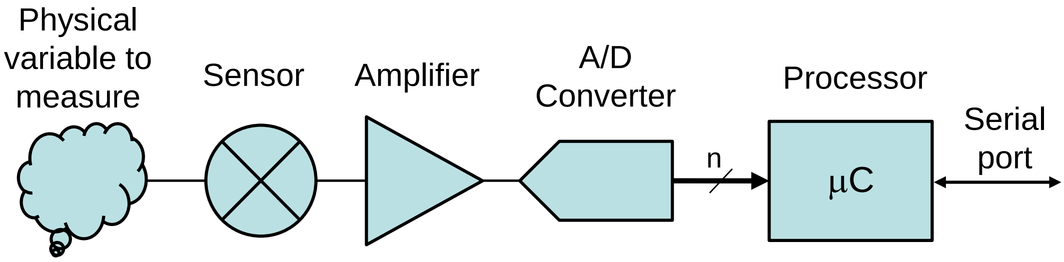
ENTIC-lab

WP3 – ELECTRONICS

PLEASE READ COMPLETELY THIS DOCUMENT BEFORE STARTING YOUR WORK

Having this document available at any time during the lab work is mandatory.



Introduction

Goal: To acquire ROUV depth along an underwater trip.

Task description: The team should design and build a prototype circuit able to estimate water depth through pressure measurement, while the ROUV sinks and travels under turbid water. Data acquisition will be performed by an Arduino board, which should be integrated together with the custom measurement circuit. The prototype circuit will be mounted on a proto-board, and then tested and calibrated using the lab instruments. Serial data communication will be added to the prototype in WP4, and then the definitive PCB (printed circuit board) version of the measurement circuitry will be implemented and mounted in the payload box.

Important: All questions in this document must be answered. The order in which you answer the questions is up to you, depending on how you organize your lab work. But, before doing any certain task, the related questions must be answered in the deliverable file under "*Answers to the WP questions*" available in Atenea. This file can be updated as many times as necessary along WP3 time. To this effect, keep the task in draft status until you finish the work package. You will not pass Part A of the subject if there are any unanswered questions.

WP3.1 Depth estimation based on pressure measurement

Pressure sensing is the most suitable low-cost depth estimation method. The dependence of pressure with depth in water can be obtained from the definition of the "atmosphere" pressure unit: 1 atm = 1 kg/cm^2, which corresponds to the pressure applied by a column of 10 m of water. 1 bar = 100 kPa = 0,986 atm ≈ 1 atm = 750 mmHg.

Question 3.1: *Which pressure increase will be observed at 3 m depth?*

Question 3.2: Will this pressure depend or not on the atmospheric pressure at water surface? Why?

In the lab, the pressure changes will be generated by a syringe and reference measurements will be available using a manometer.

3.1.1. Pressure sensing

The pressure sensor used in the ROUV is the Freescale Semiconductor MPX2100AP. It is based on a diaphragm, which converts pressure into deformation, and a set of piezoresistors implanted in the diaphragm surface. These resistors change their value due to deformation.

The diaphragm (see Fig.1, left) presents positive deformation (extension) in the centre and negative deformation (compression) at the periphery. By placing four piezoresistors in this area, positive and negative resistance variations can be obtained.

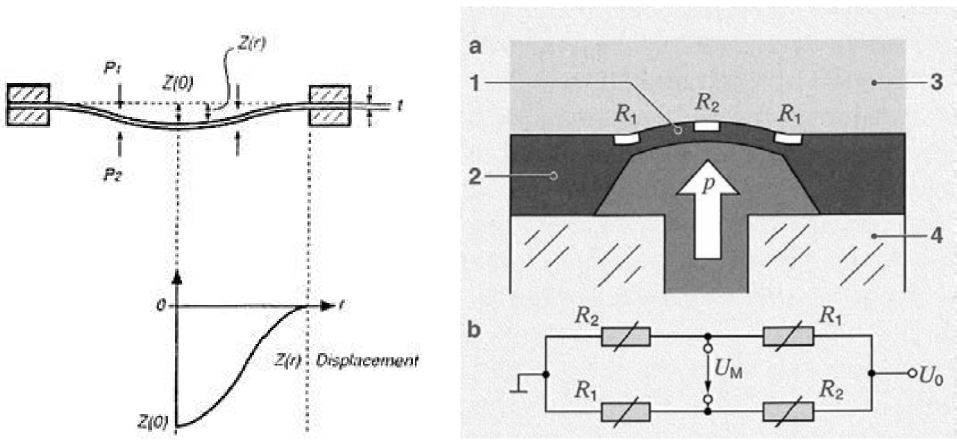


Fig. 4.1

In piezoresistive layers, the resistance varies due to strain (deformation + mechanical stress). This produces a small relative variation x<<1 from a base value R_0, as follows:

$$R = \rho \cdot \frac{L}{d} \qquad R = R_o \cdot (1 + k \cdot \frac{\Delta L}{L}) = R_o \cdot (1 + x)$$

Accordingly to their position in the diaphragm area, when pressure is applied two resistors will have a resistance increase $R_0(1+x)$, while the other two will have a decrease $R_0(1-x)$.

