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ABSTRACT

After we all have learned our life lessons about health, the improvement of medical technology, and the ease of access to resources during the pandemic, for that sense, ‘biomedical applications’ are highly important and significant. However, in the era of the wristwatch, the majority of wearable feedback sensors now on the market are physical feedback sensors based on physiological responses like heart rate or pulse. They are unable to examine the molecular state of the human body's health. Invasive devices include blood glucose metres and other devices that do molecular level analyses. This project examines the viability of the novel detection technique for health using sweat by the familiar one: the pH scale approach.

The main objective is to employ biofluids like sweat more frequently for human body examinations rather than blood or urine. A painful and cumbersome way of extracting samples from the human body has been replaced with sweat, a new biofluid through which the samples are readily gathered. In this project, we're aiming to investigate the sample that has been taken and evaluate the health using the analysis of the samples that have been obtained.

We may learn a lot about our health from the molecular markers found in sweat. Variations in sweat pH (i.e., acidity or alkalinity), for example, can help with the identification of skin problems including dermatitis, acne, and other skin infections as well as whether our body is dehydrated.

In order to prevent future health deterioration, such situations can be signalled to the individual utilising a sweat sensor in a mobile application. ESP32 and pH sensor are used in hardware, while communication to Blynk and Thingspeak. The user can monitor his sweat pH values on Thingspeak, by undergoing a test on sweat sample after regular intevals of time. On Blynk application too, alerts are simultaneously sent along with the display on the pH gauge.

FIGURE DESCRIPTIONS

TABLE DESCRIPTIONS

CHAPTER – 1

INTRODUCTION

After the pandemic era, we have valued the importance of health and have witnessed a significant amount of increase in the technological advancements in the Health industry.

1.1 MOTIVATION

Understanding and analysing life in all of its manifestations, from very vast to very minute scales, is the goal of education. Understanding is just one aspect of schooling; the other vital aspect is applying and innovating with that information. Understanding a functioning principle and using the underlying information are both necessary for technological innovation. These findings have significantly impacted a number of sectors, including engineering, medicine, the military, and many more.

The Medical Industry has grown exponentially as a result of technology, which has helped many people by identifying illnesses, treating them, better understanding how the human body functions, and making life easier.The most recent advancements in technology for enhancing life are mostly dependent on mobile and Bluetooth applications, which are now widely utilised in medical technology. For instance, electrocardiograms, blood pressure monitoring, and blood sugar monitoring.

In the same light, we think that there are only a handful of exceptional uses, such as using sweat samples to diagnose disorders.
This line of thinking has inspired us to create a sweat diagnostics application. An application that is user-friendly and detect the imbalances of electrolytes can be approximately determined by a non- invasive and convenient methodology.

1.2 INTRODUCTION

1.2.1 BIOMEDICAL

The application of engineering principles and problem-solving methodologies to biology and medicine is known as biomedical engineering. This is clear in every aspect of healthcare, from diagnosis and evaluation to treatment and recovery.

Engineering is a creative subject that has produced concepts for everything from sonar to aeroplanes, skyscrapers to automobiles. The field of biomedical engineering focuses on developments that enhance human health and medical care on all fronts.

Whether it be an advanced prosthetic limb or a discovery in the identification of proteins within cells, biomedical engineering integrates elements of mechanical engineering, electrical engineering, chemical engineering, materials science, chemistry, mathematics, and computer science and engineering with human biology to improve human health.

1.2.2 ELECTROCHEMISTRY

The study of the correlation between electrical energy and chemical changes is the focus of the branch of chemistry known as electrochemistry. Electrochemical reactions are those in which electric currents are either generated or input. These responses can be roughly divided into two categories, electrical energy produces chemical change i.e., the electrolysis phenomenon and chemical energy to electrical energy conversion. i.e., the production of electricity using redox reactions that occur naturally.

When electrons go from one element to another during specific sorts of reactions, electricity can result (such as redox reactions). Electrochemistry often deals with the overall reactions when several redox reactions take place at the same time and are connected by an appropriate electrolyte and an external electric current.

1.2.3 INTERNET OF THINGS (IoT)

IoT, or the Internet of Things, refers to the overall network of interconnected devices as well as the technology that enables communication between them as well as with the cloud. We now have billions of devices connected to the internet as a result of the development of low-cost computer chips and high bandwidth telephony. This implies that commonplace gadgets like vacuum cleaners, cars, and robots might employ sensors to gather data and respond wryly to consumers. The Internet of Things connects commonplace "things" to the web. Since the 1990s, computer engineers have started incorporating sensors and CPUs into commonplace items. However, because the chips were large and heavy, progress was first slow. Low-power computer chips called RFID tags were first used to track expensive devices. As computing devices have shrunk in size, these chips have also become smaller, faster, and smarter.

The cost of consolidating computing power into small objects is now much lower. For example, you can use his MCU with less than 1MB of onboard RAM. B. For light switches, add connectivity with the Alexa Voice Service feature. An entire industry has sprung up focused on filling homes, stores and offices with his IoT devices. These smart objects can automatically send data to and from the Internet. All of these "invisible computing devices" and related technologies are collectively referred to as the Internet of Things.

1.2.4 EMBEDDED SYSTEMS

As its name suggests, Embedded means something that is attached to another thing. An embedded system can be thought of as a computer hardware system having software embedded in it. An embedded system can be an independent system or it can be a part of a large system. An embedded system is a microcontroller or microprocessor based system which is designed to perform a specific task. For example, a fire alarm is an embedded system; it will sense only smoke.

An embedded system has three components hardware, software application and Real Time Operating system (RTOS) that supervises the application software and provide mechanism to let the processor run a process as per scheduling by following a plan to control the latencies. RTOS defines the way the system works. It sets the rules during the execution of application program. A small scale embedded system may not have RTOS.So, we can define an embedded system as a Microcontroller based, software driven, reliable, real-time control system.

Characteristics of an Embedded System Single-functioned, Tightly constrained, Reactive and Real time, Microprocessors based Memory Connected, HW-SW systems

Existing wearable detection technologies of the smartwatch age, on the other hand, are largely physical feedback sensors based on physiologic responses such as heart rate or pulse. They are unable to assess the health of the human body at the molecular level. Invasive instruments with molecular level analysis, such as blood glucose metres, exist. This study aims to validate the viability of new detection method.

The pH scale approach of most accessible, non-invasive and convenient biofluid - SWEAT.

1.3 THE PH SCALE APPROACH

Wearable physical sensor advancements have been spectacular, resulting in a slew of consumer electronics items that detect characteristics such as activity, posture, heart rate, respiration rate, and blood oxygen level.

Because of the inherent difficulties in gathering and processing physiological fluids, progress in the development of wearable chemical sensors has been delayed. Sweat provides a vast store of biomarkers that is available constantly, on-the-go, and non-invasively in this setting. Apart from sweat sensing, we are contemplating discussing other core areas such as material science, device development, sensing methods, power production, and data processing.

The project's key goals are as follows:

Continuous monitoring of PH levels, data monitoring utilising Thingspeak cloud technology, alerts under unusual situations using the Blynk app and this process is accomplished by utilising the ESP32 module(using Wifi Module).

CHAPTER – 2

HUMAN BODY AND BIOFLUIDS

2.1 HUMAN ANATOMY

The physical substance of the human organism, formed of live cells and extracellular components and organised into tissues, organs, and systems, is known as the human body.

Humans, being members of the order Primates in the subphylum Vertebrata of the phylum Chordata, are, of course, social creatures. The human animal, like other chordates, has a bilaterally symmetrical body that is defined at some stage during development by a dorsal supporting rod (the notochord), gill slits in the throat, and a hollow dorsal nerve cord. The first two of these traits are only present in humans during the embryonic stage; the notochord is replaced by the vertebral column, and the pharyngeal gill slits are totally eliminated. In humans, the dorsal nerve cord is the spinal cord. The human body is a vertebrate with an internal skeleton that contains a backbone of vertebrae

2.2 CHEMICAL COMPOSITION OF THE BODY

The human body is mostly composed of water and organic molecules such as lipids, proteins, carbohydrates, and nucleic acids. Water may be present in the body's extracellular fluids (blood plasma, lymph, and interstitial fluid) as well as within cells. It acts as a solvent, without which life's chemistry would not be possible. The human body is composed of around 60% water by weight. The biological macromolecules namely lipids, proteins, carbohydrates, nucleic acids

LIPIDS, which primarily consist of fats, phospholipids, and steroids, are important structural components of the human body. Fats serve as a source of energy for the body, and fat pads also act as insulation and shock absorbers. Phospholipids and the steroid molecule cholesterol are important components of the cell membrane.

PROTEINS- Proteins are also an important structural component of the body. Proteins, like lipids, are key components of the cell membrane. Furthermore, protein is found in extracellular materials such as hair and nails. Collagen, the fibrous, elastic substance that makes up much of the body’s skin, bones, tendons, and ligaments, is also present. Proteins also serve a variety of functions in the body. Enzymes, which are biological proteins that catalyse the chemical processes required for life, are very crucial.

CARBOHYDRATES- Carbohydrates are mostly used as fuel in the human body, either as simple sugars in the bloodstream or as glycogen, a storage substance found in the liver and muscles. Carbohydrates are found in small amounts in cell membranes, but unlike plants and many invertebrates, humans have very little structural carbohydrate in their bodies.

NUCLEIC ACIDS- The genetic elements of the organism are made up of nucleic acids. Deoxyribonucleic acid (DNA) contains the body’s genetic master code, the instructions that each cell follows. The hereditary features of each individual person are determined by DNA, which is passed down from parents to offspring. Ribonucleic acid (RNA), of which there are various forms, aids in the execution of the DNA instructions.

