Sensor controller*

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ABSTRACT

The customer's demands on the Naiad AUV included that there should be sensors for the pressure, temperature and salinity of the surrounding water. These sensors are read by a Generic CAN controller which is a piece of hardware that is used in many roles throughout the project. A circuit board known as the *Sensor board* serves as an electrical interface between the sensors and the Generic CAN controller.

At regular intervals, the Generic CAN controller sends a CAN message known as the *Sensor message* containing the latest readings of pressure, temperature and salinity. These values can be used to determine the speed of sound in water, which is important for sensors like sonar and hydrophones, or to determine the current depth of the AUV.

1. INTRODUCTION

The customer's demands on the Naiad AUV included that there should be sensors for the pressure, temperature and salinity of the surrounding water. These readings are needed for two reasons:

- The speed of sound in water is needed to get accurate positional readings from sensors such as sonar and hydrophones. Since these only measure the time it takes for sound to travel a certain distance, multiplication by the speed of sound gives the distance travelled by the sound.

- The salinity of the water will affect the density of the water. Given an estimation of the density of the water a pressure reading will give an estimation of the current depth of the AUV. This reading will not be affected by drift (unlike inertial sensors for example).

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A Generic CAN controller was used to handle the sensors. The *Generic CAN controller* is a small (approx. 76 by 40 millimetres) electronic board that has an AT90CAN128 microcontroller [1], an MCP2551 CAN transceiver [6] and all the peripheral circuitry needed for these as well as its own power supply. The Generic CAN controller is used throughout the project for several tasks. It can be connected to the CAN bus and has two UART buses as well as an SPI bus.

An electronic board known as the *Sensor Controller Board* was built to provide an electrical interface between the sensors and the Generic CAN controller. The Sensor Controller Board is "stacked" on top of the Generic CAN controller. This structure can be seen in Figure 1.

The AT90CAN128 microcontroller on the Generic CAN controller runs a program known as the *AT90CAN_Sensor_Controller* that reads the sensor values and outputs their readings on the CAN bus.

Due to the financial situation of the project, the salinity sensor was never purchased and because of this no circuitry or software regarding the salinity sensor could ever be tested.

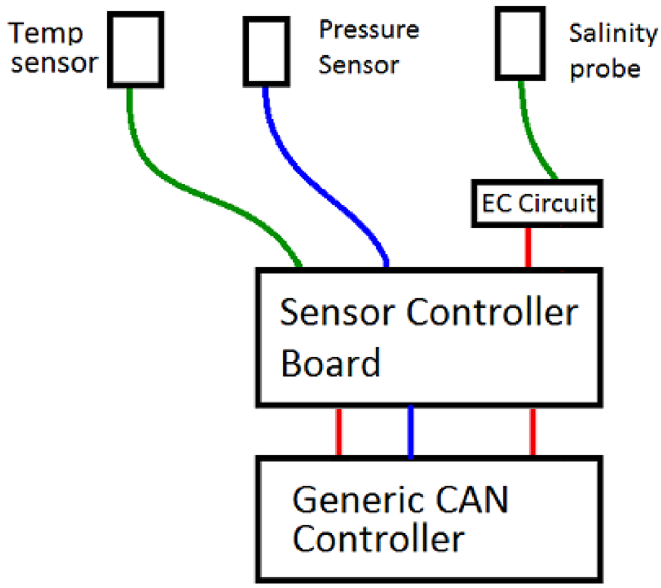

Figure 1: The structure of the Sensor Controller. Blue lines indicate 1-Wire interfaces, green lines are analog interfaces and red lines are UART interfaces.

2. IMPLEMENTATION

The temperature sensor used was the *DS18B20* digital temperature sensor [2]. This sensor communicates over a 1-Wire interface. Since the Generic CAN controller does not have a 1-Wire interface, a DS2480B integrated circuit was used to convert between the 1-wire interface and UART (which the Generic CAN controller supports).

The pressure sensor used was the *IMCL Low Cost Submersible Pressure Sensor* [5]. The interface from the pressure sensor could be chosen when ordering the sensor so a simple analog voltage in the range of 0 to +5 Volt was chosen since this is the range of the analog-to-digital converter on the AT90CAN128 microcontroller. Consequently, no interface circuitry was needed for the pressure sensor.
The customer's demands for the Naiad AUV included that it was to be able to go to a depth of 15 meters. At this depth the absolute pressure is approximately 2.5 bars (1 bar from the atmospheric pressure and 1 bar per 10 meters of water). The range of pressure for the pressure sensor was chosen to be 0 to 3 bars in order to provide some margin. This range could also be chosen when ordering the sensor.

The salinity sensor chosen was the *Atlas Scientific E.C Circuit* [3]. The E.C Circuit is connected to a probe whose output the E.C Circuit measures. The E.C Circuit has a serial interface that is connected to one of the UART busses of the AT90CAN128 microcontroller.

