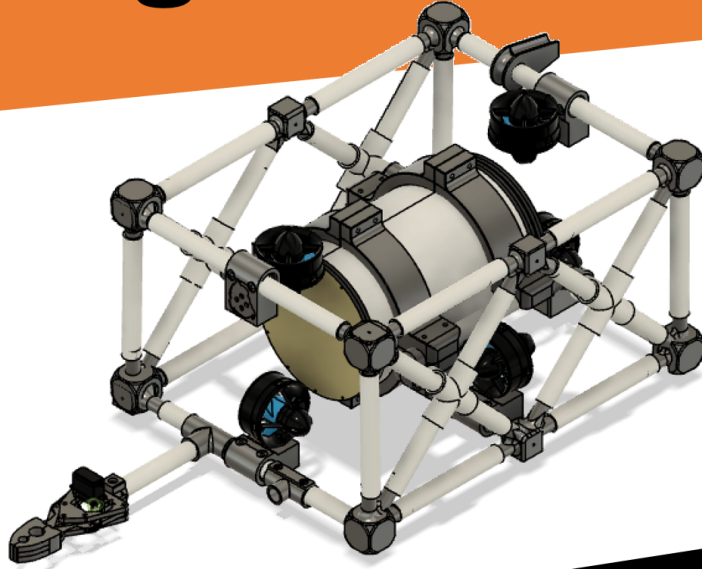# Milligan Robotics

Lawrence the Annihilator

Members:

Henry Holben: CEO

Caleb Turner: CFO, Software

Haley Brannan: Project Manager, Software

Darrin Pickelheimer: Chief Safety Officer, Mechanical

Chris Heaton: Chief of Electrical

Jacob Russell: Electrical

Landen Street: Electrical

Weston Street: Electrical

Steven Shake: Chief of Mechanical

Ben Hawkins: Mechanical

Chance Hall: Mechanical

Megan Miles: Mechanical

Gracie Crabtree: Chief of Software

Johnathan Betances: Software

Faculty Advisors:

Dr. Ian Lundholm

Dr. Teresa Carter

Alumni Advisors:

Ian Kelly, class of 2021

Ryan Kelly, class of 2021

I. Abstract

We are Milligan Robotics, Milligan's student-run, student-led, robotics team. Our mission is to seek to honor God as a team of servant leaders by addressing environmental and humanitarian challenges through the exploration and development of robotics applications.

We have designed and constructed a Remote Operated Vehicle (ROV) with which we will compete in the Explorer class of MATE ROV's 2022 ROV event. This ROV, dubbed *Lawrence the Annihilator*, is the third ROV Milligan Robotics has produced and will be the second to compete in a MATE ROV competition.

II. Project Management

A. Organization

Milligan Robotics is divided into three branches: electrical, mechanical, and software. Teammates serve in varying capacities with a team leader overseeing each branch, team officers who manage the team or as members who lead the development of particular parts.

Milligan Robotics Org Chart
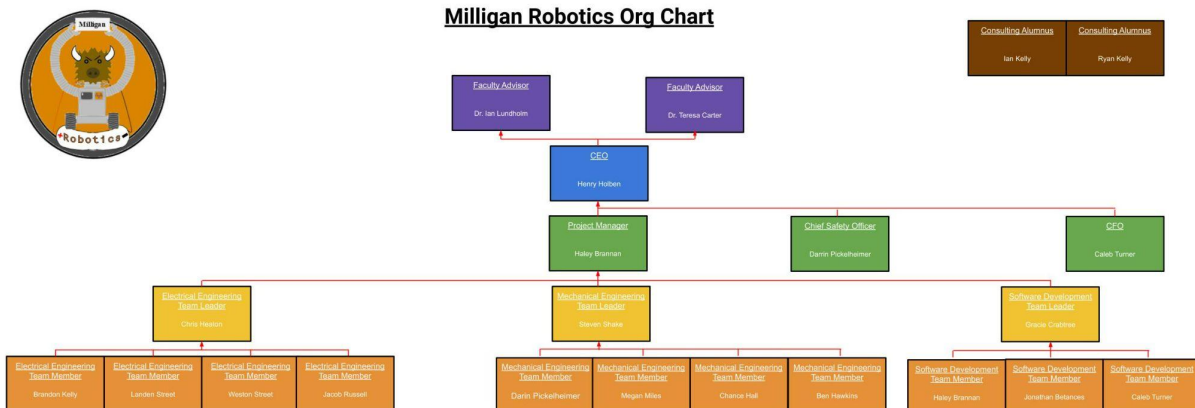
B. Budget

Milligan Robotics was given a $2000 budget by Milligan University to fund its activities. The team also reused parts from its previous ROV, TRILOBYTE to save money.

|		Team fills this out					Caleb	Dr. Lundholm fills this out					Price total	Amt left in budget
Date listed	Point person	Item	Description (Mfr. #, color, etc.)	Qty	Projected price (including S&H, tax)	Link	CFO approval	Date ordered	Actual Price	Receipt	Shipping info	Date recieved	$2,009.88	-$9.88
11/3/2021	Henry	Single Output Power Supply 48 Volts @ 42 Amps, 2000W	Meanwell	1	$464.76	RSP-2000-48		11/4/2021	$464.76	amazon				
11/3/2021	Henry	Heavy Duty Power Pole Connectors	Mouser	10	$15.20	1339G3-BK		11/4/2021	$15.20		Already past			
11/3/2021	Henry	Anderson Power Pole Housing	Mouser	3	$24.33	SBS50BLU		11/4/2021	$32.01	mouser				
1/26/2022	Henry	AN-22F Diecast Aluminum NEMA Enclosure	Polycase, natural color	1	$59.39	https://www.polyca		1/26/2022		polycase	1Z472462036	1/28/2022		
1/28/2022		Gyroscope/acceleration sensor	Adafruit; Black; has holes,	1		Adafruit 9-DOF LS	☐							
1/28/2022	Henry	AN-23F Diecast Aluminum NEMA Enclosure	bigger + mounting plate access	1	$94.36	https://www.polyca	☑	2/2/2022	$94.36	poly	track		polycase	$153.75
2/1/2022	Darin	Gyroscope/acceleration sensor	Different from the one above	1	$43.90	Amazon.com: Adal	☑	2/2/2022	$43.90	gyro	Monday		lowes	$102.35
2/7/2022	Henry	Kingmax Servomotor	don't order this yet. On hold for		$73.95	F3A Unlimited King	☐						amazon	$243.74
2/7/2022	Henry	Annimos Servo motor	Order this one- cheaper than th	2	$18.99	Amazon.com: ANN	☑	2/10/2022	$40.96				blue robotics	$666.24
2/17/2022	Henry	Penetrators	coregrips	at leas	$14.08	50.11409 PA/SW J	☑						MATE registratio	$400.00
2/14/2022	Caleb	70ft PVC @ Lowes	SDR 13.5 10ft sections	7	$35-40	Charlotte Pipe 1/2-	☑	2/19/2022	$89.97		lowes run			
2/23/2022	Caleb	Camera				Amazon.com : ELF	☐							
2/24/2022	Landen	Waterproof Junction box (for cameras)	Zulkit 5.9x3.9x2.8 inch box	4 penc	$13.99	Zulkit Box	☑	3/1/2022	$55.28					
3/2/2022	Chris	Fuse block					☐	3/2/2022	$27.43					
3/11/2022	Darin	5 way connectors					☐	3/11/2022	$17.55					
3/23/2022	Chris	Scotch 2228 Mastic 10-ft Black Electrical Tape in the Electrical Tape department at Lowes.com		1	$12.38	https://www.lowes.	☑	3/24/2022	$12.38		lowes run			
3/23/2022		Reusable zip ties			$7.67		☐	3/23/2022	$7.67					
3/25/2022	Caleb	Connector for Camera			$8.39	Amazon	☐	3/25/2022	$8.44					
3/29/2022		Leak sensor from Blue Robotics	has multiple probes, if that is im		$37.76	alternative	☐							
		USB to ethernet adapter			$15.35	amazon	☐	3/31/2022	$15.35					
4/13/2022	Henry	Blue robotics pressure cannister	acrylic	1	$250.00	Underwater Subse	☐			This is just the whole order				
4/13/2022	Henry	O-ring flange	aluminum	1	$110.00	Underwater Subse	☐				https://www.ups.			
4/13/2022	Henry	Pressure Cannister end cap (through holes)	aluminum	1	$60.00	Underwater Subse	☐							
4/13/2022	Henry	Pressure Cannister end cap clear -(wait, we could get a dome instead)	acryllic	1	$60.00	Underwater Subse	☐							
4/13/2022	Henry	Orange Penetrators	for 5.5 mm diameter cables	5	$50.00	WetLink Compress	☐							
4/13/2022	Henry	Green Penetratraor	for 4.5 mm diameter cables	11	$62.00	WetLink Compress	☐	4/22/2022	$666.24					
4/22/2022	Darin	Blue RTV					☐		$7.42					
4/25/2022		MATE Registration Fee					☐	4/25/2022	$400.00					
5/6/2022		More servos	amazon	4			☐							
5/9/2022		fishes	walmart	4			☐							
5/10/2022		arducam	amazon	1			☐							

III. Design

    A. Design Philosophy

In 2021, the Milligan ROV TRILOBYTE utilized software that was designed to be stackable, allowing for easy modification and additions in the future. To continue developing our ROV with future developing and the end-user in mind, this year we sought to develop a modular platfrom for the ROV's construction.

We believe that modular development offers better experience to the end-user. A modular robotics system should allow for easy modification, assembly, and repair of the ROV and to minimize waste by producing parts that can be reused after a particular configuration is discarded.

