DIY Submersible ROV

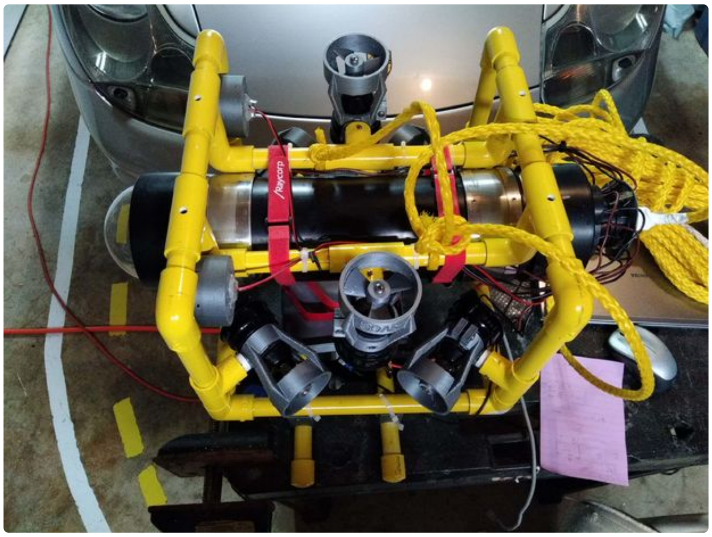
by dcolemans

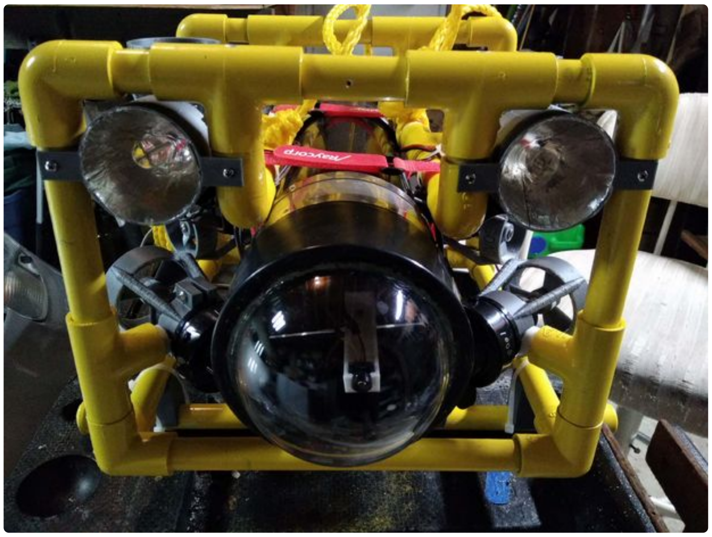
How hard could it be? It turns out that there were several challenges to making a submersible ROV. But it was a fun project and I think it was quite successful. My goal was to have it not cost a fortune, have it easy to drive, and to have a camera to show what it sees underwater. I didn't like the idea of having a wire dangling from the driver's controls, and I have a variety of radio control transmitters already, so that's the direction I went, with the transmitter and control box separate. On the 6 channel transmitter I used, the right stick is used for forward/back and left/right. The left stick is Up/Down and turn Clockwise/CCW. This is the same setup used on quad-copters, etc.

I looked online and saw some pricey ROVs and saw a few with "vectored thrusters". This means the side thrusters are mounted at 45 degree angles and combine their forces to move the ROV in any direction. I had built a mecanum wheel rover already and I thought the math there would apply. (Ref. Driving Mecanum Wheels Omnidirectional Robots). Separate thrusters are used for diving and surfacing. And "vectored thrusters" sounds cool.

For ease of driving it, I wanted depth hold and heading hold. This way the driver doesn't have to move the left stick at all except for diving/surfacing or turning to a new heading. Turns out this was also a bit of a challenge.

This Instructable is not intended as a set of directions for doing it yourself. The intent is more to provide a resource that someone might draw from if they intend to build their own submersible ROV.





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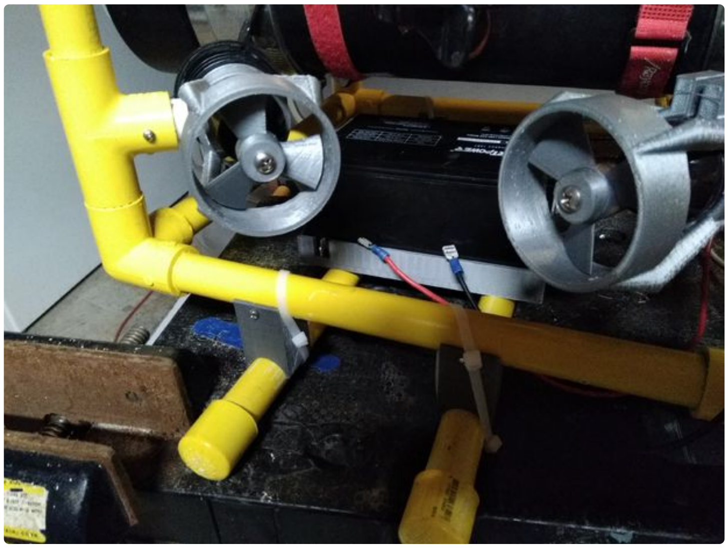
Step 1: The Frame

This was an easy choice. Looking to see what other folks had done pushed me in the direction of 1/2 inch PVC pipe. It's cheap and easy to work with. I came up with an overall design that would accommodate the side thrusters and the up/down thrusters. Soon after assembly I sprayed it yellow. Oh yeah, now it's a submarine! I drilled holes in the tubing top and bottom to allow it to flood. For attaching stuff I tapped threads into the PVC and used 4 40 stainless screws. I used a lot of them.

