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Water Quality Measuring Station

pH, Turbidity and temperature measurement

Helsinki Metropolia University of Applied Sciences

Bachelors Degree

Degree Programme in Electronics

Thesis

24.5.2017

Author Title	Bishal Sigdel Water Quality Measuring Station
Number of Pages	28 pages + 3 appendices
Date	24 May 2017
Degree	Bachelor of Engineering
Degree Programme	Electronics
Specialisation option	
Instructor(s)	Matti Fischer, Principal lecturer, Metropolia UAS
<p>This project is carried out for the measurement of quality of water for the Metropolia UAS using sensors and microcontroller. Water is indispensable for the living beings, and clean water is critical because of the modern world pollutions into the water in different forms. This project focuses on how we can measure and analyse the quality of water.</p> <p>This project focuses on measuring pH, Turbidity and Temperature of water. These three factors are considered because pH determines either the water be acidic or basic, Turbidity helps to determine the amount of solid particle, whereas these values may slightly differ with the change in temperature.</p> <p>The need for maintaining the quality of water is essential since the water is used or consumed by living beings in many different ways. Whether it is for a human being or aquatic plants or fishes, the properly maintained water is crucial for the proper sustainability. The measurement was first carried out by taking each sensor separately. After the completions of analysing sensors result, the circuit was combined to work all sensors together in the same microcontroller. The data was presented in serial monitor and then to the LabVIEW. LabVIEW shows the graph of each voltage retrieved from the sensors. Finally, the value of all the sensors was presented clearly in the user interface made using LabVIEW.</p>	
Keywords	Sensor, Acidity, alkalinity, suspended particles, Turbidity, pH

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Appendix 1. Complete prototype in Breadboard of Water Quality Measuring Station

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WQMS	Water Quality Measuring Station
EEPROM	Electrically Erasable Programmable Read-only Memory
LED	Light Emitting Diode
UN	United Nations
TSS	Total Suspended Solids
BNC	Bayonet Neill-Concelman
PTS	Potential Trouble Source
GND	Ground
MCU	Micro-Controller Unit

1 Introduction

This thesis includes the information concerning the research and development of a simple and convenient water quality measuring device which was carried out for the Metropolia UAS. Furthermore, this document is considered beneficial for the development of water quality measuring devices for the measurement and analysis of water used for living things, for example, human beings, animals as well as marine fishes and plants. We consume water every day, so it is indispensable for us. Therefore, water should be checked now and then. Since water has a direct effect on life on earth; it has become crucial to check whether the water is in good condition to use.

Checking the quality of water requires much hard work. Most of the things that exist in the earth dissolve in water, and it is very hard to determine the amount of the material mixed in it. For determining the number of materials in water requires much hard work and is time-consuming. It has become necessary with the evolving technology a quick and efficient method determine the quality of water.

This project focuses on checking the pH value, turbidity and temperature, which can be verified on a daily basis. It includes the description of the needed sensors and its specifications. This project includes the schematic, layout of the whole project idea. Every sensors Logic and layout is presented in a clear and sophisticated method. The circuit design for the device is also presented and described. It has all the necessary materials for the project to be completed in an easy and straightforward way. Every step about how to make the device is fully described with some pictures in it. It is possible to make the device either from the starting phase, or you can select the parts and combine it. Therefore, it has two ways to make the device.

It is quite a new step in developing water quality measuring device, which will be helpful for the new researchers to go through the development of a new improved device for the quality check of water. This project focuses on the present requirement for the development of sanitation in water. There are many other factors which could be found in water, but these three factors like pH, turbidity and temperature are crucial to determine the quality. It helps to determine either water is basic or acidic as well as to determine the number of solid particles dissolved in water. As a whole, this project contributes to

determining the quality of water in a convenient and user-friendly method for measuring the pH, turbidity and temperature.

2 Water

Water is most indispensable for living life, and the quality of water is the essential part we should take care of all the time before consuming. Because of modern technology, water is polluted in a different form. As a result, it is necessary to be careful about the cleanliness of the water. Since, living things and beings health are mostly dependent on the water, which is why quality check of water in every process is becoming essential, and it should be taken care.

According to the world water quality statistics, about two millions of sewage waste from the agriculture, industry and homes are discharged to the water every day. This is same as the human population in the world. All aspects of life on Earth are permeated by Water. For sustaining living beings and plants, water is essential. To maintain ecosystems, water plays a vital role in the maintenance of human health, daily needs and for the well-being.

Water helps us to sustain and create job opportunities in various sectors like fisheries, agriculture, aquaculture and many others. For producing electricity, producing foods, production of fuels water plays a vital role. The electricity generated using fast flowing river is the noiseless and pollution less method. A cycle of continuous evaporation, precipitation and runoff are the natural resources which maintain the renewal of fresh water in the world.

Water is available everywhere on the Earth, and about 70 percent of the world's area is covered with water. Most of the living thing those exist in this world largely made of water. The human body consists about two-thirds of water.

The water is a liquid which is colourless, odourless and tasteless. The scientist who was an Italian, "Stanislao Cannizzarro" defined the chemical formula of the water molecule. Water molecular formula is H_2O . Water is also called Universal solvent because of its ability to react with most of the substances. Even though pure water is not conductive for

electricity, but the substances that mix up with the water makes it possible to conduct electricity. Water boils at 100 °C and freezes at 0 °C.

Water volume changes with the change in temperature. When the water cools, it starts to contract, and the maximum density it can contract is 1 gram per cubic centimetre at 4 degree Celsius. If we cool it further, it expands, at the freezing point, it expands most. Water has more volume when it is in liquid form, which explains why the ice cube floats in the water or other liquids. Even though the density property of water is of slight importance to the beverage example, it has considerable impact on the survival of aquatic life inhabiting a body of water. Waters density property has an essential importance for the survival of aquatic life.

3 Current Situation

Water quality is our goal, we have to consider different types of thing that pollute the water, and when we check the quality of water, there are the most important factors we can depend on to check it. Water quality measuring device is important in medicine, biology, agriculture, forestry, food science, environmental science, oceanography, Civil engineering, chemical engineering, nutrition, water treatment and water purification, and many other applications.

The pollution in water is increasing day by day, and many researchers and scientists are trying to solve the problem by checking and maintaining the quality of water. This project focuses mainly on the quality check of water. The aim of the project is to test the water quality artificially so that it will be possible to keep human life safe from the polluted water. Analysing the condition and checking whether the water is favourable for the living beings and plants is the main target.

There are different kinds of the available water quality measuring device on the market, ranging from cheap to expensive ones and house to industrial applications. Devices are very costly and hard to understand for the consumer and might be affordable but can not fulfil the needs of quality checking ineffective and fast ways.

3.1 Available Devices and ways

Top available Water quality testing devices available in the market according to the wonderfulengineering.com website are as follows [1]:

- HM Digital TDS-4 Pocket Size TDS Tester Meter
- Digital Aid Water Tester
- Etekcity Digital Handheld TDS Meter
- Dr.Meter TDS-3C Water Quality
- Sunny Water Tester
- Water quality Meter by generic
- Play X-STORE Water Quality Meter
- APEC Water Systems Digital Meter
- Started Filter Tester

The above-given water testers measure either turbidity or pH, but none of them measures the pH, turbidity as well as the temperature of the water. Some other water quality testers only measure the pH of water. If all the parameters are available in the device, then that device is not affordable for common people. Since it is not available on the market, this project includes all three required parameters for checking the quality of water in affordable cost. This project will compare the value of pH, Turbidity and temperature of the water and determines whether the water is suitable for the normal use.

Today's modern technology has led the world in very much further than slow and dumb devices. At one fingertip, many of the information is gathered easily with the help of new technology. This thesis also targets to get more than one information from one device in easy, fast and efficient ways. There are different better industrial applications for measuring pH, turbidity are available, but if compared the prices, it is very high. This project will be helpful to develop industrial applications in low prices as compared to the recently available in the market.

