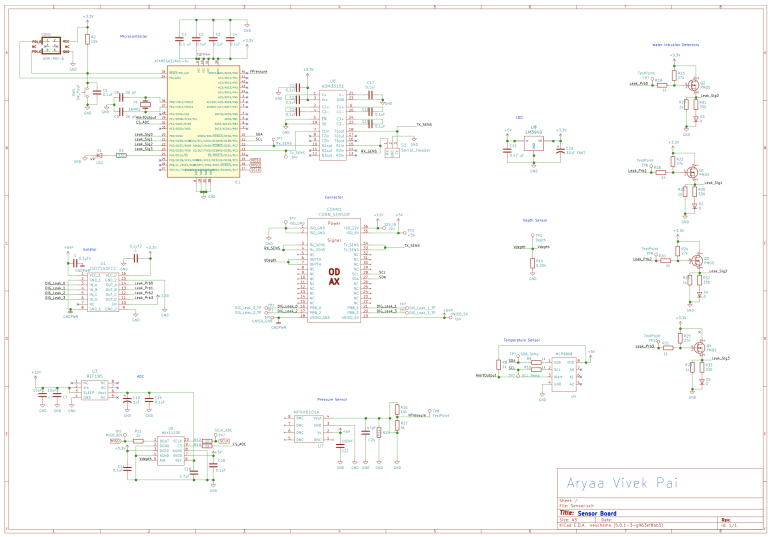
Cornell University Autonomous Underwater Vehicle Team

Fall 2018

Sensor Board



Documentation

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Contents

1 Abstract

The Sensor Board serves as an intermediary between the various sensors and the main computer of the submarine. It collects data from the on-board pressure, temperature and water intrusion detection sponges as well as an external depth sensor and communicates it to the Serial Board in a RS-232 serial interface. This year, many amendments have been made to the Sensor Board. A completely new temperature sensor and ADC has been used. A few adjustments were made to the pressure sensor circuitry.

2 Design Requirements

The Sensor Board requires the following components:

- 1 Internal temperature sensor [MCP9808]
- 1 Internal pressure sensor [MPXH6101A]
- 4 External water intrusion detection sponges to alert the computer when there is a leakage.
- 1 External depth sensor 1 On board Analog to Digital Converter [MAX11100]

The power connections required for the sensor board are:

- +12V power for the REF195 voltage reference.
- +5V power for the temperature,pressure sensor and ADC, as well as for the LM3940 LDO regulator used to produce a 3.3V line.
- +5VP input from the Power Board for the isolator.
- Unisolated Ground for the isolator.
- Isolated Ground for all the other connections

3 Previous Designs

This is the ninth version of CUAUV's Sensor Board and the first one to use a digital sensor instead of the analog sensors, used in the previous years. The new temperature sensor is completely digital and was chosen as the first step towards completely digitizing the board in the future. As a digital

temperature sensor was used, it was ineffective to use the last year's ADC, which not only took up a lot of space but also needed an external crystal oscillator circuitry and had many features that were unused. Therefore, it was replaced by a smaller ADC this year. The water intrusion circuitry and pressure sensor have not been changed, although the analog data from the pressure sensor is converted to digital using the microcontroller's in build ADC.

4 High Level Description

The Sensor Board circuitry mainly focuses on the temperature and pressure sensors, the water intrusion detector circuitry as well as the ADC, which includes a band gap reference voltage. The MCU and level shifter circuitry and the LDO regulator complete the board.
The Sensor Board receives three power input lines, the 12V line is used by the voltage reference, the +5V line powers the temperature and pressure sensors and the analog side of the ADC, where as the 5VP is used by the isolator. The LDO uses the +5V power line to produce a steady +3.3V power that is used by all the other components on the board.
The analog data collected from the pressure sensor is converted to digital the MCU's ADC, while the data from the external depth sensor is converted to digital using the on-board ADC and transmitted to the ADC via SPI. The data from the temperature sensor, which is already in digital,is fed into the MCU using I2C. The four water intrusion sensors are simple sponges that connect the output line to ground when wet. This signal is amplified by a PMOS and passed through an isolator to reduce noise. As it only had two possible output, it is not converted to digital but directly connected to the MCU. The 3.3V output signal from the MCU is then passed through a level shifter to amplify to 20V before communicating it to the Serial Board through the RS-232. specification.