    B. Mechanical Design

Frame: Milligan Robotics' modular design philosophy is most apparent in the design of Lawrence the Annihilator's frame. The frame consists of PVC pipe fitted together with 3d printed parts.
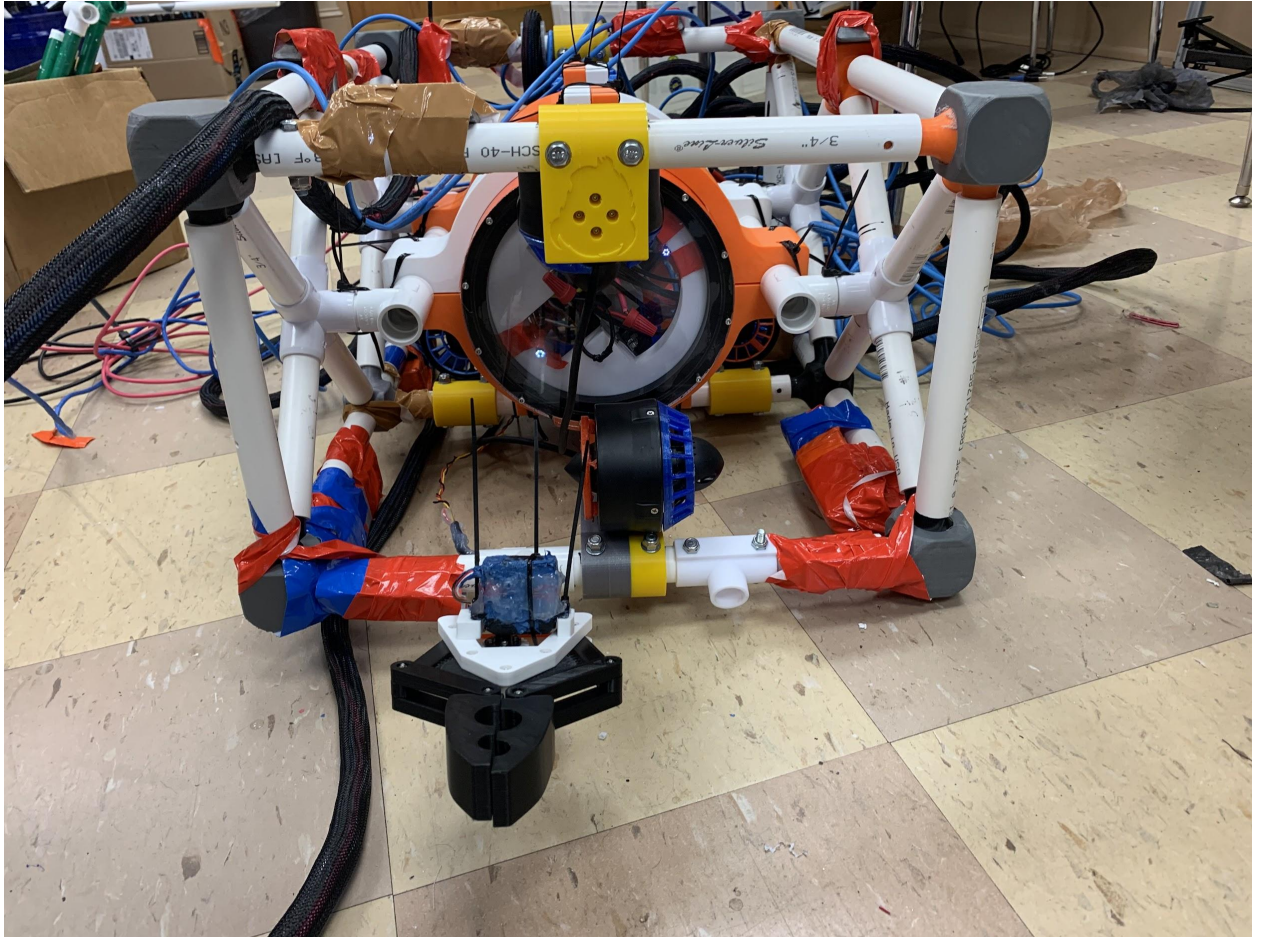
Combined PVC and 3D Printed Frame, tied together with triangular and square construction, bolts, and Zip-Ties. Our team collectively decided on utilizing ¾ inch schedule 40 PVC piping as our main product for the frame. This was chosen because of its strength, durability, low cost, light weight, regulated standard sizes, and ease of use. The frame was built with a truss style design to create rigidity throughout the frame. After fitting one of the side truss style sides together it was apparent that no mechanical tie was needed to hold it together. The reason for the use of a multitude of 3D printed

connectors was due to the custom nature of the design and shape. We also found that using 3D printed parts allowed the team to learn more about design and building strength into a product that can break easily if not designed or printed correctly. There were countless lessons in design geared towards building strength and flexibility into 3D printed PLA parts. Our team strived to create a frame that housed most of the parts inside the frame to protect itself from damage and limit failure. This frame was originally designed around a rectangular junction box that mimicked the overall shape of the frame. This rectangular junction box failed in the end as we scrambled to purchase a new larger canister and retrofit it into the frame. This was achieved through our team's ability to adapt and quickly work together to implement a new plan.

The frame parts that our team has designed and printed are described as follows:

(2) Five-way ¾ inch schedule 40 PVC, 3D printed male connectors, made of PLA. These parts tie the two center bottom sections of the truss frame together by inserting into the inside of the PVC tube and mechanically tying them together with a ¼ inch bolt or Zip-Tie. These parts were printed with 5 perimeter walls and 25 percent infill. They were designed with multiple holes in them for added strength as well as quick evacuation of air and water through the parts. The seams were convex and concaved for strength.

(2) Four-way ¾ inch schedule 40 PVC, 3D printed male connectors, made of PLA. These parts tie the two center top sections of the truss frame together by inserting into the inside of the PVC tube and mechanically tying them together with a ¼ inch bolt or Zip-Tie. These parts were printed with 5 perimeter walls and 25 percent infill. They

were designed with multiple holes in them for added strength as well as quick evacuation of air and water through the parts. The seams were convex and concaved for strength.

(8) Four-way ¾ inch schedule 40 PVC, 3D printed male connectors, made of PLA. These parts tie the eight corners of the two side trusses together by inserting into the inside of the PVC tube and mechanically tying them together with a ¼ inch bolt or Zip-Tie. These parts were printed with 5 perimeter walls and 25 percent infill. They were designed with multiple holes in them for added strength as well as quick evacuation of air and water through the parts. The seams were convex and concaved for strength.

(6) Eight-inch Junction Box Canister brackets. These canister bracket pieces were designed in quarters to fit on the tray of the 3D printer. They use a mechanism of clamping by tightening two ¼ inch bolts on each junction. Two of the four junctions fit around the ¾ inch schedule 40 PVC pipe utilizing a through bolt to create a secure mechanical connection. These brackets hold the canister to the frame. These parts were built with PLA on a 3D printer.

(6) Thruster Bracket for the T200 Thruster. This bracket connects to ¾ inch schedule 40 PVC, and is 3D printed with PLA. This bracket utilizes two ¼ inch through bolts to secure the bracket to the PVC pipe. One buffalo head is imprinted into the side of the bracket.
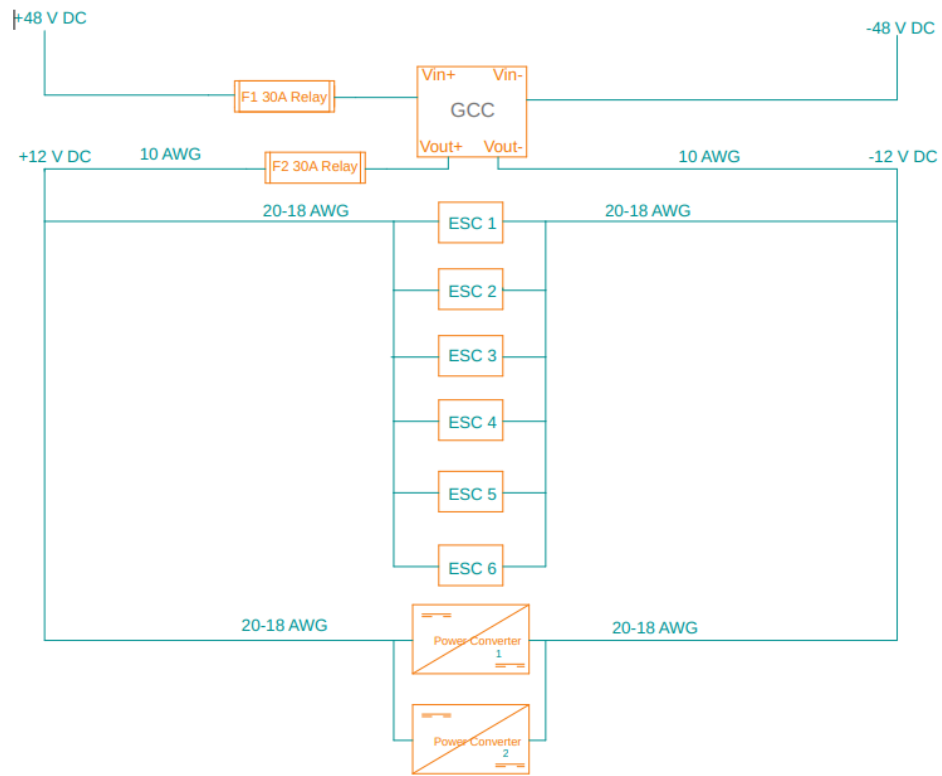
(8) Corner Bumpers. These bumpers were printed on the 3D printer with 2 perimeter walls made out of flexible TPU. These bumpers were stretched over the (8) Four-way ¾ inch schedule 40 PVC, 3D printed male connectors, made of PLA. Once

stretched around the male connectors and fitted to the frame the bumpers cannot be

removed without disassembling the frame first. These bumpers give the ROV soft

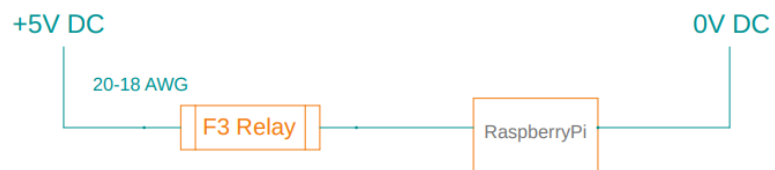landing points to protect the pool and the ROV from damage.
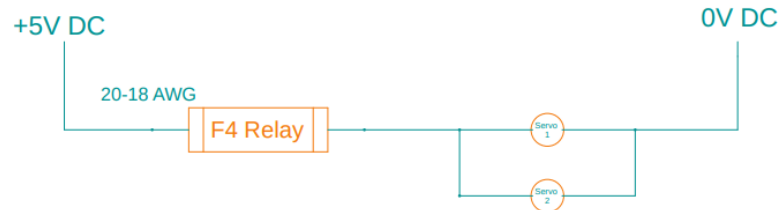
    C. Electrical Design