Shown at a later stage are skids that are held away from the bottom by 3d printed risers. The risers were needed to make it so the battery could be removed and replaced. I 3d printed a tray to hold the battery. The battery is secured in the tray by a velcro strap. The Dry Tube is also held onto the frame with velcro straps.



Step 2: The Dry Tube

First pic is the buoyancy test. Second pic attempts to show how thruster wires are led into potted bullet connectors. Third pic is more of the same plus the additional bump for potting depth meter and its wires. Fourth pic shows pulling apart the dry tube.

Buoyancy

The Dry Tube contains the electronics and provides most of the positive buoyancy. The ideal is a small amount of positive buoyancy, so if things go wrong the ROV will eventually float to the surface. This took a bit of trial and error. The assembly shown here during a float test took several pounds of force to get it to submerge. This led to any easy decision to mount the battery on-board (as opposed to power coming over the tether). It also led to cutting the tube down in length. It turns out a 4 inch tube provides about 1/4 pound of buoyancy per inch of length (I did the math once but this is a guess). I also ended up putting PVC "skids" on the bottom. They have screw on ends where I put in lead shot for fine tuning the buoyancy.

Water Tight Seal

Once I settled on using epoxy to seal seams and holes, and settled on using neoprene hub-less connectors, the ROV was reliably watertight. I struggled for awhile with "waterproof" ethernet connectors, but in the end I gave up on these and just drilled a small hole, led the wire in, and "potted" the hole with epoxy. After the hub-less connectors were tightened in place, trying to remove them was difficult. I discovered that a little smear of white grease made the Dry Tube pull apart and push together a lot easier.

To mount the acrylic dome I carved a hole in a 4" ABS cap leaving a ledge to receive the edge of the dome. Initially I tried hot glue, but that leaked immediately and I went to epoxy.

Inside

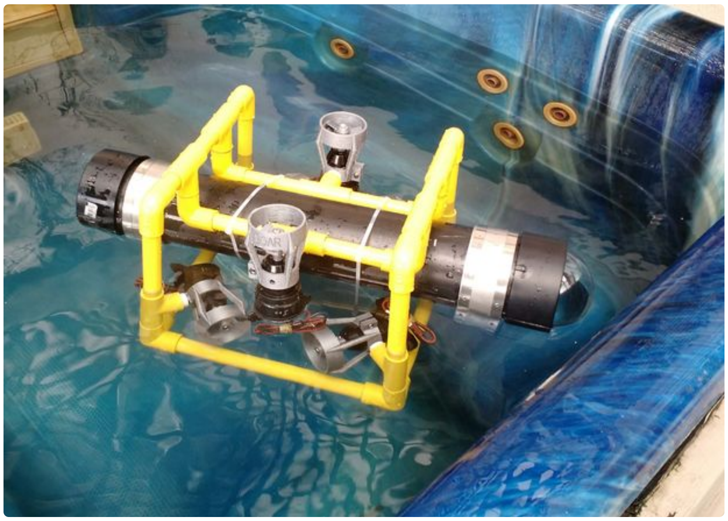
All the inside electronics are mounted on a 1/16 inch aluminum sheet (with standoffs). It's just under 4 inches wide and extends the length of the tube. Yeah, I know it conducts electricity, but it also conducts heat.

