

Small Team of Autonomous Robotic Fish (STARFish):  
Command And Control  
(Report of Practical Training at Acoustic Research Laboratory,  
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## 1 Introduction

The project aims at building a team of small low-cost Autonomous Underwater Vehicles (AUVs) being able to perform survey, sensing and tracking missions. The use of a team of AUVs can provide many advantages over a single complex AUV including redundancy and fault tolerance, simultaneous spatial sampling, larger coverage, better navigation.

The base AUV consists of three sections - the nose cone, C3 section and the tail section. The nose cone of the AUV houses the forward looking sonar, altitude sensor (bottom looking range finder) and the depth sensor (pressure sensor). The C3 section contains the AUV's main CPU, navigational sensors and communication systems. The C3 section also has a pinger and a strobe mounted on it to aid search and recovery. The tail section houses the AUV's thruster and control fins. Along with these it also contains a substantial percentage of the batteries. Depending on missions, payloads may be added to the base AUV. In a group mission different AUVs may have different payloads. Each payloads must be neutrally buoyant and must meet the specifications outlined.

## 2 Sections of The AUV

The nose cone contains the following sensors.

- Altitude Sensor - Tritech Micron Echo Sounder DST
- Depth Sensor - Druck PDCR/PTX 1830
- Obstacle Avoidance Sonar - Tritech Micron DST Sonar
- Variable Ballast
- Emergency Ballast Release
- Leak Detector

The tail section contains the following sensors:

- Thruster - Technadyne Model 520 DC Brushless Thruster
- Variable Ballast
- Leak Detector

- Batteries

The C3 section of the base AUV houses the command & control algorithms, the communication systems and some of the batteries. It holds the AUV's main controller (Pentium class PC104+ system). This section contains a wireless LAN adapter, a GPS receiver, a GSM modem, an emergency pinger, a strobe light and an acoustic modem. The wireless LAN adapter should be tuned for higher power to provide a longer range link to buoys or mother ship. The GPS receiver helps the AUV identify its location when at the surface. The acoustic modem enables communication when submerged. The emergency pinger, strobe light and GSM modem are primarily intended as recovery aids. This section also houses some of the batteries. The batteries are placed in the lower part of the section to provide robustness against roll.

The communication tower is mounted on top of the C3 section. Antennas for GPS, GSM modem, acoustic modem and wireless LAN can be fixed onto this mounting plate. Along with these, an acoustic pinger and strobe is also connected on this plate. An external connector for a tether is provided on the communication tower. The connector shall enable the tether to supply power to the AUV as well as provide Ethernet connectivity into the AUV's internal systems.

The Advanced Navigation Payload houses a Doppler velocity log for getting good an accurate velocity estimate. The payload section contains the following:

- Doppler Velocity Log (DVL) - Teledyne Explorer
- Leak Detector

### 3 Internship Work

There are a lot of disadvantages to having all the peripherals controlled by the PC104 processors in C3 section. Firstly, it will consume a lot of processing power to keep monitoring the peripherals and log all of their data for a black-box, and this will interfere with the main function of the processors which is to run the navigational and control algorithms. Secondly, it will increase the number of interconnections between all the different sections, which not only increases water and pressure proofing problems, but also, future payload sections will have to be designed taking into consideration its placement with respect to the rest of the sections.

Hence, it was decided to have a microcontroller running in each of the different sections, which monitors and keeps a log of all the data collected by the sensors in that sections. The data is passed on to the central PC104s via Ethernet when it is called for by the latter. Also, in view of the similarity of the protocols involved in controlling the sensors, it was decided to design a generic board to be used in all the sections, which can then be programmed by a removable media like flash drive.

The microcontroller (ARM cored STR912FW44) and the evaluation board (from IAR) were procured and tested, and the basic functionality ensured. A major part of the internship involved checking the schematic of the board provided by the manufacturer and weeding out the components which weren't needed. Then the small peripherals (like temperature sensor with the Analog-to-Digital Converter, Ethernet controller, power supplies) were designed and tested, and redesigned according to requirements. This involved reading through a lot of datasheets and benchmarking papers, trying out several components, and suitably changing them according to requirements and local availability. Some peripherals also required I2C addresses to be hardwired, which had to be done optimally without causing conflicts. Once the microchips were fixed, their footprints were created, and virtual components made on the schematic and PCB layout tool from PADS. The whole board was designed so as to occupy minimum space. Several other small circuits were also designed, like the capacitor bank required by the thruster.

The second part of the internship was to calculate the power consumption of each section at the different voltage levels, which are 3.3V, 5V (in two parts, one which can be cut off and one which cannot), 8V, 12V, 24V and 48V. These had to be calculated taking into consideration all possible usage of power, like all components working at maximum power consumption, even high initial current as taken by thrusters. This was because it was undesirable that the rest of the controllers would get a mild "cardiac arrest" when the thrusters powered up or down. Where calculation was not possible, tests had to be taken to see the optimum power consumption. An exhaustive list of components and their power consumption at different voltages was compiled, and the power supplies were designed to be

able to supply the requisite amount of current. The design process, as above, involved creating virtual components and their footprints, so as to have everything ready for PCB design.

The pressure sensor used in the wet part of the nose section was of the passive kind. The pressure sensor worked on a constant voltage, and drew current proportional to the ambient pressure. One of the problems faced was to convert this signal to a digital signal, readable by one of the standard protocols like I2C. Due to the noisy nature of the system ground, a high side current sense had to be used, which gave out the voltage corresponding to the current drawn. The resistances used by the current sense device had to be optimally figured out so that the rated depths would lie in the most accurate range of the device, while disturbing the rest of the circuit as little as possible. This voltage was then converted to I2C by using an I2C-based Analog-to-Digital Converter.

As mentioned above, the only wiring running through the different sections would be Ethernet and main 48V supply (the rest of the voltages would be generated in each section using DC-DC converters). However, there had to be a backup to Ethernet communication in case it failed. This was decided to be implemented by two wires or "Run Level Bus". The four different states which can be generated by two lines would denote the current state of the AUV in the broad sense, like "Normal", "Sleep", "Low Power" or "Emergency". Pure hardware control was designed so that only controllers (and leak detectors) would be able to write "Emergency" to the bus, and all other components would read and understand the emergency condition and take predetermined action, even in the absence of Ethernet communication. The design of the control was also attempted.

These design projects were also interspersed with testing of several components at the in-house tank for their working, their protocols, and sometimes even pressure sensitivity. The components tested included the Inertial Measurement Unit (IMU), the Micron DST Forward-Looking SONAR for obstacle avoidance, the Micron Echo-Sounder to measure altitude from the bed, and the Doppler Velocity Log (DVL, to measure the actual velocity of the AUV, and the surrounding water). The protocols and data formats were figured out, and appropriate programs were written to send commands to and receive data from these sensors. The sensors were very expensive (the DVL, for example, costing upward of 30,000 USD) and had to be handled very delicately.

## 4 Results

The entire project was in a very exciting phase during the period of the internship, and it is hoped that the above work contributed in its own small way to the ambitious project.

## 5 References

1. Starfish Wiki (Private) <http://www.arl.nus.edu.sg/starfish>.

## 6 Acknowledgements

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