Along with the macromolecules, the body's components also comprise different inorganic minerals in addition to water and organic substances. *Calcium, phosphorus, sodium, magnesium, and iron* are among the most important. A major portion of the body’s bones are composed of calcium and phosphorus crystals. *Calcium and sodium* are both present as ions in the blood and interstitial fluid. *Phosphorus, potassium, and magnesium ions*, on the other hand, are plentiful in the intercellular fluid. All of these ions are essential to the body’s metabolic functions. Iron is mostly found in haemoglobin, the oxygen-carrying pigment found in red blood cells. Cobalt, copper, iodine, manganese, and zinc are other mineral elements of the body present in minute but required proportions.

2.3 ORGANISATION OF THE BODY

The cell is the fundamental living unit of the human body, as well as other creatures. The human body is made up of billions of cells, each of which is capable of growing, metabolism, responding to stimuli, and, with a few exceptions, reproducing. Although the body contains over 200 distinct types of cells, they may be divided into four fundamental groups,

epithelial tissues, which cover the body’s surface and line the internal organs, body cavities, and passageways.

muscle tissues, which are capable of contraction and form the body’s musculature.

nerve tissues, which conduct electrical impulses and make up the nervous system.

connective tissues, which are composed of widely spaced cells and large amounts of intercellular matrix and which bind together various body structures.

Organs, serves as the next level in the hierarchy in the body. An organ is a collection of tissues that form a separate anatomical and functional entity. Thus, the heart is a four-tissue organ whose duty is to pump blood throughout the body. Of fact, the heart does not work in isolation; it is part of a system that includes blood and blood arteries. The organ system, then, is the greatest degree of bodily structure.

The body has nine primary organ systems, each of which is made up of many organs and tissues that act as a functional unit. Each system's primary parts and functions are mentioned below.

The *integumentary system*, which consists of the skin and accompanying tissues, protects the body from hazardous microbes and toxins while also preventing water loss.

The *musculoskeletal system* (also referred to separately as the muscle system and the skeletal system), composed of the skeletal muscles and bones (with about 206 of the later in adults), moves the body and protectively houses its internal organs.

The *respiratory system*, composed of the breathing passages, lungs, and muscles of respiration, obtains from the air the oxygen necessary for cellular metabolism; it also returns to the air the carbon dioxide that forms as a waste product of such metabolism.

The *circulatory system*, composed of the heart, blood, and blood vessels, circulates and transports fluid throughout the body, providing the cells with a steady supply of oxygen and nutrients and carrying away waste products such as carbon dioxide and toxic nitrogen compounds.

The *digestive system*, which includes the mouth, esophagus, stomach, and intestines, breaks down food into useable components (nutrients) that are then absorbed from the blood or lymph; this system also removes useless or extra food as faecal waste.

The excretory system, composed of the kidneys, ureters, urinary bladder, and urethra, removes toxic nitrogen compounds and other wastes from the blood.

The *nervous system*, composed of the sensory organs, brain, spinal cord, and nerves, transmits, integrates, and analyses sensory information and carries impulses to affect the appropriate muscular or glandular responses.

The *reproductive system*, composed of the male or female sex organs, enables reproduction and thereby ensures the continuation of the species.

The *endocrine system*, which is made up of hormone-secreting glands and tissues, functions as a chemical communications network for coordinating diverse physiological activities.

Biofluids or biological fluids, can be expelled (like urine or sweat), secreted (like breast milk or bile), drawn with a needle (like blood or cerebrospinal fluid), or formed as a result of a pathological disease (like diabetes) (such as blister or cyst fluid). The term biofluid is used as a noun (as in the aforementioned biofluids) as well as an adjective (as in biofluid dynamics and biofluid mechanics).

Body fluids, often known as bodily fluids or biofluids, are liquids found within the human body. Total body water is around 60% of total body weight in lean healthy adult men; it is often somewhat lower in women (52-55%). The exact amount of fluid to body weight is inversely related to the quantity of body fat.

The complete body of water is split into fluid compartments in a two-to-one ratio between the internal fluid (ICF) compartment (also known as space, or volume) and the extracellular fluid (ECF) compartment (space, volume): There are 28 (28-32) litres inside cells and 14 (14-15) litres outside cells.

Body fluid is the term most often used in medical and health contexts. Modern medical, public health, and personal hygiene practices treat body fluids as potentially unclean.

Blood is a bodily fluid in the circulatory system of humans and other animals that moves metabolic waste products away from cells while delivering vital chemicals such as nutrition and oxygen to them. Blood in the circulatory system is also known as peripheral blood, as are the blood cells it contains.

Blood is made up of blood cells suspended in plasma. Plasma, which makes up 55% of blood fluid, is largely water (92% by volume) and contains proteins, carbohydrates, mineral ions, hormones, carbon dioxide (plasma is the primary medium for excretory product transfer), and blood cells themselves.

Albumin, is the most abundant protein in plasma, and it regulates blood colloidal osmotic pressure. The blood cells consist mostly of red blood cells (also known as

RBCs or erythrocytes), white blood cells (also known as WBCs or leukocytes), and platelets (also called thrombocytes). Red blood cells are the most numerous cells in vertebrate blood. These include haemoglobin, an iron-containing protein that aids in oxygen transport by reversibly binding to this respiratory gas, boosting its solubility in blood. Carbon dioxide, on the other hand, is usually carried extracellularly as a bicarbonate ion in plasma.

The heart's pumping function circulates blood through blood arteries throughout the body. Blood performs many important functions within the body, which includes Supply of oxygen to tissues (bound to haemoglobin, which is carried in red cells), Supply of nutrients such as glucose, amino acids, and fatty acids (dissolved in the blood or bound to plasma proteins (e.g., blood lipids)), Removal of waste such as carbon dioxide, urea, and lactic acid, Immunological functions, including circulation of white blood cells, and detection of foreign material by antibodies, Coagulation, the response to a broken blood vessel, the conversion of blood from a liquid to a semisolid gel to stop bleeding, Messenger functions, including the transport of hormones and the signaling of tissue damage and Regulation of core body temperature

Urine, is a liquid by-product of human and many other animal metabolisms. Urine travels from the kidneys to the urinary bladder via the ureters. Urine is discharged from the body through the urethra as a result of urination.

Many by-products of cellular metabolism, such as urea, uric acid, and creatinine, are nitrogen-rich and must be removed from the circulation. These by-products are excreted from the body through urine, which is the major way for excreting water-soluble compounds. A urinalysis can identify nitrogenous wastes in mammals.

Urine is essential to the nitrogen cycle on Earth. Urine fertilizes the soil and hence aids plant growth in healthy environments. As a result, pee may be utilized as fertilizer.

Adult humans make around 1.4 L of pee per day, with a typical range of 0.6 to 2.6 L per person per day, produced in approximately 6 to 8 urinations per day depending on hydration, activity level, ambient conditions, weight, and the individual’s health. Urine production that is excessive or insufficient requires medical care.

A diet high in protein from meat and dairy, as well as alcohol consumption, can lower urine pH, whereas potassium and organic acids from fruit and vegetable diets can raise the pH and make it more alkaline.

2.4 SWEAT

Sweating is a physiological process that aids in controlling body temperature. Sweating is the expulsion of a salt based fluid from your sweat glands, which is also known as perspiration. Sweating can be brought on by changes in your body temperature, the environment, or your emotional state. Armpits are among the body parts where sweating occurs most frequently. Face; palms of hands; and soles of feet

A healthy level of sweating is a necessary body function. Both insufficient and excessive perspiration might lead to issues. Absence of sweat raises your chance of overheating, which can be harmful. Over sweating may have more negative psychological effects than negative physical effects.

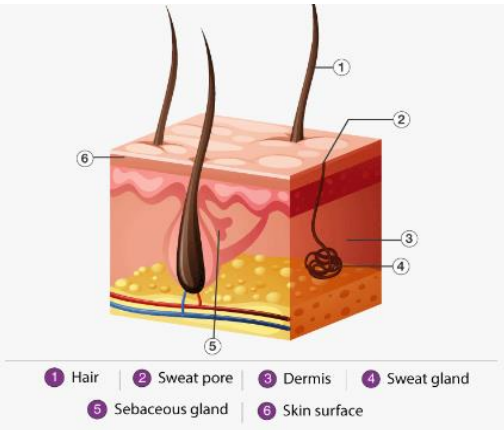


Fig. 2.1 Sweat Gland

HOW SWEATING FUNCTIONS

Eccrine and apocrine are the two different categories of sweat glands.

The eccrine sweat glands -Your body’s eccrine sweat glands, which are dispersed throughout, create an odourless, light sweat.

The apocrine sweat glands – The hair follicles of the following body parts contain the majority of the apocrine sweat glands: scalp, armpits and groyne

These glands secrete a thicker, greasy perspiration with a distinct odour. Body odour develops when the bacteria on your skin reacts with the breakdown of apocrine sweat. Your autonomic nervous system regulates how much you perspire. Your nervous system’s autonomous portion is the one that operates without conscious thought.

Sweating escapes through skin ducts when it’s hot outside or when your body temperature rises as a result of physical activity or a fever. As it evaporates, it cools you off and moisturises the skin on your body. The majority of perspiration is water, although a small percentage contains salt and fat.

Causes of sweating

Sweating is a common part of daily life and is completely normal. But a number of factors can induce excessive perspiration which are *high temperature*, The primary factor causing an increase in perspiration is a higher body temperature or surroundings temperature.

Foods, Additionally, your diet may cause you to sweat. The term “gustatory sweating” refers to this form of perspiration. Spicy foods are one possible trigger.