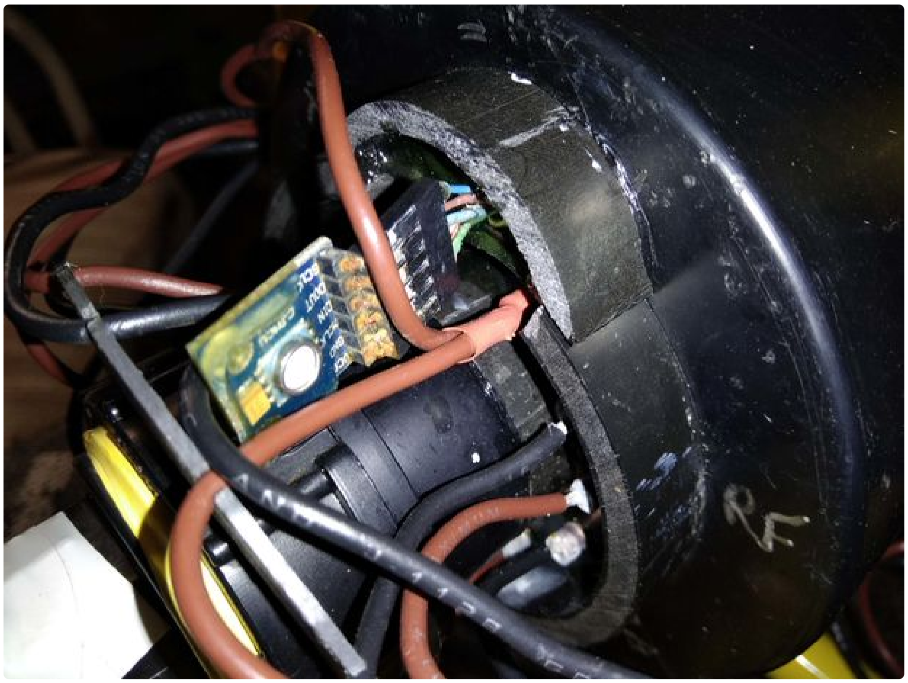
Wires Coming Through

The rear 4" ABS cap got a 2 inch hole drilled into it and a 2" ABS female adapter glued in. A 2" plug got a hole drilled in for the Ethernet wire to come through and be potted. A little piece of 3" ABS glued on also made a little circle area for "potting".

I drilled what seemed like plenty of holes (2 for each thruster), but I wish I had done more. Each hole got a female bullet connector shoved into it (while hot from the soldering iron). The thruster wires and battery leads got the male bullet connectors soldered on.

I ended up adding a little ABS bump to give me a place for the depth gauge wire to come through and be potted. It got messier than I would have liked and I tried to organize the wires with a little holder with slots in it.

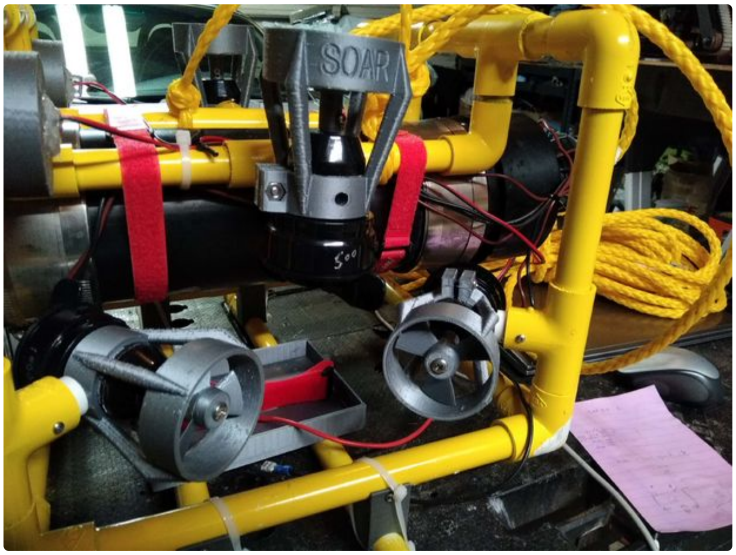




Step 3: DIY Thrusters

I got a lot of ideas from the web and decided to go with bilge pump cartridges. They're relatively cheap (about $20+) each and have about the right amount of torque and speed. I used two 500 Gallons/hour cartridges for the up/down thrusters and four 1000 GPH cartridges for the side thrusters. These were Johnson Pump Cartridges and I got them via Amazon.

I 3d printed the thruster housings using a design from Thingaverse, ROV Bilge Pump Thruster Mount. I also 3d printed the propellers, again with a design from Thingaverse, ROV Bilge Pump Thruster Propeller. They took a little adapting but worked pretty well.



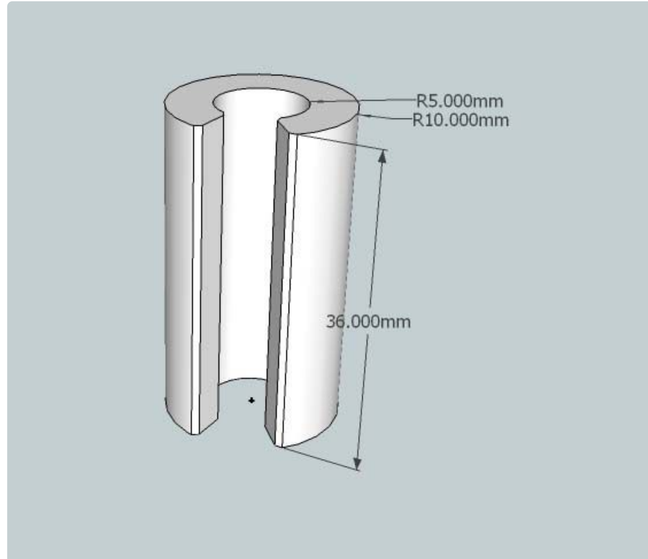
Step 4: Tether

I used a 50 foot length of Cat 6 Ethernet cable. I pushed it into 50 feet of polypropylene rope. I used the end of a ball point pen taped onto the cable and took about an hour pushing it through the rope. Tedious, but it worked. The rope provides protection, strength for pulling and some positive buoyancy. The combination still sinks but not as badly as the Ethernet cable by itself.

Three of the four cable pairs are used.