4 Water Quality Measuring Station

Water Quality Measuring Station is a device/Station designed to measure the quality of water by analysing the water pH, turbidity and temperature. Since water can contain many impurities which could result in dirtiness in the water as well as the acidity or alkalinity, WQMS determines the pH and turbidity as well as temperature. The simple flowchart of WQMS is shown in figure 1.

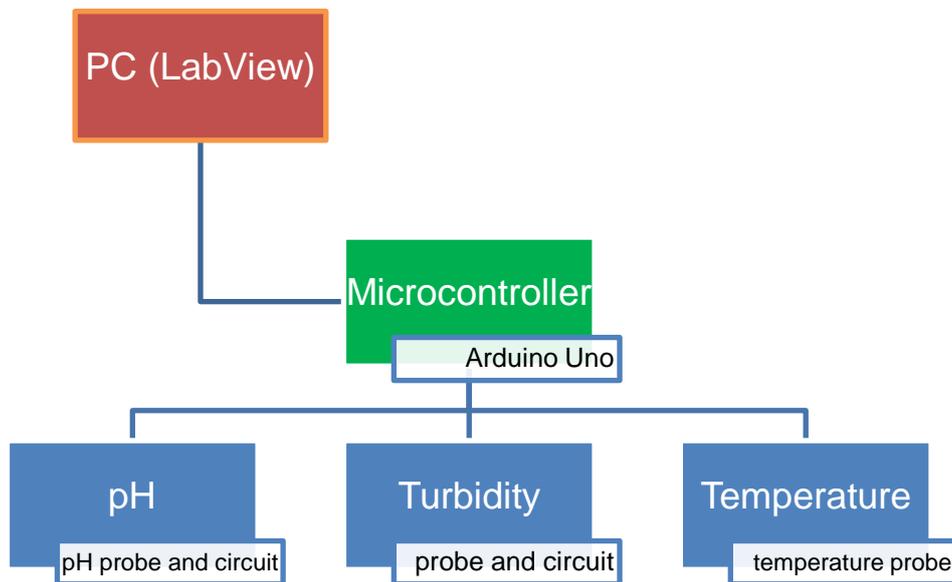


Figure 1: Water Quality Measuring Station

This station consists of three different sensors, Microcontroller and PC unit. Sensors help to derive data from the water and microcontroller processes the data and presented in the PC user interface using the LabVIEW software. LabVIEW is interfaced with the microcontroller and data are derived to the program and presented in a graphical as well as showing the specific real time values of the pH, turbidity and temperature.

4.1 pH sensor

pH sensor (SKU:SEN0161) is a sensor which detects pH of water. The term “pH” set off from Latin and is an acronym for “potentia hydrogenii” – the power of hydrogen. The measurement of PH has a broad variety of industrial applications. It concerns us how we

can check the quality of water using pH. First of all, pH is the hydrogen-ion concentration in water-based solutions, which indicates the acidity and alkalinity in the solution.

Dissociation constant (k_w) is the multiplication of molar concentration of hydrogen and hydroxyl ion in the water. If we know the value of the at least two of the component value among these three (Dissociation constant, hydrogen and hydroxyl ion), we can calculate the value of other remaining unknown value. At the temperature of 25°C, the value of dissociation constant (k_w) is 10^{-14} . pH is defined as the negative logarithm of the hydrogen ion activity.

$$pH = -\log_{10}(a_H) \quad (1)$$

The molar concentration of hydrogen ions product by an activity coefficient is the hydrogen ion activity, which takes into account the interaction of hydrogen ions with other chemical species in the solution. In the practical case, pH is usually defined to be the negative logarithm of the hydrogen ion concentration.

$$pH = -\log_{10}(H^+) \quad (2)$$

pH value is measured with the range of 0 to 14, even though solvents containing non-water solutions might have the value over or below this range. At the room temperature of 25°C, a neutral water has a pH value of 7.0, whereas solutions with pH less than 7 are acidic and solutions with pH more than 7 are alkaline. To manage and represent the broad range of ion activity, a logarithmic pH scale is used [2].

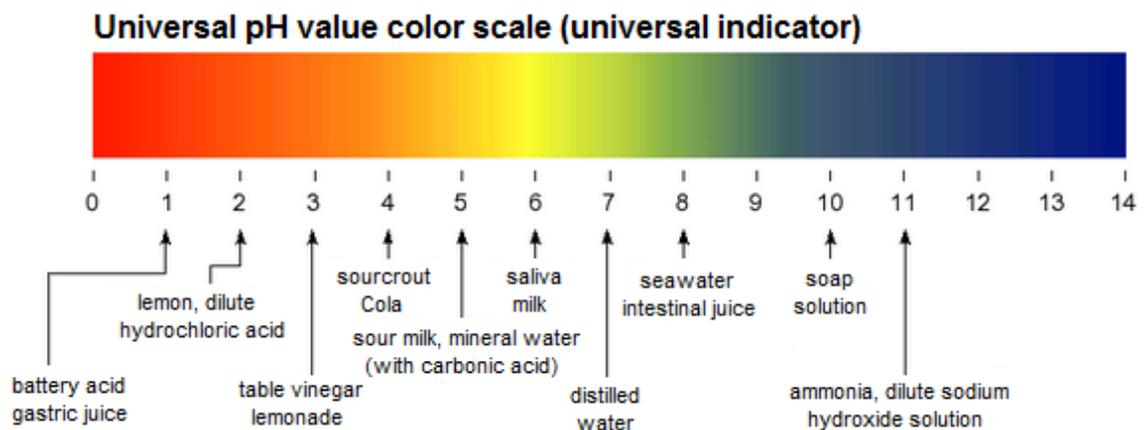


Figure 2 Universal pH indicator

In figure 2, scale for universal pH indicator is shown. It is well known that litmus paper is most commonly used simple pH testing method. Figure 2 shows the colour change of litmus paper with the different value of pH. The standard water pH range suitable could range from 6.5 to 8.5, and the pH range for groundwater systems could be between 6 and 8.5. To determine the significance of pH in water, it has two parts that are combined to make the pH sensor which is described in the pages below: -

4.1.1 pH probe

pH meter used here measures the difference in electrical potential between a pH electrode and a reference electrode. The change in potential difference among the electrodes defines acidity and alkalinity/basicity of the solution. This kind of pH meter can be used in various applications ranging from laboratory experimentation to quality control.

A pH probe consists of the electrode, glass membrane and housing. It has a simple, convenient and practical connection and features. BNC connector is connected to pH circuit and circuit into any analog input on microcontroller to read pH value easily. pH probe comprises of two major parts.

- Measuring electrode: - The first part is measuring electrode which is made up of a glass electrode and is also mentioned to as a skin or active electrode.
- Reference electrode: - The second one which is used to receive the supplied voltage, which is reference electrode and is also stated as a standard electrode.

For the measurement of the pH, the potential between the two electrodes inside the glass membrane are determined. One electrode is reference electrode for providing a reference voltage, and another one is measuring electrode which is sensitive to the pH value.

Clearly, the electrode is comprised of pH glass electrode and silver (Ag) or silver chloride (AgCl) reference electrode composition, which is referred to as pH measuring elements to help measure the pH value of water or another solvent. There are many available pH measuring devices. For example, litmus paper, digital pH meter, etc. We use this sensor

because of its convenience to use with the microcontroller connectivity, affordability and easy for production. The picture of pH probe shown figure 3.



Figure 3. pH probe [3]

Specification of pH sensor:

Module Power: 5 V
PH Measuring Range: 0-14
Accuracy varies with only ± 0.1 pH (25 degree Celsius)
Response time is less than 1 min
Has a BNC connector to connect pH sensor
Power indicator LED
Gain Adjustment Potentiometer

The dimension for the pH probe is illustrated in the following figure 4.