Medicines and disease, taking medications and having certain conditions, such as cancer, fever and medications to lower fever

Stress and feelings, You may also get a cold sweat from the following feelings and situations, resentment; dread; embarrassment; anxiety; Emotional stress.

Sweat is a biofluid that is accessible to us without any invasion and it doesn’t involve inconvenient method like urine sample collection or so. At least to an extent we can determine the health of electrolytes from the body, based on the electrode potential of the sweat sample without the involvement of diagnostics, advanced or costly choices.

2.4.1 RELATIONSHIP BETWEEN HEALTH AND SWEAT

Multiple scientific disciplines are interested in the complicated biofluid that is human perspiration. Through innovative uses and increased customization of medical interventions, metabolicomics study of sweat promises to enhance screening, diagnosis, and self-monitoring of a variety of illnesses.

A growing body of research on human sweat, or biofluid, is being done in a variety of domains, including dermatology, paediatrics, toxicology, analytical chemistry, infectious illnesses, etc. Currently, chloride sweat testing, which is used to diagnose cystic fibrosis, is the main clinical application of sweat in medicine (CF). The difficulties with sweat collection and the variety and repeatability of tests have limited the use of sweat in medical practise. To characterise the "sweat metabolome" and how it fits into the larger picture of the human metabolome, as well as to determine whether there is a need for wider use of sweat metabolomic testing, further research and standardised protocols are currently needed.

FUNCTIONS OF SWEAT

TEMPERATURE AND FLUID HOMEOSTATIS

Sweating plays a crucial role in controlling the core temperature through water evaporative heat dissipation. This concept is supported by the observation that eccrine sweat generation is under the control of cholinergic and, to a lesser extent, adrenergic innervation, which is principally responsible for blood flow regulation and vasodilation of superficial blood vessels. This system is stimulated by a variety of factors, such as temperature, feelings, mental stimulation, and gustatory stimulation.

SWEAT ELECTROLYTE REGULATION

Sodium is a key component of sweat that has an influence on the fluid balances in humans. Some people can sweat off as much as 4-6 g of sodium each day, which is comparable to 12–15 g of sodium chloride, especially if they are working in moderately hot settings, when the concentrations of sodium in sweat can range from 20–100 mmol/L. Through a variety of well-known anion exchangers, including Na^+/K^+-ATPases (on basolateral membranes) and cystic fibrosis transmembrane conductance regulators, eccrine gland duct cells reabsorb various ions, including Na^+ and Cl. It has been shown that sweat Na^+ and Cl concentrations rise with ageing until ages 12 to 19, after which they stabilise.

Since sweat has a pH range of 4-6.8 and is more acidic than plasma, acid-base homeostatic processes are likely involved in sweating. The pH of sweat rises to top limits of around 6.8, which is still more acidic than plasma, with higher flow rates during activity or at temperatures exceeding 31 °C.

SKIN PROTECTION

Additionally, sweat has lubricating, water-proofing, antibacterial, and skin barrier-promoting qualities that help skin act as the body's first line of defence against a variety of environmental irritants. In extremely hot weather, apocrine and sebaceous glands' lipid-rich secretions can emulsify the eccrine glands' perspiration to form a hydrolipid layer that is less likely to evaporate. This is considered crucial in preventing dehydration. Since sweat has a more solid lipid composition in lower temperatures, sources of unwelcome moisture like rain or snow should theoretically be more successfully rejected by its covering of the skin and hair.

IMMUNE SYSTEM

Sweat may influence immune-mediated communications in both positive and negative ways, according to the theory. For instance, perspiration is well-known for aggravating atopic dermatitis (AD) lesions and is linked to increased itching (pruritus), which is linked to higher expression of IL-31 (a more recent member of the IL-6 family of cytokines) in tissue samples of worsened AD lesions.

METABOLIC AND INFECTIOUS DISEASES

Sweating serves as a helpful clinical indication for a variety of illnesses due to the changes in sweat that are associated with various pathological disorders. Both excessive sweating (hyperhidrosis) and insufficient sweating (hypohidrosis), whether local or systemic, may be early indicators of illnesses or ailments that affect the entire body. Preeclampsia is associated with impaired overall perspiration, which is assumed to be due to a reduction in the plasma clearance of vasoactive amines.

LIPID HOMEOSTATIS

Dietary changes are associated with variations in sebum production. While a high-fat diet promotes sebum production in the context of psoriasis, caloric restriction lowers it in the context of obesity. Triglycerides, cholesterol, and related esters are excreted in greater quantities in sebum when calorie consumption is increased.

CHAPTER-3

HARDWARE IMPLEMENTATION

Components used,

Ion sensitive electrode, a device that would collect the electrical signals from sweat. This can be implemented by glass electrode.

Sensor, it collects the data from the electrode and transmits. This can be implemented by using Analog pH Sensor.

Micro-Controller, used to process the analog data into digital and also capable of transmitting data to the user using Wi-Fi module. This can be achieved by ESP32.

Power Supply, used to supply power to the Board and we are using a 5V adapter.

BNC Probe, It is a guided media that will connect the Ion Selective Electrode to the sensor.

Arduino IDE, an Integrated Development Environment for developing the source code, compilation and uploading the code into the micro-controller.

Blynk and Thingspeak, a user interface which gives information about sweat pH via mobile applications.

Before we discuss components in further sections, discussing about arduino IDE is essential

DISCUSSION - ARDUINO IDE

Integrated Development Environment "IDE" For Arduino

Introduction to Arduino IDE

IDE stands for "Integrated Development Environment" :it is an official software introduced by Arduino.cc, that is mainly used for editing, compiling and uploading the code in the Arduino Device.

Almost all Arduino modules are compatible with this software that is an open source and is readily available to install and start compiling the code on the go.

In this article, we will introduce the Software, how we can install it, and make it ready for developing applications using Arduino modules.

Arduino IDE Definition

Arduino IDE is an open source software that is mainly used for writing and compiling the code into the Arduino Module.
It is an official Arduino software, making code compilation too easy that even a common person with no prior technical knowledge can get their feet wet with the learning process.
It is easily available for operating systems like MAC, Windows, Linux and runs on the Java Platform that comes with inbuilt functions and commands that play a vital role for debugging, editing and
compiling the code in the environment.
A range of Arduino modules available including Arduino Uno, Arduino Mega, Arduino Leonardo, Arduino Micro and many more. This IDE is compatible for any kind of boards by installing relevant boards from the board manager.
Each of them contains a microcontroller on the board that is actually programmed and accepts the information in the form of code.
The main code, also known as a sketch, created on the IDE platform will ultimately generate a Hex File which is then transferred and uploaded in the controller on the board.
The IDE environment mainly contains two basic parts: Editor and Compiler where former is used for writing the required code and later is used for compiling and uploading the code into the given Arduino Module.
This environment supports both C and C++ languages.
This figures below describes the IDE labels and functionalities.

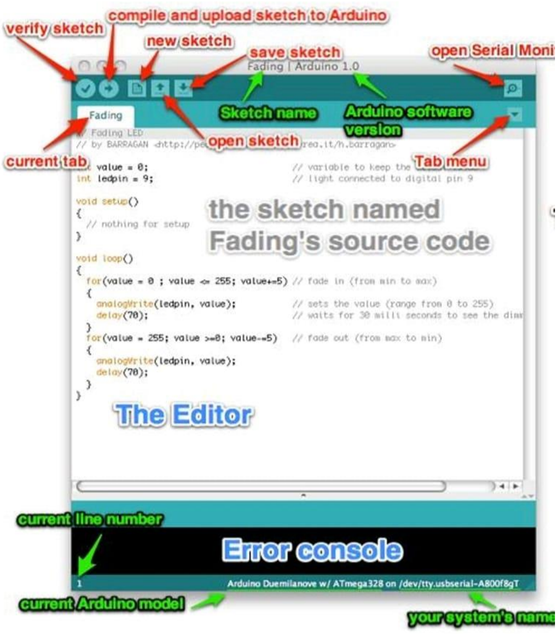


Fig. 3.1 Arduino IDE - labeled

Fig. 3.2 Menu bar – Arduino IDE

The check mark appearing in the circular button is used to verify the code. Click this once you have

The check mark appearing in the circular button is used to verify the code. Click this once you have written your code.
The arrow key will upload and transfer the required code to the Arduino board.
The dotted paper is used for creating a new file.
The upward arrow is reserved for opening an existing Arduino project. * The downward arrow is used to save the current running code.
The button appearing on the top right corner is a Serial Monitor – A separate pop-up window that acts as an independent terminal and plays a vital role for sending and receiving the Serial Data. You can also go to the Tools panel and select Serial Monitor pressing Ctrl+Shift+M all at once will open the Serial Monitor. The Serial Monitor will actually help to debug the written Sketches where you can get a hold of how your program is operating. Your Arduino Module should be connected to your computer by USB cable in order to activate the Serial Monitor.
* You need to select the baud rate of the Arduino Board you are using right now. For my Arduino Uno Baud Rate is 9600, as you right the following code and click the Serial Monitor, the output will show as the image below.

- The check mark appearing in the circular button is used to verify the code. Click this once you have
- The arrow key will upload and transfer the required code to the Arduino board.
- The dotted paper is used for creating a new file.