- Camera Video signal and ground ----> Arduino OSD shield in the control box
- ArduinoMega PPM signal and ground <---- RC receiver in the control box
- ArduinoMega Telemetry signal --> RS485 ----> matching RS485 --> Arduino Uno in the control box

Based on comments from another Instructables contributor, I realized that having the tether dragging on a lake bottom would not be good. In the swimming pool test it was not a problem. So I 3d printed a bunch of clip-on floats, using PLA and thicker walls than usual. Picture above shows the floats deployed on the tether, grouped more closely close to the ROV but averaging about 18 inches apart. Again per the other contributor's comments, I put floats into a mesh bag tied to the tether bundle to see if I had enough.


R5.000mm
R10.000mm
36.000mm

Step 5: On Board Electronics

First pic shows camera and compass. Second pic shows what happens when you keep adding stuff. Third pic shows underside-mounted motor controllers with aluminum slabs as alternative heat sinks.

Dry

- Camera – Micro 120 Degree 600TVL FPV cam
    - Mounted on 3d printed holder that extends it out into the dome

- Tilt Compensated Compass – CMPS12
    - Built-in Gyro and Accelerometer readings automatically integrated with Magnetometer readings to compass reading stays correct as ROV bops around
    - Compass also provides temperature reading

- Motor Drivers – Ebay – BTS7960B x 5
    - Large Heat sinks had to be removed to save space
    - Mounted w heat transfer grease onto ¼" aluminum slabs
    - Aluminum slabs mounted directly on both sides of aluminum electronics shelf
    - Experience shows drivers operate well under capacity so heat is not a problem

- Arduino Mega
- RS485 Module to beef up serial telemetry signal
- Current sensor Power module
    - Provides up to 3A of 5v power for electronics
    - Measures Amperage up to 90A going to 12v motor drivers
    - Measures battery voltage

- Relay (5v) to operate 12v lights

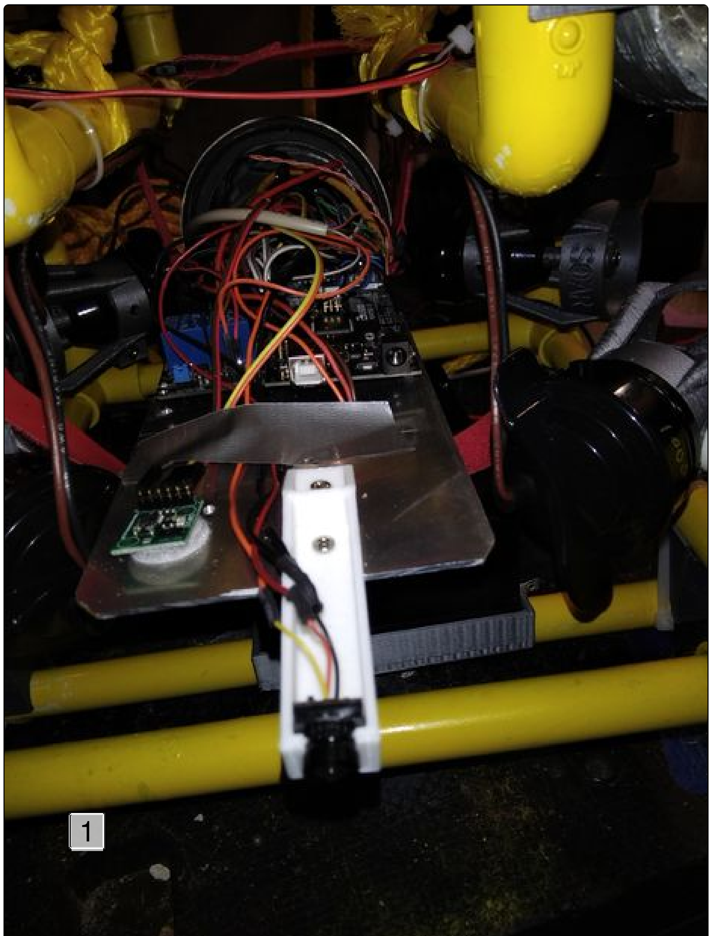
Wet

- Pressure (depth) Sensor Module – Amazon – MS5540-CM
    - Also provides water temperature reading