SID Diagram (Power)

+48 V DC   -48 V DC

| F1 30A Relay |

Vin+   Vin-

GCC

Vout+   Vout-

+12 V DC   10 AWG | F2 30A Relay | 10 AWG   -12 V DC

20-18 AWG   ESC 1   20-18 AWG

ESC 2

ESC 3

ESC 4

ESC 5

ESC 6

20-18 AWG   Power Converter 1   20-18 AWG

Power Converter 2

Power Converter 1

+5V DC   0V DC

20-18 AWG

| F3 Relay | RaspberryPi

Power Converter 2

+5V DC   0V DC

20-18 AWG

| F4 Relay | Servo 1

Servo 2

I. **Parts**

Electronic Speed Controller (ESC)

Price: $30.00

Blue Robotics Basic ESC

Model Number:

How to Use:

http://www.therobotguyllc.com/wp-content/uploads/2019/08/R30iA-Mate-Controller-Maintenance-Manual.pdf

1. Initializing the ESC:

   a. Connect the three motor wires to the motor in any order. However, know that switching any two wires will change the direction of the motor so it's best to keep all thrusters hooked up the same way–white to white, green to green, blue to blue.

   b. Connect the red and black wires to a power source such as a battery or power supply. For the ROV, the red and black wires were connected to the positive and negative terminals of the fuse block. The fuse block is then powered by the golf cart converter (*Needs fact checked- its wired up to GCC in ladder diagram but not for sure the exact connections). With a motor connected, you hear three beeps in rising pitch indicating all three wires are connected.

Ground Terminals

BATTERY

DEVICE

Positive Terminals
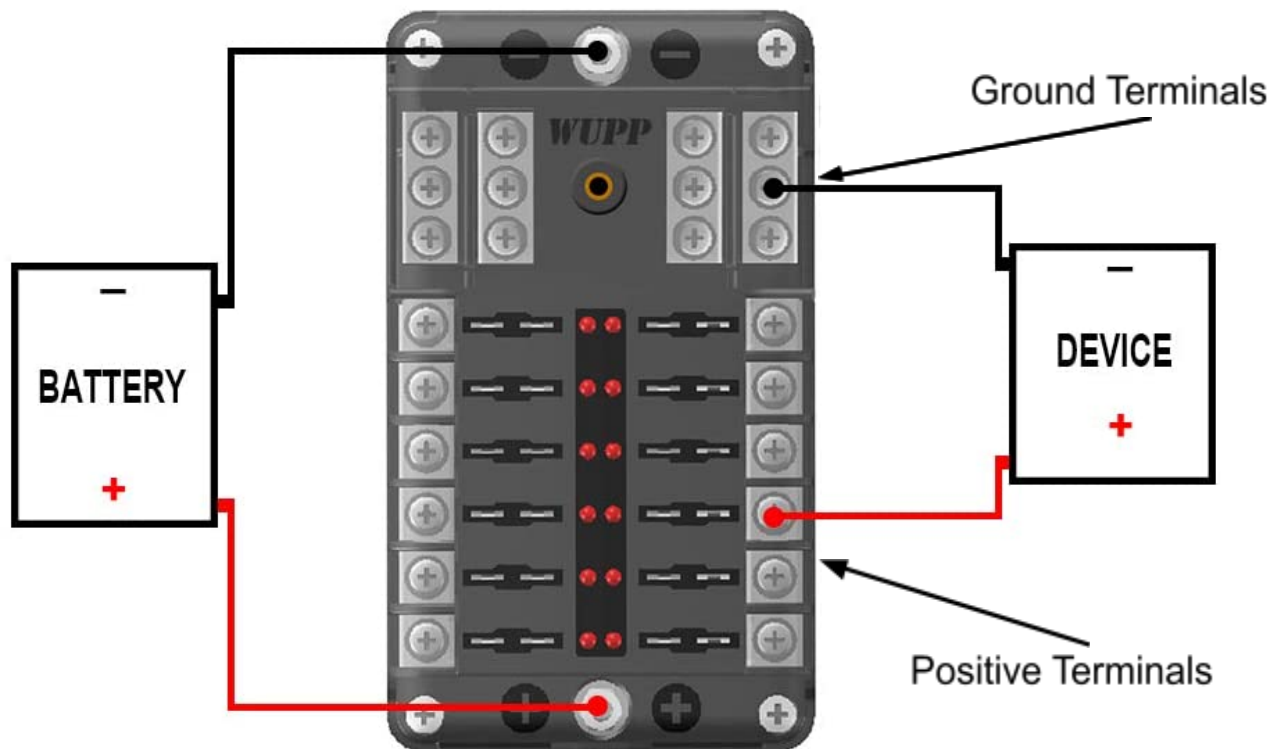
c. The signal wires (black and white) are wired to a Raspberry Pi (see page #*). The white wire is the signal and the black is ground, so wire the white into a GPIO pin and the black into the GRD pin.

d. Send a *stopped* signal (1500 microseconds) for a few seconds to initialize the ESC. You will hear two tones indicating initialization and then you can send a signal from 1100-1900 μs to operate the thruster. For forward

thrust use 1500-1900 µs. For reverse thrust, use 1100-1500 µs (more on this below specifications).

Specifications:

Parameter	Value
Electrical	-
Voltage	7-26 V
Max Current	30 A (depending on cooling)
Physical	-
Weight	16.3 g
Power Connectors	Spade terminals for No. 6 screw
Motor Connectors	Tinned wire ends
Signal Connector	3 pin servo connector(0.1" pitch) (ground, blank, signal) *(connector not used in current version for the ROV)

Pulse Width Signal	-
Signal Voltage	3.3-5V
Max Update Rate	400 Hz (2500 µs)
Max Forward	1900 µs
Max Reverse	1100 µs
Signal Deadband	+/- 25 µs (centered around 1500 µs)
Firmware Defaults	-
Directionality	Bidirectional (center throttle is zero/stopped)

Thermal Protection	
Temperature	**Motor Power Limit**
≥140°C	**75%**
≥145°C	**50%**

≥150°C	**25%**
≥155°C	**0%**

More info about the specifications:

- **Pulse Width Modulation (PWM)** - Method used to reduce average power supplied by an electrical signal. This is done by effectively switching the power supplied on and off at fast, user-controlled rates (a pulse). This provides a percentage of power (duty cycle) that, in simple terms, means the user can turn the switch on for small periods of time to mimic delivering a specific voltage output below the max voltage. Why are we using PWM? The thrusters need to have varying amounts of voltage to run not only at different speeds but run in different directions.

- **Max Update Rate** - One cycle. How fast it switches between high and low states–higher frequency means higher average voltage. An important thing to note is that switching between on and off doesn't happen immediately.

- **Duty Cycle** - a percentage that means how long the signal reads high compared to the total time to complete one cycle which in this case is 400 Hz. Each cycle is 400 Hz or 2500 μs, so if the max forward signal is 1900 μs, the switch will be on for 1900 μs and off for 600 μs (2500-1900=600).

  To calculate duty cycle, divide the time the switch is on by the total cycle time and multiply by 100:

$$\frac{1900 \, \mu s}{2500 \, \mu s} * 100\% = 76\%$$

Multiplying this percentage by the max voltage will give you the average voltage

output for that duty cycle.

$$12 \, V * 0.76 = 9.12 \, V$$

This means that, in the software, when you initiate *max forward* by sending a

signal of 1900 μs, the ESCs will output on average 9.12 V. Now in our case, the

thrusters operate at 7-20 V which is where the power converters come in at.

- The terms **max forward, max reverse, and stopped** are meant to relate the

   functions of the ESC to thruster control. The values they represent are the

   numerator in the duty cycle ratio that correlates to a specific function that the

   thrusters will perform. Max forward is the highest amount on the duty cycle range

   that will make the thrusters move forward. As stated before, if you send a signal

   from 1500-1900 μs (60%-76% duty cycle), the thrusters will receive the output

   that makes them move forward. Max reverse is the lowest signal on the duty

   cycle range that will make the thrusters go in the reverse direction (1100-1900 μs

   or 44%-60% duty cycle). When the ESC receives a *stopped* signal, it will put the

   thrusters in idle (forward and reverse meet in the middle) at the end of the cycle.

   Another note: generally, in PWM, the idle is set to the 50% duty cycle so that the

   switch would be on the same amount of time it is off, but that is not the case in

   this scenario. Normally, you would also be able to send a signal of 2500 μs which

would just be the switch left on for the entire cycle, but the firmware in the Blue
Robotics

- **Signal Deadband** - this is an extremely small period of time between cycles that
provides complementary outputs which are both set to low. This is just to prevent
"shoot-through" current that would lead to unnecessary overheating or device
failure.

- **Thermal Protection** - part of the already existing firmware that will lower the
power when the ESC reaches a certain temperature.

Golf Cart Converter
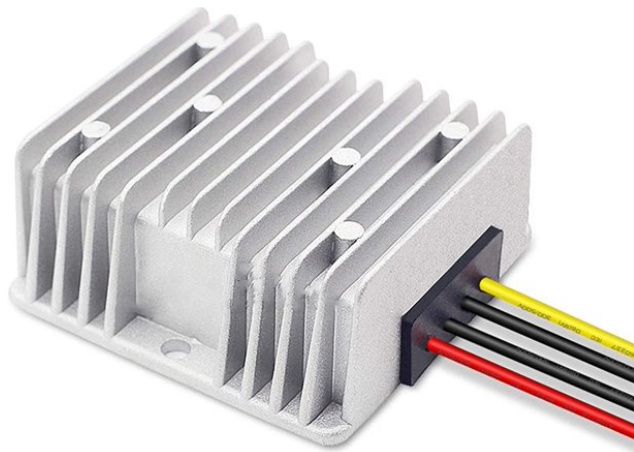
Overview

Price: $19.99

The Golf Cart Converter is a voltage regulator that reduces the 30-60 volts supplied to 12 volts. All components for the ROV run under 12 volts

Specifications

- Input Voltage Range: 30-60V DC(36V/48V)

- Output Voltage: DC 12V **±2%** , Output Current:10A, Out Power:120w, High Conversion Efficiency: up to 96%

- Protection: Built in overload, over-current, over-temperature and short-circuit protection.

