# MEASUREMENT OF SEA WATER PARAMETERS USING MEMS TECHNOLOGY

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# MEASUREMENT OF SEA WATER PARAMETERS USING MEMS TECHNOLOGY

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MEASUREMENT OF SEA WATER PARAMETERS USING MEMS TECHNOLOGY

FUNDA ACAR

APPROVED BY:

Asisst. Prof. Hakan Gürkan Işık University ____________

(Thesis Supervisor)

Asisst. Prof. Ümit Güz Işık University ____________

Prof. Serdar Özoğuz Istanbul Technical University ____________

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MEASUREMENT OF SEA WATER PARAMETERS USING MEMS TECHNOLOGY

## Abstract

The system is used to measure the pressure and the temperature values up to hundred meters of the sea water. This project is also called as expendable environmental probe. The probe contains a temperature sensor, a pressure sensor, and system electronics. It is needed for the calculation of the performance of the sonar of warships, oceanographic institutes and oceanographic purposes.

The probe include the sensors which developed by using Micro Electro Mechanical Systems technology. The probe is an expendable probe capable of reaching over hundred metres of depth when dropped from a moving ship, and a thin conducting wire is transferred through the data to the ship. This data is collected, stored, and displayed the data acquistion system.

Data was collected from the temperature and the pressure sensors but the data could not displayed the data acqusition system with one wire system. One wire system is used only a few meters but I want to communicate the system up to hundred meters. Therefore I decided to use two wire system with communication module. In conclusion, the system was prepared in conformance with hardware design and the communication system was changed with two wire system design.

DENİZ SUYU PARAMETRELERİNİN MEMS TEKNOLOJİSİ KULLANARAK ÖLÇÜLMESİ

# Özet

Sistem deniz suyunun yüz metreye kadar sıcaklık ve basınç değerlerini ölçmek için kullanılmaktadır. Bu proje harcanabilir çevresel sonda olarak da adlandırılabilir. Sonda bir adet sıcaklık sensörü, bir adet basınç sensörü ve sistem elektroniğini içermektedir. Bu sisteme savaş gemilerinin sonarlarının preformansının hesaplanmasında, oşinografi enstitülerinde ve oşinografik amaçlarda ihtiyaç duyulmaktadır.

Sonda içerisinde mikro elektromekanik sistem teknolojisi ile geliştirilmiş sensörler bulunmaktadır. Hareket eden gemiden atılan tek kullanımlık sonda, yüz metre derinliğe kadar ulaşmaktadır ve veriler ince iletken bir tel aracılığı ile gemiye gönderilmektedir. Bu veriler toplanıp, depolanıp ve veri sağlama ünitesinde gösterilmektedir.

Veriler sıcaklık ve basınç sensörlerinde toplanılmış fakat veri sağlama ünitesine tek tel ile gönderilememiştir. Sonda içerisindeki sistem gemideki ünite ile tek tel ile iletişim kurmak istediğinde sorun oluşmuştur. Tek tel ile iletişim sistemi sadece kısa mesafeler için kullanılmaktadır fakat sistemin yüz metrede haberleşmesini istedim. Sistem donanımsal olarak kurulmuş ve prototip dizaynı çift tel olarak değiştirilmiş, haberleşme sağlanmıştır.

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The last words of thanks go to my family. I thank my parents for their patience and encouragement.

To my family

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## List of Symbols/ Abbreviations

| | |
|---|---|
| $\lambda$ | Wavelength |
| XBT | Expendable Bathythermograph |
| XTCD | Expendable Temperature Conductivity Depth |
| BB | Bottom Bounce |
| CZ | Convergence Zonea |
| SE | Sonar Equation |
| SL | Projector Source Level |
| TL | Transmission Loss |
| AN | Ambient Noise |
| AG | Array Gain |
| RD | Recognition Differential |
| TS | Target Strength |
| RL | Reverberation Level |
| N | Noise |
| PL | Propagation Loss |
| SL | Source Level |
| TS | Target Strength |
| DI | Directivity Index |
| MEMS | Micro ElectroMechanical System |
| SDL | Serial Data Line |

| | |
|---|---|
| SCL | Serial Clock |
| ACK | Acknowledge |
| NACK | Not Acknowledge |
| ADC | Analog Digital Converter |
| dB | Decibel |
| c | Sound Speed |
| T | Temperature |
| S | Salinity |
| ppt | Part Per Thousand |
| Z | Depth |

# CHAPTER 1

# Introduction

The measurement methods and techniques have been developing within the new possibilities. The system has been using by oceanographers and navies for many years nevertheless the electronic part has been designed by using technology in sixties. The response time and accuracy are very important for oceanographic research and navies. Nowadays micro system and also nano system technologies are using by designer because of their advanced properties: more sensitivite, cost effective and the electronic components are taking a small space.

The aim of this master thesis is to develop a system that measures of the sea parameters using the micro electro mechanical system technology. The report covers the properties of the environment and the design of the measurement tool. An overview of the principles implied in the design process provides a better understanding of the operating of the system.

## 1.1.Outline of the Thesis

This thesis is organized as follows. In Chapter 2, I introduce the related background knowledge about Underwater acoustics, Oceanography, Ocean acoustic enviroment and SONAR system. In Chapter 3, I introduce sound speed profiles and propagation examples in sea water. In Chapter 4, I present the system that is used in sensors in overview of MEMS. In Chapter 5, system design is introduced by two section: hardware and sotware design. Chapter 6, Related works is the last chapter of this thesis. In this chapter I intorduce two system which have similar properties and system design with my project. In Chapter 7, I present conclusion and future work.

# CHAPTER 2

# Related Background Knowledge

## 2.1. Underwater Acoustics

Underwater acoustics is the science of sound in water, most commonly in the ocean, and encompasses not only the study of sound propagation but also the masking of sound signal by interfering phenomenon and the signal processing for extracting these signals from interference.

The science of underwater acoustics began in 1490, when Leonardo Da Vinci wrote, “If you cause your ship to stop and place the head of a long tube in the water and place the outer extremity to your ear, you will hear ships at a great distance from you.” In 1687 Isaac Newton wrote his Mathematical Principles of Natural Philosophy which included the first mathematical treatment of sound. The next major step in the development of underwater acoustics was made by Daniel Colladon, a Swiss physicist, and Charles Strum, a French mathematician. In 1826, on Lake Geneva, they measured the elapsed time between a flash of light and the sound of a submerged ship’s bell heard using an underwater listening horn. They measured a sound speed of 1435 meters per second over a 17 kilometer distance, providing the first quantitative measurement of sound speed in water. In the 19th century an underwater bell was used as an acillary to lighthouses to provide warning of hazards. In 1877 Lord Rayleigh wrote the “Theory of Sound” and established modern acoustic theory. The sinking of Titanic in 1912 and the start of World War 1 provided the impetus for the next wave of progress in underwater acoustics.

The world’s first patent for an underwater echo ranging device was field at the British Patent Office by English meteorologist Lewis Richardson a month after the sinking of the Titanic, and a German physicist Alexander Behm obtained a patent for an echo sounder in 1913. Canadian Reginald Fessenden, while working for the Submarine Signal Company in Boston, built an experimental system beginning in 1912, a system later tested in Boston Harbor, and finally in 1914 from the U.S. Revenue (now Coast Guard) Cutter Miami on the Grand Banks of Newfoundland Canada. In that test, Fessenden demonstrated depth sounding, underwater communications (Morse Code) and echo ranging (detecting an iceberg at two miles or 3 km range). The so-clled Fessenden oscillator, at 500 Hz frequency, was unable to determine the bearing of the berg due to the 3 meter wavelength and the small dimension of the transducer’s radiating face (less than 1 meter in diameter). During World War 1 the need to detect submarines prompted more research into the use of sound. The British made early use of underwater hydrophones, while the Frech physicist Paul Langevin, working with a Russian immigrant electrical engineer, Constantin Chilowski, worked on the development of active sound devices for detecting submarines in 1915 using quartz. Although piezoelectric and magnetostrictive transducers later superseded the electrostatic transducers they used, this work influenced future designs. Lightweight sound sensitive plastic film and fiber optics have been used for hydrophones, while Terfenol-D and PMN (lead magnesium niobate) have been developed for projectors.

In 1919, the first scientific paper on underwater acoustics was published, theoretically describing the refraction of sound rays produces by temperature and salinity gradients in the ocean. The range predictions of the paper were experimentally validated by transmission loss measurements.

### 2.2. Oceanography

Oceanography is a discipline that studies the ocean and physical, chemical and biological properties of the sea. It covers a wide range of topics, including marine organisms and ecosystem dynamics, ocean currents, waves, and geophysical fluid dynamics, plate tectonics and the geology of the sea floor, and fluxes of various chemical substances and physical properties within the ocean and across its boundaries.

### 2.3. Ocean Acoustic Environment

The acoustic properties of the ocean such as the paths along which sound from a localized source travel are mainly dependent on the ocean sound speed structure which in turn is dependent on the oceanographic environment. The combination of water column and bottom properties leads to a set of generic sound propagation paths descriptive of most propagation phenomena in the ocean. [1]

### 2.4.SONAR (Sound Navigation And Ranging)

Sonar (sound navigation and ranging) uses underwater sound for the detection, classification and location of underwater targets.

#### 2.4.1.Passive Sonar:

Passive sonar listens to the sound radiated by a target using a hydrophone that is called as an underwater microphone and detects signals against a background of the ambient noise of the sea and self noise of the sonar platform. The nature of the signal, its frequency spectrum and how it varies with time, will help to classify the target.

Passive sonar depends on projector source level, transmission loss, ambient loss, array gain and recognition differential. Some basic passive systems cannot detect signals because of the target quiet, noisy or far away.

