Design and Development of a Submersible ROV

for Rapid Assessment of Ecosystem Health

by

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The US EPA is interested in quickly assessing the health of ecosystems to allow policy makers to react confidently, and in real-time to environmental threats. Unfortunately, the heavy time commitment of existing data collection techniques, combined with the wide range of variables involved in ecosystem health do not allow such quick assessments.

In an attempt to fix this problem, I've developed an ROV named SMARTSEA (Semi-autonomous, Modular, and Affordable Research Tool for Submersed Ecosystem Analysis), which utilizes digital video as a data collection tool. Digital video can simultaneously provide countless variables such as organism populations, sunlight, turbidity, sediment types, etc. However, for much of the data available from digital video to be accurate, the camera must be delivered without disturbing its surroundings. The system which I developed provides rapidly deployable and maneuverable video recording by housing two digital video cameras on the SMARTSEA, remotely operated vehicle platform. Because of the small, quiet thrusters used for mobility, along with the forward placement of the camera away from the thrusters, the camera's surroundings remain undisturbed during recording. Therefore, the system's mobility allows rapid collection of data over a large area, in deep (70 feet) or shallow (three feet) water, while it can also record undisturbed, dynamic variables, such as fish populations.

The requirements given to me by Giancarlo Cicchetti regarding the ROV's capabilities and development can be seen in table 1. SMARTSEA's final design can be seen in the figure 2 which documents the development process. The decisions of which components were used and why are described in table 2. The finalized circuit design is shown in figure 1. A list of submersed and on-boat components is presented in table 3.

As can be seen in figure 1, a Basic Stamp microcontroller was used as a middle man between sensors/controls and the motors. This is because microcontrollers are more easily interfaced with digital electronics due to their multiple I/O pins. Also, this microcontroller-centered organization allows for future movement of all electronics onto the submersible for full autonomy in the future.

The laptop connected to the Basic Stamp microcontroller provides a visual display of SMARTSEA's behavior, which is very helpful when the ROV is not visible from the boat. The visual display is constantly updated by reading tilt sensor, pressure sensor, and compass sensor values which have been relayed by the Basic Stamp from the submersed sensors. The laptop also allows a user to easily create a 'mission file' for autonomous control of the ROV. By comparing the real-time sensor values from the ROV with the commanded values in the mission file, the laptop sends appropriate motor commands to the microcontroller to make the ROV follow the mission steps in sequence.

To help protect SMARTSEA from failure of the Playstation2 digital controller, a backup, purely analog control system was also developed. This simple switching mechanism allows full forward, full reverse, and full stop control over the two thrust motors and the vertical trolling motor.

Finally, while SMARTSEA is functionally complete, in the future, a hydrodynamic outer shell will be added, and the propeller guards may be replaced with more aesthetically pleasing material (they are currently made of modified buckets).

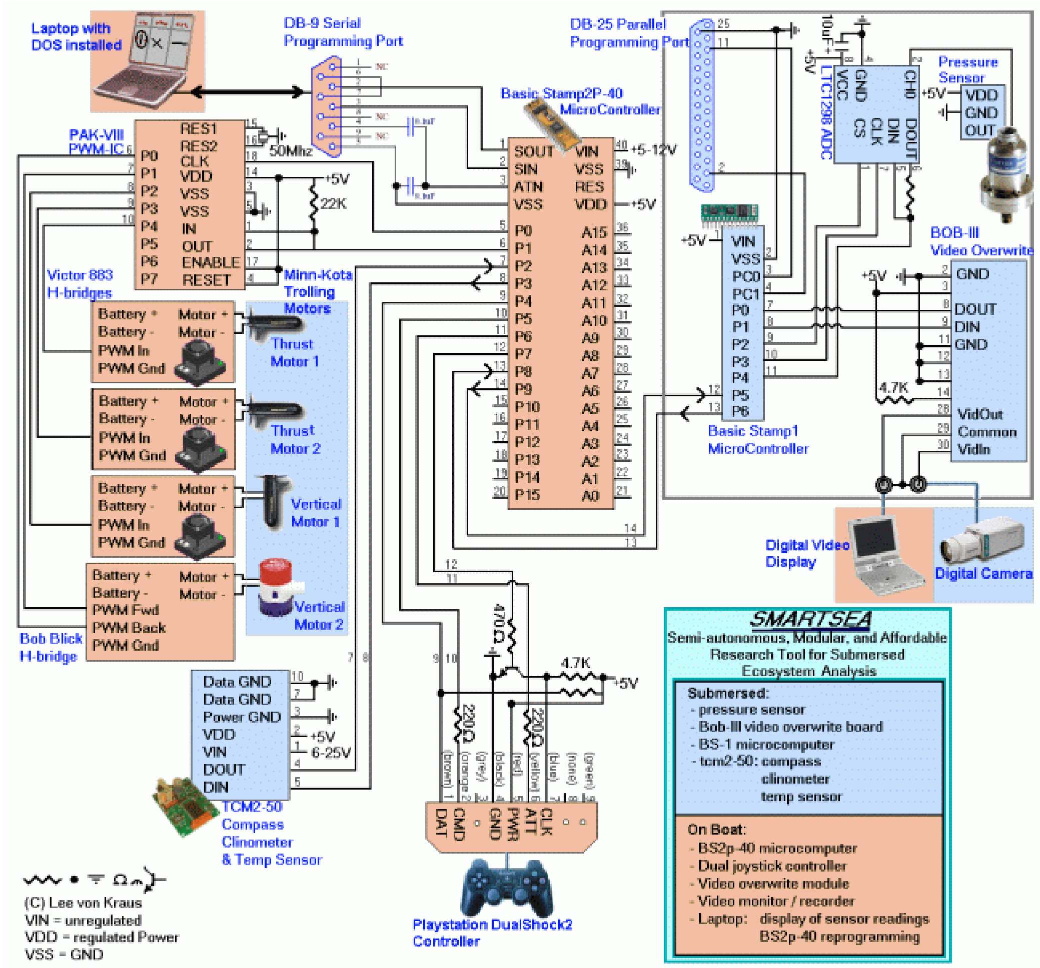
Table 1:	
Deployable in shallow water	
➢	In-house water proofing of trolling motors, proved sufficient for 70ft depths.
Ability to stay a constant distance from the bottom to allow visual area calculations.	
➢	A sled can be attached/detached from SMARTSEA, allowing a bottom and free swimming
Control over a wide range of speeds from very slow to fast speeds	
➢	A manual controller was chosen with analog joysticks to allow over 200 levels of speed
Small turning radius	
➢	Dual thrusters allow turning in place (one in forward, one in reverse)
Very low cost (< $1200)	
➢	Used only off the shelf parts
Ability to go in a straight line without supervision	
➢	Used a very accurate electronic compass integrated with a microcomputer to allow