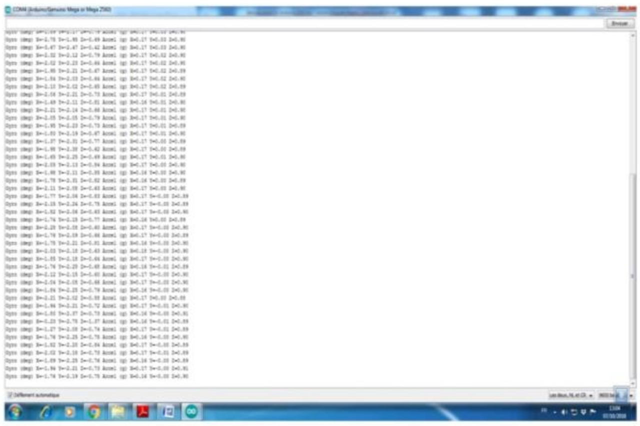


Fig. 3.3 Serial Monitor

Serial Monitor is usually similar to terminal, where the results of desired outputs can be measured and verified in it.

Uploading

Before uploading your sketch, you need to select the correct items from the **Tools > Board** and **Tools > Port** menus. Once you've selected the correct serial port and board, press the upload button in the toolbar or select the Upload item from the Sketch menu. The Arduino Software (IDE) will display a message when the upload is complete, or show an error.

Libraries

Libraries are very useful for adding the extra functionality into the Arduino Module. There is a list of
libraries you can add by clicking the Sketch button in the menu bar and going to Include Library.

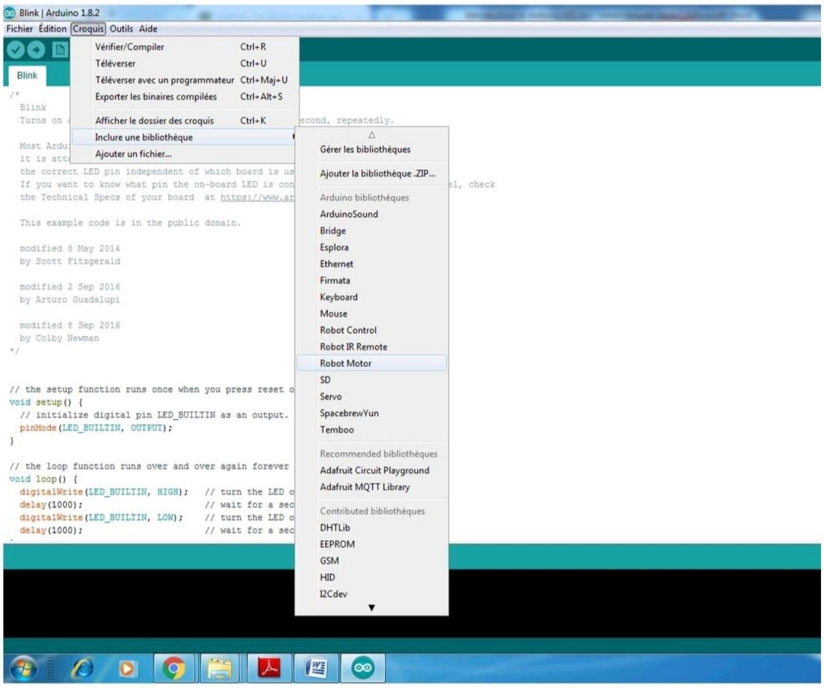


Fig. 3.4 Inclusion of Libraries in IDE

As you click the Include Library and Add the respective library it will on the top of the sketch with a #include sign. Suppose including the EEPROM library, Temperature sensors DHT11/22, LCD or I2C
library it will appear on the text editor as
#include <EEPROM.h>.
#include <dht.h>
#include <I2Cdev.h>
Most of the libraries are preinstalled and come with the Arduino software. However, we can also download them from the external sources. Making Pins As Input or Output The digitalRead and digitalWrite commands are used for addressing and making the pins as an
input and output respectively. These commands are text sensitive.
digitalWrite starting with small “d” and write with capital “W”. Writing it down with Digitalwrite or
digitalwritewon’t be calling or addressing any function.
Selecting Board of Arduino
In order to upload the sketch, we need to select the relevant board we are using and the ports for that operating system. As we click the Tools on the Menu, it will open like the figure below.

Just we go to the “Board” section and select the board we would like to work on. Similarly, COM1,

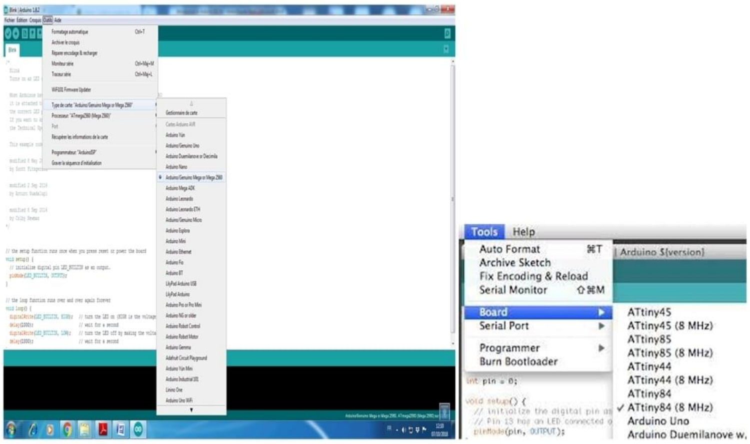


Fig. 3.5 Inclusion of boards in IDE

COM2, COM4, COM5, COM7 or higher are reserved for the serial and USB board. we can look for the USB serial device in the ports section of the Windows Device Manager. Figure shows an example.

*After correct selection of both board and serial port ,click the verify and then upload button appearing in the upper left corner of the six button section or you can go to the Sketch section and press verify/compile and then upload.

- After correct selection of both Board and Serial Port, click the verify and then upload button appearing
- The sketch is written in the text editor and is then saved with the file extension .ino.

*As we upload the code , TX and RX LEDs will blink on the board, indicating the desired program is running successfully.

- As we upload the code, TX and RX LEDs will blink on the board, indicating the desired program is

Declarations

Variables

Whenever you’re using Arduino, you need to declare global variables and instances to be used later on. In a nutshell, a variable allows you to name and store a value to be used in the future. For example, you would store data acquired from a sensor in

order to use it later. To declare a variable you simply define its type, name and initial value.
It's worth mentioning that declaring global variables isn't an absolute necessity. However, it's advisable that you declare your variables to make it easy to utilize your values further down the line.
Whenever you're using Arduino, you need to declare global variables and instances to be used later on. In

Instances

In software programming, a class is a collection of functions and variables that are kept together in one place. Each class has a special function known as a constructor, which is used to create an instance of the class. In order to use the functions of the class, we need to declare an instance for it.

Setup()

Every Arduino sketch must have a setup function. This function defines the initial state of the Arduino
upon boot and runs only once.
Here we'll define the following:
Pin functionality using the pinMode function
Initial state of pins
Initialize classes
Initialize variables
Code Logic

Loop()

The loop function is also a must for every Arduino sketch and executes once setup() is complete. It is the main function and as its name hints, it runs in a loop over and over again. The loop describes the main logic of your circuit.

HARDWARE IMPLEMENTATION

The flow of the block diagram emphasises that the collected sweat sample is given to the pH sensor that is a combination a glass electrode and a microcontroller(pH 4502C) and gives it's analog output to the ESP32 which processes, converts analog to digital data and sends information as well as alerts to the user through WiFi onto the mobile applications namely Blynk and Thingspeak.

SET UP IN PROTEUS FROM THE AVAILABLE COMPONENTS IN LIBRARIES

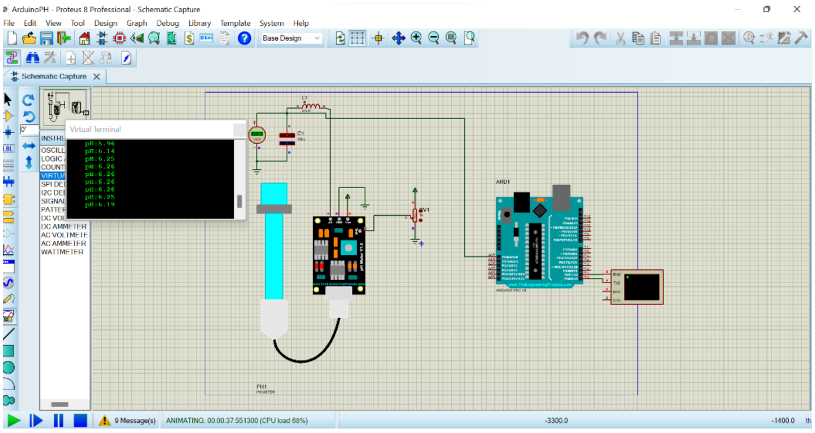


Fig. 3.17 software simulation

Before implementing on hardware, we have verified the output using proteus. It is described in appendix in detailed.