The E.C Circuit outputs the conductivity of the water, the Total Dissolved Solids (TDS) of salt in the water, as well as the salinity expressed as an integer number in the Practical Salinity scale of 1978. Out of these, only the last is used.
Three types of probes can be used. One for fresh water, one for brackish water and one for salt water. The ranges of salinity each probe can measure do overlap, but a correct probe must be chosen or the salinity reading can come out of range.

Readings from all sensors will be put in the same CAN message containing 5 payload bytes according to Table 1[1]. This CAN message is called the *Sensor_Message* and is sent at regular intervals.

2.1 Temperature sensor

To receive the data from the temperature sensor a protocol converter between UART and 1-wire communications has been used. In order to read the temperature a set of characters have to be sent from the UART to the converter which interprets the received characters and generates the corresponding 1-wire signals. The temperature sensor detects the signals, makes an analog-to-digital conversion of the temperature and puts the data on the 1-Wire bus. Afterwards, the converter takes the data from the 1-Wire bus, translates it into characters and sends them over the UART to the AT90CAN128.

On the AT90CAN128 the characters are computed into a value with a resolution of 1 degree Celsius, which is more than enough, since the speed of sound doesn't change that much at this little temperature variation. A procedure has been written so that when it is called it will take a temperature reading and return the computed temperature.

[1]Since only a precision of 1 degree C is used for temperature readings, the temperature could be represented by just one signed byte. Initially, a higher precision was intended to be used on the Temperature sensor.

2.2 Pressure sensor

Since the pressure sensor is analog, the AVR.AT90CAN128.ADC library [4] is used to read the analog output of the sensor whenever a CAN message is to be sent with sensor readings. This analog-to-digital value is converted to millibars before being sent as a CAN message.

2.3 Salinity sensor

The E.C Circuit [3] is a circuit board in itself with header pins on its underside. These are in turn connected to matching header sockets on the Sensor Controller Board.
The E.C Circuit is dependent on a temperature reading of the water in order to provide accurate readings. Hence, the AT90CAN_Sensor_Controller software first makes a temperature measurement before sending a command to the the E.C Circuit. The command will be of the following format:

17.5,C<*carriage return*>

The "17.5" is the measured temperature, the "C" tells the E.C Circuit to make continuous measurements. When the temperature changes, a new command is sent to the E.C Circuit in order to keep it updated with an accurate temperature reading.
The responses from the E.C Circuit have the following format:

50000,32800,32<*carriage return*>

The last number ("32" in this example) represents the salinity in the Practical Salinity scale of 1978. The two other numbers represent the conductivity of the water and the Total Dissolved Solids (TDS) of salt in the water and are discarded. The salinity reading will be in the range 0 to 42. If the reading was out of range the value "--" will replace the numerical value.
The salinity reading will be output from the E.C Circuit at regular intervals. The latest reading is stored as a variable so that it can easily be fetched when it is time to send a CAN message with sensor data. This variable is initiated at 254, meaning that no measurement has been done. If the salinity sensor is not connected to the UART bus of the Generic CAN controller, this variable will never be set to any other value and consequently the value 254 will always be output on the CAN bus.

Table 1: Payload bytes of the Sensor CAN message

Bytes	Data type	Meaning
1 - 2	Integer_16	Temperature in 16^{ths} of degrees C, e.g. +20.25 will be sent as 324 (00000001 01000100 in binary).
3 - 4	Unsigned_16	Pressure in millibars.
5	Unsigned_8	Salinity in the Practical salinity scale, 0-42. 255 means that the value is out of range. 254 means no measurement has yet been done.

3. RESULT

Since the project ran out of time not all of the goals set for the Sensor Controller were achieved.

3.1 Temperature sensor

A small PCB prototype which contains the converter circuit was built and connected to the temperature sensor and the Generic CAN controller. The tests results were very good. The entire temperature range was not tested, only from +15 degrees Celsius to +100 degrees Celsius due to the lack of equipment to create the rest of the temperature range, but for this range the sensor performed very well.

3.2 Pressure sensor

The pressure sensor was never put through any major tests. This was due to time limits and the inherent difficulty of creating sufficient levels of pressure to perform a test.
The only practical way to do this is to submerge the sensor in water. The depth needed[2] to test the whole range of pressure would mean that either a very long cable would need to be attached to the sensor (and made waterproof), or, that one puts the sensor, the Sensor controller and some hardware for logging the sensor readings in a waterproof hull. The latter could be easily be done once the AUV's hull is completed, but this stage was not reached during the duration of the project.

A simple test was done where it was connected to a voltage source and its output voltage measured. The result from this test was good. However, more testing and calibration will be needed.

3.3 Salinity sensor

Since the salinity sensor was never purchased, no results regarding it were obtained.

4. CONCLUSION

Since the project ran out of time the Sensor Controller was never completed.

4.1 Future work

The Sensor Controller will need to be tested with its sensors before it is used.
When purchased, the salinity sensor will need to be calibrated. No work has been done regarding calibration of the salinity sensor. The temperature and pressure sensors are also likely to need some form of calibration.

[2]Approximately 20 meters to get an absolute pressure of 3 bars.

5. REFERENCES

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