Passive Sonar equation (1) is:

$$SE = SL - TL - AN + AG - RD \qquad (1)$$

SE = Sonar Equation

SL = Projector Source Level (Equipment Parameter)

TL = Transmission Loss ( Medium Parameter)

AN = Ambient Noise ( Medium Parameter)

AG = Array Gain ( Additional Parameter)

RD = Recognition Differential ( Additional Parameter)

### 2.4.2.Active Sonar:

Active sonar uses an underwater loudspeaker that is known as transducer , to generate a pulse of sound which travels through the water to a target and is returned as an echo to a hydrophone. Active sonars can be called as echo ranging systems. The echo has to be detected against a background of noise and unwanted echoes from the sea surface and sea bed and from scatterers within the volume of the sea. The speed of sound in the sea is known in this way the echoing target and the time transmission of a pulse are simply calculated .

Active Sonar equation (2) is:

$$SE = SL - 2\ TL + TS - RL - RD \quad (2)$$

TS = Target Strength ( Target Parameter)

RL = Reverberation Level ( Additional Parameter)

Propagation Loss equation (3) is:

$$2\ PL = SL + TS - N + DI + 10 \log T - 5 \log d \quad (3)$$

N = Noise

T = Temperature

d = Depth

All terms are in dB form; here are some possible values:

PL, the propagation loss, might be 80 dB

SL, the projector source level, might be 210 dB

TS, target strength, might be 0 dB

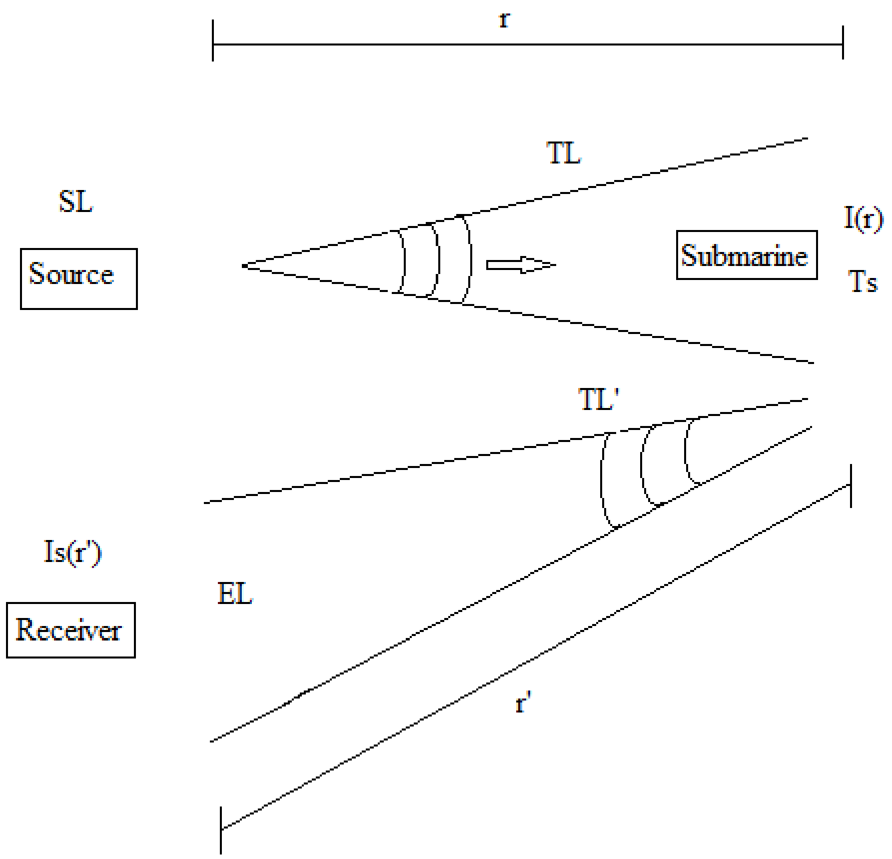



Figure 2.1. The expression for target strength

The speed of sound is differ with respect to environment. In water, the speed of sound is about 4,3times grater than its speed in air at sea level, but very much slower than the speed of light. The speed of sound:

In water: 1450 m/s (for a salinity of 35 ppt, at 0°C)

1545 m/s (for a salinity of 35 ppt, at 30°C)

The Sound speed increases by 1.6 m/s per 100m depth increase.

In air : 340 m/s

The speed of light : $3x10^8$ m/s

Velocity is related by equation (4)

$$c = \lambda . f \tag{4}$$

where

$c$ = velocity (m/s)

$f$ = frequency (Hz)

$\lambda$ = wavelength (m)

At 1000Hz we have $\lambda$ = 1.5 m, and at 10 kHz we have $\lambda$ = 150 mm. The speed of light is $3x10^8$ m/s. At a typical radar frequency of 2000 MHz the wavelength is $\lambda$ = 150 mm. Transmitting and receiving arrays are comparable for many radar and sonar system because of they have dimensions of several wavelengths.

# CHAPTER 3

## Sound Speed in Sea Water

The sound speed in the ocean is an increasing function of temperature, salinity and pressure and also these are a linear function of depth. The sound speed is describes as in equation: [1]

$$c = 1449.2 + 4.6\,T - 0.055\,T^2 + 0.00029\,T^3 + (1.34 - 0.010\,T)(S - 35) + 0.016\,Z \quad (5)$$

Where d

c is the sound speed in m/s,

T is the temperature in °C,

S is the salinity is part per thousand (ppt),

Z is the depth in m.

This equation is valid for $0 \leq T \leq 35$ °C, $0 \leq S \leq 40$ ppt, and $0 \leq Z \leq 1000$ m.

The sound speed in sea is 1450 m/s for a salinity of 35 ppt, at 0°C and 1545 m/s for a salinity of 35 ppt, at 30°C. The Sound speed increases by 1.6 m/s per 100m depth increase.

Below some approximate coefficients are denoted for sound speed valid for use with this standard sound speed:

Temperature: $\Delta c / \Delta t = +3.4$ m/s per °C (5a)

Salinity : $\Delta c / \Delta s = +1.2$ m/s per ppt (5b)

Pressure(depth): $\Delta c / \Delta z = +17$ m/s per 1000m (5c)

### 3.1.Sound Speed Profiles

Oceanographic parameters are related the geography and affected by the location, the season, the time of day and the weather. The sound speed profiles changing as function of depth, temperature and salanity (usually constant at 35 ppt but some enviroments have diffirent salinity).

Low salinity means very low attenuation coefficients and therefore reduced propagation loss. In warmer season or part of a day, the temperature increases near the surface therefore sound speed increases. The speed of sound is a positive function of depth. This near surface heating and subsequent cooling has a profound effect on surface ship sonars. Thus the diurnal heating causes poorer sonar performance in the afternoon, a phenomenon known as the afternoon effect.

The speed sound profiles are complicated mixing of the surface layer (Figure 3.1) by wind and wave actvity at the air – sea interface. This near surface mixed layer has a constant temperature (except in calm, warm surface). Sound tends to be trapped in this layer by surface reflection and upward reflactions.

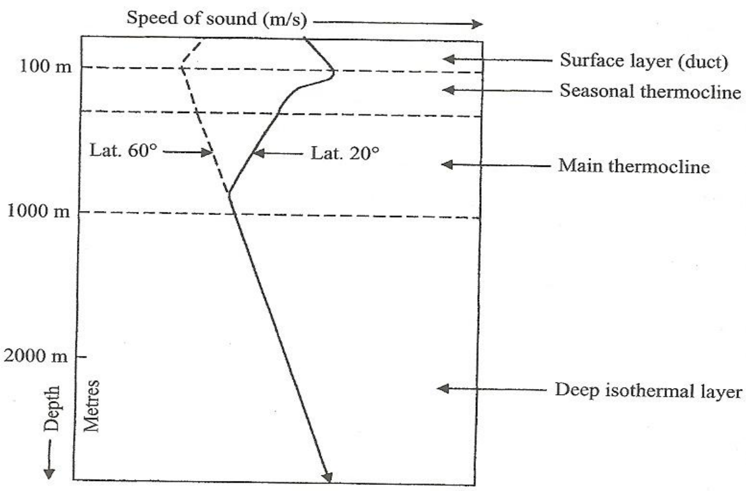



Figure 3.1. Typical deep sea Sound Speed Profiles

Below the mixed layer is the seasonal thermocline (Figure 3.1) where the temperature decreases with depth and therefore the sound speed also decreases with depth. During summer and autumn the thermocline is strong and identifiable. During winter and spring it is weak and merges with the surface layer.

The main thermocline layer is little affected by the seasons.The temperature is constant and the pressure increases with depth therefore the net effect of temperature and pressure changes is to reduce the sound speed. The upper region is dependent on season and time of day, which, in turn, affects sound propagation in the water column. The tendency is shown in the dashed curve of Figure 2 for a latitude of about 60°.