The four resistors are connected in pairs in the opposite diagonal branches of a Wheatstone bridge, as shown in Fig. 4.2.

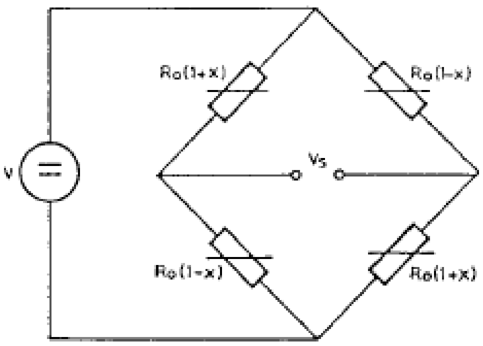


Fig. 4.2

Question 3.3: *Analyse the circuit of Fig. 4.2 and obtain the output voltage V_S. Then, find the dependence of V_S on the relative variation due to deformation (x) and on the power supply voltage (V).*

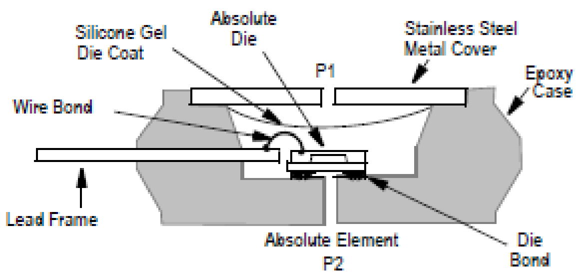


Fig. 4.3

The deformation of the diaphragm and the variation of the internal resistors are internal data generally unknown in commercial pressure sensors. The manufacturer data sheet gives information about the output voltage variation for a given input pressure at a nominal power supply voltage. These data can be provided as a sensitivity (S = voltage/pressure [mV/kPa]) or as a voltage at full-scale pressure, from which the sensitivity can be obtained assuming 0 V at 0 Pa.

Question 3.4: *The datasheet of the sensor is available in Atenea. Identify there the full scale output, and then deduce the sensor sensitivity and its value when the supply voltage is not 10 V but 5 V.*

Question 3.5: *What output voltages V_0 will provide the sensor at the water surface (at P=100 kPa) and at 3 m depth?*

Question 3.6: *In a real case and due to changing atmospheric conditions, the pressure at the water surface can be different than 100 kPa, discuss how you could fix such effect and obtain the correct pressure data.*

3.1.2 Amplification stage

The output of the Wheatstone bridge is a differential (floating) voltage, that is, the voltage difference between two nodes. In addition, it is a small value. A differential amplifier can be used to perform signal conditioning, i.e. to obtain the voltage difference and to multiply it by a known factor. This device is commercially available as a single chip. The Texas Instruments INA126 monolithic differential amplifier is the chosen one for this purpose, see datasheet in Atenea. The inner circuit of this device, a two OpAmp differential amplifier, is shown in Fig. 4.4.

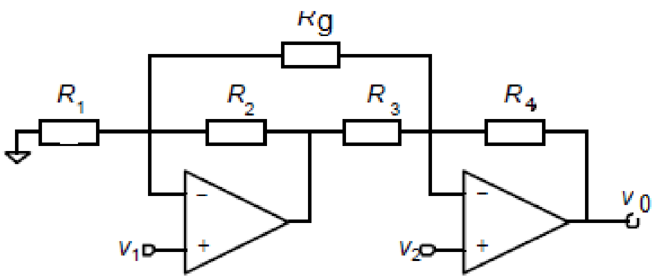


Fig. 4.4

> ***Question 3.7:*** *Analyse the circuit of Fig. 4.4 and obtain its gain expression $V_0/(V_2-V_1)$ when $R_1/R_2=R_4/R_3$. Identify the role of R_g as a gain trimmer without compromising the R_1-R_4 resistance matching.*
>
> ***Question 3.8:*** *Compare this result with the gain expression provided by the manufacturer using the resistor values shown in the INA126 datasheet.*
>
> ***Question 3.9:*** *Identify the saturation voltage of the amplifier.*
>
> ***Question 3.10:*** *Which amplifier gain is necessary to obtain the maximum amplifier voltage output for 3 m depth? Which R_g resistor value will provide this gain?*

Build the sensor + amplifier circuit on the protoboard. Set the power supply to 5V DC and use the syringe, the manometer and the multimeter to check the circuit and obtain several different pressure measurements.

> ***Question 3.11:*** *Obtain in the lab 10 measurement points along the measurement range. Draw its graphical representation, calculate and plot the linear regression and the linearity error (lineal regression straight line – measured points).*

- Perform these calculations both in Excel and in MatLab.
- Include in your answer the raw data, the Excel plot, the MatLab plot and the MatLab code.
- To become familiar with MatLab you have an introductory document available in Atenea. MatLab help is also a good resource to start working with this software.
- To calculate the linear regression, consider the MatLab function *polyfit*.