5 Implementation

5.1 Sensor Circuitry

The circuitry surrounding the Temperature sensor were taken from the recommendations in the data sheet. The data from the sensor is transmitted to the MCU using I2C and thus has SCL and SDA lines connections to the MCU. The Alert pin on of the sensor, used for testing, is connected directly

to the MCU.
The pressure sensor connections are also done according to the given recommendation, with the addition of a pull down resistor and two capacitors. The output signal is passed through a voltage divider before connecting it to the MCU's ADC. After the boards had been manufactured, faults were found the voltage divider circuitry. The two resistors used in the voltage divider were both connected to the output signal, while only one should have been connected to the output signal and other to ground. This fault was rectified by cutting traces on the board and making the required connections. However, a new board was printed which had the correct connections.
The data from the external depth sensor is sent to the ADC after passing it through a pull down. resistor.
The water intrusion detection sensors has the input signal, which have been pulled up before passing it through the PMOS. When there is a leak and the sponges become wet enough to conduct to the ground, the transistor output is high. This output is transmitted to the MCU through an isolator and also indicated by the LED. The output does not need to be converted to digital. Since this signal is very sensitive, it is important to amplify it using a transistor and use isolated ground and isolated +5V power to prevent it from being disrupted by the noise. The circuitry for the isolator is taken directly from last year's design and is powered by +5VP one side and +3.3V on the other.

5.2 ADC and band gap Voltage Regulator Circuitry

The ADC converts the analog data from the external depth sensor to digital. The design for the ADC is implemented as specified in the data-sheet. It uses the +5V power input for the analog side and the +3.3V for the digital side. It has the standard MISO, SCLK and chip select lines to connect it to the MCU via SPI.
A band gap voltage reference regulator [REF195] is connected to it to improve its accuracy. This works on a +12V power input line.

5.3 Microcontroller and Level Shifter

The microcontroller's main purpose is to convert the digital data from the sensors to a serial interface so that it can be communicated to the main computer. The MCU is also used to convert the analog signal from the pressure sensor to a digital signal. The temperature sensor, connected to the ADC via I2C, directly sends a digital signal. The data from the depth

sensors is converted to digital using the ADC, which is connected to the MCU via SPI. The signals from the water intrusion detectors are directly connected to the MCU.
The MCU has its own Level Shifter that amplifies the 3.3V output signal that is prone to noise, to a 20V signal. This is to convert it to the RS-232 specification that is used for communication with the Serial Board. The MCU has an external crystal oscillator and a voltage supervisor, which is a part of the reset mechanism. Like every other board on the submarine, it also has a heartbeat LED, helpful for debugging.

5.4 Layout

The Layout of the Sensor Board was made according following the schematic. The board has four layers, the second layer form top is GND and the third is Power. The heartbeat LED is on the top left corner on the front side of the board. All the LEDs and ICs are on the front side of the board. The pressure sensor and temperature sensor are on the top left of the board, while the water intrusion detection LEDs and its respective ciruitry are on the right side. As Depth is the most important signal on the board, the ADC and voltage reference required to process it are on the bottom part of the board, close to the connector. There are test points for depth, pressure, temperature and the four leak signals as well as all the power and ground voltages supplied to it.
The Layout of Sensor Board for Odysseus and Ajax are different because the 12V and 5V pins on the connector for Ajax back plane are switched.

