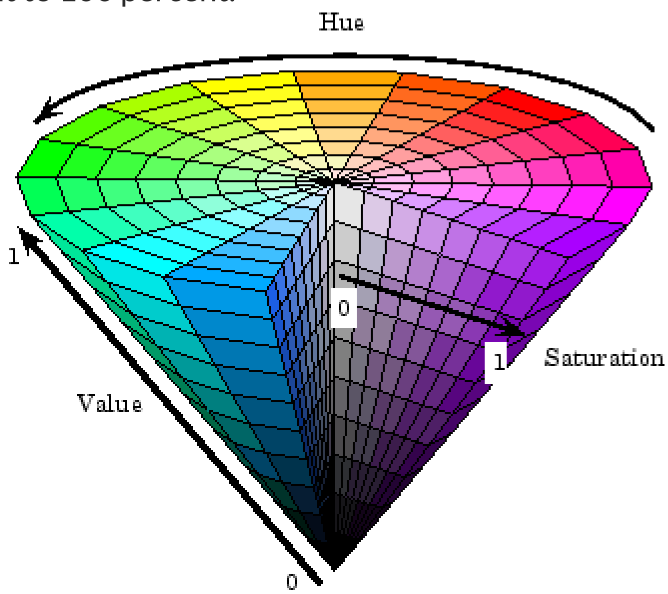
An **RGB colour space** is any additive colour space based on the RGB colour model. A particular RGB colour space is defined by the three chromaticity of the red, green, and blue additive primaries, and can produce any chromaticity that is the triangle defined by those primary colours. The complete specification of an RGB colour space also requires a white point chromaticity and a gamma correction curve. As of 2007, sRGB is by far the most commonly used RGB colour space.
RGB is an abbreviation for red–green–blue.



The **HSV colour wheel** is depicted as a cone or cylinder.
Some colour pickers use the acronym HSB, which substitutes the term "Brightness" for value, but HSV and HSB are the same colour model. Photoshop uses HSB.

- Hue is expressed as a number from 0 to 360 degrees representing hues of red (which start at 0), yellow (starting at 60), green (starting at 120), cyan (starting at 180), blue (starting at 240) and magenta (starting at 300).
- Saturation is the amount of gray from zero percent to 100 percent in the colour.

- Value (or brightness) works in conjunction with saturation and describes the brightness or intensity of the colour from zero percent to 100 percent.



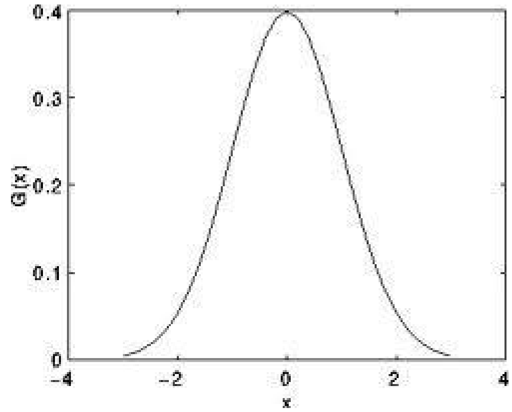
SMOOTHING OF IMAGES USING GAUSSIAN BLUR

Smoothing, also called *blurring*, is a simple and frequently used image processing operation. There are many reasons for smoothing. In this tutorial we will focus on smoothing in order to reduce noise (other uses will be seen in the following tutorials).To perform a smoothing operation we will apply a *filter* to our image. The most common type of filters are *linear*, in which an output pixel's value (i.e. $g(i,j)$) is determined as a weighted sum of input pixel values (i.e. $f(i+k,j+l)$) :

$$g(i,j) = \sum_{k,l} f(i+k, j+l)h(k,l)$$

$h(k,l)$ Is called the *kernel*, which is nothing more than the coefficients of the filter. It helps to visualize a *filter* as a window of coefficients sliding across the image.

Probably the most useful filter, Gaussian filtering is done by convolving each point in the input array with a *Gaussian kernel* and then summing them all to produce the output array.



Assuming that an image is 1D, one can notice that the pixel located in the middle would have the biggest weight. The weight of its neighbours decreases as the spatial distance between them and the centre pixel increases.