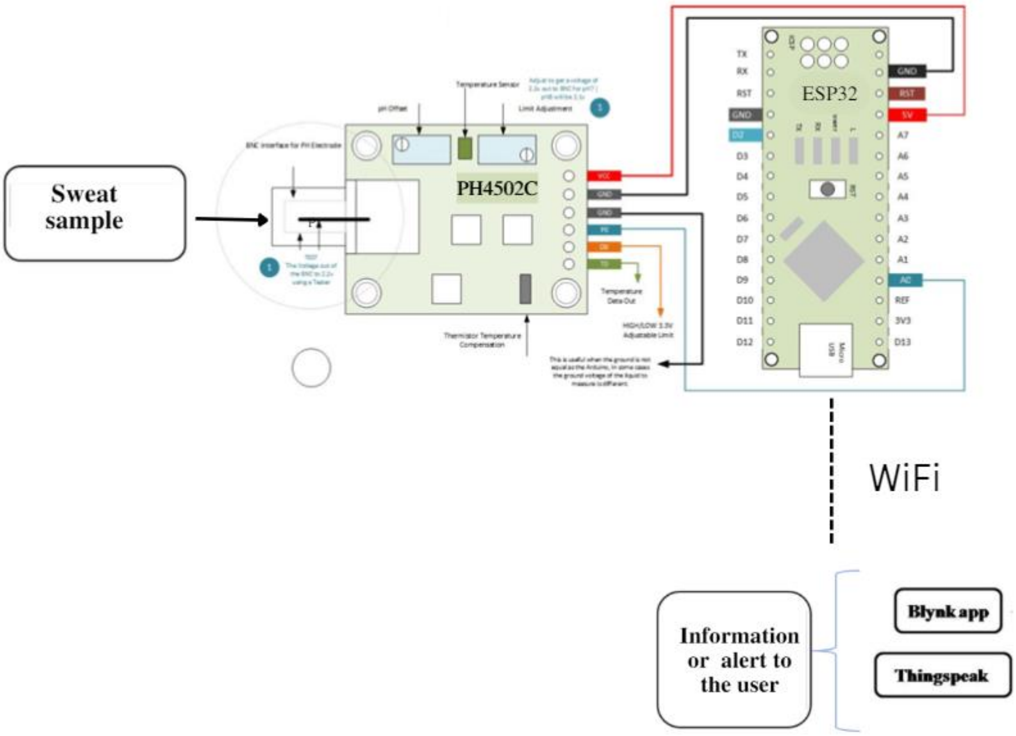


Fig. 3.8 Block Diagram

The pH sweat analyser’s functioning is described in the flow chart above. The electrode probe is dipped into the sweat sample and allowed to settle there for some time. By using a reference electrode and the electrolysis principle, the electrode probe begins separating the concentration of minerals in the sample and creating a potential difference of that solution. With the aid of a tiny resistance, the pH sensor transforms the created potential difference into an analogue electrical output. The output from pin A0 is this analogue electrical signal.

Now, we wire up pin A0 from the pH sensor to pin "Vp" in the ESP32 microcontroller board in order to convert the electrical signal from analogue to digital using the ESP32 board's analogue to digital converter.

Next, we attempt to connect the ESP32 board to the IoT clouds. We use the Thingspeak and Blynk IoT mobile applications as our IoT clouds, respectively, to record and save the pH value of our sweat as well as to get notification alerts.

We use the Wi-Fi Module integrated into the ESP32 microcontroller to interface the microcontroller and the two IoT clouds in order to do this. The ESP32 is in STA(Station mode) that utilizes an existing wifi to transmit the data over it.

In the further chapters and sections, we will discuss about each block and the flow as per the diagram above.

3.1 SWEAT COLLECTION METHODS

Sweat for analysis can be produced by,

Thermal stress, either by placing the subject in a room at 90 F for one to two hours or by encasing the trunk and extremities in a plastic bag.

Heat trapping clothes, Spending some time in sauna – steam sauna or infrared sauna Strenuous workout – Exercise, Gym Activities, Running, Walking and other.

Iontophoresis - Several active research groups rely on a chemical pilocarpine iontophoresis method of inducing sweat. This method takes advantage of the bioelectric properties of skin which allow the application of low intensity electrical current (i.e. 1.5 mA) for 5 min. The resulting opposition offered by skin to this electrical current, called bio-impedance, is present in intra-and extra-cellular fluids and the capacitive reactance of cell membranes. For a topically applied chemical such as pilocarpine (0.5% pilocarpine nitrate solution), a drug with cholinergic parasympathomimetic activity which aims to stimulate primarily the muscarinic receptors of eccrine sweat glands, to be absorbed through human skin, the electrical current must overcome the bio-impedance imposed on its flow to reach the target tissue of sweat glands with sufficient intensity. This bio-impedance can be influenced by a range of factors, some of which are electricity source-dependent such as the distance between electrodes positioning, pulsed direct current vs constant direct current source, and size and content of iontophoresis electrodes (typically containing 70% copper, 30% zinc with diameter of 30 mm).

Exercise, temperature, stress, psychological state, relative humidity, hormonal and sympathetic/parasympathetic nervous system parameters, diet, skin colonisation factors, xenobiotics exposure – both purposeful and non-purposeful – can influence sweat volumes and content.

3.2 PH SENSOR – PH4502C

3.2.1 General

The Model PHE-45P pH Sensor measures the pH of aqueous solutions in industrial and municipal process applications. It is designed to perform in the harshest of environments, including applications that poison conventional pH sensors. All seals are dual o-ring using multiple sealingmaterials. The sensor is designed for use with the Omega PHTX-45 Monitor/Analyzer.

SENSOR FEATURES

A high volume, dual junction salt bridge is utilized to maximize the in-service lifetime of the sensor. The annular junction provides a large surface area to minimize the chance of fouling. Large electrolyte volume and dual reference junctions minimize contamination of the reference solution. The salt bridge is replaceable.

The reference element of the sensor is a second glass pH electrode immersed in a reference buffer solution. This glass reference system greatly increases the range of sensor applications.

An integral preamplifier is encapsulated in the body of the sensor. This creates a low impedance signal output which ensures stable readings in noisy environments and increases the maximum possible distance between sensor and transmitter to 3,000 feet (914 meters).

System diagnostics warn the user in the event of electrode breakage, loss of sensor seal integrity or integral temperature element failure.

Pt1000 RTD. The temperature element used in the PHE-45P sensor is highly accurate and provides a highly linear output.

Fig. 3.9 Analog pH Sensor

PH Probe Sensor Pinout

TO – Temperature output

DO – 3.3V Output (from pH limit pot)

PO – PH analog output

Gnd – Ground for PH probe

Gnd – Ground for board

VCC – 5V DC

POT 1 – Analog reading offset (Nearest to BNC connector)

POT 2 – PH limit setting

PH probe module Offset and how to use it.

This board have the ability to supply a voltage output to the analogue board that will represent a PH value just like any other sensor that will connect to an analog pin. Ideally, we want a PH 0 represent 0v and a PH of 14 to represent 5V.

This board by default have PH 7 set to 0V (or near it, it differs from one PH probe to another, that is why we have to calibrate the probe.

This means that the voltage will go into the minuses when reading acidic PH values and that cannot be read by the analog Arduino port. The offset pot is used to change this so that a PH 7 will read the expected 2.5V to the NodeMCU analog pin, the analog pin can read voltages between 0V and 5V hence the 2.5V that is halfway between 0V and 5V as a PH 7 is halfway between PH 0 and PH 14,

You will need to turn the offset potentiometer to get the right offset, The offset pot is the blue pot nearest to the BNC connector. To set the offset is easy. First, you need to disconnect the probe from the circuit and short circuit the inside of the BNC connector with the outside to simulate a neutral PH (PH7). A piece of wire is taken, strip both sides, wrap the one side around the outside of the BNC connector and push the other side into the BNC hole. This short-circuit represents about a neutral PH reading of 7.

There are two ways to do the adjustment. If you have a multi-meter handy you can measure the value of the PO pin and adjust the offset potentiometer until PO measures 2.5V. Just write the calibration code in Arduino IDE and select respective board and COM port, open serial monitor and view the reading there. All this sketch does is to print the volts it receives from the analog pin and print it to the serial monitor. It of course first changes the digital value to volts to make it easier. Now simply turn the offset pot until it is exactly 2.5V.

3.2.2 SPECIFICATIONS

Heating voltage: 5+-0.2V (AC - DC)

Working current: 5-10mA

The detection concentration range: PH0-14

The detection range of temperature: 0-80 centigrade

The response time: ≤ 5S

Stability time: ≤ 60S

Power consumption: ≤ 0.5W

The working temperature: -10-50 centigrade (the nominal temperature 20 centigrade)

Working humidity: 95%RH (nominal humidity 65%RH)

Service life: 3 years

Size: 42mm x 32mm x 20mm

The output: analog voltage signal output

PINOUT

TO – Temperature output

DO – 3.3V pH limit trigger

PO – PH analog output

Gnd – Ground for PH probe

Gnd – Ground for board

VCC – 5V DC

POT 1 – Analog reading offset (Nearest to BNC connector)

POT 2 – PH limit setting

PH limit setting

There is another pot that acts like a limit switch. Basically, the D0 pin on the sensor board will supply 3.3V to the pin until a preset PH value (that you set with the limit pot) is reached, at this point a red LED will light up and the pin will go down to about 0V.

Connecting and calibrating the PH probe.

The hard part is over and this offset does not have to be set again, even if you change PH probes. We have PH probes available here: PH probe Electrode BNC connector.

Here are couple of things to know about PH probes:

The probes readings change over time and need to be calibrated every now and again to make sure the value is still the same and be adjusted if it did change.

You need at least one PH buffer solution to calibration your PH probe. They are available at many different PH values, A buffer solution of 6.86 and 4.01 is most common as it covers the range of most applications. If you are only going to use one buffer solution make sure its value is near the value range you will use in your normal tests – if it is pool water a buffer solution of 6.86 is usually near enough.

Buffers come in pre-made solutions or as a powder. I prefer the powder because it is cheaper and does not have an expiration date. The powder is easy to make up as well, I suppose it depends on the power you will use, the one I use you add the powder to 250ml distilled water and stir until all powder is dissolved. It will last about a month once you added water to it.

A PH probe takes some time to get to the right value, allow it to be in the liquid you want to measure for at least two minutes or longer, it does not mean it will be stable at one ph value, it will jump around a bit between 3 or 4 values but on the last digit, for example, between 6.84 – 6.88

PH values differ in different temperatures, although that might sound cumbersome, in the temperature range between 10 – 30 degrees Celsius the PH does not differ and from 30 degrees Celsius it goes up with about a pH of 0.01 to 50 degrees Celcius that is about 0.06. In most uses, it will be below 30 degrees Celsius and temperature does not have to be calculated in. Hook up your PH probe after you removed the wire you used to short-circuit the BNC connector

We have followed software method to calibrate the electrode probe, the source code used during calibration is in the further section. We have also verified using the hardware method, and checked the analog output using the multi-meter.