Table 2:	
Victor 883	▪ 60 Amp capability allows plenty of room above 30A max draw of motors ▪ very rugged (used in Battlebots)
PS2 joystick controller	❖ very cheap ❖ two joysticks for turning and vertical motor control ❖ many buttons for lights, autonomous/manual mode switching, special turning options, heading selection. ❖ very rugged (deals with constant smashing on buttons by gamers) ❖ comfortable for long use (gaming) ❖ latch register design simple to interface with. ❖ works on 5V
PAK VIII PWM Chip	▪ designed for use with Basic Stamp ▪ allows less frequent update of PWM by Basic Stamp, (stamp has no parallel processing, so it cannot PWM and do anything at same time) ▪ allows wide range of PWM pulse width, which insured compatibility with Victor 883 ▪ multiple channel-outs, so stamp can control multiple motors simultaneously through one PAK-VIII ▪ works on 5V
Qbasic Compiler	❖ free ❖ easy to make graphical interfaces ❖ requires only DOS (can work on old laptops)

TCM2-50 Sensor Module	▪ two 50 degree tilt sensor ▪ temp sensor (detect temp w/in its water tight container, to detect overheating by electronics). ▪ has hard-metal calibration to deal with constant magnetic disturbances due to metal or motors. ▪ simple serial interface allows querying of all of these sensors easily. ▪ works on 5V
BOB-III Video Overwrite Card	❖ compatibility with basic stamp ❖ can communicate serially with 2400 baud (low enough for BS1) ❖ works on 5V
Basic Stamp 1	▪ cheapest stamp ▪ can integrate with ADC chip and BOB-III
ULN2803 Analog to Digital	❖ simple to interface to BS1 ❖ works on 5V
Minn Kota Endura30 trolling motors	▪ provide enough thrust (30lb), 60lb with two thrusters. ▪ company is well respected for its products. ▪ information was available that the motors were inherently water proof to 30ft depth. ▪ required the least amount of amps of any new trolling motor.
Fiberglass C-Channels	❖ 8” width allowed vertical motor to be in-line with structure. ❖ 8” width also allowed stable attachment of thrust motors. ❖ fiberglass is strong and easy to work with. ❖ width and walls were big enough to fit water proof electronic boxes within the recess.
22 Gauge Cable	▪ calculated to allow 30 Amps to reach the motors through 115 feet of cable.
Basic Stamp 2p-40	❖ I had experience in using basic stamps in the past. ❖ acts as a middle man between the laptop and the sensors/controllers/actuators via I/O pins. ❖ allows potential future placement of all electronics onto the submersed structure (with only the laptop on the boat).

Table 3:	
Boat-Side Components:	• 1 BS2p40 • 1 PAK-VIII • 3 Victor 883s • 1 Bob Blick h-bridge • 1 PS2 controller • 2 12V batteries in series for motors • 1 9V electronics battery

Submersible-Side Components:	♦ 1 video overwrite module - bs1 - bob-III - ADC chip - pressure sensor ♦ 1 TCM2-50 - compass - roll sensor - tilt sensor - temperature sensor ♦ 2 Minn Kota Endura30 thrust trolling motors ♦ 1 Minn Kota Endura30 vertical trolling motor ♦ 1 Rule 200 bilge pump ♦ 1 forward low light camera ♦ 1 downward camera



<u>Figure 1:</u> a circuit diagram showing the entire SMARTSEA electronics system. In the upper right is the video overwrite module (contains BOB-III, pressure sensor, ADC, and Basic Stamp1). In the center is the Basic Stamp 2p-40 microcontroller which serves as the middle man between the sensors, controller, laptop, and motors.

<u>Figure 2:</u> pictures documenting the construction of SMARTSEA. The object housed in front of the vertical motor in the first picture is a Quanta (like a mini YSI). The second picture shows SMARTSEA hooked up to a 12V battery for motor testing. The third picture shows SMARTSEA hooked up to the battery and to the control circuitry (laptop, Basic Stamp 2p-40, PS2 controller, etc). The fourth picture shows SMARTSEA on a boat ready for field testing. The fifth pictures shows the first field test (Styrofoam strapped on for extra buoyancy). The sixth picture shows SMARTSEA after the field test with Styrofoam still attached.