- **Input Current: 10A (max) ; No-load input current: ≤10mA**

- **Ripple Wave: 50Mv**

- **Starting Delay time: ≤ 2S**

- **Efficiency: ≥95%**

- **Operating Temperature:-40 ~ 80℃**

- **Weight: 248g / 8.75oz**

- **IP68 Waterproof Module**

- **Overload, overcurrent, overheat, short circuit, low load intelligent protection**

Dimensions:

**2.9" x 2.9" x 1.22" (74mm x 74mm x 31mm)**

Weight:

248 grams

Installation

- Red/Black (+V,-V) pair of wires are connected directly to power supply. There are two black wires on the golf cart converter. The red and black that are next to each other are the ones plugged into power supply. Red - Red, Black - Black

- Yellow and black(other black) wires are wired to the fuse box. The yellow goes into the positive terminal of the fuse box. The black goes into the negative terminal of the fuse box.
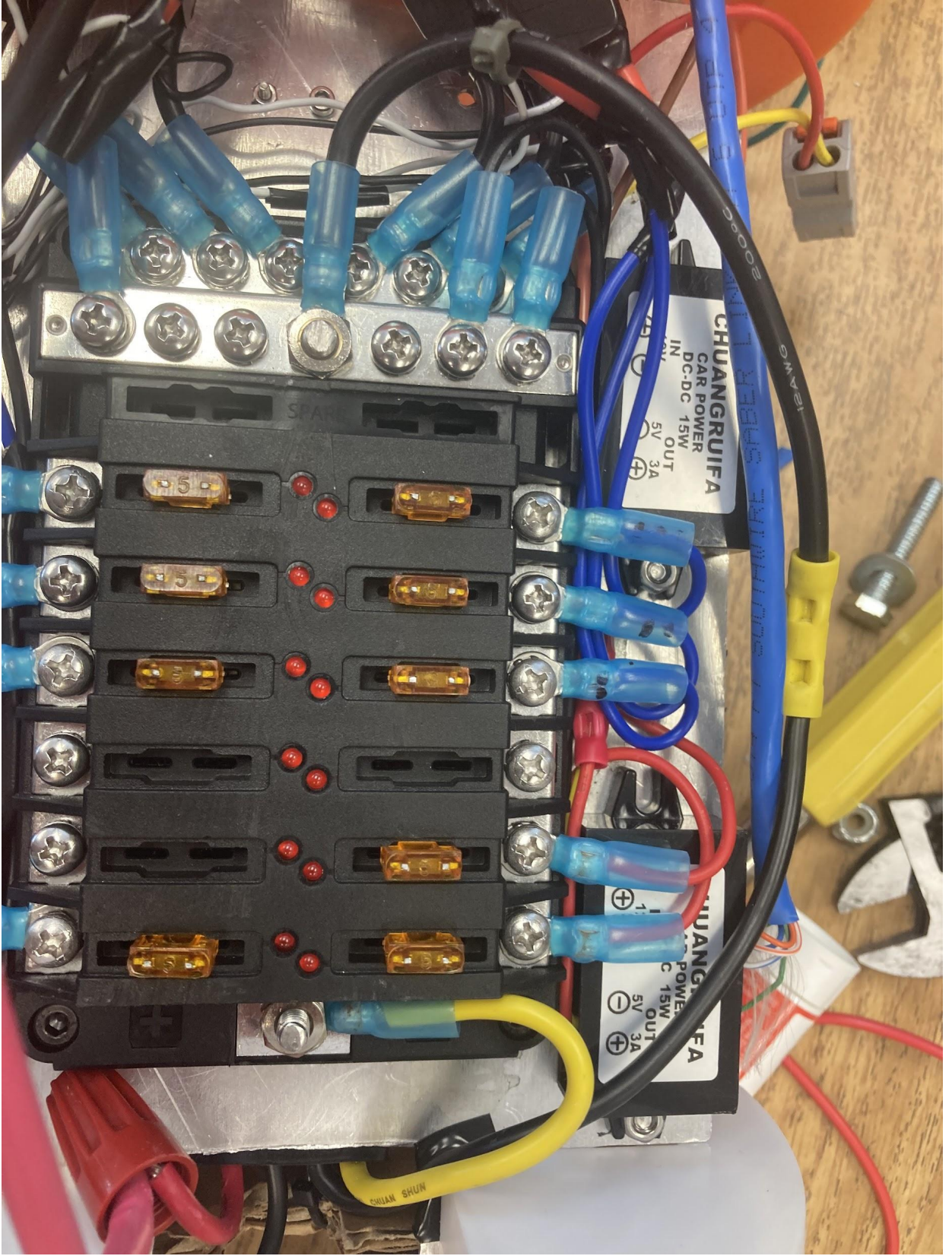
Raspberry Pi Model 4B
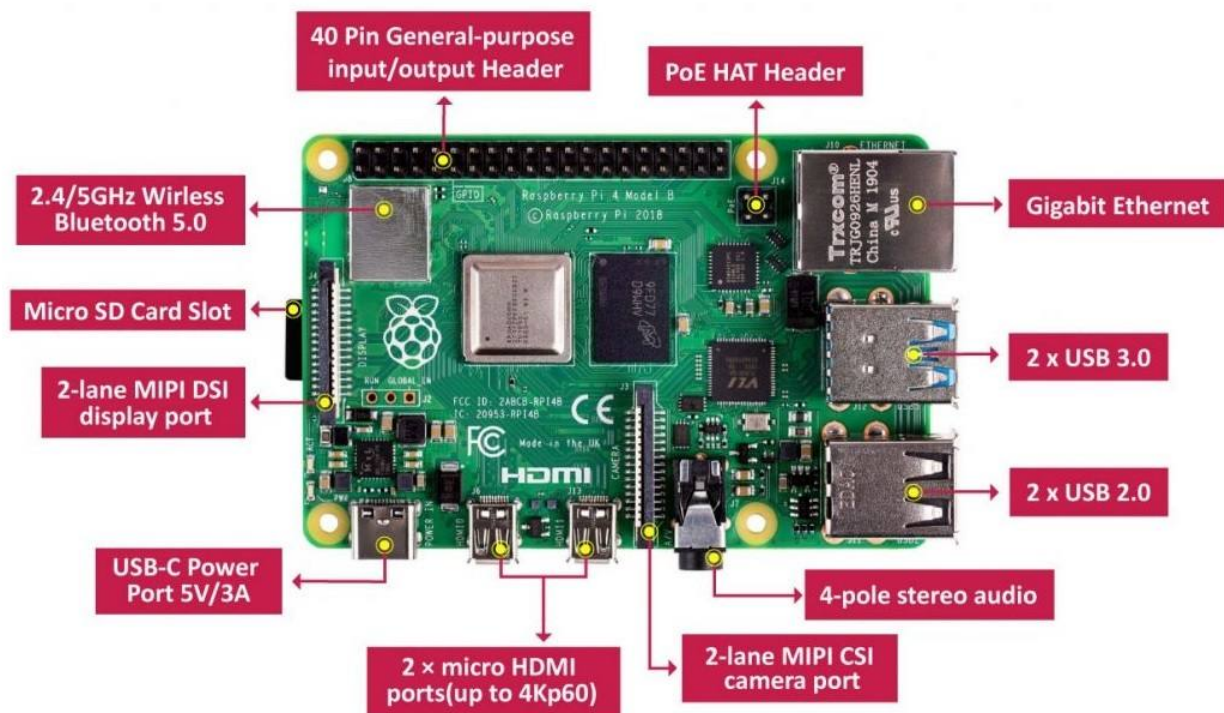
Price: $219.00

How to Use:

Raspberry Pi Model 4B- The Raspberry Pi is a credit-card sized single-board computer that is capable of performing various computing tasks. The Raspberry Pi is designed to run on 5 volts plus or minus 5% (4.75 V - 5.25 V).

Headers, Ports, etc.:

- Broadcom BCM2711, Quad core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz
- 4GB LPDDR4-3200 SDRAM

- 2.4 GHz and 5.0 GHz IEEE 802.11ac wireless, Bluetooth 5.0, BLE

- Gigabit Ethernet

- 2 USB 3.0 ports; 2 USB 2.0 ports.

- Raspberry Pi standard 40 pin GPIO header (fully backwards compatible with previous boards)(**Max current per GPIO - 16mA but should not exceed 50mA overall**)

- 2 × micro-HDMI ports (up to 4kp60 supported)

- 2-lane MIPI DSI display port

- 2-lane MIPI CSI camera port

- 4-pole stereo audio and composite video port

- H.265 (4kp60 decode), H264 (1080p60 decode, 1080p30 encode)

- OpenGL ES 3.1, Vulkan 1.0

- Micro-SD card slot for loading operating system and data storage

- 5V DC via USB-C connector (**minimum 3A* recommended**)

- 5V DC via GPIO header (**minimum 3A* recommended**)

- Power over Ethernet (PoE) enabled (requires separate PoE HAT)

- Operating temperature: 0 – 50 degrees C ambient (**MAX: 85 degrees**)

* A good quality 2.5A power supply can be used if downstream USB peripherals consume less than 500mA in total.