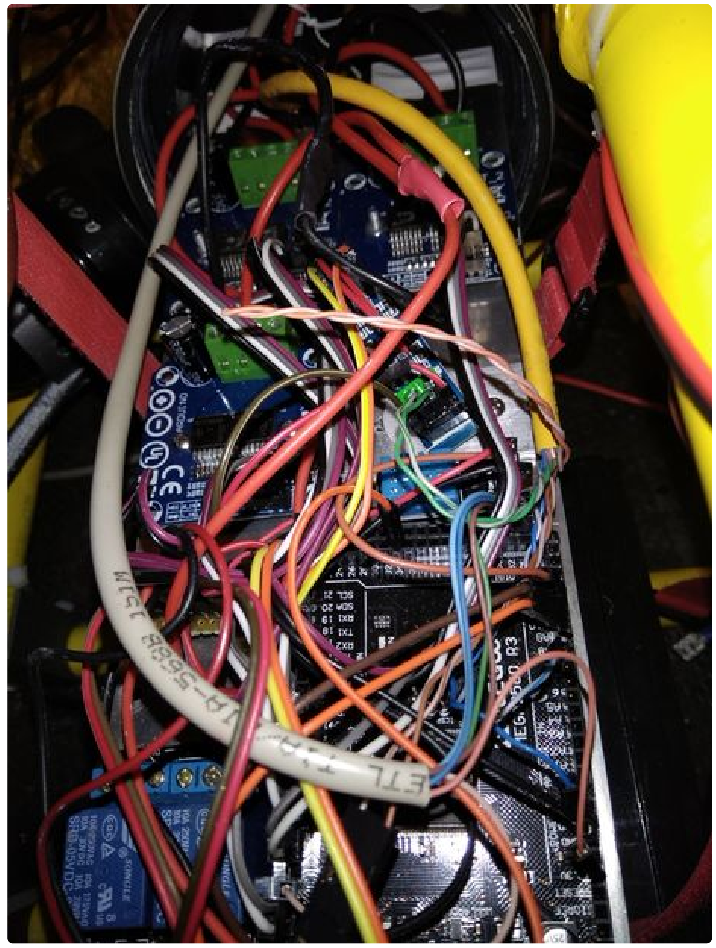
- 10 Amp/Hr 12 volt AGM battery

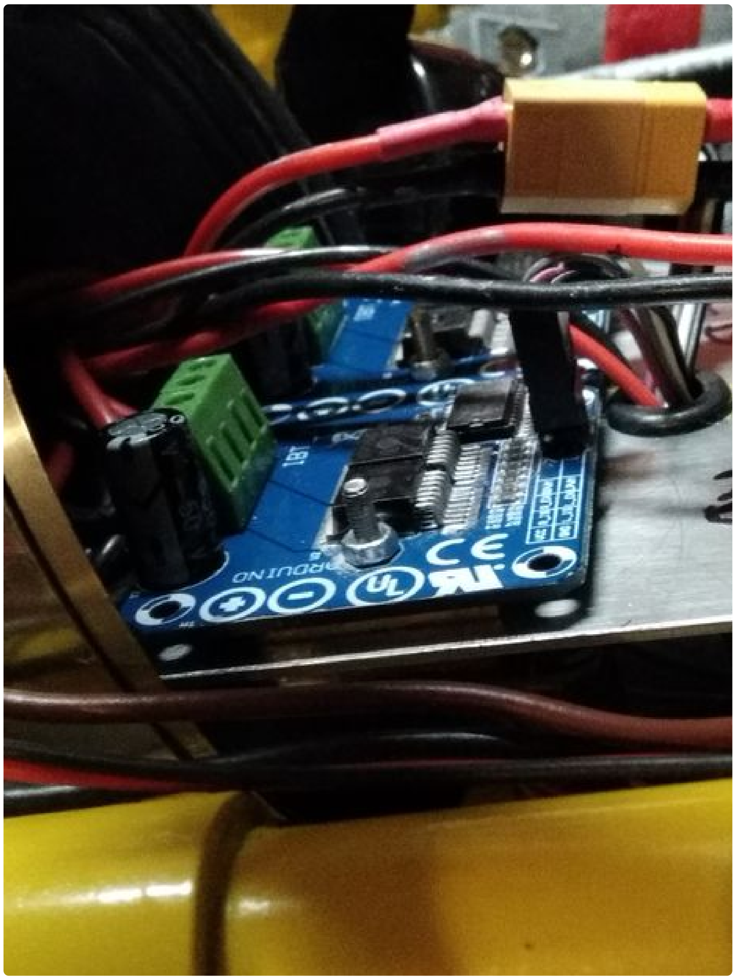
I had concerns that a lot of electrical contacts were exposed to water. I learned that in fresh water, there is not enough conductivity to cause a problem (short circuits etc.), that the current takes the "path of least resistance" (literally). I'm not sure how all this would fare in seawater.

Wiring Outline (see SubDoc.txt)



1. Camera on 3d printed holder. Compass at left





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Step 6: SubRun Software

The first video shows Depth Hold working pretty well.

The second video is a test of the Heading Hold feature.

Pseudocode

The Arduino Mega runs a sketch that performs the following logic:

1. Gets PPM RC signal over tether
    1. Pin Change Interrupt on data calculates individual channel PWM values and keeps them updated
    2. Uses Median filter to avoid noise values
    3. PWM Values assigned to Left/Right, Fwd/Back, Up/Down, CW/CCW and other ctls.
2. Gets water depth
3. Logic to allow CW or CCW twist to finish
4. Looks at driver controls
    1. Uses Fwd/Back and Left/Right to calc strength and angle (vector) for driving side thrusters.
    2. Checks for Arm/Disarm
    3. Uses CW/CCW to calc twist component or
    4. Reads compass to see if heading error and calculates corrective twist component
    5. Uses strength, angle and twist factors to calc power and direction for each of four thrusters
    6. Uses Up/Down to run Up/Down thrusters (two thrusters on one controller) or
    7. Reads depth meter to see if depth error and runs Up/Down thrusters to correct
5. Reads power data
6. Reads temperature data from depth meter (water temp) and compass (internal temp)
7. Periodically sends telemetry data up Serial1
    1. Depth, Heading, Water Temp, Dry Tube Temp, Battery Voltage, Amps, Arm Status, Lights status, Heartbeat
8. Looks at Light Control PWM signal and turns light On/Off via relay.