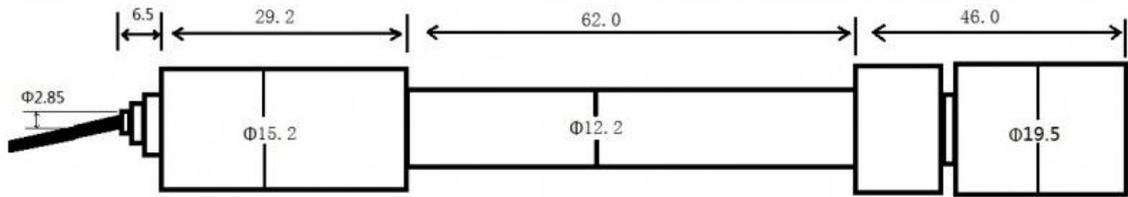


Figure 4 PH probe dimension [3]

The probe measures the potential between the electrodes and potential is converted to pH value. The reference table for the conversion of millivolts to pH is given in Table 1 below.

Table 1. Voltage to pH value conversion [3]

Voltage (mV)	pH value	Voltage (mV)	pH value
414.12	0.00	-414.12	14.00
354.96	1.00	-354.96	13.00
295.80	2.00	-295.80	12.00
236.64	3.00	-236.64	11.00
177.48	4.00	-177.48	10.00
118.32	5.00	-118.32	9.00
59.16	6.00	-59.16	8.00
0.00	7.00	0.00	7.00

Since pH probe is sensitive to the different chemicals; it should be taken care of properly. Precautions for the probe are given below: -

- ❖ Clean electrode probe is a must. Therefore it should be cleaned with fresh water every time after the use.
- ❖ The solution of the reference electrode is a solution of 3NKCL.
- ❖ Unsteady pollutions should be avoided for the accurate measurement.
- ❖ Do not immerse the pH electrode in acid chloride solution for the long term.

- ❖ Do not keep the rubber thing outside the glass probe during the measurement, so that no salt bridge formed of that rubber.

4.1.2 pH circuit

pH circuit is designed using voltage converter and two operational amplifiers. As well as, BNC connector, and different capacitor and resistor as per the need of the circuit layout. The operational amplifier (CA3140AMZ) integrates the input voltage and sends it to the inverting amplifier (TL081BCDG4) which has the gain of 1. Moreover, the output voltage is referred to the microcontroller analog pin (as desired) using the pin 1 in module interface.

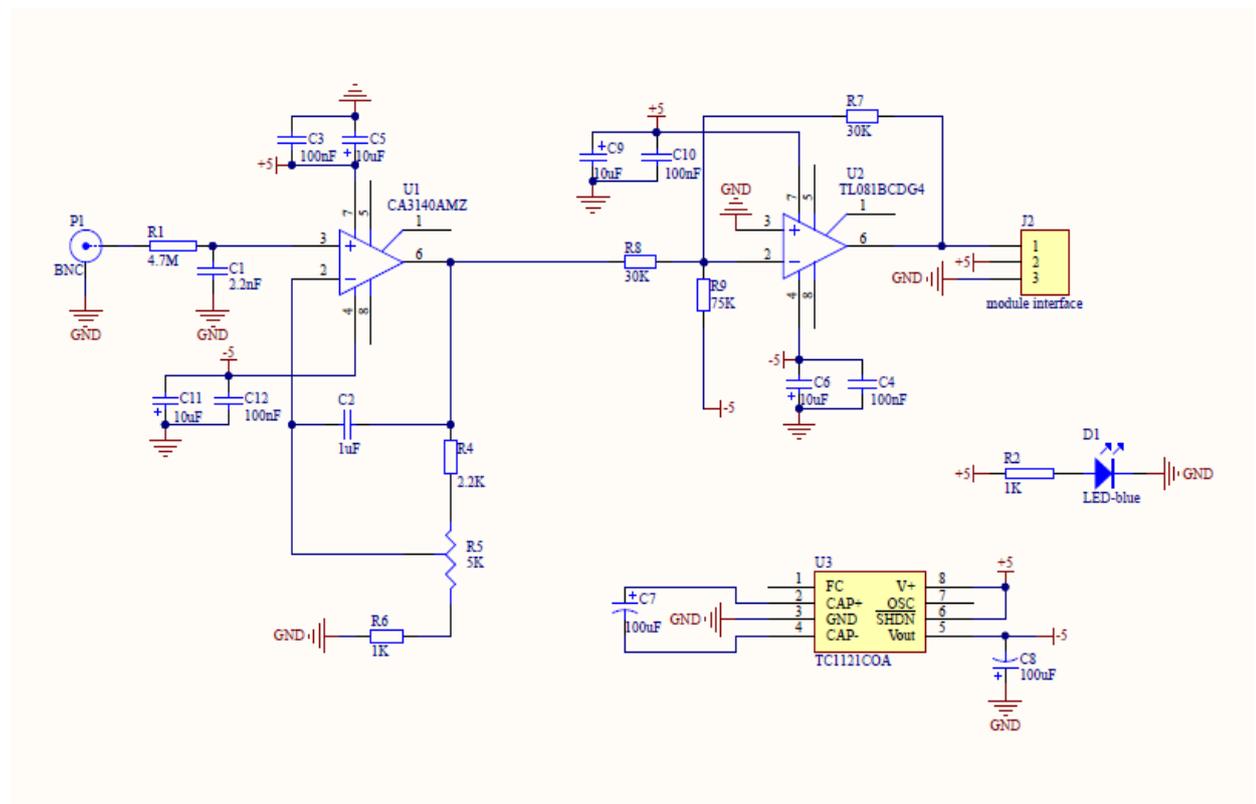


Figure 5 pH Circuit Schematic [3]

As shown in figure 5, the signal is passed from the probe through BNC connector; it has a typical resistance of 10-1000 M ohm. So, to keep the current small as possible operational amplifier CA3140AMZ is used. Resistor R5 is the variable resistor which can be used to adjust the gain. Data is transferred to the circuit through BNC connector. Then

passed to the CA3140AMZ and then to the TL081BcdG4 operational amplifier which is used for inverting the phase with the gain of 1. The Voltage converter and operational amplifiers are described.

TC1121 is 100mA Charge Pump Voltage Converter with Shutdown. It has following features: -

- It allows the use of small capacitors for high-frequency operation.
- Operates at low current -50uA
- Output Current max (100mA)
- (inverter mode) Input voltages (2.4 to 5.5 V) can be converted to the corresponding negative output voltage.
- Two capacitors are only used.
- It is possible to select Oscillator Frequency that ranges from 10 KHz to 200KHz.
- For saving power shutdown input is possible.
- Inductors are not required.

CA3140AMZ is an operational amplifier used in the pH circuit. It has the output of MOSFET input/output. For providing the very high input impedance, it contains a gate protected MOSFET transistors in the input circuit. Features are as follows: -

- input Stage of MOSFET
- Very high input impedance
- Input Voltage Range with extensive common mode
- Input current is very low
- Replaces 741 type in many applications.
- Lead (Pb) free

TL081BCDG4 is an operational amplifier used in pH circuit. It has low power consumption. It has low input Bias and offset currents. Total Harmonic Distortion is low and has high input impedance. It also has high slew rate.

4.2 Turbidity Sensor

Turbidity is the most difficult property of water to analyse. Since turbidity is the optical property of water; it has quite many ways to measure the amount in water. Turbidity sensor is used to check some dirt materials (solid particles) in the water. Turbidity Sensor (SKU: SEN0189) includes turbidity probe and Turbidity circuit to derive data to the microcontroller.

Turbidity is the total amount of particles in the water, which makes waters visibility worse, as a result of which turbidity is considered as the optical property of water. Hence, for determining turbidity, optical devices are used. For example, sending the light from one element and receiving by the other. According to the amount of light received or scattered turbidity is measured. When the suspended solid amount increases, the water's turbidity level (and cloudiness or haziness) increases. Turbidity sensors are used in river and stream gaging, effluent measurements in ponds, wastewater and control instrumentation for settling ponds, sediment research, and various laboratory measurements [4].