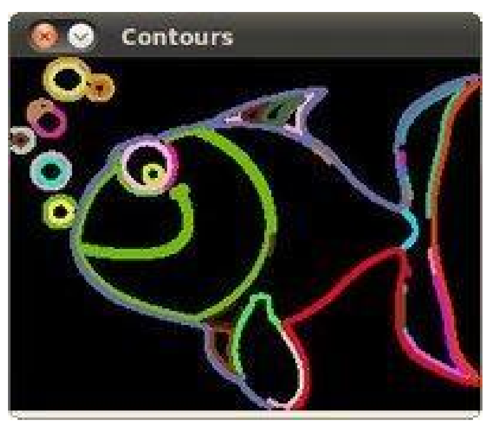
2D Gaussian can be represented as:

$$G_0(x, y) = Ae^{\frac{-(x-\mu_x)^2}{2\sigma_x^2} + \frac{-(y-\mu_y)^2}{2\sigma_y^2}}$$

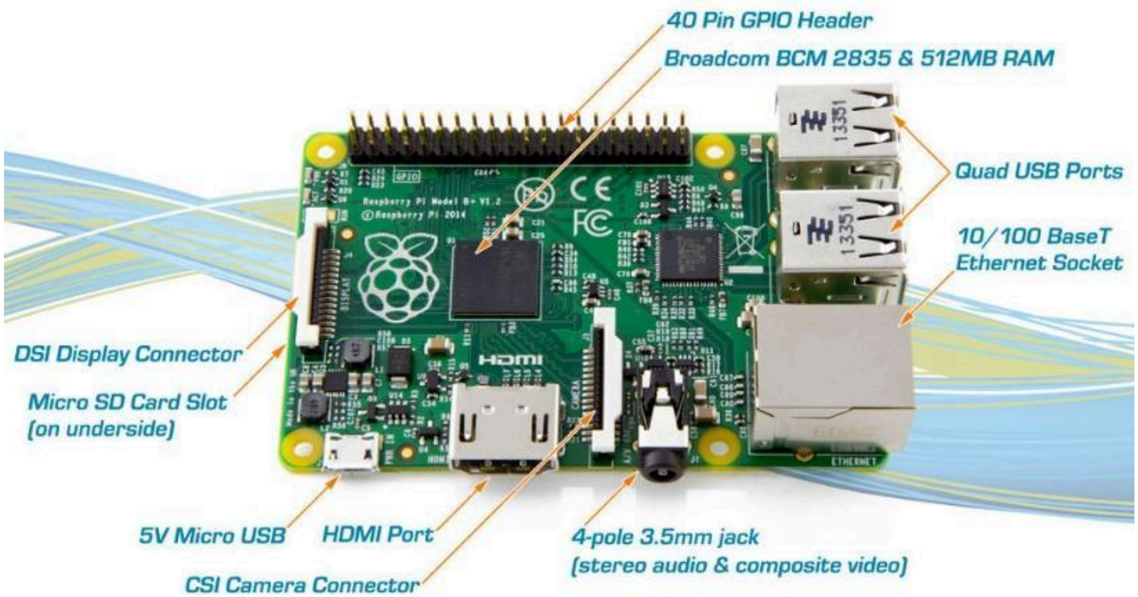
Where μ is the mean (the peak) and σ represents the variance (per each of the variables x and y)

CONTOUR DETECTION

Contours can be explained simply as a curve joining all the continuous points (along the boundary), having same colour or intensity. The contours are a useful tool for shape analysis and object detection and recognition. For better accuracy, use binary images. So before finding contours, apply threshold or canny edge detection. Since OpenCV 3.2, **findContours()** no longer modifies the source image but returns a modified image as the first of three return parameters. In OpenCV, finding contours is like finding white object from black background. So remember, object to be found should be white and background should be black.



PROCESSING UNIT: All the processing has been done in Raspberry Pi 2.



GARBAGE CLASSIFICATION USING CASCADE CLASSIFIER:

First, a classifier is trained with a few hundred sample views of a particular object (here for garbage), called positive examples, that are scaled to the same size (say, 20x20), and negative examples - arbitrary images of the same size.

After a classifier is trained, it can be applied to a region of interest (of the same size as used during the training) in an input image. The classifier outputs a “1” if the region is likely to show the object , and “0” otherwise. To search for the object in the whole image one can move the search window across the image and check every location using the classifier. The classifier is designed so that it can be easily “resized” in order to be able to find the objects of interest at different sizes, which is more efficient than resizing the image itself. So, to find an object of an unknown size in the image the scan procedure should be done several times at different scales.

The word “cascade” in the classifier name means that the resultant classifier consists of several simpler classifiers (*stages*) that are applied subsequently to a region of interest until at some stage the candidate is rejected or all the stages are passed.