### 3.2. Propagation Examples

The principal characteristic of deep water propagation is the existence of an upward refracting sound speed profile which permits long range propagation without significant bottom interaction. Hence, the important ray paths are either refracted refracted or refracted surface – reflected. Typical deep water environments are found in all oceans at depths exceeding 2000 m. [2]

### 3.2.1.Propagation of Sound In The Sea

#### 3.2.1.1.Deep Sound Channel

Sound speed is minimum between the main thermocline and the deep isotermal layer, at the minimum point sound tends to be focused by refraction. The depth at which this channel, the source is placed close to the minimum which may be only a few hundred meters at high latitudes and, because the spreading is cylindrical, very long range propagation is possible. Best results are achieved when the receiver is close to the axis of the channel. Figure 3.2 shows a source placed at a depth close to the sound speed minimum and with a vertical beamwidth of about 20°. [2]

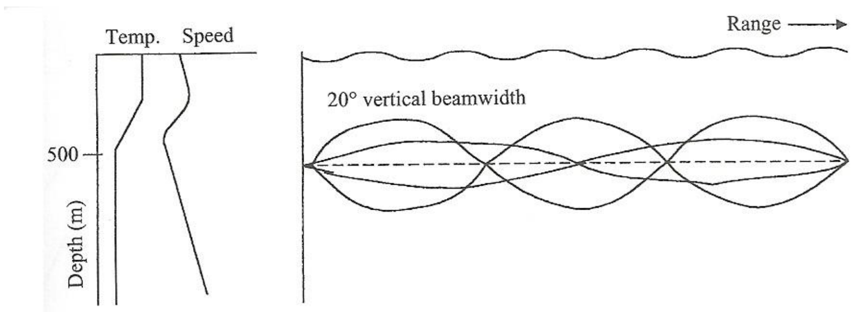



Figure 3.2. Deep Sound Channel Propagation

### 3.2.1.2.Reliable Acoustic Path

To improve detection of shallow targets, the source places at least 1000m deep in the sea (Targets at typical submarine diving depths) (Figure 2.3). The path is known as 'reliable' because it is insensitive to highly variable surface effects and bottom losses. Conditions for reliable acoustic path exist when the source is placed at a depth, where the sound speed is equal to the sound speed at the surface (Figure 3.4.). [2]

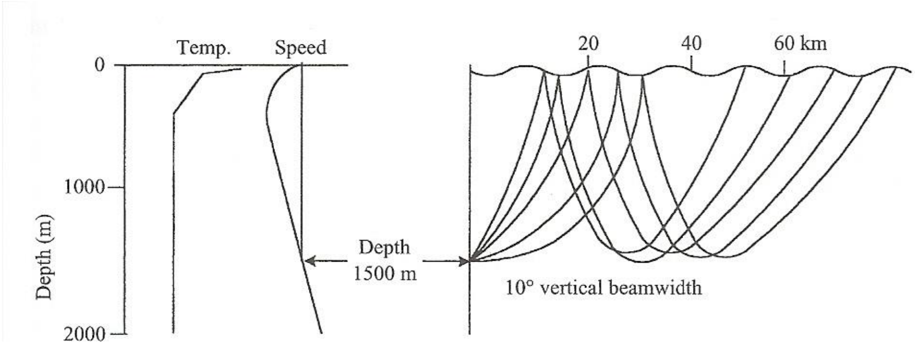



Figure 3.3. Deep Source : Reliable Acoustic Path

A capability to set the sonar beam vertically by 10° vertical beamwidth as well as a capability to deploy the sonar at variable depths will assist in reducing the shadow zones that would otherwise exist.

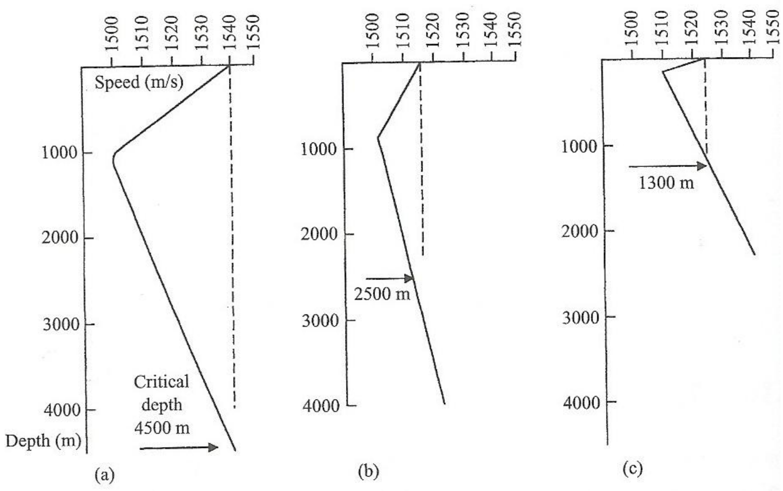



Figure 3.4. Critical Depths for Reliable Acoustic Path : (a) Tropical, Latitude 20° (b) Temperature, Latitude 50° (c) Mediterranean

### 3.2.1.3.Surface Duct Propagation

The depth of the surface duct as small as 5m and as great as 200m. The sound speed increases with pressure as a function of depth, in the same time temperature decreases with depth (Ducts of 50 – 100 m are common in the colder waters of the world). The sound speed begins to reduce until the minimum of the deep sound channel is reached.

Figure 3.5 shows the effect on sound transmitted from a source within the duct. Rays that are projected close to horizontal are refracted upwards and undergo multiple surface reflections. On the other hand, rays which penetrate the layer are refracted downwards at first, thus producing a zone, know as a shadow zone, where hardly any sound energy penetrates. Targets within the shadow zone, below the layer, are therefore difficult to detect. As with all propagation in the sea, no mode is perfectly described by a simplified ray trace. The shadow zone is an area where the sound intensity is greatly reduced and the transition from the surface duct is not abrupt. [2]

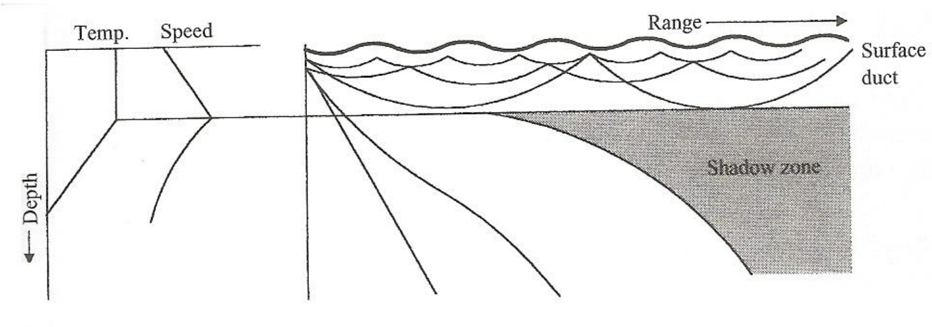



Figure 3.5. Surface Duct Propagation : Shallow Source

Increasing the depth of the source so that it is below the layer (Figure 3.6) has the effect of increasing the range of the start of the shadow zone, but it may then extend into the duct. As with deep source channel and reliable acoustic path modes, the ability to manoeuvre in depth, a variable depth sonar deployed from a moving surface ship or a hovering helicopter, offers significant operational advantages.

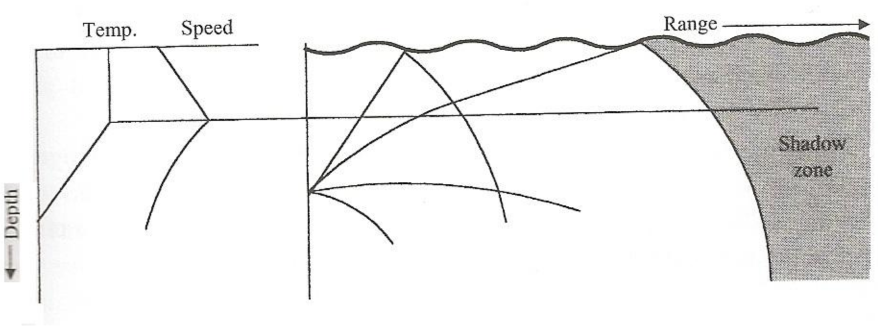



Figure 3.6. Surface Duct Propagation : Deeper Source

### 3.2.1.4.Convergence Zone Propagation

Rays projected at steeper angels of depression are bent downwards at first, producing a shadow zone. At greater depths the pressure bends these rays upwards to form annuli of high intensity (Figure 3.7); each annulus is known as a convergence zone. The temperature increases with depth and the sound speed increases with respect to pressure and temperature. On the other hand, the temperature have a constant value below about 100 m, but at the same time the pressure has increasing, therefore the sound speed begins to increas after 1000 m. The water must be deep enough for upwards refraction to prevent the rays from hitting the bottom. Typically the water depth must be in excess of 3000 metres. Depending on the bottom depth, the first convergence zone will occur at around 30 – 50 km and will be 3- 5 km wide. [2]

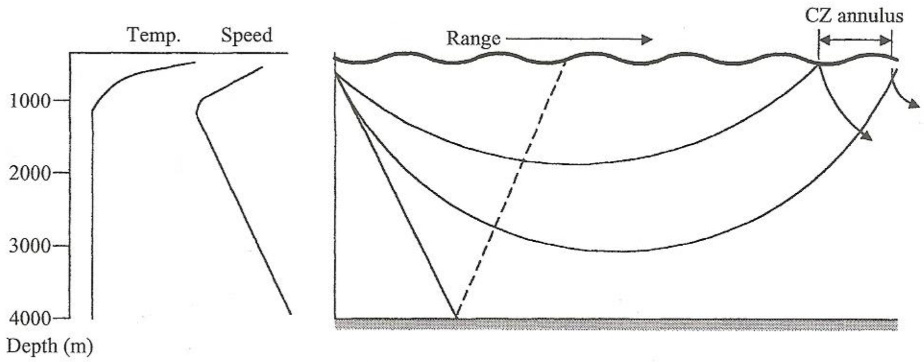



Figure 3.7. Convergence Zone Propagation

Active systems can make detections at the range of first convergence zone, but the second or third convergence zone for passive system.