In other words, Turbidity is the measure of a number of particles in the water. It is taken as the optical property of water and is an expression of the amount of the light that is scattered by the suspended particles in the water when a light is shined through the water sample. As the intensity of scattered light is increased, the turbidity increases. The materials that cause water to be turbid include clay, silt, finely divided inorganic and organic matter, algae, soluble coloured organic compounds, and plankton and other microscopic organisms.

Turbidity is measured in Nephelometric Turbidity Units (NTU). During the period of low flow, many rivers are a clear green colour, and turbidity is low, usually less than 10 NTU. During rainstorm, floods, water flows fast and mixes with the different particles, which makes the turbidity of water high.

High Turbidity has effect in the lakes, rivers and ponds. Because of the turbidity lakes and ponds are filled faster with the solid particles and causes aquatic life in danger for habitat. These kind of particles provide the place which could be suitable for the pollutants, mostly metals and bacteria. This is the reason why turbidity measurements can be used as an indicator of possible pollution in a water body. [5]

An extreme amount of turbidity in drinking water is aesthetically not good, and can cause a health concern. Turbidity can also provide the shelter and food for the pathogens. If not removed, turbidity can help regrowth of pathogens in the supply system, leading to waterborne disease epidemics, which have caused significant cases of gastroenteritis throughout the world. Micro-organisms find a turbidity as attachment place and can stay and grow, which leads to the microbe survival and health effects to the human beings. [4]

4.2.1 Turbidity Probe

As shown in figure 6, Turbidity probe is made of plastic covered circuit. Inside the housing, it contains a probe circuit which includes photo emitting diode and phototransistor which receives the light. It is made waterproof so that the water does not move inside the housing. The amount of light received determines the turbidity of water. As the particles in the water increases, the amount of light transmitted decreases, which helps us to measure the amount of turbidity in water.

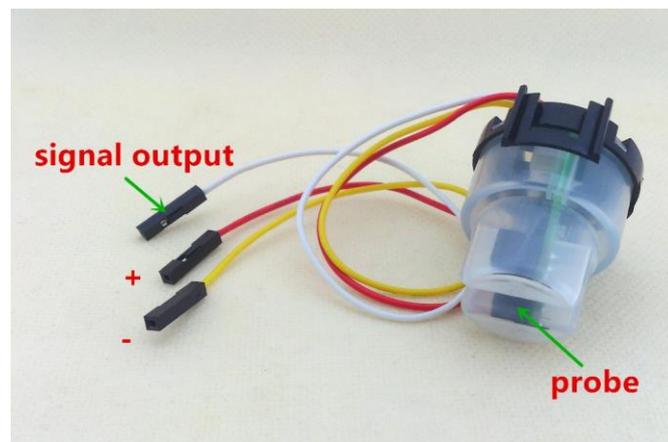


Figure 6 Turbidity Probe [6]

The Circuit design inside the turbidity probe is shown figure 7. As mentioned earlier it has Photo transmitter diode and a transistor which acts as a receiver in this circuit. These are the essential component of the turbidity sensor.

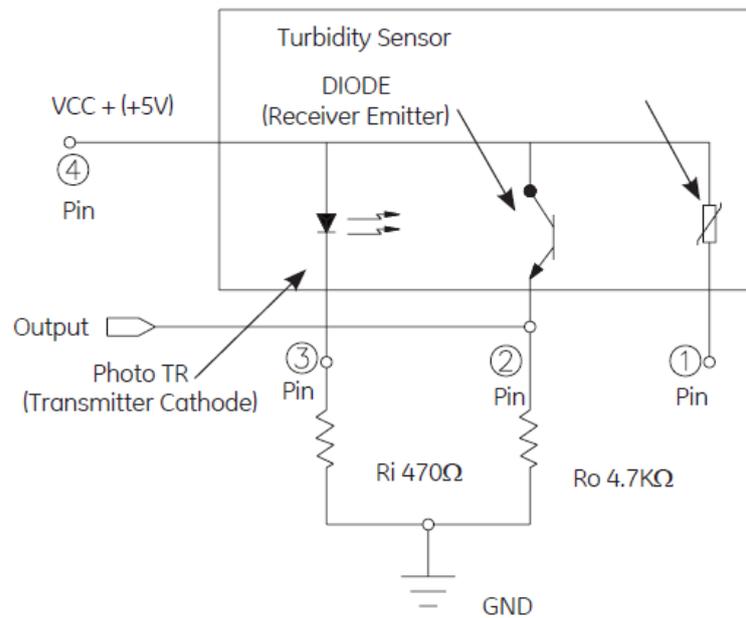


Figure 7 Circuit Schematic for Turbidity Probe [7]

In figure 7. Pin 4 is connected to the VCC (+5 V) which is used to supply the power to the diode and transistor. Photo TR (Transmitter Cathode) emits the light and transistor is the receiver. R_i and R_o are the pull-down resistor which is connected to the ground (GND). The final data is sent out to the circuit through output pin. The amount of Turbidity is determined by the amount of received light between these Photo TR and Transistor.

4.2.2 Turbidity Circuit

Turbidity Circuit is the key circuit which is connected to the turbidity probe to measure the turbidity of the water. It provides analog and digital signal output modes. The threshold is adjustable when in digital signal mode. It is possible to select the mode according to the MCU. Analog Mode is selected to acquire the analog signal, and the digital mode is chosen for the digital signal.

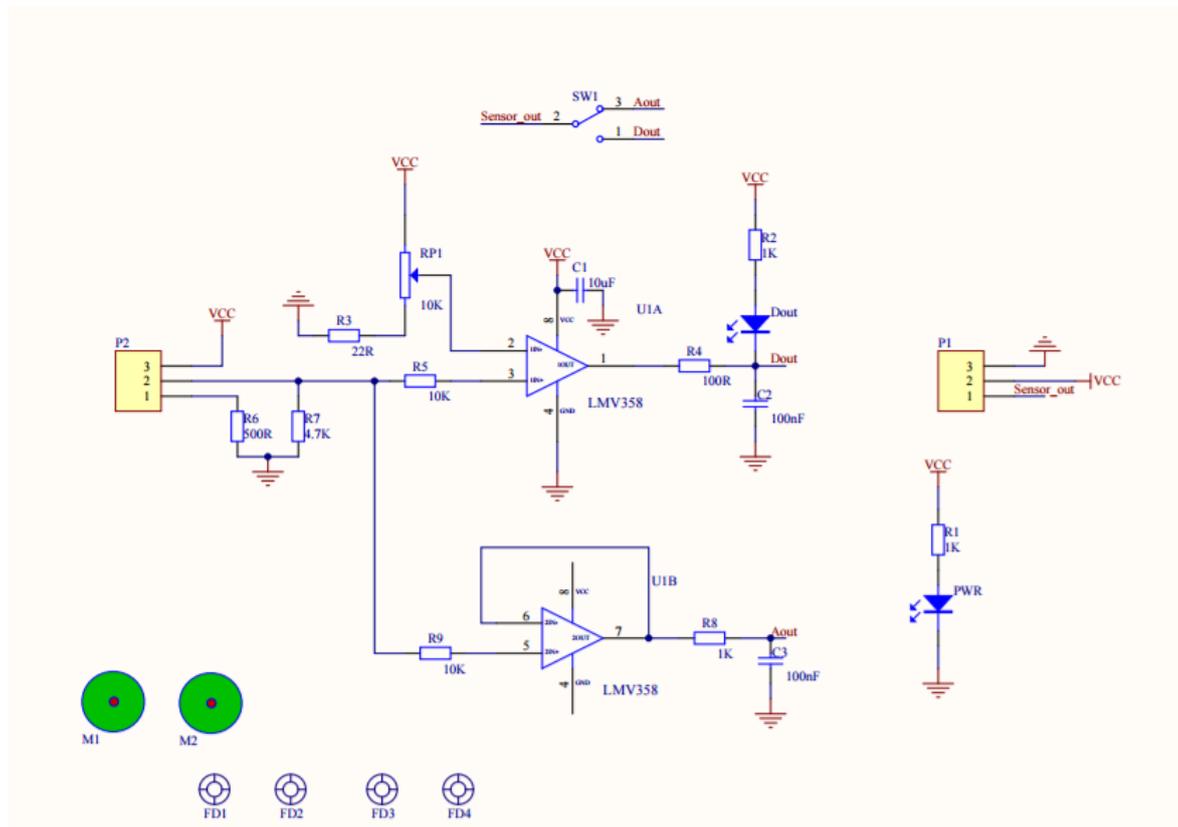


Figure 8 Turbidity circuit schematic [6]