https://www.raspberrypi.com/software/

Dimensions:
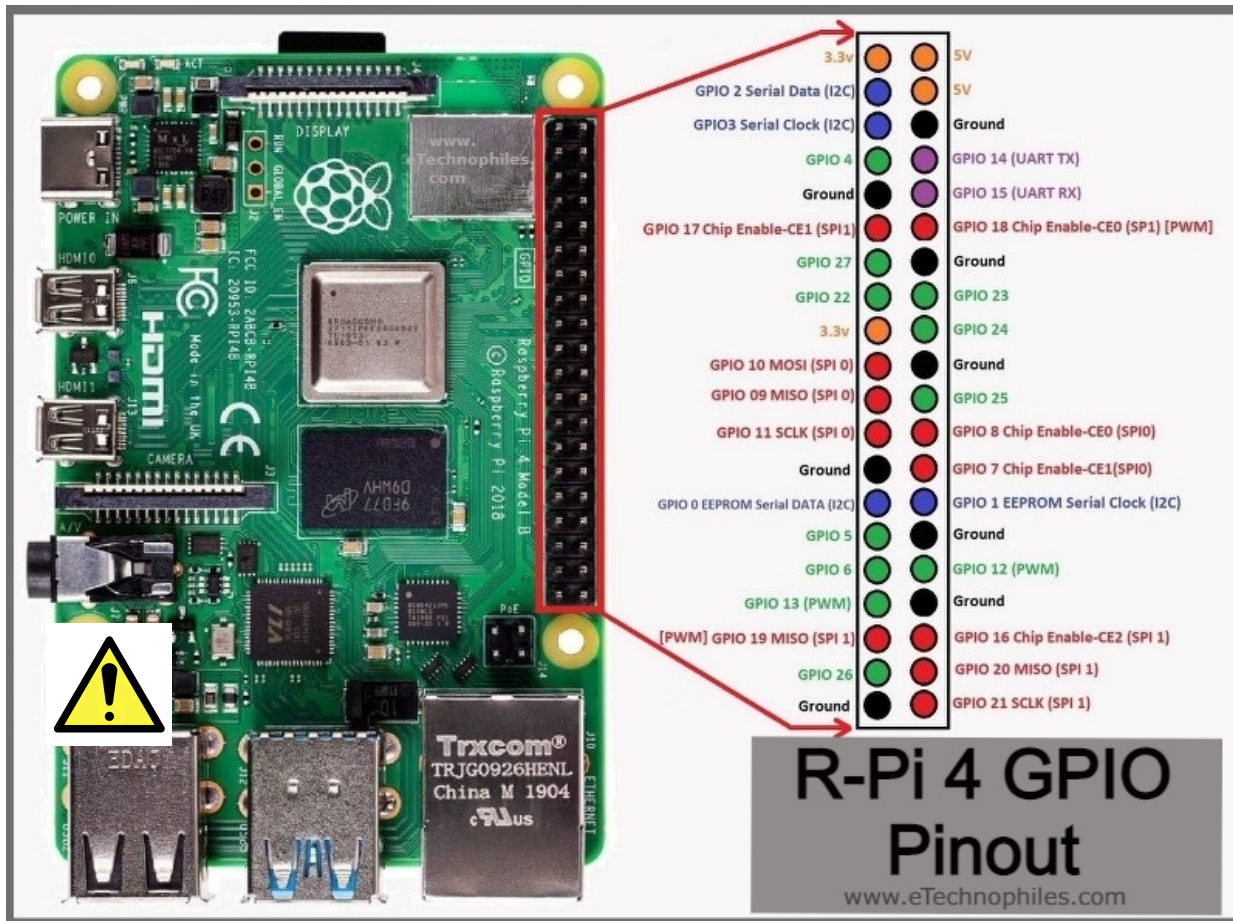
Height: 2.22 in (56.5 mm)

Width: 3.37 in (85.6 mm)

Depth: 0.43307 in (11 mm)

Weight: 1.62 oz (46 g)

(What does what on the board, how to use specific ports, what type wires are used for each port(especially obscure ones), software implementation)

Specifications: (all that's needed for specs is probably just the two pictures here and maybe a schematic, which needs to be updated)

Warning

- Do NOT connect the 5V pins with any of the other GPIO ports. A Raspberry Pi can be directly powered by these pins or supply power to external hardware, but the pins not labeled 5V can only handle 3.3 Volts.
- The Raspberry Pi has little to none protection circuitry like most computer

motherboards have. They are more susceptible to electrostatic discharge (static shock).

- Do NOT overload the Pi. There is a polyfuse that will protect against overcurrent and it also has an overheating safety feature but there is no safety feature in place for overvoltage.
- Do NOT connect the 5V or 3.3V pins to ground. This creates a short circuit and will burn the Pi up.

The easiest way to control the GPIO pins is using the RPi.GPIO Python library. Installing the library is easy if you follow my RPi.GPIO Installation Guide. Once installed using the pins is as easy as :

```
1    import RPi.GPIO as GPIO
2
3    # Use GPIO numbers not pin numbers
4    GPIO.setmode(GPIO.BCM)
5
6    # set up the GPIO channels - one input and one output
7    GPIO.setup(7, GPIO.IN)
8    GPIO.setup(8, GPIO.OUT)
9
10   # input from GPIO7
11   input_value = GPIO.input(7)
12
13   # output to GPIO8
14   GPIO.output(8, True)
```

Depth Sensor
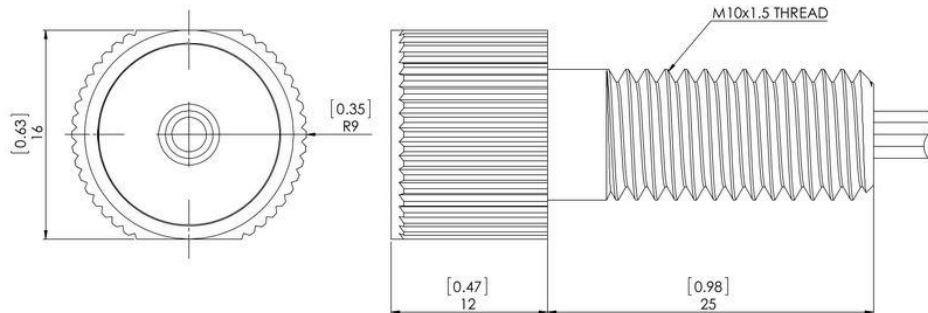
Price: $85.00 (CITE BLUE ROBOTICS SITE FOR MOST OF THIS)

Key Features

- **High resolution pressure and temperature sensor up to 300m (1000ft).**

- **Resolution of .2 mbar in freshwater.**

- **Operates at 0-30 Bar of pressure**

- **Operates at 2°C to 40°C (approximately 35°F to 105°F)**

- **Operates on 3v3 I²C voltage with the capability of operation at a maximum voltage of 5.5 V.**

- **The temperature sensor is used to more accurately measure pressure.**

- **Altitude sensor**

About

The Blue Robotics depth sensor (TE Connectivity Measurement Specialties' MS5837-30BA) is a **Piezo-Resistive** sensor, designed to be faster and more precise than other diaphragm type pressure sensors. The diaphragm for this sensor is formed on a Piezo Silicon piece that flexes when positive and negative pressure is applied. The change in the structure of the Piezo crystals results in a change in resistance of the material.
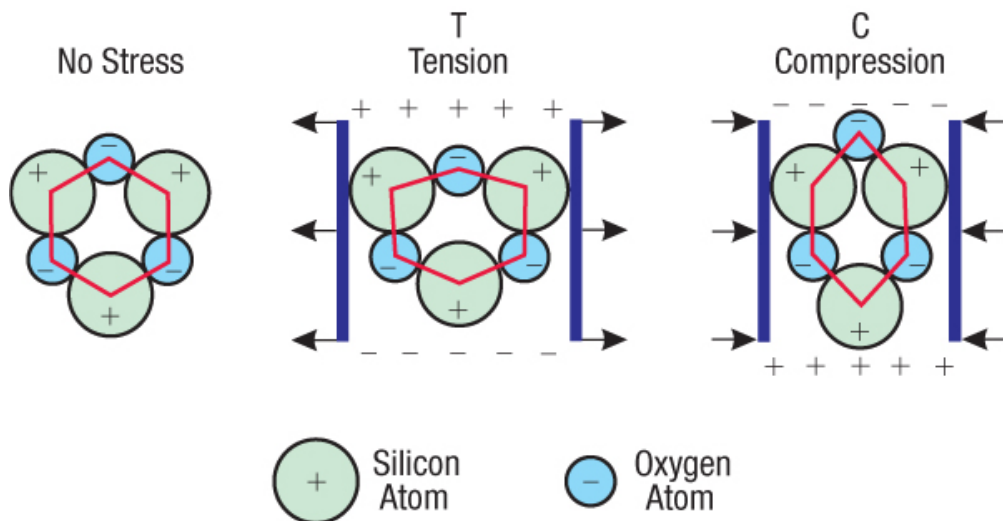
These resistance changes can be implemented into digital logic and calculate the pressure more precisely, making it suitable for digital circuitry and microcontrollers.
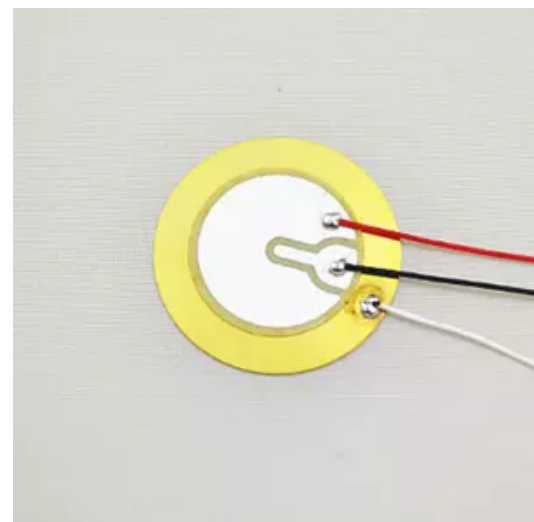
Sealing

The depth sensor uses an O ring that is placed in the groove of the penetrator. There is also gel and a stainless steel cap that makes the sensor water resistant. The recommended hole size for the penetrator is **10-10.5 mm.**

Safety

It is recommended that the depth sensor be completely dried out once daily to maintain accurate readings.

Connections

DF13 Connector
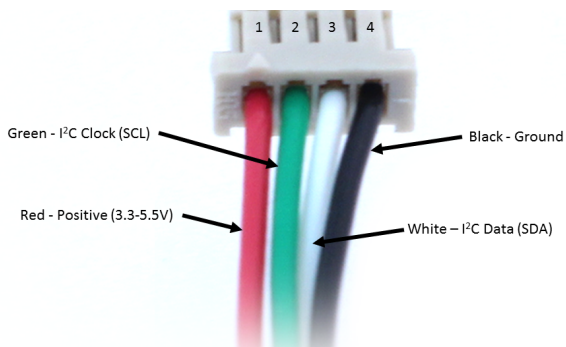
The **red wire** (3.3V-5.5V) and the **black wire** (ground) will be connected to the 3.3V pin and ground pins on the Raspberry Pi. The **green wire** (clock) and the **white wire** (data) can be connected to the assigned GPIO pins in the code.