### 3.2.1.5.Bottom Bounce Propagantion

Propagation is possible by using bottom reflections (Figure 3.8). The effectiveness of the mode is determined by the nature of the bottom,whether it is absorptive or reflective, and how the bottom loss varies with angle of incidence. As with convergence zones, there exist a range annulus, which varies with depresion angle of the sonar beam, and at small angles of incidence this annulus can be very wide. No focusing gain exists and the bottom reflection loss is typically between 10 and 20 dB. Therefore the mode is very demanding in projector power and array size because of the lower frequencies necessary to limit absorption over the long range paths. [2]

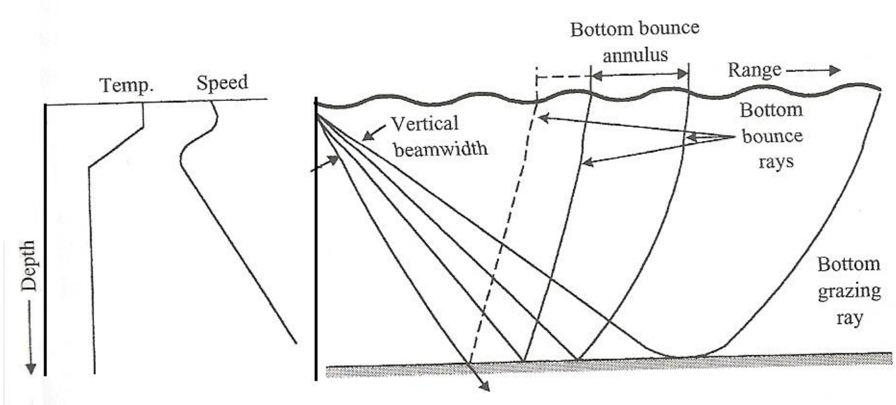



Figure 3.8. Bottom Bounce Propagation

Successive range annuli exist at multiples of the first annulus. The propagation losses ( two-way ) will prohibit the use of any but the first for active system,but passive system can make detections at the range of the second annulus. The range annuli for bottom bounce mode are significantly wider than for the focused convergence zone mode. There must always be a shadow zone out to some minimum range, at least 10 km, dependent on depth and the allowable angle of depression of the sonar beam.

# CHAPTER 4

# Overview of MEMS

## 4.1. Microsystem Design

The design for microsystems requires the integration of the related manufacturing and fabrication processes (Figure 4.1) is a major difference between mechanical engineering design of microsystems and other products. For example, components such as gears, bearings, and fasteners in a mechanical system can be purchased from suppliers without the knowledge of how these components are produced. In microsystems, which involve MEMS components, however, the situation is quite different.

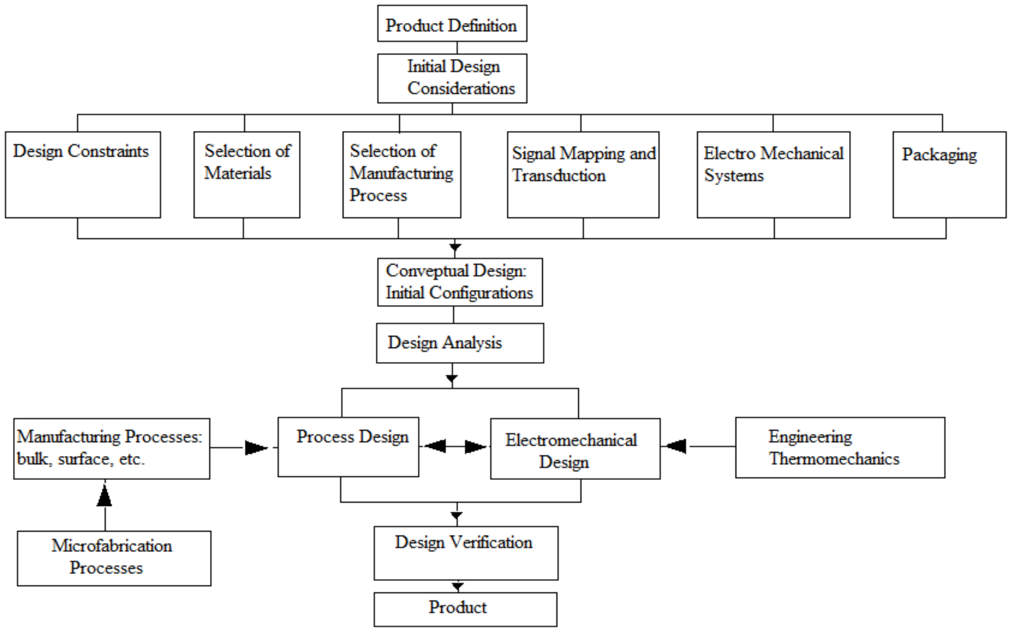



Figure 4.1. Mechanical Design of Microsystems

### 4.2.Micro Electromechanical Systems (MEMS)

Micro electromechanical systems (MEMS) are small integrated devices or systems that combine electrical and mechanical components. A MEMS contains components of sizes in 1 micrometer to 1 milimeter. MEMS extend the fabrication techniques developed for the integrated circuit industry to add mechanical elements such as beams, gears, diaphragms, and springs to devices. [3]

MEMS device applications include inkjet-printer cartridges, accelerometers, miniature robots, microengines, internal sensors, microtransmissions, optical scanners, fluid pumps, transducers, and chemical, pressure and flow sensors...

Construction of integrated electromechanical systems and fabrication of MEMS with miniaturixation, multiple components, microlectronics are the adventages of the micro electromechanical systems. MEMS are also a new method for designing mechanical devices and systems. [3]

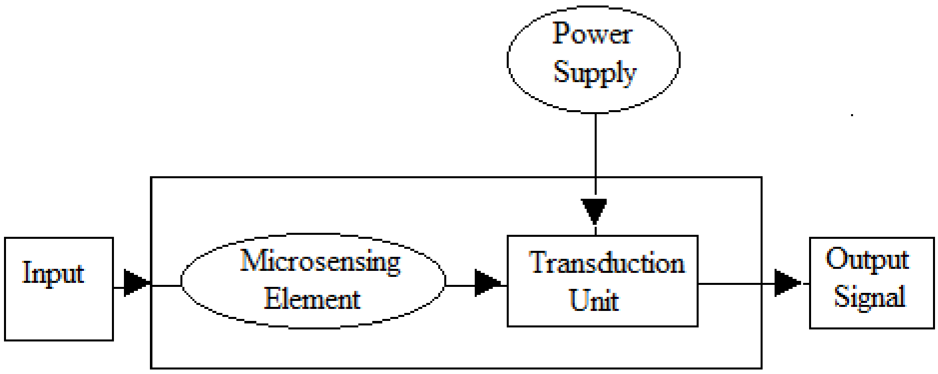



Figure 4.2. MEMS as a microsensor

A sensor is a device that converts one form of energy into another and provides the user with a usable energy output in response to a specific measurable input. A smart sensor unit would include automatic calibration, interference signal reduction, compensation for parasitic effects, offset correction, and self – test. In this thesis, pressure and temperature MEMS sensors are planed to use in the electronic part. Therefore I want to present properties of pressure and thermal sensors.

#### 4.2.1. Pressure Sensors

The first microsensor was the silicon (Si) pressure sensor. In 1954 is was discovered that the piezoresistive effect in germenyum (Ge) and silicon (Si) had the potential to produce Ge and Si strain gauges with a gauge factor 10 to 20 times greater than those based on metal films. As a result, Si strain gauges began to be developed commercially in 1958. The first high volume pressure sensor was marketed by National Semiconductor in 1974. The sensor included a temperature controller for constant temperature operation. Improvements in this technology since then have included the utilization of ion implamentation for improved control of the piezoresistor fabrication.

There are generally two types of pressure sensor: absolute and gage pressure sensors. The absolute pressure sensor has an evacuated cavity on one side of the diaphragm. The measured pressure is the absolute value with vacuum as the reference pressure. In the gage pressure type, no evacuation is necessary. There are two different ways to apply pressure to the diaphragm. With back side pressurization, as illustrated in Figure 12.a , there is no interference with signal transducer, such as a piezoresistor, that is normally implanted at the top surface of the diaphragm. The other way of pressurization front – side pressurization, Figure 4.3 (b) , is used only under very special circumstances because of the interference of the pressurizing medium with the signal transducer. Signal transducers are rarely placed on the back surface of the diaphragm because of space limitation as well as awkward access for interconnects. [4]

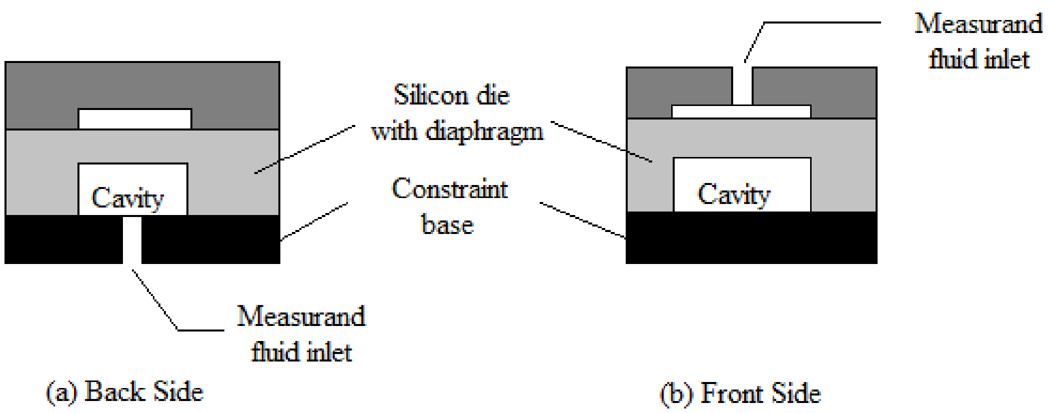



Figure 4.3. Pressure Sensor

### 4.2.2.Thermal Sensors

Thermocouples are the most common transducer used to sense heat. They operate on the principle of electromotive force, emf, produced at the open ends of two dissimilar metallic wires when the junction of the wires, called the head, is heated. Figure 4.4 (a), The temperature rise at the due to heating can be correlated to the magnitude of the produced emf, voltage. These wires and junction can be made very small in size. By introducing an additional junction in the thermocouple circuit, as shown in Figure 4.4 (b), and exposing that juction to a different temperature than the other, one would induce a temprature gradient in the circuit itself. This arrangement of thermocouples with both hot and cold junctions can produce the Seedbeck effect, discovered by T. J. Seedbeck in1821. The voltage generated by the thermocouple can be evaluated by

$$V = \beta . \Delta T \qquad (6)$$

$\beta$ is the thermoelectric power, Seedbeck coefficient

$\Delta T$ is the temperature difference between the hot and cold junctions

In practice, the cold junction temperature is maintained constant, at 0°C, by dipping that junction in ice water. The coefficient $\beta$ depends on the thermocouple wire materials and the range of temperature measurements [3, 5].