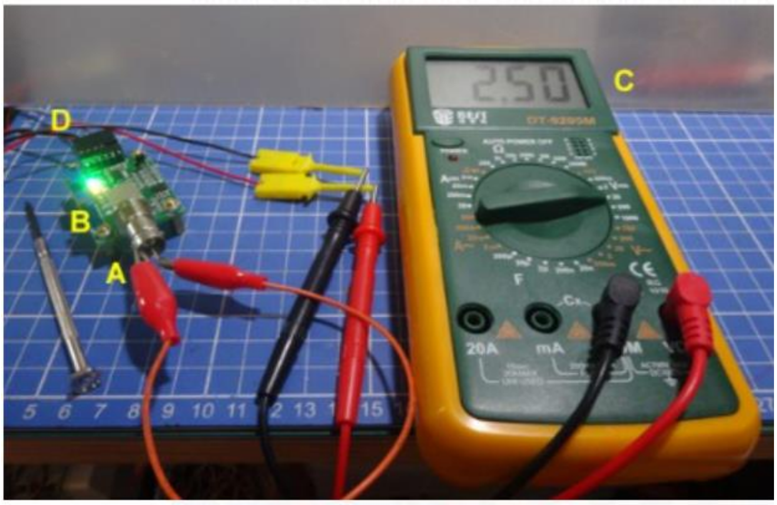


Fig. Multimeter Verification

RESULT after Calibration

Real-time Verification of solutions with certain specific pH value.

pH Buffer Solution of pH : 3 ± 0.2

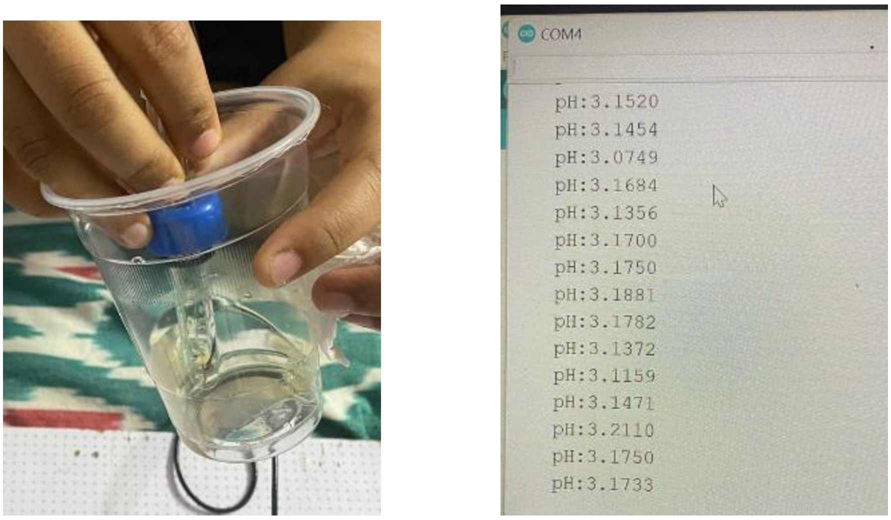


Fig.3.10 pH 3 Buffer Solution – pH verification

Soap Water of pH - 10 ± 0.2

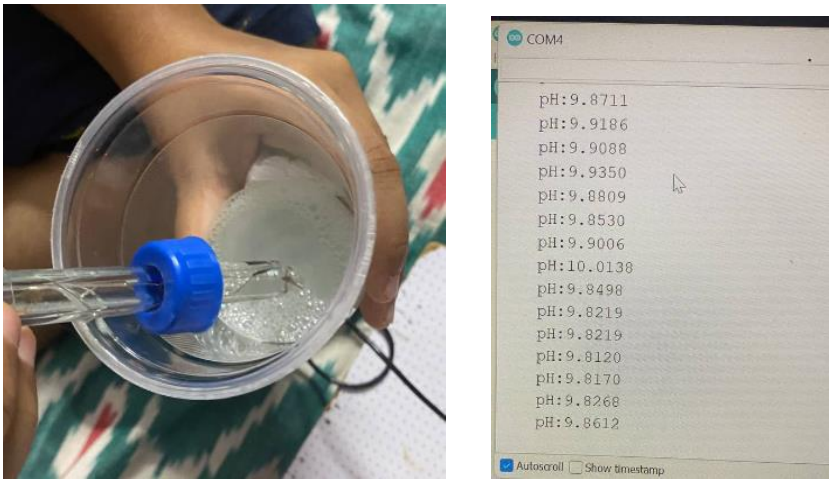


Fig. 3.11 Soap Water – pH verification

Water with pH 7 ± 0.2

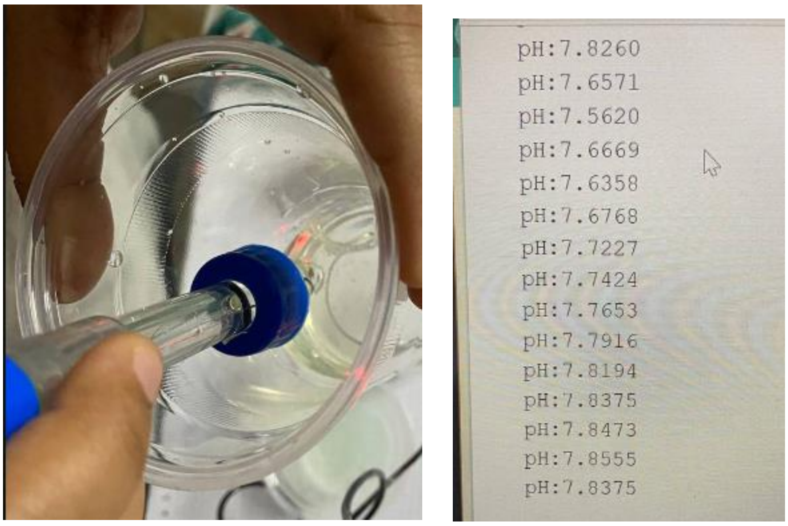


Fig. 3.12 Water – pH verification

3.3 ESP32

The ESP32 is a series of chip microcontrollers developed by Espressif.

Mainly because of the following features they are popular:

Low-cost, you can get an ESP32 starting at $6, which makes it easily accessible to the general public;

Low-power, the ESP32 consumes very little power compared with other microcontrollers, and it supports low-power mode states like deep sleep to save power;

Wi-Fi capabilities, the ESP32 can easily connect to a Wi-Fi network to connect to the internet (station mode), or create its own Wi-Fi wireless network (access point mode) so other devices can connect to it—this is essential for IoT and Home Automation projects—you can have multiple devices communicating with each other using their Wi-Fi capabilities;

Bluetooth, the ESP32 supports Bluetooth classic and Bluetooth Low Energy (BLE)—which is useful for a wide variety of IoT applications;

Dual-core, most ESP32 are dual-core they come with 2 Xtensa 32-bit LX6 microprocessors: core 0 and core 1.

Rich peripheral input/output interface the ESP32 supports a wide variety of input (read data from the outside world) and output (to send commands/signals to the outside world) peripherals like capacitive touch, ADCs, DACs, UART, SPI, I2C, PWM, and much more.

Compatible with the Arduino *"programming language"*, those that are already familiar with programming the Arduino board, you'll be happy to know that they can program the ESP32 in the Arduino style.

Compatible with *MicroPython*, you can program the ESP32 with MicroPython firmware, which is a re-implementation of Python 3 targeted for microcontrollers and embedded systems.

3.3.1 SPECIFICATIONS

Wireless connectivity WiFi, 150.0 Mbps data rate with HT40 (IEEE 802.11 b/g/n)

Bluetooth, BLE (Bluetooth Low Energy) and Bluetooth Classic

Processor, Tensilica Xtensa Dual-Core 32-bit LX6 microprocessor, running at 160 or 240 MHz

ROM, 448 KB (for booting and core functions)

SRAM, 520 KB (for data and instructions)

RTC fast SRAM, 8 KB (for data storage and main CPU during RTC Boot from the deep-sleep mode)

RTC slow SRAM, 8KB (for co-processor accessing during deep-sleep mode)

Embedded flash, flash connected internally via IO16, IO17, SD_CMD, SD_CLK, SD_DATA_0 and SD_DATA_1 on ESP32-D2WD and ESP32-PICO-D4.

Low Power, ensures that you can still use ADC conversions, for example, during deep sleep.

Peripheral Input/Output, peripheral interface with DMA that includes capacitive touch.

ADCs (Analog-to-Digital Converter), DACs (Digital-to-Analog Converter)

I²C (Inter-Integrated Circuit), UART (Universal Asynchronous Receiver/Transmitter), SPI (Serial Peripheral Interface)

I²S (Integrated Interchip Sound), RMII (Reduced Media-Independent Interface)

PWM (Pulse-Width Modulation), Security, hardware accelerators for AES and SSL/TLS. The pinout of the ESP32 is described as below.