Datasheets

DIGITAL INPUTS (SCL, SDA)

Parameter	Symbol	Conditions	Min.	Typ.	Max	Unit
Serial data clock	SCL				400	kHz

ELECTRICAL CHARACTERISTICS

Parameter	Symbol	Conditions		Min.	Typ.	Max	Unit
Operating Supply voltage	V_{DD}			1.5	3.0	3.6	V
Operating Temperature	T			-20	+25	+85	°C
Supply current (1 sample per sec.)	I_{DD}	OSR	8192		20.09		µA
			4096		10.05		
			2048		5.02		
			1024		2.51		
			512		1.26		
			256		0.63		
Peak supply current		during conversion			1.25		mA
Standby supply current		at 25°C (V_{DD} = 3.0V)			0.01	0.1	µA
Power supply hold off for internal reset [3]		VDD < 0.1V		200			ms
VDD Capacitor		From V_{DD} to GND		100	470		nF

(3): Supply voltage power up must be continuous from GND to VDD without any step

Depth Sensor Software

The software can be installed via Github.

Example code
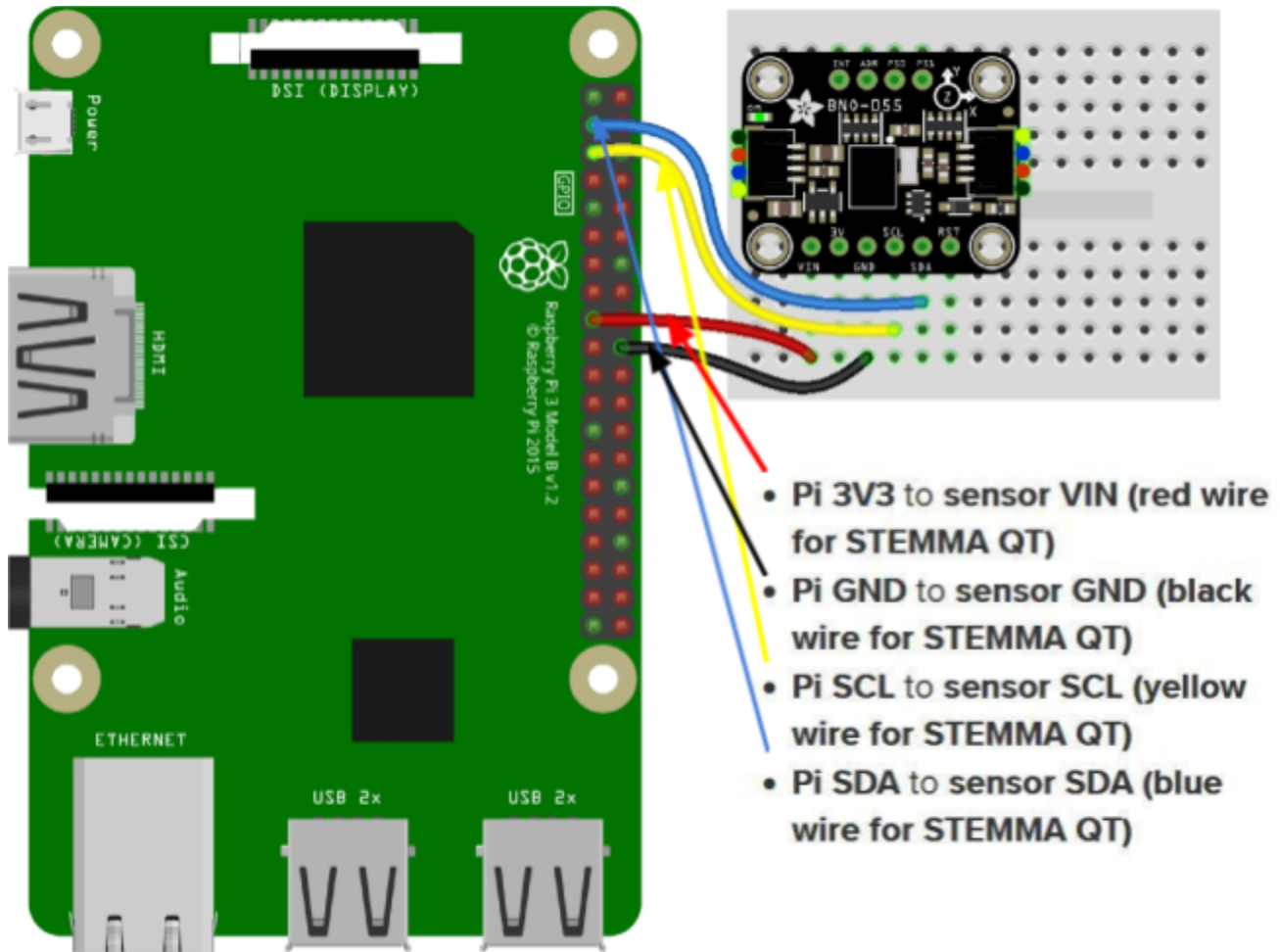
```
36
37   #include <Wire.h>
38   #include "MS5837.h"
39
40   MS5837 sensor;
41
42   void setup() {
43
44     Serial.begin(9600);
45
46     Serial.println("Starting");
47
48     Wire.begin();
49
50     // Initialize pressure sensor
51     // Returns true if initialization was successful
52     // We can't continue with the rest of the program unless we can initialize the sensor
53     while (!sensor.init()) {
54       Serial.println("Init failed!");
55       Serial.println("Are SDA/SCL connected correctly?");
56       Serial.println("Blue Robotics Bar30: White=SDA, Green=SCL");
57       Serial.println("\n\n\n");
58       delay(5000);
59     }
60
61     // .init sets the sensor model for us but we can override it if required.
62     // Uncomment the next line to force the sensor model to the MS5837_30BA.
63     //sensor.setModel(MS5837::MS5837_30BA);
64
65     sensor.setFluidDensity(997); // kg/m^3 (freshwater, 1029 for seawater)
66   }
67
68   void loop() {
69     // Update pressure and temperature readings
70     sensor.read();
71
72     Serial.print("Pressure: ");
73     Serial.print(sensor.pressure());
74     Serial.println(" mbar");
75
76     Serial.print("Temperature: ");
77     Serial.print(sensor.temperature());
78     Serial.println(" deg C");
79
80     Serial.print("Depth: ");
81     Serial.print(sensor.depth());
82     Serial.println(" m");
83
84     Serial.print("Altitude: ");
85     Serial.print(sensor.altitude());
86     Serial.println(" m above mean sea level");
87
88     delay(1000);
89   }
```

Adafruit BNO055 Absolute Orientation Sensor

<u>**Assembly**</u>

Raspberry Pi 4 Model B to I2C IMU

The Following connections should be soldered to the gyroscope.

- **Pi 3V3** to **sensor VIN** (red wire for STEMMA QT)
- **Pi GND** to **sensor GND** (black wire for STEMMA QT)
- **Pi SCL** to **sensor SCL** (yellow wire for STEMMA QT)
- **Pi SDA** to **sensor SDA** (blue wire for STEMMA QT)

Connections and Pins
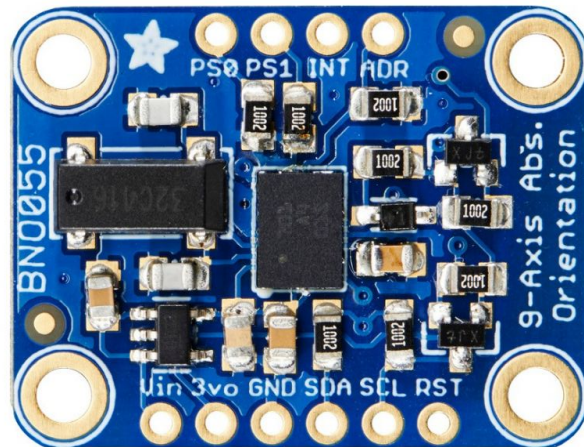
Bottom Pins

Vin - Power supplied input from 3.3 V to 5.0 V

3vo - Output voltage using linear voltage regulator and can supply up to 50 mA

GND - Ground

SDA - Data I^2C pin that connects to the assigned GPIO pins on the Raspberry Pi

SCL - Clock I^2C pin that connects to the assigned GPIO pin on the Raspberry Pi

RST - Reset pin that resets the sensor. To reset the sensor, set the RST pin to low, then high

Top Pins

PSO and **PS1** - Typically used for updating the firmware if a new update should be released. The HID I^2C driver and UART can also be implemented with these pins. HID

I²C can be used to reduce the number of drivers and UART is another serial communication system.

INT - Interrupt output signal when a specified event occurs.

ADR - Address pin that allows the address of the BNO055 to be changed, useful when using two ICs on the same I²C bus.

Software

Install Circuit Python

Latest Release of Circuit Python (7.1.1)

https://github.com/adafruit/circuitpython/releases

Version 7.2.0 is also releasing soon.

(Optional) Install all current libraries.

- https://circuitpython.org/libraries
- The bundle version should match with the version of Circuit Python you are using. **When running v7.1.1, download the 7.x library bundle.**
- Unzip the file, open the resulting folder and find the lib folder. Open the lib folder and find the library files you need to load. Create a lib folder on your CIRCUITPY drive. Copy the individual library files you need to the lib folder on your CIRCUITRY drive. More details are available here.

Install the BNO055 Libraries

Adafruit Library Bundle for BNO055

https://github.com/adafruit/Adafruit_CircuitPython_BNO055

This should include the following libraries in the installation found in setup.py on the GitHub page:

- Adafruit Blinka

- Adafruit Register

- Adafruit Bus Device

Potentially more libraries could be included.