In figure 8 of turbidity circuit schematic, P2 contains the input pins which is sent to the voltage follower which has the gain of 1. Since the Arduino data pins require 20 mA current to work, current is amplified using ten times bigger input resistor than the output. Aout is the analog output pin which is used to get the analog signal. It is also possible to select the digital output signal if needed. SW1 is the switch to select between analog and digital mode.

LMV358 is a low voltage operational amplifier used in turbidity circuit because of its low voltage characteristic. Since turbidity measured with low voltage data transfer, the LMV358 amplifier is suitable for the turbidity circuit. It operates in the range of 5-30 V. It can be used at the temperature between 40°C to 125°C. It does not have crossover distortion. It has Low supply current of 210 uA. It also has ESD protection (2000 V - Human body mode, 1000 V - charged device model). It features rail to rail output swing. The performance of this amplifier ranges from 2.7 V to 5 V.

4.3 Temperature Sensor

The temperature sensor (DS18B20) used for measuring the temperature of water for this project. When the accurate measurement is needed, we should always consider the temperature. The increase in temperature of water increases the ionisation rate. As a result, the result shown at 10°C is different than at 25°C with the same value of pH and turbidity. Temperature plays a vital role when measuring water quality. For example, pH value as well as turbidity changes with the change in Temperature. pH is temperature dependent, when the temperature goes up, the rate of ionisation increases and vice versa.

As the increase in temperature in any solutions causes a decrease in viscosity and an increase in mobility of ions in that solution. Since temperature is an essential part of the changes of the values of materials in the water, the temperature sensor used. Sensing the temperature is critical. Temperature is the key element for determining much other application for water quality analysis [8].

Speed and response of the pH electrode can differ with the change in temperature. Temperature can also have effects on the Calibration isothermal point, thermal equilibrium, chemical balance and electrode slope. At the normal operations with the change in temperature, result may vary a little in acid region, whereas, it can be quite dramatic in the alkaline region.

Table 2. Change in pH for solutions due to change in temperature [9]

pH Range	Temperature		
	0°C	25°C	60°C
Acid	pH 0.99	pH 1.00	pH 1.01
Neutral	pH 7.47	pH 7.00	pH 6.51
Base	pH 14.94	pH 14.00	pH 13.02

Table 2 shows the variations of pH value with the change in temperature. Acid has a slight variation in the pH value as the temperature changes to 25°C and 60°C than at 0°C. At the neutral value of pH, it has slightly more variations as compared to the acid. Whereas, for the bases, it has a dramatic variation with change in temperature between 0°C, 25°C and 60°C with the change of pH value of about 2.

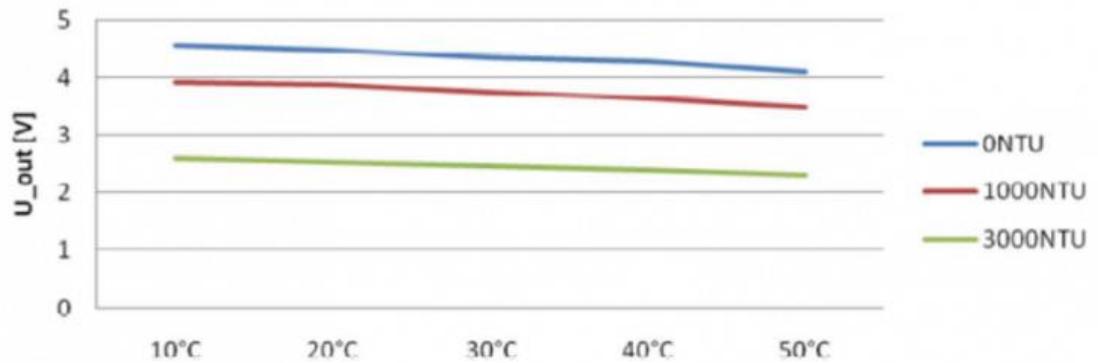


Figure 9 Characteristic curve of Temperature vs. Voltage for turbidity [6]

Change in temperature also changes the value of Turbidity. In figure 9, change of turbidity value shown as the temperature changes. Since the increase in the temperature increases the molecules ionisation rate, which results in the decrease in the transfer of light from diode to transistor slightly less than the lower temperature. As a result, the turbidity increases with the increase in temperature. At the same NTU different value of voltage achieved with a slight change in it.

4.3.1 Sensor

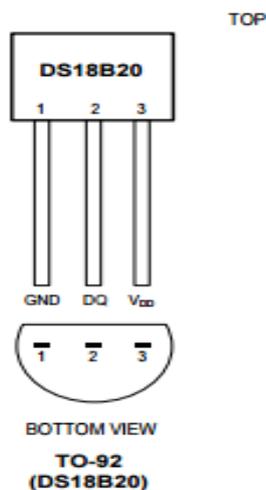


Figure 10. DS18B20 temperature sensor [10]

DS18B20 (Temperature Sensor) is Digital thermometer which is used in this Project. Figure 10 shows the DS18B20 pins from the bottom and top view. This temperature sensor requires data pin, Ground pin and the power pin. It delivers 9-bit to 12-bit Celsius temperature measurements. Moreover, the DS18B20 can derive power directly from the data line (“parasite power”), excluding the requirement for an external power supply.

This temperature sensor has many benefits and features as compared to another sensor available in the market. It cuts component amount with combined temperature sensor and EEPROM (measures temperatures from -55°C to 125°C , $\pm 0.5^{\circ}\text{C}$ Accuracy from -10°C to $+85^{\circ}\text{C}$, a programmable resolution from 9 bits to 12 bits and No external components required). For the operation of retrieving data, parasitic power mode requires two pins (DQ and GND) [11].

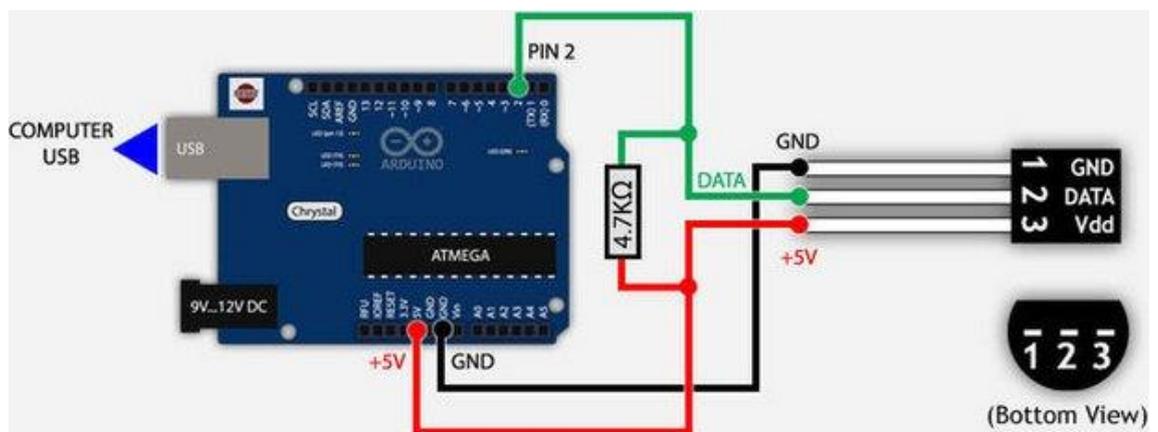


Figure 11 Temperature Circuit [8]

Figure 11 shows the temperature circuit to determine the temperature of the water. It is a simple circuit which includes pull-up resistor with the value of $4.7\text{ K}\Omega$ (most commonly used). The data pin is connected to the digital pin 2 of the microcontroller kit whereas VDD to the +5 V pin and GND pin of the sensor to GND pin of the microcontroller. To derive the data to the microcontroller in the form of degree Celsius ($^{\circ}\text{C}$), Arduino is programmed which requires OneWire.h library available in the public domain.