6 Software Walk-Through

The Sensor Board's main function is to read the data from each on the on board sensors and send it to the main sub computer over serial. The Sensor Board's main code is divided into five c files.
The depth.c file reads the data from the depth sensor and sends the actual depth, converted using the on board ADC to the main computer. SPI is used to communicate with the ADC. It also contains functionality to convert depth using the ADC of the mictrocontroller. This is only used for debugging purposes.
The pressure.c file reads data from the pressure sensor and converts it using the microcontroller ADC.
The temperature.c file reads data from the temperature sensor using I2C and sends it to the main computer.

The leak.c file lights on the respective water intrusion detection LED if its signal is high.
The last file is main.c, where the code for heart beating and communicating to all the sensors are actually called.
The temperature.c and leak.c files are currently not functional and will be completed before the summer. In addition to these files the auv_serial library, sensor.h and sensor.toml files are used.

7 Known Issues

The Sensor Board has a history of short circuiting due to isolated events. So far, there have been two PCBs which were populated with the components required for basic microcontroller and serial functionality but have short circuited. The first board shorted because a signal higher than 3.3V was given to the microcontroller by the pressure sensor because of the faulty circuitry, which could not be handled by the microcontroller. One of the reasons the second board shorted was the lack of space between the components and the left edge of the board. Due to this, the board is only powered on using the test board or on switchboard mat.
In the Ajax back plane, the 12V and 5V connections for Sensor Board connector are switched, as compared to the one according to which the board has been designed. This was rectified by cutting the traces from the connector and using rework wires from the pads on the connector to the 12V and 5V test point.

8 Current Status

Two boards have been populated and tested to give a stable depth reading. Although both the boards have temperature and water intrusion detection components populated, their functionality has not been tested yet. The Pressure sensor has not been populated to avoid the risk of shorting the board due to the above mentioned faults in the circuitry. The reason for the delay in the testing and populating this board was because the accurate functioning of the depth was prioritized over others. The board will be completely populated and tested over the summer with the corrected layout.

A Appendix

The Appendix consists of the final layout and schematic of the Sensor Board as well as the Pinouts and Data sheets for all components on the board.

A.1 Pinouts

A.1.1 Sub Connector

Odysseus

1,2	GND
3,4	RX_SENS
6,7	VDepth
16	Leak_Prb0
17	Leak_Prb2
18	GND PWR
19	+5VP
21	Leak_Prb1
20	Leak_Prb3
27	SDA
28	SCL
34,33	TX_SENS
35	+5V
36	+12V

Ajax

1,2	GND
3,4	RX_SENS
6,7	VDepth
16	Leak_Prb0
17	Leak_Prb2
18	GND PWR
19	+5VP
21	Leak_Prb1
20	Leak_Prb3
27	SDA
28	SCL
34,33	TX_SENS
35	+12V
36	+5V