Installing the necessary libraries from PyPI

https://circuitpython.readthedocs.io/projects/bno055/en/latest/

Usage Examples

A few ways to start using the BNO055:

Installing from PyPI

On supported GNU/Linux systems like the Raspberry Pi, you can install the driver locally from PyPI. To install for current user:

```
pip3 install adafruit-circuitpython-bno055
```

To install system-wide (this may be required in some cases):

```
sudo pip3 install adafruit-circuitpython-bno055
```

To install in a virtual environment in your current project:

```
mkdir project-name && cd project-name
python3 -m venv .env
source .env/bin/activate
pip3 install adafruit-circuitpython-bno055
```

Usage Notes

Of course, you must import the library to use it:

```
import adafruit_bno055
```

This driver takes an instantiated and active I2C object as an argument to its constructor. The way to create an I2C object depends on the board you are using. For boards with labeled SCL and SDA pins, you can:

```
import board

i2c = board.I2C()
```

Once you have the I2C object, you can create the sensor object:

```
sensor = adafruit_bno055.BNO055_I2C(i2c)
```

And then you can start reading the measurements:

```
print(sensor.temperature)
print(sensor.euler)
print(sensor.gravity)
```

All uses for the BNO055

Three axis orientation data based on a 360° sphere

- **Absolute Orientation** (Quaternion, 100Hz)

  Four point quaternion output for more accurate data manipulation

- **Angular Velocity Vector** (100Hz)

  Three axis of 'rotation speed' in rad/s

- **Acceleration Vector** (100Hz)

  Three axis of acceleration (gravity + linear motion) in m/s^2

- **Magnetic Field Strength Vector** (20Hz)

  Three axis of magnetic field sensing in micro Tesla (uT)

- **Linear Acceleration Vector** (100Hz)

    Three axis of linear acceleration data (acceleration minus gravity) in m/s^2

- **Gravity Vector** (100Hz)

    Three axis of gravitational acceleration (minus any movement) in m/s^2

- **Temperature** (1Hz)

    Ambient temperature in degrees cels

BNO055 Datasheets

OPERATING CONDITIONS BNO055						
Parameter	Symbol	Condition	Min	Typ	Max	Unit
Supply Voltage (only Sensors)	V_{DD}	--	2.4	--	3.6	V
Supply Voltage (µC and I/O Domain)	V_{DDIO}	--	1.7	--	3.6	V
Voltage Input Low Level (UART, I2C)	V_{DDIO_VIL}	V_{DDIO} = 1.7-2.7V	--	--	0.25	V_{DDIO}
		V_{DDIO} = 2.7-3.6V	--	--	0.3	V_{DDIO}
Voltage Input High Level (UART, I2C)	V_{DDIO_VIH}	V_{DDIO} = 1.7-2.7V	0.7	--	--	V_{DDIO}
		V_{DDIO} = 2.7-3.6V	0.55	--	--	V_{DDIO}
Voltage Output Low Level (UART, I2C)	V_{DDIO_VOL}	V_{DDIO} > 3V , I_{OL} =20mA	--	0.1	0.2	V_{DDIO}
Voltage Output High Level (UART, I2C)	V_{DDIO_VOH}	V_{DDIO} > 3V , I_{OH} =10mA	0.9	0.8	--	V_{DDIO}
POR Voltage threshold on VDDIO-IN rising	V_{DDIO_POT+}	V_{DDIO} falls at 1V/ms or slower	--	1.45	--	V
POR Voltage threshold on VDDIO-IN falling	V_{DDIO_POT-}		--	0.99	--	V
Operating Temperature	T_A	--	-40	--	+85	℃
Total supply current normal mode at T_A (9DOF @100Hz output data rate)	$I_{DD} + I_{DDIO}$	V_{DD} = 3V, V_{DDIO} = 2.5V	--	--	12.3	mA
Total supply current Low power mode at T_A	I_{DD_LPM}	V_{DD} = 3V, V_{DDIO} = 2.5V	--	--	0.4	mA
Total supply current suspend mode at T_A	I_{DD_SuM}	V_{DD} = 3V, V_{DDIO} = 2.5V	--	--	0.04	mA

Cite adafruit.com, BOSCH

HERE CAN ADD ALL 6 or 7 data sheets if we want to.

ANNIMOS 25kg RC Digital Servo Motors

ANNIMOS 25kg RC Digital Servo Motors (x2)

Price: $18.99

The 25kg servo motors are lightweight, water resistant and high torque motors used to control the arm of the ROV. The arm and claw is designed to manipulate objects in its environment and is controlled by the 25kg servo motors.

Electrical Specification

Operating voltage range: 4.8 - 6.8V

Operating speed (5.0V): 0.15 sec/60 degree

Operating speed (6.8V): 0.13 sec/60 degree

Stall torque (5.0V): 21kg/cm

Stall torque (6.8V): 25kg/cm

Control Specification:

Control System: PWM (Pulse width modulation)

Pulse width range: 500~2500 μsec

Neutral position: 1500μsec

Running degree: 180° (when 500~2500 μsec)

Dead band width: 3 μsec

Operating frequency: 50-330Hz

Rotating direction: Counterclockwise (when 500~2500 μsec)

Mechanical Specification:
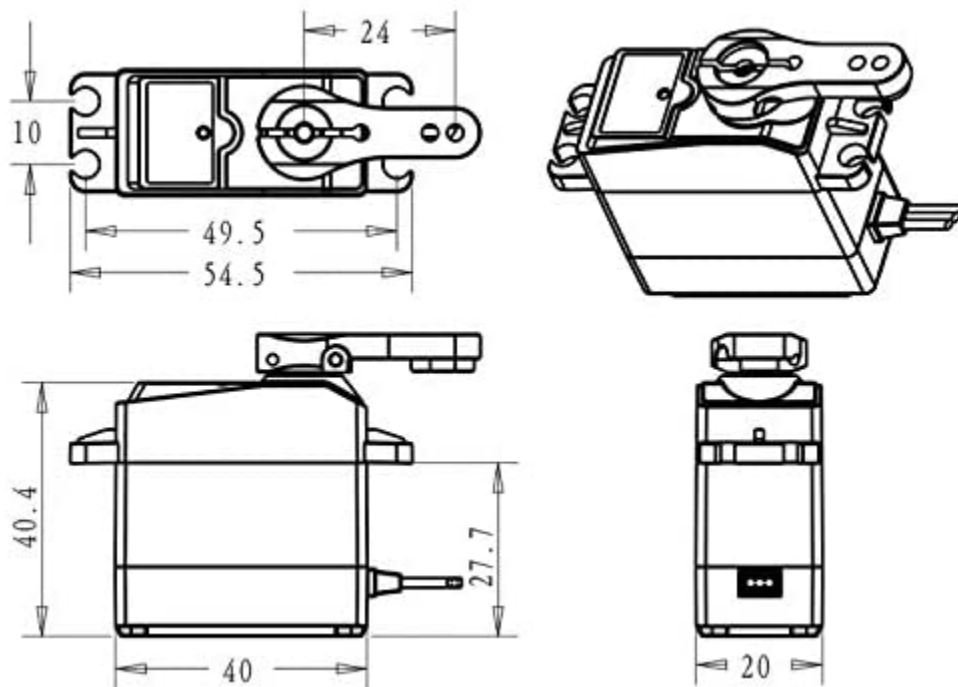
Gear ratio: 275

Bearing: Double bearing

Connector wire: 17.7inches(450mm)

Motor: 3-pole(s)

Waterproof performance: IP66

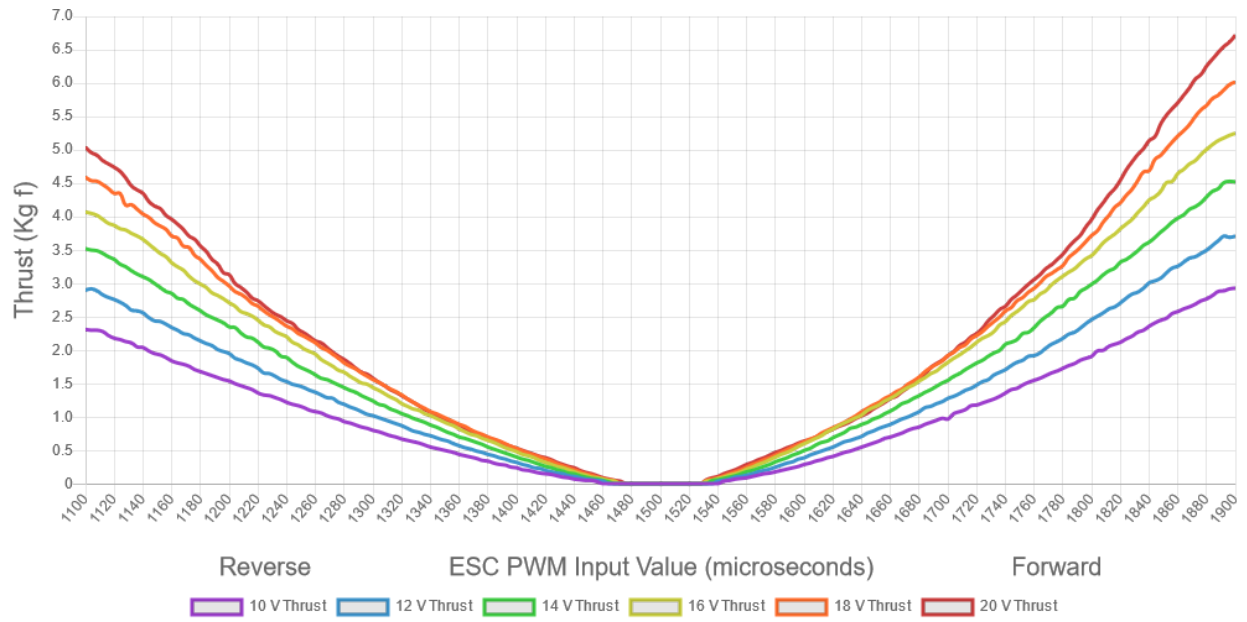Dimensions:1.57 x 0.78 x 1.59in (40 x 20 x 40.5 mm)

Weight:2.64oz (75g)