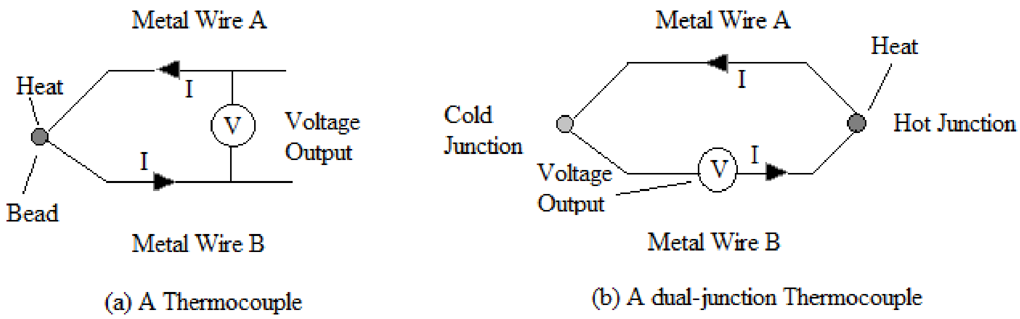



Figure 4.4. Thermocouple

# CHAPTER 5

## System Design

The system is deployed from the sea surface and measurements of temperature and function of depth. The measurement system (Figure 5.1) is divided into two main parts the Shipborn Section and Expendable Section. Data is transmitted to the sea surface with wire.

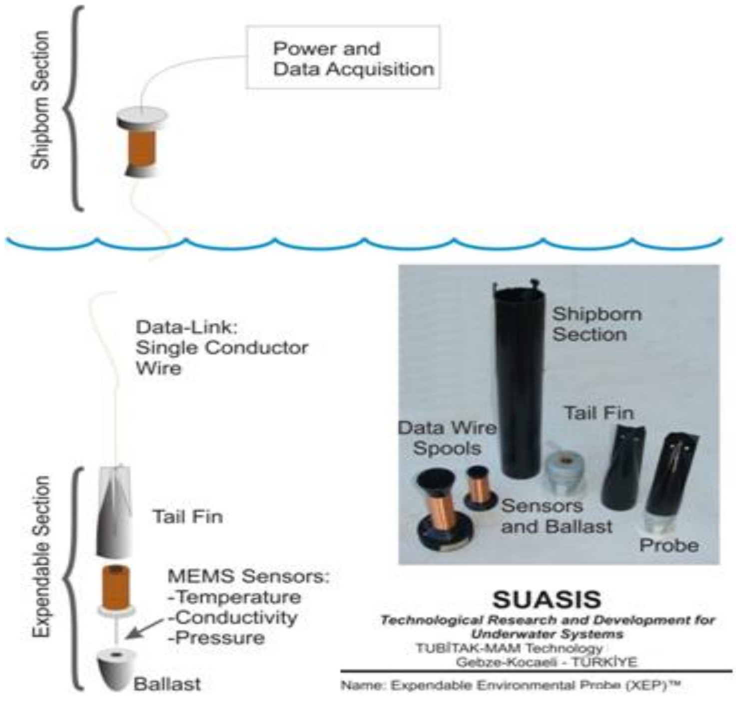



Figure 5.1. System Design

### 5.1.1.Expendable Section

Expendable section is under water part of the system. It is named probe which is included data wire spools, tail fin, sensors and ballast. Temperature and pressure sensor are in the ballast part that is made decomposed material. The circuit board is between the ballast and data wire pools. The data which is received from the sensors, transmitted to the surface by data wire.

### 5.1.2.Shipborn Section

Shipborn Section is comprised power and data acquisition system. The conducting wire is transferred the data from sensors to the shipborn section. This data is collected, stored, and displayed the data acquisition system.

## 5.2. Hardware Design

During this project, we wanted to transfer data using one wire conducting wire but the system could not work at long distance. Therefore I decided to use two wire interfaces transfer data with $I^2C$ communication module.

Hardware design (Figure 5.2) is divided into expendable and shipborn section. In expendable section , I used pressure sensor, temperature sensor and eZ430-f2013 that is a MSP 430 development tool providing to evaluate microcontroller and complete an entire code in USB stick. Back side of the development tool is a removable part. I programed the eZ430-f2013 to measure pressure and temperature and than removed the target board (back side). The USB port provides to operate the low power (about 3.3V) MSP430 so no external power supply is required. When the target board is removed, we should connect minimum 3 V to transfer the signal.

MSP430F2013 includes a 16-bit Sigma Delta Analog to Digital converter, 16-bit timer, Watchdog timer, brownout detector, a USI module supporting SPI and I2C.

In the shipborn section, I used the MSP430 LauchPad that is similar with eZ430F2013. Two of them have communication module which named I2C and they are programable and low powered system. I used I2C communication module to communicate each other to transfer data which are received pressure and temperature sensors. Finally temperature and pressure sensors values  shows in the LCD screen.

Hardware design and components are showed below the figure

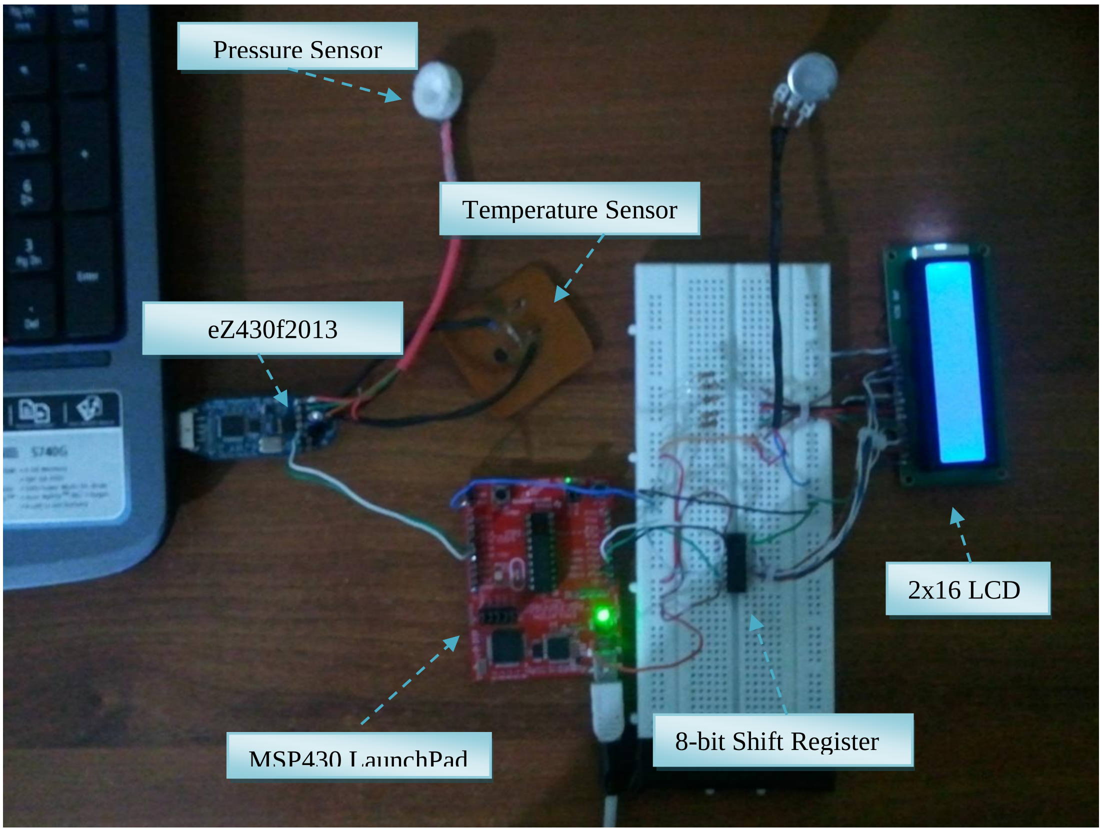



Figure 5.2. Hardware Design of the System

### 5.3. Software Design

The electronic parts of the system is included temprature sensor, pressure sensor, microcontroller and one wire device. Microcontroller unit is programed to receive data from the sensors and to transfer with $I^2C$ communication module.

In this system I used MSP430F2013 mixed signal microcontroller. The unit has built in communication capability using synchronous protocols (SPI and $I^2C$) and a 16-bit Sigma-Delta analog to digital converter.

The one wire device is DS2482 one wire master. The DS2482 is an $I^2C$ to 1-Wire bridge device that interfaces directly to standard, 100kHz max, or fast , 400kHz max, $I^2C$ masters to perform bidirectional protocol conversion between the $I^2C$ master and any downstream 1-Wire slave devices. In this project, microcontroller unit connected to the 1-Wire master device and they are communicated each other with $I^2C$ communication protocol.

### 5.3.1.Master – End Interface Devices

This section is important to design system by using the properties of the 1-wire master system in network between microcontroller and 1-wire device. The master-end hardware is a critical factor in determining the limitations of a 1-Wire network design. Sophisticated drivers intended for very long lines can perform poorly when used with short and medium length networks. Simple hardware interfaces intended for short wires, therefore in this thesis 1-Wire networks could not perform well in the larger wiring system.