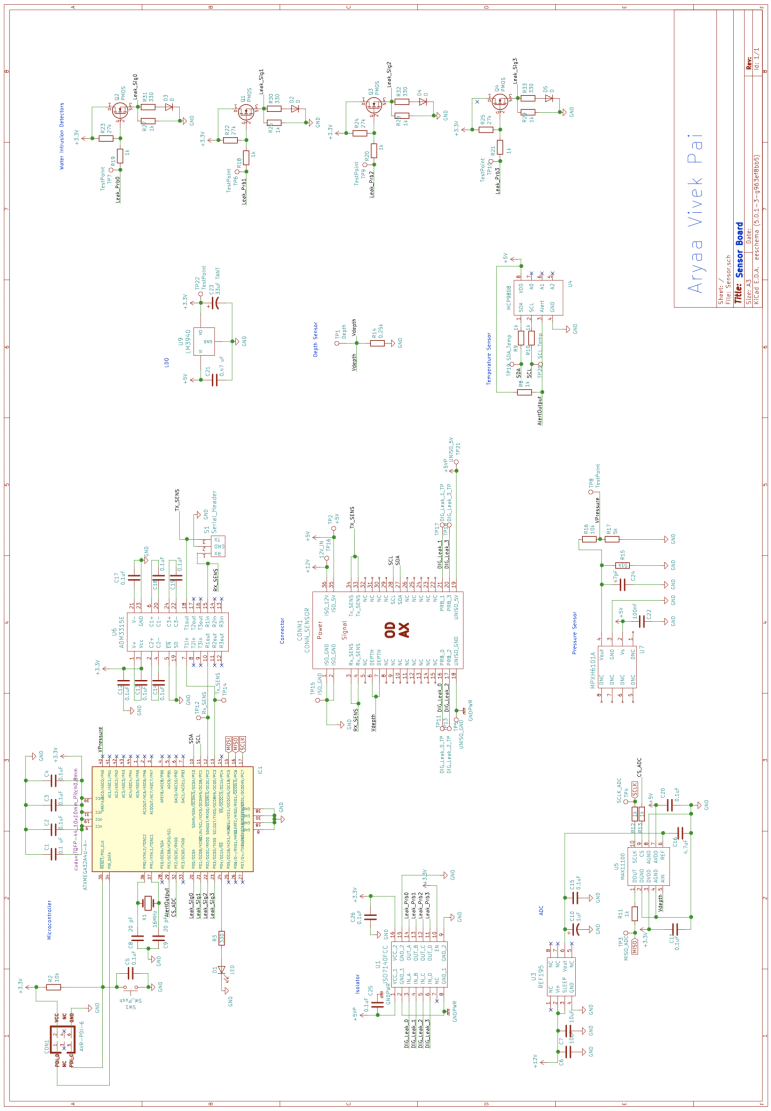
A.2 Part References

A.2.1 Analog

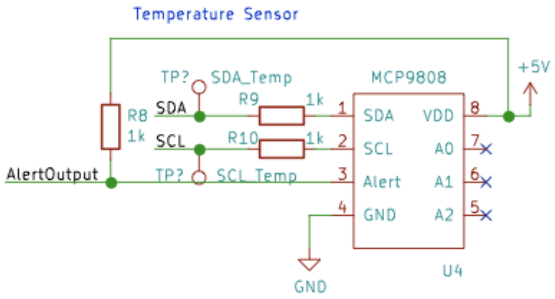
LM3940 Voltage regulator	LM3940 Datasheet
MCP9808 Temperature Sensor	MCP9808 Datasheet
MPXH6101A Pressure Sensor	MPXH6101A Datasheet
MAX11100 Analog to Digital Convertor	MAX11100 Datasheet
REF195 Voltage Reference	REF195 Datasheet
ATXMEGA32A4U-A- Microcontroller	ATXMEGA32A4U-A- Datasheet
ADM3315E Level Shifter	ADM3315E Datasheet
TPS3809K33 Voltage Supervisor	TPS3809K33 Datasheet