Vectored Thrusters

The magic for controlling the side thrusters is in steps 4.1, 4.3 and 4.5 above. To pursue this, look in the code at the Arduino tab titled runThrusters functions getTransVectors() and runVectThrusters(). Clever math was copied from various sources, primarily those dealing with mecanum wheel rovers.

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Step 7: Floating Control Station (updated)

6 Channel RC transmitter

Control Box

The original control box (old cigar box) that held electronics not on the sub has been replaced by a floating control station.

Floating Control Station

I began to be concerned that my fifty foot tether was not long enough to get anywhere. If I'm standing on a dock, then much of the tether will be taken just getting out into the lake and there won't be any left for diving. Since I had a radio link to the control box already, I got the notion of a floating waterproof control box.

So I did away with the old cigar box and put the control box electronics onto a narrow piece of plywood. The plywood slips into the 3 inch mouth of a plastic three gallon jug. The TV screen from the control box had to be replaced with a video transmitter. And the RC transmitter (the only part still on shore) now has a tablet with video receiver mounted on top. The tablet can optionally record the video it displays.

The lid of the jug has the power switch and voltmeter, tether attachment, RC whisker antennas, and rubber ducky video transmitter antenna on it. When the ROV pulls out into the lake I didn't want it to tip the control jug too far so I installed a ring near the bottom where the tether is led and where a retrieval line will be attached. I also put about 2 inches of concrete at the bottom of the jug as ballast so it floats upright.

The floating control station contains to following electronics:

- RC Receiver – with PPM Output
- Arduino Uno
- OSD Shield - Amazon
- RS485 Module to beef up serial telemetry signal
- Video Transmitter
- Volt meter to monitor 3s Lipo Battery health
- 2200 mah 3s Lipo Battery

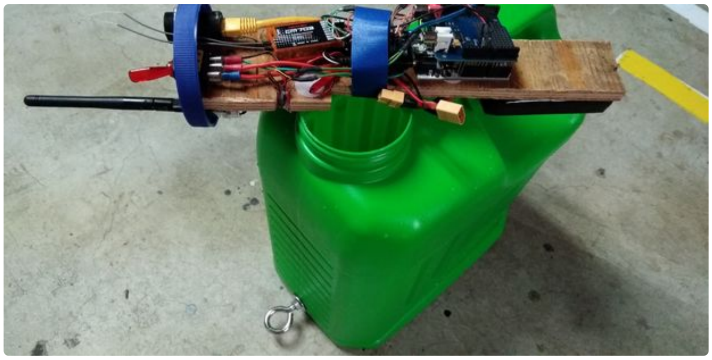
On Screen Display (OSD)

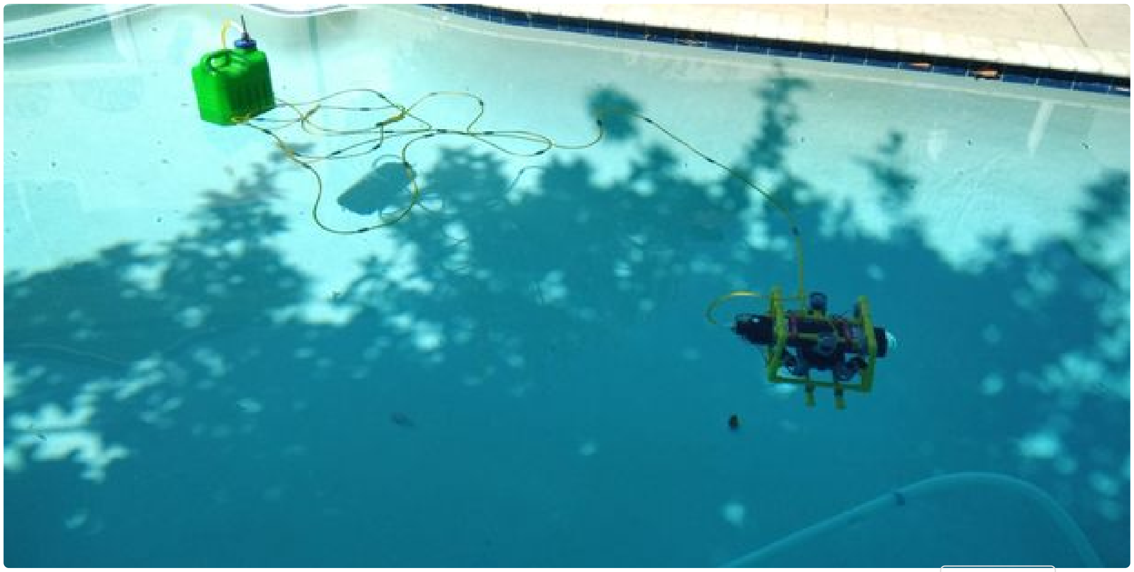
In the quad-copter world, telemetry data is added to the FPV (First Person Video) display at the drone end. I didn't want to put any more stuff into the already crowded and messy Dry Tube. So I opted to send the telemetry up to the base station separately from the video and put the info on the screen there. An OSD Shield from Amazon was perfect for this. It has a video in, video out, and an Arduino library (MAX7456.h) that hides any mess.