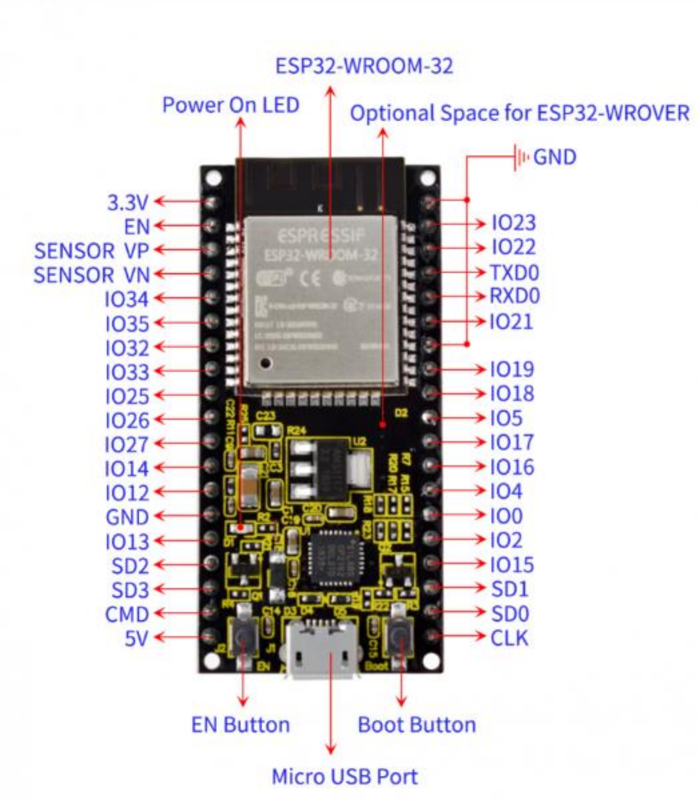


Fig. 3.13 ESP32 PIN OUT

Wifi

ESP32 Wi-Fi Feature List

The following features are supported:

- 4 virtual Wi-Fi interfaces, which are STA, AP, Sniffer and reserved.
- Station-only mode, AP-only mode, station/AP-coexistence mode
- IEEE 802.11b, IEEE 802.11g, IEEE 802.11n, and APIs to configure the protocol mode
- WPA/WPA2/WPA3/WPA2-Enterprise/WPA3-Enterprise/WAPI/WPS and DPP
- AMSDU, AMPDU, HT40, QoS, and other key features
- Modem-sleep
- The Espressif-specific ESP-NOW protocol and Long Range mode, which supports up to **1 km** of data traffic
- Up to 20 MBit/s TCP throughput and 30 MBit/s UDP throughput over the air
- Sniffer

Both fast scan and all-channel scan
Multiple antennas
Channel state information

Station (STA) Mode

The ESP8266 that connects to an existing WiFi network (one created by your wireless router) is called Station (STA)

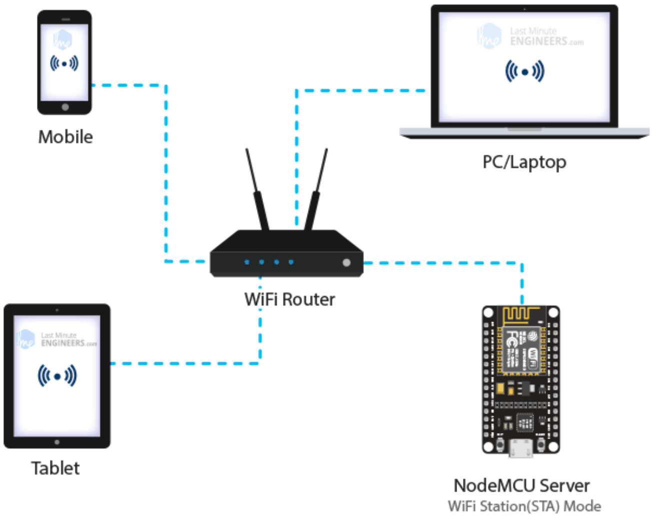


Fig. operation of ESP32 in STA mode

In STA mode ESP8266 gets IP from wireless router to which it is connected. With this IP address, it can set up a web server and deliver web pages to all connected devices under existing WiFi network. Below is a “big scenario” which describes some small scenarios in station mode:

ESP32 Wi-Fi Station General Scenario

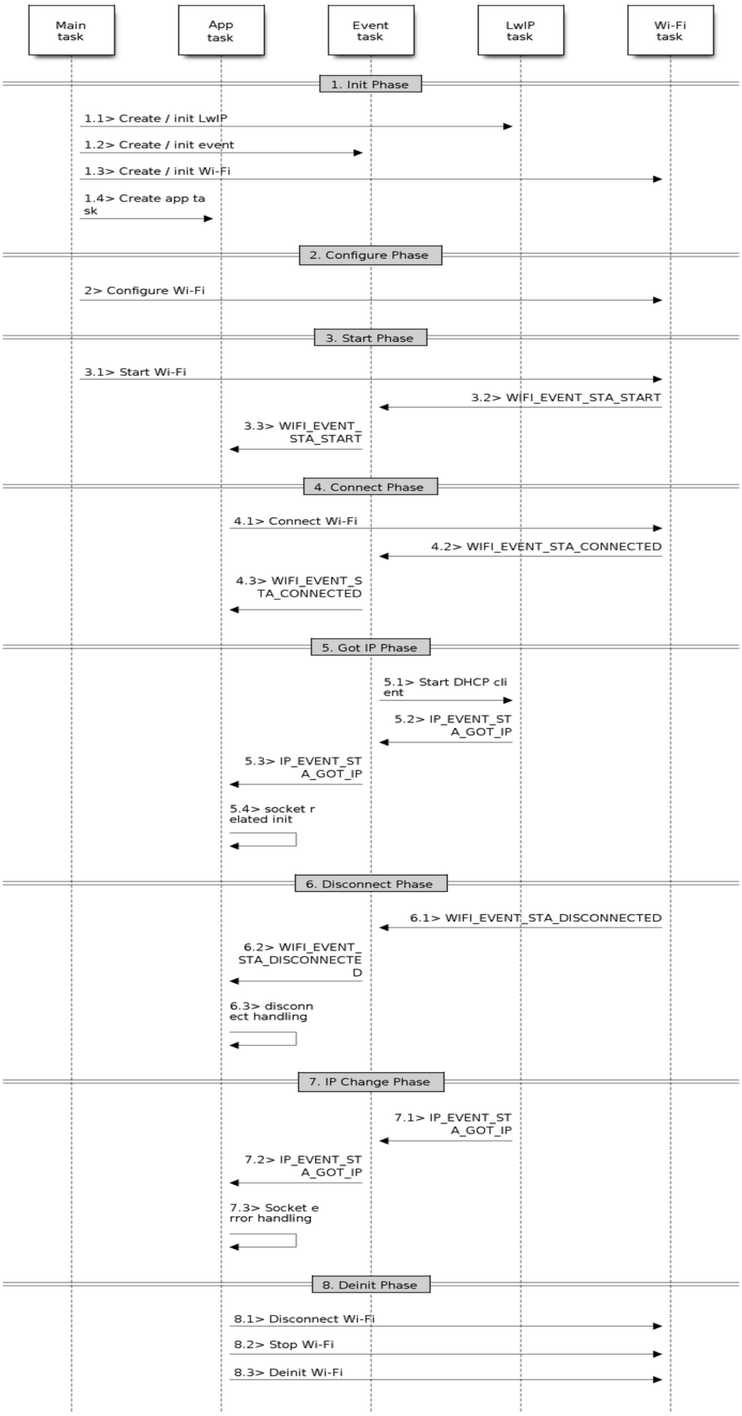


Fig. Sample Wi-Fi Event Scenarios in Station Mode

ESP32 Architectural Block diagram

Below is the Architectural block diagram of ESP32 which shows all the functional blocks of ESP32 SOC.

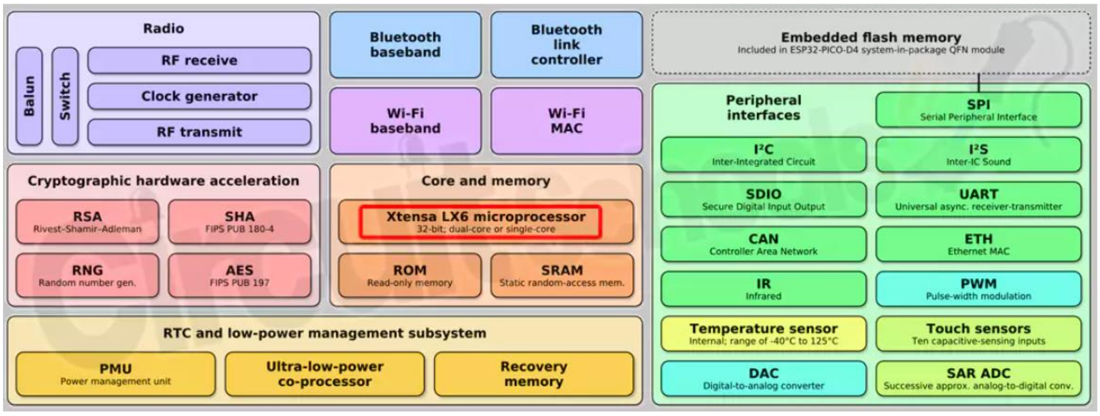


Fig. ESP32 Architectural Block Diagram

WIRELESS CONNECTIVITY

The ESP32 SoC chip has WiFi connectivity, being compatible with 802.11 b / g / n in the 2.4GHz band, reaching speeds of up to 150 Mbits/s. It also includes Bluetooth communication compatible with Bluetooth v4.2 and *Bluetooth Low Energy* (BLE).