A.3 Schematics

A.3.1 Sensor Board

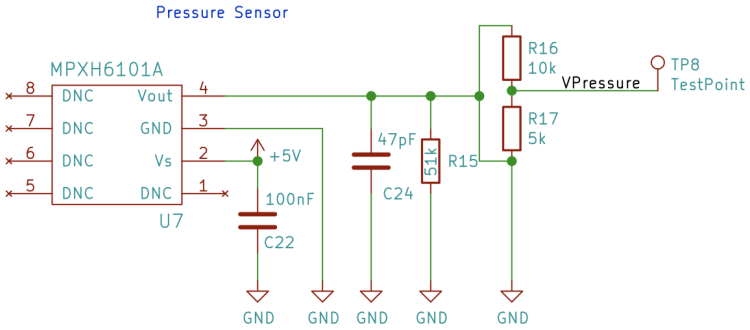


A.3.2 Temperature Sensor

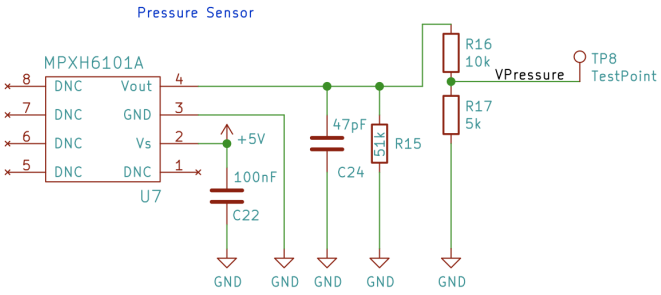


A.3.3 Pressure Sensor

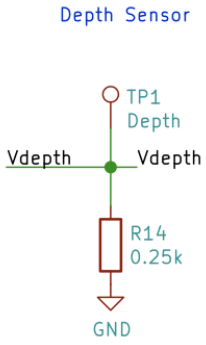
Original



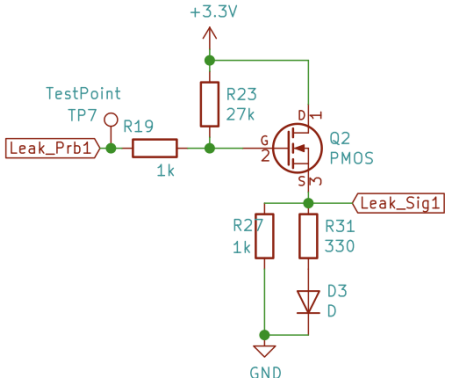
Corrected



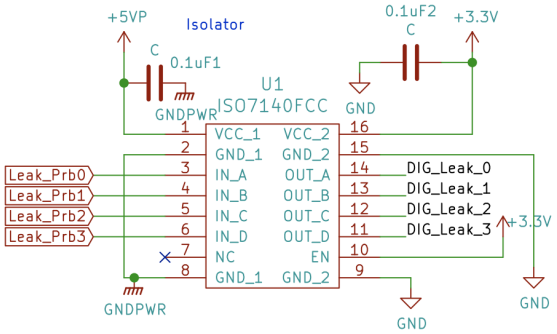
A.3.4 Depth Sensor



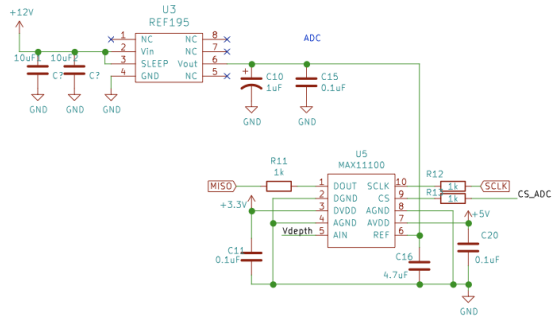
A.3.5 Water Intrusion Detector



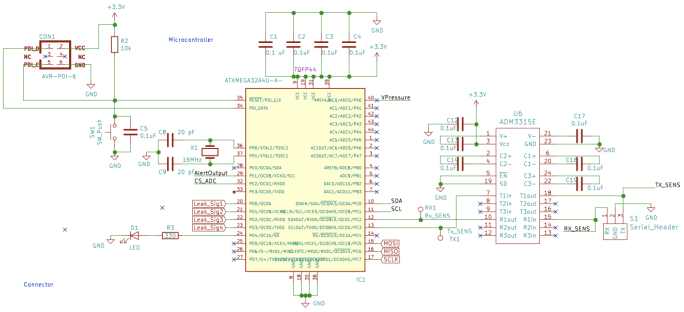
A.3.6 Isolator