4.4 Microcontroller

The world is full of microcontrollers. Every application we use from home to industrial includes microcontroller as a central processing unit. It is a core part of the system and is responsible for the main function. There are different kinds of microcontroller available for example, Arduino, MSP430, Teensy, etc.

This project uses Arduino Microcontroller. Arduino is an electronics platform, which is available easily and it is easy to use. It is an open-source platform. It can also be said as microcontroller kit which is designed to ease the development of different electronic projects. There are different kinds of microcontroller kit available like Arduino Uno, Arduino Mega, Arduino Duo, etc. Arduino detects the activity by getting inputs from the sensors and marks its surroundings by controlling lights, motors, and many actuators. Arduino Uno is used here because of its simplicity and affordability.

Worldwide use of Arduino by students, programmers, professionals, hobbyists has made Arduino readily available, and their help has added up to an improbable amount of bases, which can be a noteworthy support to interested student and researchers. For the fast prototyping which might be helpful to the students, Arduino was developed at the Ivrea Interaction Design Institute as a tranquil tool.

It is used for different kinds of projects and applications because of its simplicity and availability. It is a perfect for the beginners who have an interest in designing and prototyping hardware and software platform. This can be used by teachers, students, musicians, artists, architects to build an interactive prototype for installations and to experiment with new ideas. There are a wide variety of other microcontrollers and platforms is accessible for physical computing. They had quite untidy specifics of microcontroller programming and infolded in an easy to use bundle. Arduino Boards are comparatively low-priced compared to other microcontroller boards. This platform software works on Windows, Macintosh OSX, and Linux operating systems which proves its convenience of use in cross platform. It has very simple, clear programming environment, which makes beginners easy to learn this platform. Since it is open- source platform and its hardware can be modified easily, it is possible to extend as desired by the user.

4.4.1 Arduino Uno

Arduino Uno is the platform used in this project because of its simplicity and convenience. This microcontroller board has ATmega328P microprocessor. It includes 14 digital input/output pins (among them six can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a power jack, a USB connection, an ICP header and a reset button. It is simple to connect to the computer and program it as needed by the user. It can be powered in two ways, with battery by using power socket or just simply connecting through USB.

Starting from A0 through A5, there are six analog inputs, and each pin has 10 bits of resolution. In total 14 pins are the digital pins, and they can be used as an input as well as output, using `pinMode()`, `digitalWrite()`, and `digitalRead()` functions in programming. These pins run at 5 Volts. Providing and receiving 20 mA current by each pin which is recommended operating condition and has an internal pull-up resistor of 20 to 50K ohm. With the intention of not damaging the microcontroller, 40 mA is the maximum current which must not be surpassed on any input and output pin.

The Arduino Uno is possible to programme with the Arduino software. The Arduino Uno contains ATmega328 microcontroller which is already programmed with the bootloader to help with equipping programs in the system. For communicating it uses STK500 protocol. Bypassing the bootloader and program the microcontroller through the ICSP header using Arduino ISP or similar is possible as well.

The software for Arduino is free to use and is easily available in the public domain. The ATmega328 contains 32 kB memory plus bootloader occupies 0.5 kB of memory. This has 2 kB of SRAM and 1 kB of EEPROM.

4.5 LabVIEW

LabVIEW stands for Laboratory Virtual Instrument Engineering Workbench, is a high-level graphical programming workbench, which uses a graphical programming language for system design and development of environments. It is developed by National Instruments (NI). Different industries for the variety of systems uses LabVIEW for the data acquisition, instrumentation control and automation. It can be used in Microsoft Windows, Unix, Linux and Mac OSx. LabVIEW can interface with various devices, instruments,

cameras, and many other applications. It is possible to make the user interface for the hardware in PC and control using LabVIEW.

LabVIEW has a fascinating and attractive graphical programming language which is easy to learn and work. It is a graphical programming environment which uses graphical notation. It differs from the other commonly known programming languages like C, C++, Java, Python or swift in which programming is with text. LabVIEW can be used to make programs that run on a variety of embedded platforms like FPGAs (Field Programmable Gate Arrays, DSPs (Digital Signal Processors), and various microprocessors. The programs that take months to complete can be accomplished using LabVIEW in hours. It is preferably designed to make measurements, analyse the data, and present the results to the user. LabVIEW is used in this project to present the final result to the user.

The microcontroller is interfaced with the LabVIEW using LINX software provided by the National instruments to derive the data using the Serial port. LINX provides LabVIEW VIs which can be used to interface with the most commonly used embedded platforms. Interfacing Arduino with LabVIEW using LINX requires installing firmware provided by LINX. To install the firmware, from the tools menu of LabVIEW, go to maker hub and install LINX firmware where it is possible to select the embedded platform like Arduino and much more.

5 Test and Measurements

Water Quality Measuring Station (WQMS) utilises all three sensors (pH, Turbidity and temperature) and microcontroller, and finally connecting to the personal computer to process and analyse the quality of water. It is a straightforward and quick device to get the measurement of quality of water.

5.1 Process

The project started with taking a measurement of each value of pH, turbidity and temperature from each sensor separately. After getting the successful results all the sensors connected to the microcontroller to make the complete device. For the first measurement, after assembling all the sensors and circuit as required, tap water of school testing.

Measurement started with a testing temperature of water by taking the hot and cold water with different temperature values. Since the turbidity sensor used in WQMS project is only applicable for qualitative analysis but not the quantitative analysis, only the voltage derived from the sensor is calculated according to the change in voltage with the modification of dirt particles in the water. For measuring the turbidity, dirt particles are added to the water with the random amount and the value of voltage achieved shows as expected. The value of voltage decreases as the dirt particles added to the water which proves that the sensor works as expected. Finally, to measure the pH value, different kind of liquid which contains acid or base are used to test the device.

5.2 Results

When the finalised device used to measure the quality of normal tap water, the device provided the pH value of 7.02 and temperature of 23 degree Celsius and providing the turbidity value of close to the pure water (500mV). This is the first test analysed after the device completion. For the confirmation of device working properly, different measurements were taken at the different temperatures, pH value and turbidity.

After the device was ready to take the measurements, the parameter used for quality analysis was compared with the reference devices. First of all, the temperature was recorded with the reference thermometer as well as with WQMS at the same water. Cold water was taken at the beginning and slowly little by the little random amount of boiled water (temperature was close to 100°C) was added. The comparison between the temperature recorded by the following devices is shown in figure 12.