WP3.2 Data acquisition with Arduino

In the lab, the analog output of the measurement circuit can be acquired with the workbench instruments: oscilloscope, multimeter, etc. However, in the ROUV data acquisition is to be performed in digital format by a programmable digital board, the Arduino Uno. This platform is based on an Atmel ATmega328 microcontroller and, among other resources, it includes 5 analog-to-digital (A/D) channels (of 10 bits each), a 16 MHz clock, a power supply circuit (providing 3.3V and 5V outputs), 14 general-purpose digital pins, an USB port and 2 TxD/RxD pins for serial communication.

Arduino is an open-source environment, with a community of developers and a lot of hard & soft resources available in internet. Complete starting information can be found at http://www.arduino.org or either at http://www.arduino.cc .

In the lab, the Arduino will be 5V powered from the computer via the USB cable. The USB will be also used to program the microcontroller from the Arduino development software. The 5V output of the Arduino will be used to power other payload electronics: sensor, amplifier, level shifter, etc.

On the other hand, the USB link will not be used in normal ROUV use out of the lab. In this case the Arduino will be powered from the 12V battery. The communication between the Arduino and the computer will be implemented in WP4 using a RS-232 serial link.

> ***Question 3.12:*** *Calculate the digital data range provided by the acquisition circuit in measurements from 0 to 3m of water depth. Consider that the 10 bit A/D converter of the Arduino assigns 0 to a 0V input and 1023 (2^{10}-1) to a 5V input.*

Let us now connect the Arduino board to the acquisition circuit mounted on the protoboard. Proceed as follows:

- Use to two 8-pin strips to connect and hold the Arduino board to the protoboard.
- Connect an Arduino GND pin (Analog pins side) to the GND track of the protoboard.
- Connect the Arduino 5V output (Analog pins side) to the voltage supply track of the protoboard.
- Connect the output of the differential amplifier (section 3.1.2) to the Arduino analog input A0.
- Using an USB cable, connect the Arduino to the computer.

After a brief start up time, the green LED indicates that the Arduino is ready to work.

The next step is to use the Arduino development software to compile and upload a program, which displays on the screen the values of the pressure measurements. Proceed as follows:

- Double click on the desktop icon to run the Arduino development software.

Go to tools → board and select Arduino Uno.

- Go to tools → ports and select COMx (Arduino Uno).
- Go to tools → programmer and select AVRISP mkII.
- Go to file → examples → basics and select AnalogReadSerial. A new sketch window, as the one shown in Fig. 4.5, opens. Close the previous (empty) sketch window.

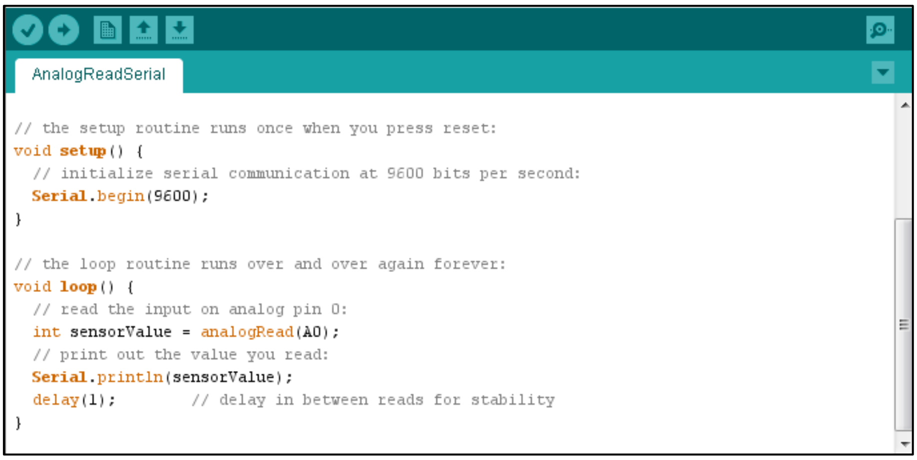


Fig. 4.5

Arduino programs are called sketches. The default programming language is a specific subset of C/C++. The language reference can be found in help → reference (it is a link to the Arduino website).

Question 3.13: *Explain briefly what is the purpose of the following functions, used in the sketch of Fig. 4.5: Serial.begin(), analogRead(), Serial.println() and delay().*

Let us now edit the sketch, compile, upload and run it on the Arduino board. Proceed as follows:

- Change the parameter of the delay() function to obtain a measurement sample each 0.5 seconds.
- Click on the icon. The sketch is compiled and, if no errors occur, it is then uploaded to the board. After that, the program runs automatically.
- Go to tools → serial monitor. This opens a window, on which the measurement data sent from the Arduino to the computer through the USB can be displayed.

Note that the uploaded program becomes resident: it starts running each time we power up the Arduino board or after pressing the reset button. Opening the serial monitor also restarts the program.

Question 3.14: While acquiring measures with the Arduino, smoothly increase the pressure to simulate a depth change from 0 m to 3 m. Do the measurement results displayed on the serial monitor match with the theoretical ones obtained in Question 3.11? If not, explain why.