The master-end hardware interfaces in most common use today are listed below:

1. Microprocessor port-pin attachments
2. Microcontroller with built in 1-Wire master
3. Synthesizable 1-Wire bus master
4. Serial-interface protocol conversions

### 5.3.2.The 1-Wire Interface

A 1-Wire network consists of a master device and one or more slave devices. The 1-Wire master can be constructed with an I/O pin of a microprocessor and manually generated timing pulses.

In this system I used the DS2482 $I^2C$ 1-Wire Master. It is an $I^2C$ to 1-Wire bridge. The DS2482 allows any host with $I^2C$ commnication to generate properly timed and slew controlled 1-Wire waveforms.

In the 1-Wire communication, there are a few basic 1-Wire functions. The first function (OWReset) resets all the 1-Wire slaves on the network, readying them for a command from the 1-Wire master. The second function (OWWriteBit) writes a bit from the 1-Wire master to the slaves, and the third function (OWRreadBit) reads a bit from the 1-Wire slaves. [7, 8]

### 5.3.2.1-Wire Communication

1-Wire is a device communications bus system designed by Dallas Semiconductor Corp. That provides low-speed data, signalling, and power over a single signal. 1-Wire is similar in concept to $I^2C$, but with lower data rates and longer range.

In the 1-Wire bus, the master and devices comminicate each other by a single line. Both power and data communications take place over this single line (Figure 5.3). The 1-Wire products provide combinations of memory, mixed signal, and secure authentication functions trough a single contact serial interface. Typical applications of 1-Wire devices are identification of print cartridges or medical consumables; calibration and control of rack cards; identification and authentication of printed circuit boards, accessories, and peripherals; and protection of intellectual property, clone prevention, and secure feature control.

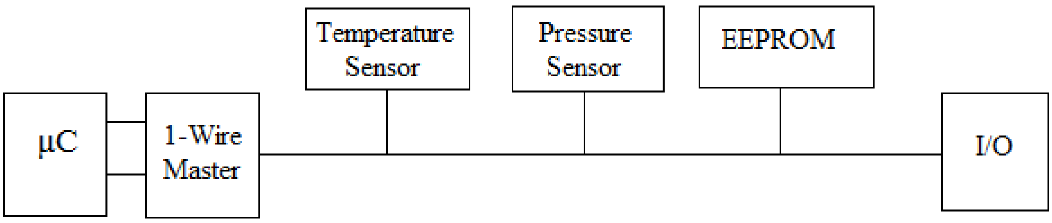



Figure 5.3. 1-Wire Commucation

### 5.3.3. I2C (Inter-Integrated Circuit)

In this thesis, I want to used $I^2C$ port of the microcontroller to communicate with 1-wire master device (Figure 5.4) at voltage 3.3 V. Philips Semicondustors developed the $I^2C$ bus 1990s and that is used to attach low speed peripherals to a motherboard, embedded system, cellphone, or other electronic devices. $I^2C$ communicates in half-duplex mode over one Serial Data lines (SDA) and one Serial Clock line (SCL), pulled up with resistors. The $I^2C$ standard defines a simple master slave bidirectional interface.

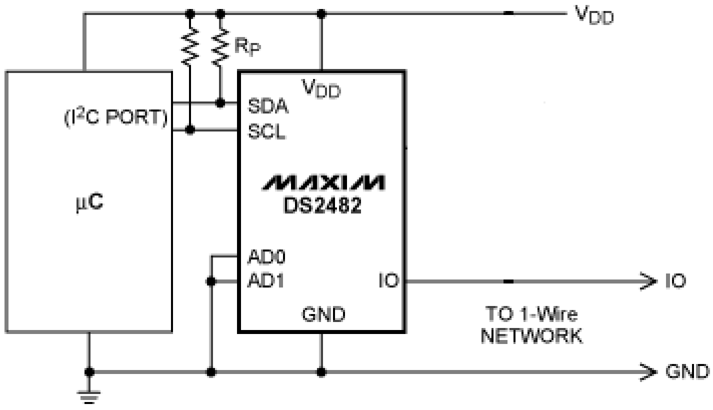



Figure 5.4. Microcontroller with 1-Wire Master

### 5.3.3.1. Clock Stretching Using SCL

Clock stretching is one of the more significant features of the $I^2C$ protocol. An addressed slave device may hold the serial clock line (SCL) low after receiving or sending a byte, indicating that is not yet ready to process more data. The master that is communicating with the slave may not finish the transmission of the current bit, but must wait until the clock line acctually goes high. If the slave is clock streching, the clock line will still be low because the connections are open drain. The same is true if a second, slower, master tries to drive the clock at the same time.

The master must wait until it observes the clock line going high, and an additional minimum time ,4µs for standard 100 kbit/s $I^2C$, before pulling the clock low again.

Although the master may also hold the SCL line low for as long as it desires, the term " clock stretching" is normally used only when slaves do it. In this thesis project the microcontroller is as an the slave device, so its $I^2C$ interface will stretch the clock after each byte, until the software decides whether to send a positive acknowledgement or a NACK. [9]

#### 5.3.3.2. Arbitration Using SDA

Every master monitors the bus for start and stop bits, and does not start a message while another master is keeping the bus busy. However, two masters may start transmission at about the same time; in this case, arbitration occurs. Slave transmit mode can be arbitrated, when a master addresses multiple slaves, but this is less common. In contrast to protocols such as Ethernet that use random back-off delays before is using a retry, $I^2C$ has a deterministic arbitration policy. Each transmitter checks the level of the serial data line (SDA) and compares it with the levels it expects; if they don't match, that transmitter has lost arbitration, and drops out of this protocol interaction.

If one transmitter sets SDA to 1 (not driving a signal) and a second transmitter sets it to 0 (pull to ground), the result is that the line is low. The first transmitter then observes that the level of the line is different than expected, and concludes that another node is transmitting. The first node to notice such a difference is the one that losses arbitration: it stops driving SDA. If it's a master, it also stops driving SCL and waits for a STOP; then it may try to reissue its entire message. In the meantime, the other node has not noticed any difference between the expected and actual levels on SDA, and therefore continues transmission. It can do so without problems because so far the signal has been exactly as it expected; no other transmitter has disturbed its message.

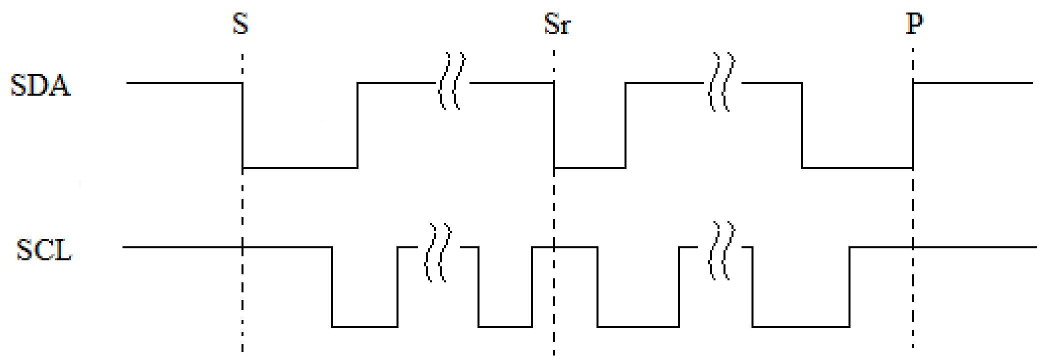
If the two masters are sending a message to two different slaves, the one sending the lower slave address always "wins" arbitration in the address stage. Since the two masters may send messages to the same slave address arbitration must continue into the data stages.

Arbitration occurs very rarely, but is necessary for proper multi-master support. As with clock stretching, not all devices support arbitration. Those that do generally label themselves as supporting multi master communication.

In the extremely rare case that two masters simultaneously send identical messages then both will regard the communication as successful, but the slave will only see one message. Slaves that can be accessed by multiple masters must have commands that are idempotent for this reason. [9]

### 5.3.4. I2C Communication

$I^2C$ communications begin with a start command, which occurs when serial data line (SDA) transitions high to low with serial clock line (SCL) high (Figure 5.5.a). One data bit transfers during each SCL clock cycle. The write cycle includes eigth data bits followed by an acknowledge (ACK) or not acknowledge (NACK) signal (Figure 5.5.b). When data is transferred over the $I^2C$ bus, it is latched into the slave on SCL's rising edge and read out of the slave on SCL's falling edge. The data on SDA must remain stable during the high period of the SCL clock pulse. A transmission is complete following a stop or repeated start command, at which point SDA transitions low to high with SCL high. Both SDA and SCL remain high when the bus is not busy. [10]




S : Start
Sr : Repeated Start
P : Stop

Figure 5.5. The 2-wire interface: Start and stop conditions to transfer data between the master and slave. [9]