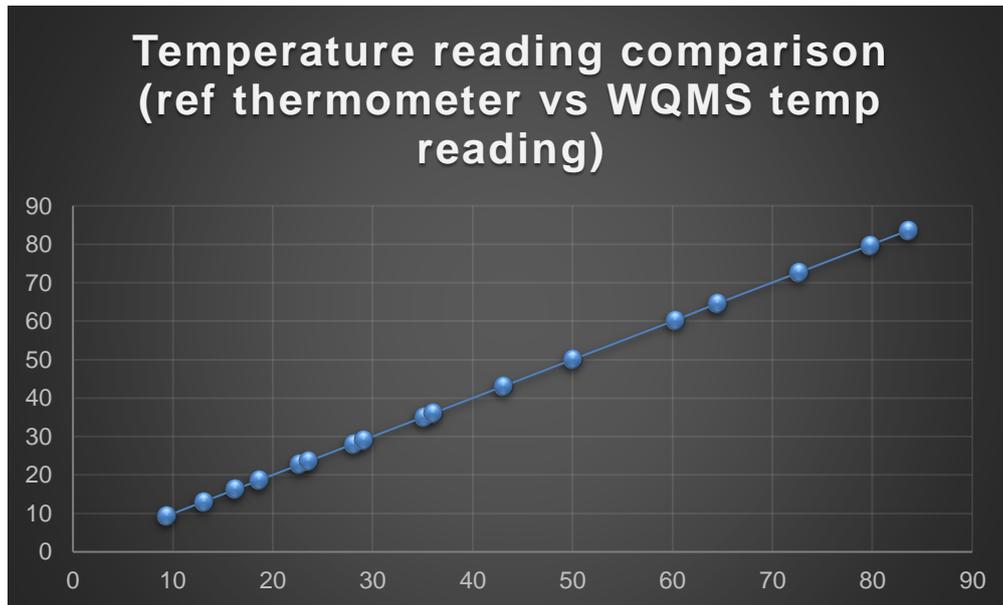


Figure 12 Temperature graph

As shown in figure 12, the temperature recorded by the different devices are almost same, which proves that the WQMS is working as expected.

WQMS was used to measure the different mix liquid pH value. Each liquid was tested separately, and pH value was recorded. pH value obtained by WQMS for various types of liquid are shown: -

Table 3 pH value obtained by WQMS

Liquid	pH value
Lemon	2.2
Tomato juice	4.13
Tap water	6.85
Distilled water	7
Soap water	11.8

Turbidity sensor used in WQMS is for qualitative analysis. Output voltage given by the WQMS determines whether the turbidity is high or low. To check WQMS is working as expected, three water sample was taken (Clear water, little turbid water and high turbid water) as shown in figure 13.

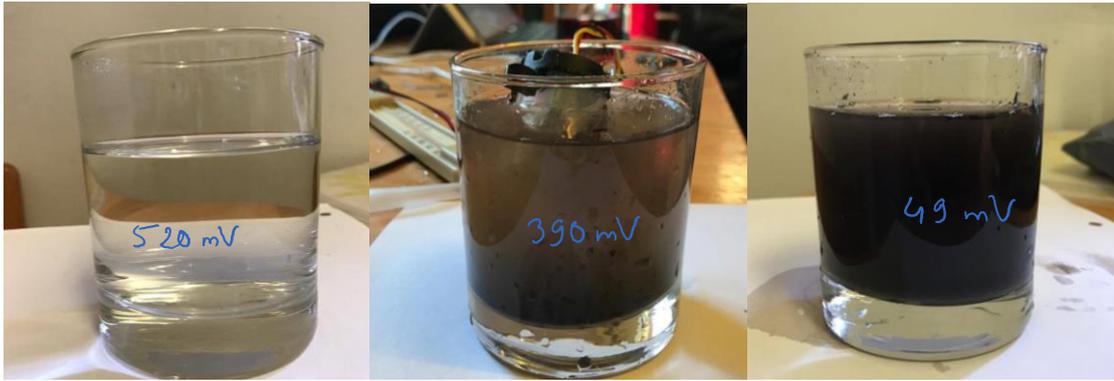


Figure 13 Water with different Turbidity level

As shown in figure 13, a voltage obtained is highest at the clean water and minimum at the very dirty water. For the clean tap water WQMS turbidity sensor shows 520mV, and when mixed a little dirt in that water value decreased to 390mV and finally when mixed lot, value decreased to very low (49 mV). Hence it proves the turbidity sensor is working fine in WQMS. In this project, turbidity is measured only for the qualitative analysis but not for the quantitative analysis. So that it is not converted to NTU (turbidity unit).

Before interfacing with the LabVIEW, WQMS was used to test the result in the Arduino Software. The result obtained in the Arduino serial monitor is shown in figure 14.

```
Turbidity: 436
Ph value: 6.94
Temperature 19.12 Deg C
```

Figure 14 Result of the tap water of lab in Arduino Serial Monitor

For getting the serial data to the LabVIEW, LINX has provided sample examples which can be installed using VI Package Manager. Multiple analog channel model is used since analog signal are received from the sensors which then presented in the live chart and accurate value is also shown indicating pH.

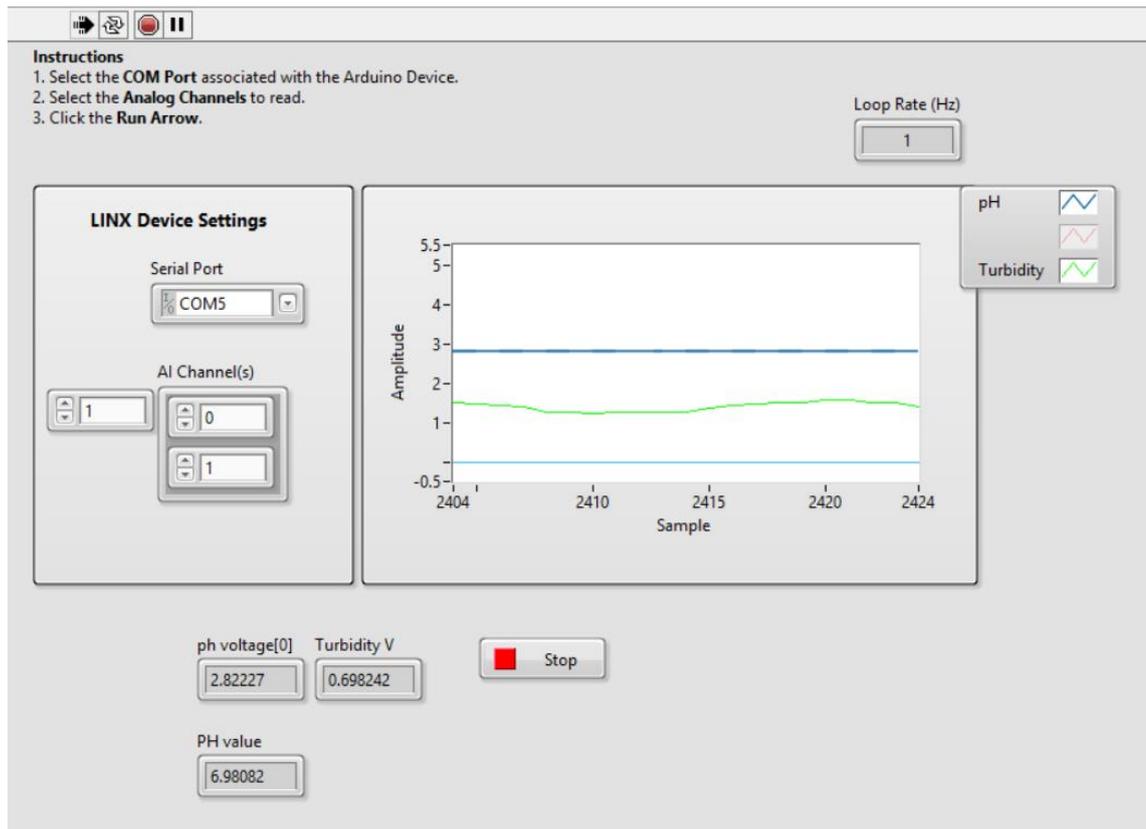


Figure 15 LabVIEW user interface

Figure 15 demonstrates the value of pH turbidity of water which is presented in the LabVIEW. The serial port is used to select the COM port where the Arduino USB cable is plugged in. AI channels include the channels for getting the sensor data, where channel 0 includes the pH data and channel 1 includes the Turbidity data. After clicking the run arrow, the user interface starts to plot the value that is derived from the WQMS. The stop button is used to halt the process.