SubBase Software

The following logic is run in a sketch on an Arduino Uno in the control station:

1. Reads pre-formatted serial telemetry message
2. Writes message to On Screen Display shield





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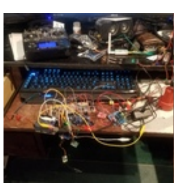
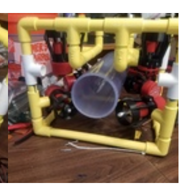
Step 8: Future Stuff

I did add a mini DVR module to the control box to sit between the OSD (On Screen Display) and the little TV to record the video. But with the change to the Floating Control Station I now rely on the tablet app to record video.

I may, if I get real ambitious, try to add a grabber arm. There are unused radio control channels and an unused cable pair in the tether just looking for work.

Glad you're making progress. I'd love to see pictures!
Re. the limitation of 8 channels - the best way in my opinion is to assign one of the non-joystick channels to be a "mode switch". In one mode it would mean the joysticks control navigating the ROV. In another position it would mean joysticks do camera control, arm control, or whatever. You wouldn't be able to navigate while doing this stuff, but I suspect you wouldn't want to or need to. By the way, unless you have separate camera panning, turning left/right does the same thing doesn't it?

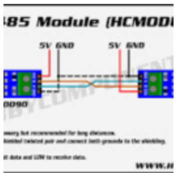
Hello again. Well my ROV is progressing well. I had a slight problem with the frame and had to raise it to get the tube to fit above the thrusters. But ill end up using those T's for lights or something. As for wiring, well all the sensors and such connected to the MEGA board are working properly. But I cant seem to get the data from the MEGA to the UNO. I tested the UNO with the OSD and the test sketches work, so I know its working. But I cant get it to display any data from the MEGA. Can you please share more info for the wiring to the rs485 and how they connect to the MEGA and UNO. I have mine as follows, but it does not work. I have tried several combos of this and still nothing.
MEGA pin 19 RX1 to RO on rs485
MEGA pin 18 TX1 to DI on rs485, i have swapped these but not working
DE and RE on rs485 to +5v, maybe this is the problem?
RS485 VCC to +5 and GND to GND on both
rs485 A to A on second rs485 and B to B, swapped this but no
on second rs485 DE and RE to +5v, again, dont know where to connect these, some web diagrams show connected to +5v
on second rs485 DI and RO I have tried on pins 0RX and 1TX on UNO, also pins 5 and 6 on uno, swapping them has no effect.
I have even tried removing the rs485 and just connecting pins 18 and 19 on MEGA to both 0 and 1, and, 5 and 6 on UNO. Doing this, i dont remember witch one worked but, I can see data using the serial monitor via the Arduino IDE with a usb connection. But even though i see the data in serial monitor, nothing on OSD. Again, I have run test sketchs on OSD and they do work, such as Hello World and Display Font.
Again, thanks for all you have done with sharing your design.



Wow! Coming along nicely. The rs485s are a pain. I had occasion to revisit them yesterday and found a pretty good diagram reminding me of how I did it. My telemetry wasn't working so I suspected the rs485s. In the end it was a bad connection and I had to use my spare tether cable pair.

I added a wiring diagram to the Instructable (See Electronics step SubDoc.txt). You know of course that pins 5 & 6 on the Uno are serial via Software Serial. And on the rs485s, you have to put 5v+ on the enable pins to send, and Ground on the enable pins to receive. You say you do see telemetry data on the serial monitor--- you mean on the Uno? If so, that would mean the RS485 is working and the problem is to do with the Uno sending text to the OSD. Are you using a MAX7456 OSD?

Misc nosy questions: How long a tether are you going for? Where are you going to put your battery? How are you going to seal the end of your acrylic dry tube?



Thanks for the reply. So while trying to figure out the rs485 i decided to bypass them, while on my desk, and just use direct serial. But I still could not get it working. Then a strange thing happened. I bumped something and lost video, but could see the OSD all of a sudden. I was blown away. So looking into it I found its actually my camera!! I posted a video below. So I will now try the rs485 chips and make sure they are working based on the diagram you shared.
To answer your questions, I plan to use a 100 ft tether. The battery will go between some skids, like a helicopter, that are not pictured. While we talked about using a polycarbonate tube that I had. Turns out that that tube was not very round and smooth. Im using the Blue Robotics flanges, end caps, and dome. When I discovered my tube would not work, I got a Blue Robotics tube also.
I made a video here:

//www.youtube.com/embed/XIHAHcylwxA

Glad you got it figured out. Doesn't sound like any great advantage using the stereo camera anyway since you'd only be using one side.
100 foot tether huh. Ar you going to poke a cat5/6 cable through the polypropylene rope as I did. It was pretty comical, having the tether draped though the garage, out the driveway, and partly into the street, all the time poking with the ball point pen "fid" and massaging the bunched up rope down the line. Your Blue Robotics stuff sounds great. Maybe you can buy a tether ready to go.

I want to use Wi-Fi module to transmit my video feed how can I use that

You can use Wi-Fi to transmit from the control box to a tablet or such. But Wi-Fi from the sub in a no go. No radio signals through water. Sent the video fee up the tether.

can you send me the circuit diagram ?