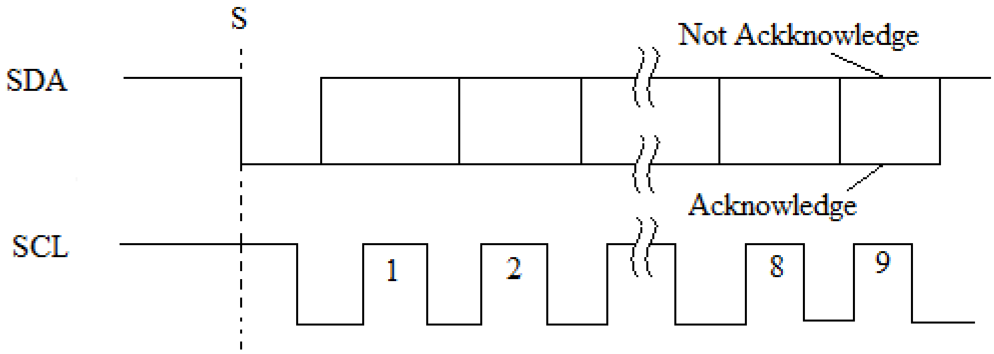
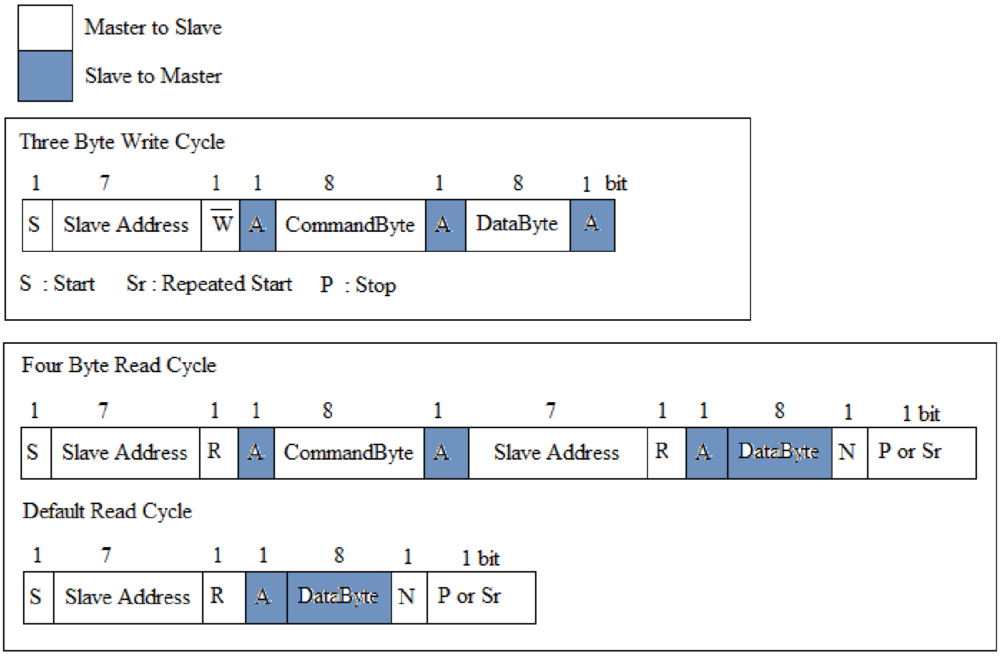



Figure 5.6. I$^2$C acknowledge bits. The 2-wire interface pulls the SDA line low data is acknowledged.[9]

An I$^2$C write cycle begins with a start command, followed by writing the 7- bit slave address and an eight bit that signals a write or read command. Set the eight bit low for a write command or high for a read command. The master releases the bus line after the eighth clock cycle. The slave holds the SDA line low on the ninth clock cycle, if the slave acknowledges a proper transmission. The slave releases the SDA line if the slave does not acknowledge a proper write command (Figure 5.6).

The master then writes an 8 – bit data byte, which is followed by a third ACK/NACK bit. The data byte (s) final acknowledge bit completes the read/write cycle, and the peripheral's outputs are updated. Figure 5.7.a illustrates an example of a write cycle.

An I$^2$C read cycle begins with a start command, followed by writing the slave address with the eight bit pulled high to signal a read command. Following an ACK/NACK bit, the master rewrites the slave address. Then following the third ACK/NACK bit, the slave takes control of the bus and writes out eight data bits at a time. See Figure 5.7.b. When reading from the same slave register as the previous reads, the master needs only write a slave's address before reading the data from that slave.




(a)

(b)

Figure 5.7. The two-wire interface transfers data eight bits at a time. Figure 5.7.a. is an $I^2C$ write-cycle example. Figure 5.7.b. shows $I^2C$ read-cycle examples.

# CHAPTER 6

## Related Works

In this section I briefly present some of the research literature related to measurement of sea water parameters.

The Expendable Bathythermograph (XBT) is one of the earliest system. This system is used by oceanographers and navies to obtain information an ocean temperature versus depth profile of up to 1500 meters. The XBT is a probe which is dropped from a ship and measures the temperature as it falls through the water. Two very small wires transmit the temperature data to the ship where it is recorded for later analysis. The probe is designed to fall at a known rate, so that the depth of the probe can be inferred from the time since it was launched. The XBT probe is produced by Tsurumi Seiki Co. and Lockheed Martin Sippican companies. [12, 13]

Other technology is called Expendable Conductivity, Temperature, Depth probe (XCTD). This is a device for obtaining a record of conductivity and temperature as a function of depth (reaching over 1000 meters) from a moving ship. Temperature and conductivity data from probe sensors are transmitted to the surface by wire. Depth is calculated from drop rate of the probe. This data, in digital form, is collected, stored, and displayed by the XTCD data acquisition system. The XCTD probe is produced by Tsurumi Seiki Co. and Lockheed Martin Sippican companies. [12, 14]

The manufacturer's (Lockheed Martin Sippician) specification for all XBT types [11] is given as:
Temperature range: -2 °C to +35 °C
Temperature resolution: 0.01 °C
Temperature accuracy: +/- 0.15 °C over full range

Temperature drift per year:

Sampling rate: 10 Hz

Depth range: Probe type dependent

Depth resolution: 65 cm except T-11 (fine structure probe)

Descent rate: Probe type dependent

Depth formula: $a . t – b . t^2$ (coefficients probe type dependent)

Depth accuracy: +/- 2 % or 5 m whichever is greater

Sea state: SS 5 maximum

Rated vessel speed: Probe type dependent

Thermal response: - In 1 m depth 63 % of a step change in temperature

- In 3 m depth 95 % of a step change in temperature

Launch height: 1 m minimum, 15 m maximum

Shelf life: 5 years

Stowage temperature range: - 60 °C to + 70 °C

Operating temp. range: 0 °C to + 50 °C

The specification for the XTCD is given by the manufacturer Tsurumi Seiki Corporation [11] as:

Temperature range: -2 °C to +35 °C

Temperature resolution: 0.01 °C

Temperature accuracy: +/- 0.02 °C over full range

Temp. sensor drift:

Conductivity range: 20 mS/cm to 74 mS/cm

Conductivity resolution: 0.017 mS/cm

Conductivity accuracy: +/- 0.03 mS/cm

Cond. sensor drift:

Sampling rate: 25 Hz

Depth range: 1000 m

Depth resolution: 17 cm

Descent rate: 3.4 m/sec

Depth formula: $a . t – b . t^2$ (a = 3.42543, b = - 4.7026 E-4) (7)

Depth accuracy: +/- 2 % or 5 m whichever is greater

Rated vessel speed: 12 knots

Life of built-in battery: 20 minutes after ready to measure

In this thesis the specification of the Expendable Enviromental Probe is desirabled:

Temperature Range: 10 to 30 °C

Temperature Accuracy: +/- 0.1°C

Depth (Pressure) Range: 0-100 m

Depth (Pressure) Accuracy: 0.3 m

Data / Power transmission: Via single wire to / from a vessel

The other and the last system which has similar properties with expendable environmental probe is the Expendable Bottom Penetrometer (XBP). It is designed by Tuncay Akal and Stoll in between 1995-1996. The system can be launched from a moving ship, aircraft, or submarine using techniques similar to those for Expendabe Bathythermographs (XBT) and Expendable Conductivity, Temerature, Depth (XCTD) .

The XBP contains a sensitive accelerometer that measures the time history of deceleration as it impacts and penetrates the sea floor. This information is integrated to obtain force exerted on the probe by the sediment as a function of depth of penetration. [15]

# Conclusion

The measurement system provides the environmental impact assessment of temperature as a function of depth. Quality of data and cost efficiency are very important for oceanographic research. Nowadays measurement technology is rapidly growing by more sensitive and cost effective components.

The similar systems have been manufacturing by the only two companies and they are comprised the whole market in the world. The Expendable Bathythermograph (XBT) is one of the earliest system. This system is used by oceanographers and navies to obtain information an ocean temperature versus depth profile of up to 1500 meters. The XBT probe is produced by Tsurumi Seiki Co. and Lockheed Martin Sippican companies. Other technology is called Expendable Conductivity, Temperature, Depth probe (XCTD). This is a device for obtaining a record of conductivity and temperature as a function of depth (reaching over 1000 meters) from a moving ship. The XCTD probe is produced by Tsurumi Seiki Co. and Lockheed Martin Sippican companies. The Expendable Bottom Penetrometer (XBP) (design by Akal and Stoll,1995, 1996) contains a sensitive accelerometer that measures the time history of deceleration as it impacts and penetrates the sea floor. If the Expendable Enviroment Probe is satisfied or improved, it could be produced by our country and enter the world market in the future.

In this thesis I learned new programs and system design techniques which are Altium Designer, Code Compoder Studio, IAR Embedded Workbench, One Wire communication system, MEMS technology, Programming of Microcontroller MSP430 series.