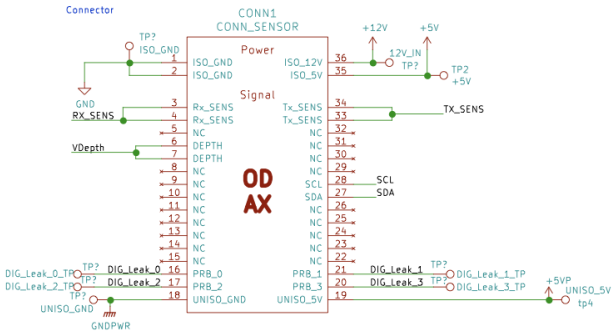
A.3.7 ADC



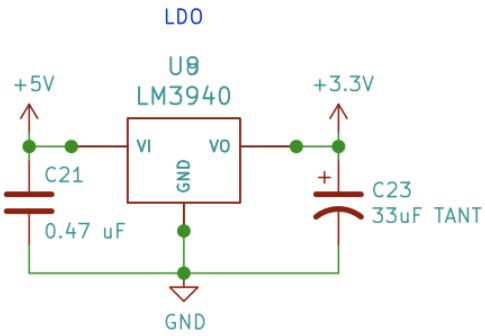
A.3.8 MCU



A.3.9 Connector

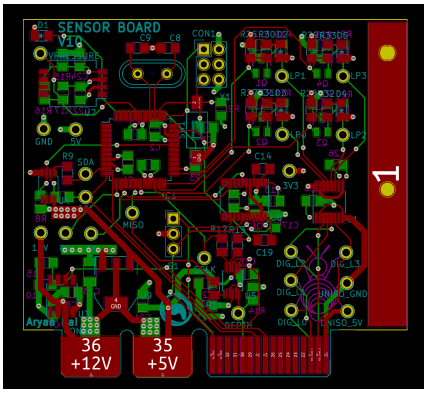


A.3.10 LDO

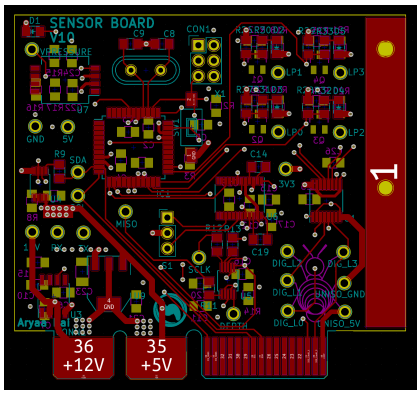


A.4 Layout

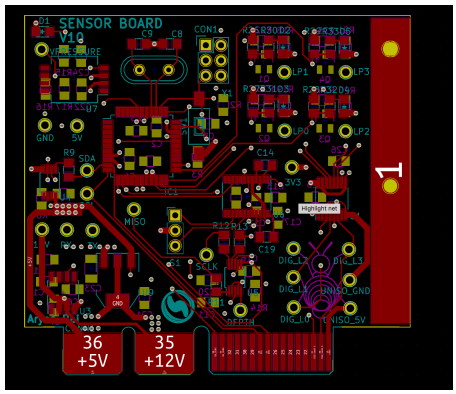
A.4.1 Complete Layout



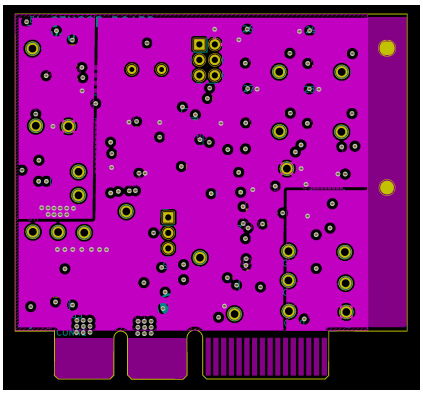
A.4.2 Front Layer - Odysseus



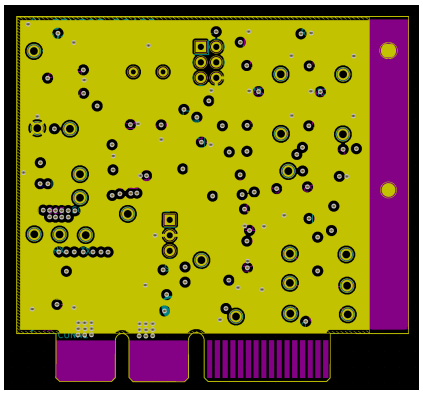
A.4.3 Front Layer - Ajax



A.4.4 Power Layer



A.4.5 Ground Layer



A.4.6 Back Layer