Not a circuit diagram per se, but I did add a wiring "diagram' or outline. See Electronics step SubDoc.txt.

Sorry. I don't have an actual circuit diagram.

My guess is that acrylic tubes are extruded acrylic versus cast acrylic. It tends to be cheaper and more available. But I see no disadvantage to polycarbonate tubing. 1/4 walls sound quite stout, at least for lake depths. Polycarbonate will machine nicely (e.g. cut threads). I'd love to see how you are putting it all together.

Hello dcolemans Do you have your file for the 3d printed 3 blade thruster propeller I would love to use the same propeller.

I used them straight from Thingiverse https://www.thingiverse.com/thing:639240. This link looks suspect here so within Thingiverse just query SOAR Propeller and pick the three bladed one.

Hi dcolemans,

I was thinking about making something like this, you said that you got the bilge pumps for cheap, can you post links as to were to buy them?

Also I voted for you!

Good old Amazon, where two day shipping has made me an impatient person. Here's the link to the 500 GPH cartridge https://www.amazon.com/gp/product/B001446X1Q/ref=o...

If the link doesn't work, just search for Johnson Marine Pump Cartridge. BTW, the 500 GPH has the same dimensions as the 1000 GPH. I guess "cheap" is relative - compared to ready to go thrusters.

Thanks!

Another question I have come across in my research into doing this project is how you connect the MS5540-CM to the Arduino. Any help would be appreciated as I cannot find any information anywhere about it.

Just saw your question...
The depth sensor is connected via SPI. I found the code somewhere, and it's all in depthSensor.ino tab.
Hope that helps.

Cool, thanks

i just want to thank you for this project!! I was just looking for ideas to buy...or better yet, MAKE an SROV for my diving business. Being that we never know what's under us, it will be nice to find potential dangers to look out for. It also helps with visual NDT inspections. I am hoping I can miniaturize this project for portability. That will be my FIRST goal. my second goal is depth challenges. Being that I'm a commercial diver, i would seriously enjoy collaborating with you on how to waterproof this project for maximum depths! I will share this effort VIA instructables when complete. I'm NOT very proficient with arduino. Would I be able to ask for your help in how you connected everything together? I would certainly give all credit due to yourself for helping me with this endeavor! It would probably be worth exploring a topside power source utilizing the remaining CAT pairs.

Thank you very much for providing this resource! I've been collecting ideas for a future ROV build for some time, and there are a number of things in your build that are new to me.

+Rather than holes in the PVC pipe, I'm considering filling the pipe with Silicone. The Silicone density is close to the density of water.

+It is unclear how you ran your wires into the dry chamber. If you ran the sheathing in as well as the wires, you can have problems. If the sheathing around the Cat6 gets nicked, water can run into your dry chamber in the sheath.

+In some builds, the tether is given a slightly positive buoyancy. The whole tether is placed in a light mesh bag. Small floats are added to the bag until reaching a slightly positive buoyancy. The floats are then attached along the tether. This way the tether does pool on the lake floor where it is more likely to be caught by something.

+My ROV will be for saltwater, so I cannot get away with a wet battery.

Re.filling the pipes with silicone: Why not just let it flood with water?

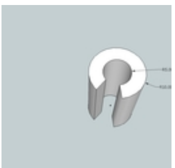
You're right about risking the cable getting nicked. I hope it's well enough protected with the rope. The depth meter wires are individually potted but not the tether cable.

You're right about the tether drooping down to the lake floor. If it all works well, I may try a longer tether at which time I'll try for positive buoyancy (maybe a larger poly rope). I've also read where folks have used cork floats strung along the tether, but that sounds like a mess. I'm not clear about how the light mesh bag approach would work... Would it uncoil as needed, coming out of the bag? Or is the bag more of a long sleeve?

Re. salt water conductivity: It would be an easy experiment to dip a couple of terminals and see how close they can get before they short out. My battery terminals are a good 2 inches apart. And maybe one could coat it all with waterproof goop. Then you'd need a reed switch inside the dry tube and a magnet on the outside.

"Why not just let it flood with water?" - I may be over thinking things, but I figure stuff in the water will get into the pipes...silt, small aquatic creatures, salt, etc. The light mesh bag is only used during the construction phase. The tether is put in the bag and placed in the water, float are added to the bag over time until the right buoyancy is reached. It is a simple way to figure out how many floats to add. As for the floats, I plan to 3D print some tapered, hollowish forms that clip or thread onto the tether...the shape of long lead sinkers. I'd fill the 3D shapes with foam. Interesting though on the battery test.

I see where you are headed with the mesh bag. Other folks have used wine corks for tether floats, but hey, we lucky folks with 3D printers... Good idea about hollow forms. Clip on would be better. They could be pretty skinny with thin plastic. Make a hole and shoot in some foam as you say. Float in pic is 30mm long.



Wow ,lotta work but you did good

Thank you.

This is a very worthy Instructable mate, hope you win the contest for it.

Thanks.

how deep can it go?

Right now it's limited by the 50 foot tether. I've only had it to swimming pool depth so far. I don't know how much pressure it will withstand before it leaks. I think the seal around the acrylic dome is weakest point. The potting around the holes seems secure and the rubber hub-less connectors seem secure too.