Blue Robotics T200 Thrusters

The ROV has six T200 thrusters to propel the robot in the water. Each thruster is paired with a speed controller (ESC) and can rotate both clockwise and counterclockwise (forward and reverse). The thrusters are also oriented with a pair to cover all axes of movement.
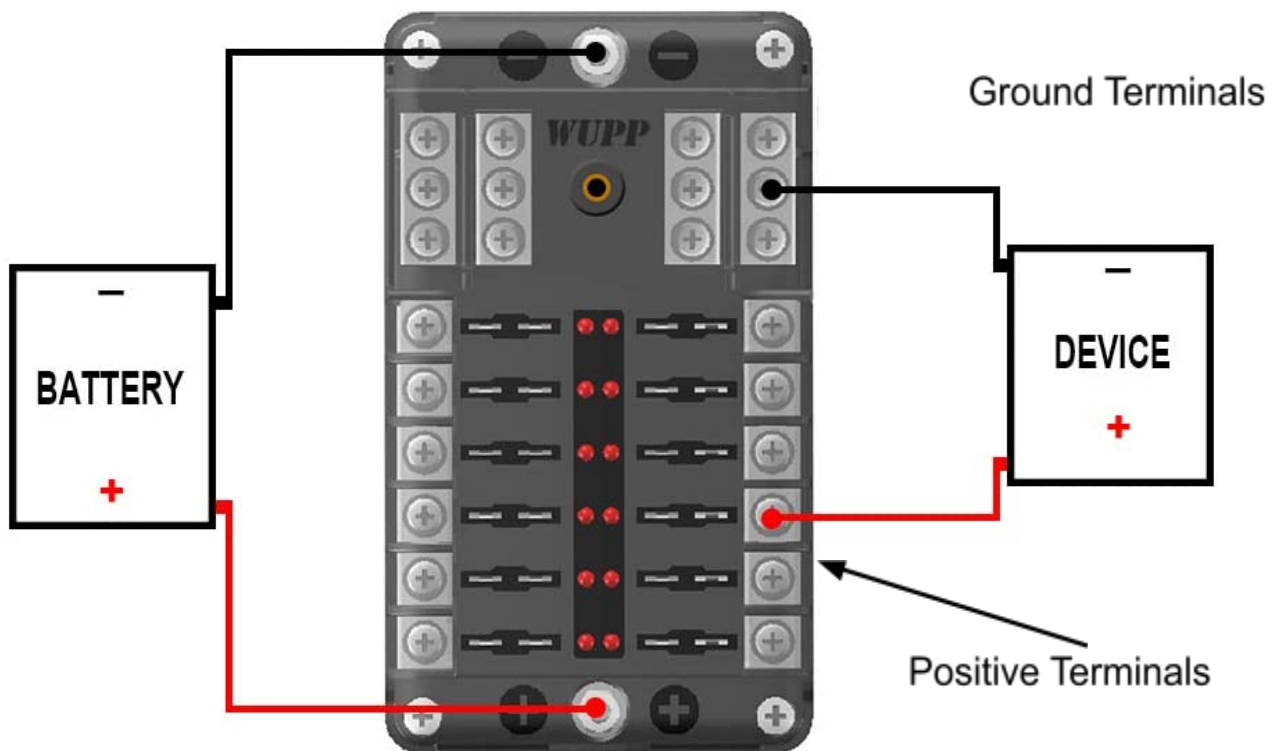
Parameter	Value	
Performance		
Full Throttle FWD/REV Thrust @ Nominal (16 V)	5.25 / 4.1 kg f	11.6 / 9.0 lb f
Full Throttle FWD/REV Thrust @ Maximum (20 V)	6.7 / 5.05 kg f	14.8 / 11.1 lb f
Minimum Thrust	0.02 kg f*	0.05 lb f*
Electrical		
Operating Voltage	7-20 volts	
Full Throttle Current @ Nominal (16 V)	24 Amps	
Full Throttle Current @ Maximum (20 V)	32 Amps	
Full Throttle Power @ Nominal (16 V)	390 Watts	
Full Throttle Power @ Maximum (20 V)	645 Watts	
Physical		
Length	113 mm	4.45 in
Diameter	100 mm	3.9 in
Weight in Air (with 1m cable)	344 g	0.76 lb
Weight in Water (with 1m cable)	156 g	0.34 lb
Propeller Diameter	76 mm	3.0 in
Mounting Hole Threads	M3 x 0.5	
Mounting Hole Spacing	19 mm	0.75 in
Cable		
Cable Used	CAB-PUR-3-16AWG-R2	
Cable Length (Standard T200)	1.0 m	39 in
Cable Length (T200 *BlueROV2* Spare)	0.71 m	28 in
Conductor Gauge	16 AWG	
Compatible WetLink Penetrator	WLP-M10-6.5MM-LC	

Connecting the T200 thrusters
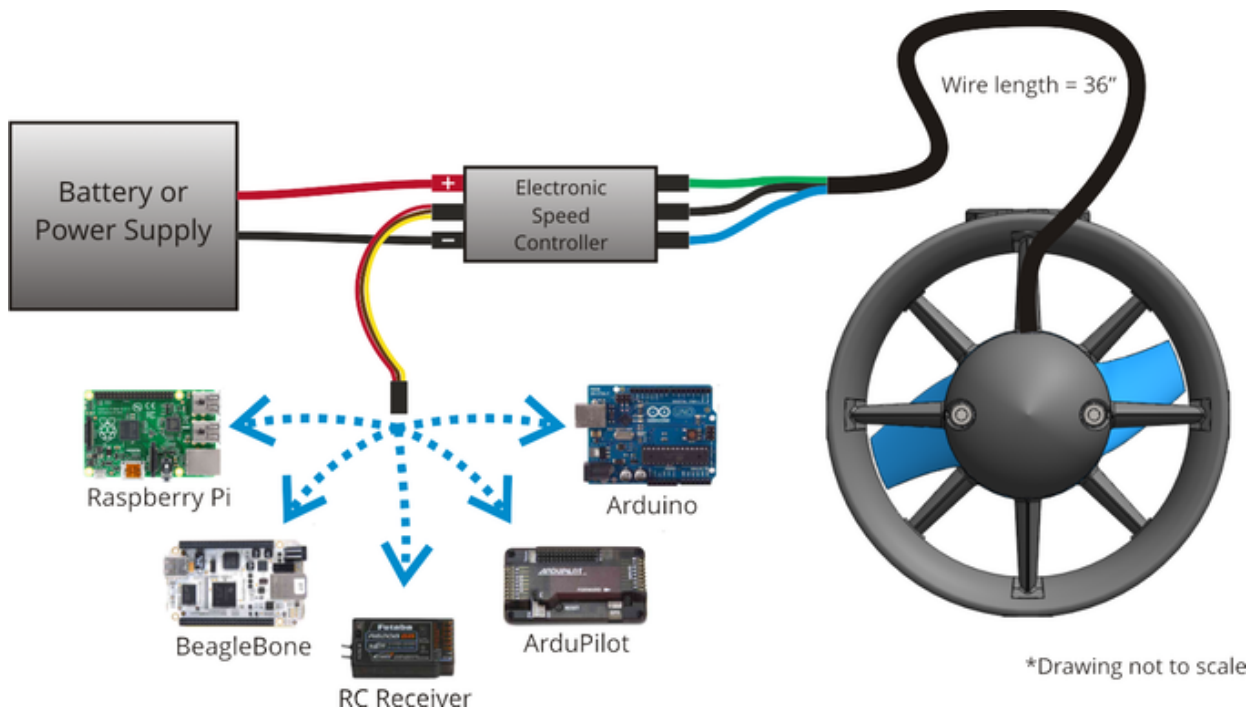
1. For the input end of the ESC, the red wire should be connected to the supplied power. For this ROV, the red wire is connected to the positive terminals of the fuse block.

2. The **black wires** on the input end of the ESC are connected to the ground terminals of the fuse block.

3. The main positive and negative wires of the fuse block are connected to the Golf Cart converter.

4. The blue, white and green wires from the T200 thrusters are connected to the ESC with its matching colors.

Parameter		Value
Performance		
Full Throttle FWD/REV Thrust @ Nominal (16 V)	5.25 / 4.1 kg f	11.6 / 9.0 lb f
Full Throttle FWD/REV Thrust @ Maximum (20 V)	6.7 / 5.05 kg f	14.8 / 11.1 lb f
Minimum Thrust	0.02 kg f*	0.05 lb f*
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Cable		
Cable Used		CAB-PUR-3-16AWG-R2
Cable Length (Standard T200)	1.0 m	39 in
Cable Length (T200 *BlueROV2 Spare*)	0.71 m	28 in
Conductor Gauge		16 AWG
Compatible WetLink Penetrator		WLP-M10-6.5MM-LC

ELP Camera Module

The ELP camera is a high resolution, auto-focusing camera with a max resolution of 2592x1944 at 15 frames per second.

Connections

The camera is connected to the Raspberry Pi with a **2.0 USB** cable with four wires

inside. For the ROV, the camera wire is spliced together using two wago connectors.

There are also four screw holes to mount the camera. The camera is mounted in a

waterproofed box and the needed connections are made with Wago connectors.

The Camera will **not** work in a USB 3.0 port

Datasheets

Power supply	USB Bus Power 4P-2.0mm socket
Operating Voltage	DC 5V
Power Consumption	150 mW (VGA - Low); 200mW (QSXGA - High)
Operating Current	Active: 140 mA; Standby: 20µA
Operating Temperature	-20~70°C

Storage Temperature	0~65°C
Board Size	38X38mm (Compatible 32X32mm)
Weight	30g
Cable	Standard 1M / 2M,3M,5M optional

Video

Lens Size	6.35mm (¼ inch)
Pixel size	1.4µm X 1.4µm
Image area	3673.6µm X 2738.4µm
Picture Format	MJPEG / YUV2 (YUYV)
Night Vision	Optional
	2592x1944 @ 15fps MJPEG / 2048x1536 @ 15fps MJPEG

Resolution and Frames	1600x1200 @ 15fps MJPEG / 1280x1024 @ 15fps MJPEG 1920x1080 @ 30fps MJPEG / 1280x720 @ 30fps MJPEG 800x600 @ 30fps MJPEG / 640x480 @ 30fps MJPEG
Focus	Auto
Adjustable Parameters	Brightness, Contrast, Saturation, Hue, Sharpness, Gamma,Gain, White balance, Backlight Contrast, Exposure
Operating Systems	WinXP/Vista/WIN7/WIN8/Linux with UVC/Mac-OS X 10.4.8 or later/Wince with UVC/Android 4.0 or above

Sslhong DC-DC Convertor

The Sslhong converter is used to convert the 12 volts from the Golf Cart converter to 5

volts and 3 A max used by the Raspberry Pi.

II. Costs

T200 Thrusters (x6)

Cost: $179.00

ANNIMOS 25kg RC Digital Servo Motors (x2)

Price: $18.99

Raspberry Pi 4B

Price: $219.00