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[15] Akal, T., *Developing Rapid Enviromental Assessment at NURC*, Oceanography, Vol.21, No:2

# Appendix: Code

**Measurement of Pressure and Temperature Code:**

```
\\ IAR Embedded Workbench 6.0
#include <io430x20x3.h>                    // Header file for MSP430F2013
#include <intrinsics.h>                             // Intrinsic Functions
#include <stdint.h>                                       // Standart Integer Types
#include <math.h>
float temperature, pressure, offset, sens_offset;
int sens;
float vfsr = 0.0000091554;     // Full scale ınput  = (Vref / 2) / GAIN) = 0.6V
                                                   //and Vfsr / 2^16 = Step Voltage
void main (void)
{
  int i = 0;
  WDTCTL = WDTPW | WDTHOLD;              // WDT Passive
  BCSCTL3 = LFXT1S_2;       // Select ACLK From VLO (no crystal)
  BCSCTL1 = CALBC1_1MHZ;          // Calibrated range for DCO
  DCOCTL = CALDCO_1MHZ;   // Calibrated tap and Modulation
  FCTL2 = FWKEY + FSSEL_0 + FN1;          // MCLK/3 for flash timing generator
  do
  {
    P1DIR = 0X01;
    P1OUT = 0X01;
    __delay_cycles(100000);
```

```
  P1DIR = 0X01;
  P1OUT = 0X00;
  __delay_cycles(100000);
  i++;
 }while(i != 4);
 SD16CTL = SD16XDIV_0 | SD16DIV_0 | SD16SSEL_1 | SD16REFON;
// SD16A configuration: clock from SMCLK, no division, internal referance on
 SD16CCTL0 = SD16OSR_1024 | SD16UNI | SD16SNGL | SD16IE;
// OSR = 1024, Unipolar, single convs, interrupts
 SD16INCTL0 = SD16GAIN_1 | SD16INCH_7 | SD16INTDLY_0;
 SD16CCTL0_bit.SD16SC = 1;
 __low_power_mode_0();
 offset = (uint16_t)SD16MEM0;
 SD16CCTL0_bit.SD16SC = 0;
 for(;;)
 {
  if(sens == 0)
  {
  SD16INCTL0 = SD16GAIN_1 | SD16INCH_1 | SD16INTDLY_0;
  // PGA GAIN = 1, external input CH = 1, interrupt after 4th result
   SD16AE = SD16AE2 | SD16AE3;       //Analog input available
   SD16CCTL0_bit.SD16SC = 1;
   __low_power_mode_0();
    sens = 1;
```

**I2C Communication Code**

**Master Code:**

```
#include "io430.h"
#include "in430.h"
char* dizi = "TEST TEMPPRESSURE";
int I2C_State;
void main(void)
{
  volatile unsigned int i;
  WDTCTL = WDTPW + WDTHOLD;  //WDT Passive
  if (CALBC1_1MHZ ==0xFF || CALDCO_1MHZ == 0xFF)
  {
    while(1);
  }
  BCSCTL1 = CALBC1_1MHZ;  // Calibrated range for DCO
  DCOCTL = CALDCO_1MHZ;  // Calibrated tap and Modulation
  P1OUT = 0xC0;
  P1REN |= 0xC0;
  P1DIR = 0xFF;
  P2OUT = 0;
  P2DIR = 0xFF;
  USICTL0 = USIPE6+USIPE7+USIMST+USISWRST;
  USICTL1 = USII2C+USIIE;
  USICKCTL = USIDIV_3+USISSEL_2+USICKPL;
  USICNT |= USIIFGCC;
  USICTL0 &= ~USISWRST;
  USICTL1 &= ~USIIFG;
  _EINT();
  while(*dizi!='\0') // repeat until the end of array
```

```
  {
    USICTL1 |= USIIFG;
    LPM0;
    _NOP();
    for (i = 0; i < 10000; i++);
  }
}
// USI interrupt service routine
#pragma vector = USI_VECTOR
__interrupt void USI_TXRX (void)
{
  switch(I2C_State)
  {
  case 0: // Generate Start Condition & send address to slave
    P1OUT |= 0x01;
    USISRL = 0x00;
    USICTL0 |= USIGE+USIOE;
    USICTL0 &= ~USIGE;
    USISRL = SLV_Addr;
    USICNT = (USICNT & 0xE0) + 0x08;
    I2C_State = 2;
    break;
  case 2: // Receive Address Ack/Nack bit
    USICTL0 &= ~USIOE;
    USICNT |= 0x01;
    I2C_State = 4;
    break;
  case 4: // Process Address Ack/Nack & handle data TX
    USICTL0 |= USIOE;
```

```
  if (USISRL & 0x01)
  {
    // Send stop
    USISRL = 0x00;
    USICNT |= 0x01;
    I2C_State = 10;
    P1OUT |= 0x01;
  }
  else
  {
    // Ack received, TX data to slave
    USISRL = *dizi;
    USICNT |= 0x08;
    I2C_State = 6;
    P1OUT &= ~0x01;
  }
  break;
case 6: // Receive Data Ack/Nack bit
  USICTL0 &= ~USIOE;
  USICNT |= 0x01;
  I2C_State = 8;
  break;
case 8: // Process Data Ack/Nack & send Stop
  USICTL0 |= USIOE;
  if (USISRL & 0x01)
    P1OUT |= 0x01;
  else
  {
    dizi++;
```

```
      P1OUT &= ~0x01;
    }
    // Send stop
    USISRL = 0x00;
    USICNT |= 0x01;
    I2C_State = 10;
    break;
  case 10:// Generate Stop Condition
    USISRL = 0x0FF;
    USICTL0 |= USIGE;
    USICTL0 &= ~(USIGE+USIOE);
    I2C_State = 0;
    LPM0_EXIT;
    break;
  }
  USICTL1 &= ~USIIFG; // Clear pending flag
}
```

**Slave Code:**

```
#include "io430.h"
#include "in430.h"
#include "lcd_595.h"
char SLV_Addr = 0x90;
int I2C_State = 0;
void main(void)
{
  WDTCTL = WDTPW + WDTHOLD;
  if (CALBC1_1MHZ ==0xFF || CALDCO_1MHZ == 0xFF)
  {
```

```
    while(1);
  }
  BCSCTL1 = CALBC1_1MHZ;
  DCOCTL = CALDCO_1MHZ;
  P1OUT = BIT7 + BIT6;
  P1REN |= 0xC0;
  P1DIR = 0xFF;
  P2OUT = 0;
  P2DIR = 0xFF;
  USICTL0 = USIPE6+USIPE7+USISWRST;
  USICTL1 = USII2C+USIIE+USISTTIE;
  USICKCTL = USICKPL;
  USICNT |= USIIFGCC;
  USICTL0 &= ~USISWRST;
  USICTL1 &= ~USIIFG;
  _EINT();
  lcd_init();
  lcd_goto(1,1);
  lcd_puts("Temperature:");
  lcd_goto(2,3);
  lcd_puts("Pressure:");
  while(1)
  {
    LPM0;
    _NOP();
  }
}
// USI interrupt service routine
#pragma vector = USI_VECTOR
```

```
__interrupt void USI_TXRX (void)
{
  if (USICTL1 & USISTTIFG)
  {
    P1OUT |= 0x01;
    I2C_State = 2;
  }
  switch(I2C_State)
  {
  case 0: // Idle, should not get here
    break;
  case 2: // RX Address
    USICNT = (USICNT & 0xE0) + 0x08;
    USICTL1 &= ~USISTTIFG;
    I2C_State = 4;
    break;
  case 4: // Process Address and send (N)Ack
    if (USISRL & 0x01)
      SLV_Addr++;
    USICTL0 |= USIOE;
    if (USISRL == SLV_Addr)
    {
      USISRL = 0x00;
      P1OUT &= ~0x01;
      I2C_State = 8;
    }
    else
    {
      USISRL = 0xFF;
```

```
      P1OUT |= 0x01;
      I2C_State = 6;
    }
    USICNT |= 0x01;
    break;
  case 6: // Prep for Start condition
    USICTL0 &= ~USIOE;
    SLV_Addr = 0x90;
    I2C_State = 0;
    break;
  case 8: // Receive data byte
    USICTL0 &= ~USIOE;
    USICNT |= 0x08;
    I2C_State = 10;
    break;
  case 10:// Check Data & TX (N)Ack
    USICTL0 |= USIOE;
    lcd_putch(USISRL);
    USISRL = 0x00;
    P1OUT &= ~0x01;
    USICNT |= 0x01;
    I2C_State = 6;
    break;
  }
  USICTL1 &= ~USIIFG; // Clear pending flags
}
```

**LCD Code:**

```
#include "io430.h"
#include "lcd_595.h"
```

```
#define E_1 0x08
#define RS_E_1 0x0C
void delay(unsigned long int d)
{
  d*=100;
  for(;d>0;d--);
}
void hc595_write(unsigned char gelen)
{
  for(char i=8;i>0;i--)
  {
    Data=0;
    if(gelen & 0x80)
      Data=1;
    Clock=1;
    Clock=0;
    come*=2;
  }
  Storage=1;
  Storage=0;
}
void lcd_write(unsigned char port)
{
  //sending first 4 bits
  hc595_write(E_1);
  hc595_write(( port & 0xF0) | E_1);
  hc595_write(((port & 0xF0) | E_1) & 0xF0);
  //sending last 4 bits
  hc595_write(E_1);
```

```
  hc595_write(( port<<4 ) | E_1);
  hc595_write(((port<<4 ) | E_1) & 0xF0);
}
void lcd_putch(unsigned char port)
{
  //sending first 4 bits
  hc595_write(RS_E_1);
  hc595_write(( port & 0xF0 ) | RS_E_1);
  hc595_write(((port & 0xF0 ) | RS_E_1) & 0xF4);
  //Sending last 4 bits
  hc595_write(RS_E_1);
  hc595_write(( port<<4) | RS_E_1);
  hc595_write(((port<<4) | RS_E_1) & 0xF4);
}
void lcd_puts(const char * s)
{
  nop();
  while(*s)
    lcd_putch(*s++);
}
void lcd_clear(void)
{
  lcd_write(0x1);
  delay(2);
}
void lcd_goto(char x, char y)
{
  if(x==1)
    lcd_write(0x80+((y-1)%16));
```

```
  else
    lcd_write(0xC0+((y-1)%16));
}
void lcd_init(void)
{
  hc595_write(0x00);
  delay(15);
  hc595_write(0x08);
  lcd_write(0x02);
  delay(2);
  lcd_write(0x28);    // 4 Bit
  lcd_write(0x0C);    // Hide
  lcd_clear();     // Clear screen
  lcd_write(0x06);    // write to rigth
  lcd_write(0x80);    // LCD First Row
}
```

# Curriculum Vitae

Funda Acar was born on 20 August 1981, in Arhavi. She received her BS degree in Electronic Engineering in 2008. Since 2010 she has been a research and development engineer at a private company.