6 Conclusions

The Goal of the thesis was to test the water quality by using the quality parameters of water (pH, turbidity and temperature) and present using the LabVIEW interface, which is achieved successfully. The report contains the details of the sensors and microcontrollers in the beginning after the description of the flow chart of the Water Quality Measuring Station (WQMS) followed by the circuit design and the specifications. Circuit design on how to interface the sensors to the microcontroller and the PC is presented clearly as well as about the operational amplifiers used in the following circuit. Finally, the result is

presented in Arduino serial monitor as well as in LabVIEW which shows the pH, turbidity and temperature values.

According to the result obtained from the WQMS, it can be concluded that the target to measure the pH, turbidity and temperature of the water was successful. These parameters of quality of water make possible to check the quality of water, which is achieved in the final results. Putting the sensors in water and analysing the quality parameters in the LabVIEW is the simple process to check the quality of water using WQMS. pH and turbidity can be calibrated if the device fluctuates then the actual result after prolonged use. Some of the tests were carried out to find out whether the quality check parameters are achieved as expected. Turbidity is shown the qualitative result because the turbidity sensor used was designed only to measure the qualitative analysis but not for the quantitative analysis. pH sensor and temperature measure the actual value as desired that is in pH unit and degree unit respectively. Device measures the quality of water based on these (pH, turbidity and temperature) parameters.

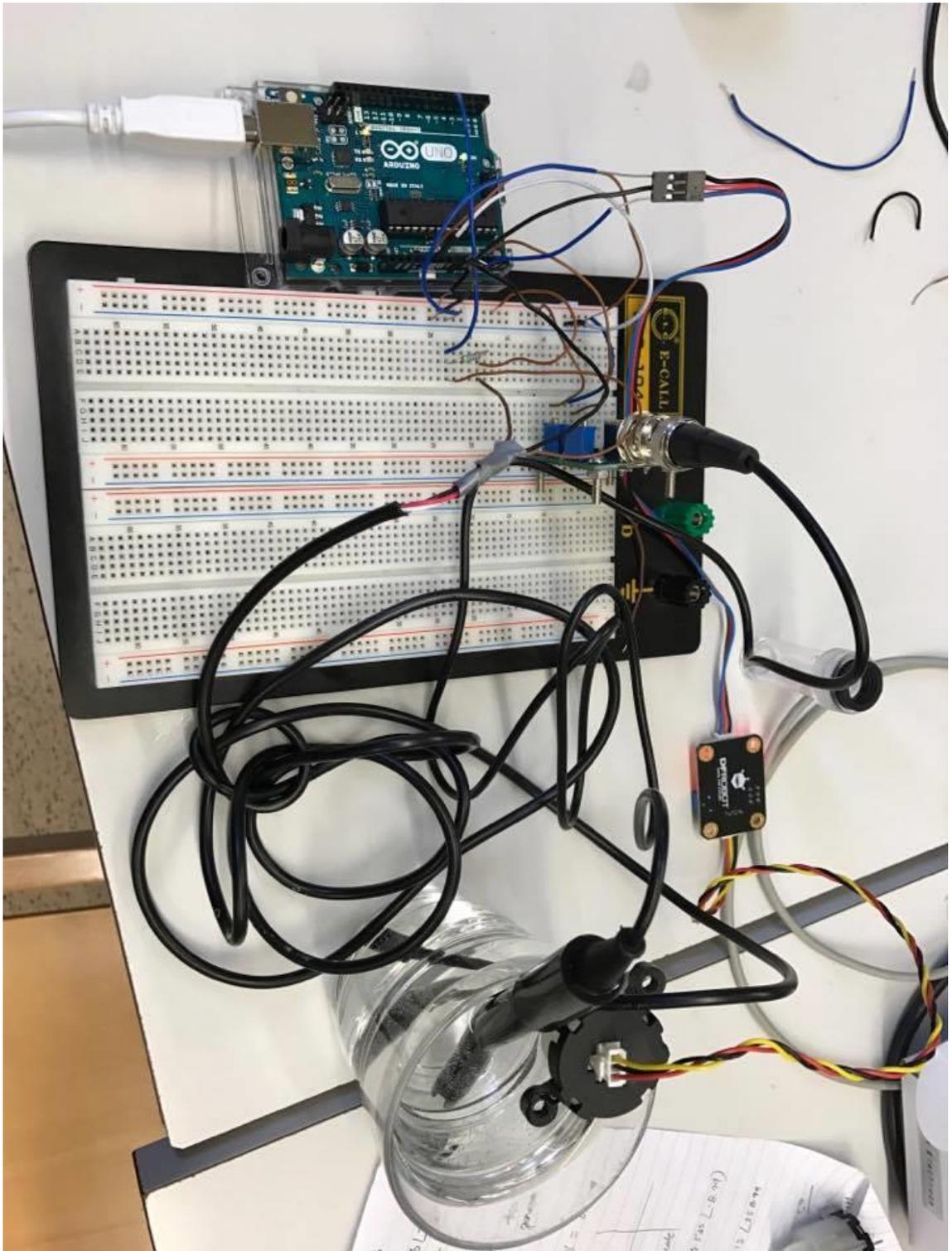
In summing up, this project clarifies the process of measurement of PH, Turbidity and Temperature measurement of water. This project also has the overall information about the hardware and software needed for the device to be ready. It includes the process of analysing and implementing the sensors into the microcontroller and then to the PC. This project will be helpful for the future references for measuring pH, turbidity and temperature of water. Moreover, in the future, WQMS can be used for the educational purpose by the students who are intended to design embedded system device to measure the quality of water at Electronics department of Helsinki Metropolia University of Applied Sciences.

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Complete prototype in Bread board, water Quality measuring station



Measurement Result of Reference thermometer and WQMS temp reading

Temperature reading in °C	
Reference thermometer	WQMS temp reading
9.3	9.26
13.02	13
16.2	16.19
18.56	18.56
22.6	22.62
23.5	23.5
28	28
29	29
35.01	35
36	36
43	43
50	50
60.23	60.2
64.4	64.5
72.6	72.62
79.7	79.7
83.5	83.5

Main code for deriving data to Arduino Serial monitor

```

#include <OneWire.h>

OneWire tempSensor(3);
// pHRead.ino

// Constants:-
const byte pHpin = A0;    // Connect the sensor's Po output
to analogue pin 0.

//Turbidity
int turbPin = A2; //turbidity pin

// Variables:-
float Po;
void setup(void) {
  Serial.begin(115200);
}

void loop(void) {
// read the input on analog pin 0:
  int sensorValue1 = analogRead(turbPin);
  // print out the value you read:
  Serial.print("Turbidity:  ");
  Serial.println(sensorValue1);

  Po = (1023 - analogRead(pHpin)) / 73.07;    // Read and
reverse the analogue input value from the pH sensor then
scale 0-14.
  Serial.print("Ph value:  ");
  Serial.println(Po, 2);                      // Print the
result in the serial monitor.

```

```
byte data[9];
int temperature;
float temperature_C;

tempSensor.reset();
tempSensor.write(0xCC); // All devices:
tempSensor.write(0x44); // Start a temperature reading

delay(1000); // Reading takes 750 milliseconds. Waiting
longer is OK.

tempSensor.reset();
tempSensor.write(0xCC); // All devices: (must be only
one device)
tempSensor.write(0xBE); // Send the content of your
scratchpad.

for (int i = 0; i < 9; i++) {
  data[i] = tempSensor.read();
}

temperature = (data[1] << 8) + data[0];
temperature_C = temperature / 16.0;
Serial.print("Temperature ");
Serial.print(temperature_C);
Serial.print(" Deg C");
Serial.println();
Serial.println();
delay(1000); }
```

LabVIEW code