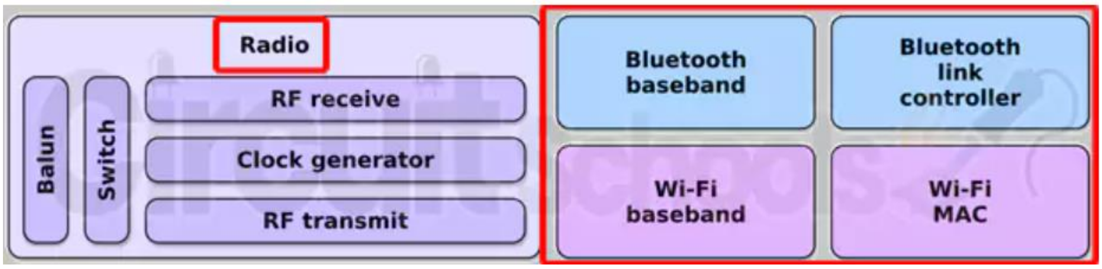


Fig. Wireless Connectivity

The radio block is closely tied to the wireless communication modules . In fact, this is the one that actually transmits and receives the information.
That is, it takes the digital data from the WiFi and Bluetooth modules and converts them into electromagnetic signals that travel through the air to communicate with your mobile phone or your *router* .
It also performs the reverse operation: translate the electromagnetic waves generated by other devices into digital data that the WiFi and Bluetooth modules are capable of interpreting.

CORE

As we have already mentioned that the ESP32 has dual core low-power Tensilica Xtensa 32-bit LX6 microprocessors.

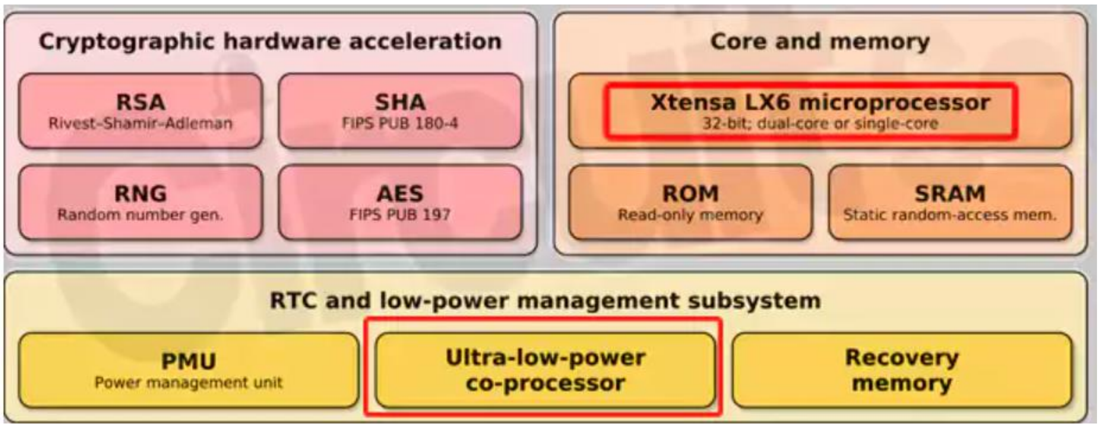


Fig. Core

As you can observe from the above core block image, it has an ultra-low-power co-processor that is used to perform analog-digital conversions and other operations while the device is operating in deep sleep low-power mode. In this way, a very low consumption by the SoC is achieved.

It is important to note that these processors offer great typical advantages of a digital signal processor:

- Operating frequency : 240 MHz (executes instructions 15 times faster than an Arduino UNO board)
- It allows to perform operations with real numbers (numbers with commas) very efficiently.
- Allows you to multiply large numbers instantly.

MEMORY

In most of the microcontrollers based on Arduino, there are three types of memories

- Program memory : to store the sketch.
- SRAM memory : to store the variables that are used in the code.
- EEPROM memory : to store variables that do not lose their value even when the device is turned off.

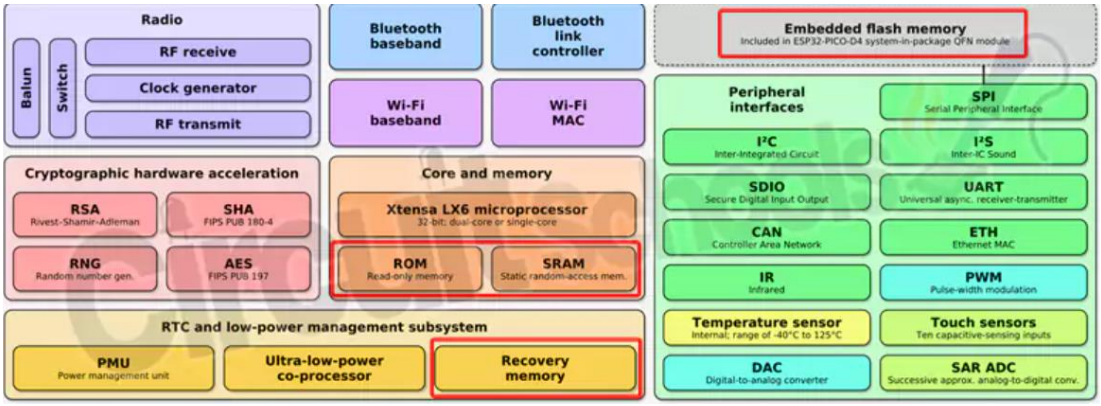


Fig. Memory

In ESP32 this does not happen, in fact there are more types of memories that are usually classified into internal and external .The internal memories are those that are already included in the SoC, and the external are those that can be added to expand the capacity of the system .Many ESP32- based development boards add external memory for a better performing system.

ESP32 Internal memories and their functions

ROM memory (448 KiB) : this memory is write-only, that is, you cannot reprogram it. This is where the codes that handle the Bluetooth stack , the Wi-Fi physical layer control, some general-purpose routines, and the bootloader to start the code from external memory are stored .

Internal SRAM memory (520 KiB) : this memory is used by the processor to store both data and instructions. Its advantage is that it is much easier for the processor to access than the external SRAM.

RTC SRAM (16 KiB) : this memory is used by the co-processor when the device operates in deep sleep mode .

Efuse (1 Kilobit) : 256 bits of this memory are used by the system itself and the remaining 768 bits are reserved for other applications.

Flash embedded (Embedded flash) : This memory is where our application code is stored. The amount of memory varies depending on the chip used:

- 0 MB (chips ESP32-D0WDQ6, ESP32-D0WD, ESP32-S0WD)
- 2 MB (chip ESP32-D2WD)
- 4 MB (Chip ESP32-PICO-D4)

For ESP32s that do not have embedded memory or simply when memory is insufficient for your application, it is possible to add more memory externally :

Up to 16 MB of external flash memory can be added . This way you can develop more complex applications.

It also supports up to 8 MB of external SRAM memory .

Therefore, it is difficult for you to find yourself limited in memory when implementing an application using this platform.

3.3.2 PURPOSE

The ESP32 is the ESP8266 successor. It adds an extra CPU core, faster Wi-Fi, more GPIOs, and supports Bluetooth 4.2 and Bluetooth low energy. Additionally, the ESP32 comes with touch-sensitive pins that can be used to wake up the ESP32 from deep sleep, a built-in hall effect sensor, and a built-in temperature sensor (recent versions of the ESP32 don't come with a built-in temperature sensor anymore).Both boards are cheap, but the ESP32 costs slightly more. Since the communication to the user, with a WiFi supported device is necessary and for the advancement of the features in ESP32 than ESP8266 with good speed was also necessary. Hence why, choosing ESP32 over any other microcontroller board was essential.

3.4 POWER SUPPLY

3.4.1 SPECIFICATIONS

One of the most widely used power sources in use today is the 5V power supply (also known as the 5VDC power supply). Transformators, diodes, and transistors are typically used in combination to convert a 50VAC or 240VAC input into a 5VDC output.

Specifications:

Input - 100-240 VAC 50/60Hz

Category - Switch Mode Power Adaptor (SMPS)

Output Type - DC

Output - 5Volts 2Amp

3.5 ELECTRODE PROBE

pH probes have two electrodes (a sensor electrode and a reference electrode) that detect the hydrogen-ion activity in a solution. The ion exchange produces a voltage, which the pH metre measures and converts into a legible pH value.

The interaction between hydrogen and hydroxide ions in a water-based solution is measured by pH (potential of Hydrogen). An acid is a solution with a high level of hydrogen-ion activity. A base, on the other hand, is a solution with a significant degree of hydroxide ion activity.

pH probes are crucial for detecting pH in a variety of sectors, which is why there are numerous pH sensors for different purposes.

pH PROBE WORKING

Most people are acquainted with using litmus paper to determine the pH of a solution. Without considering the hydrogen ion concentration, litmus paper changes a distinct colour matching to the pH chart; however, a pH metre must detect the hydrogen ion concentration using a pH probe.

A pH metre measures the electrical potential (voltage) produced by the solution being tested, and the potential difference is used to calculate the pH. Because an acidic solution contains more positively charged hydrogen ions than an alkaline solution, it has a higher electrical potential to create an electrical current.

A pH metre is made up of three parts: the metre (moving-coil or digital), a reference pH electrode, and a pH probe that is put into the fluid being evaluated.

Inside the body of the majority of pH probes are two electrodes: a measuring electrode (glass electrode) and a reference electrode. The glass electrode includes a reference electrolyte (often potassium chloride) with a neutral pH of 7, and hence a precise number of hydrogen ions.

The pH electrode in the glass electrode measures the difference in pH between the pH electrode and the fluid being tested. The electrode achieves this by detecting the voltage differential between the electrode and the solution's hydrogen ions. We already know the pH value of the glass electrode composition, so this is a simple calculation.

pH ELECTRODE WORKING

Although there are many different types of pH electrodes available for use in both industrial and scientific settings, they are often composed of glass, making them brittle and necessitating hydration. The pH probe storage solution is why we supply every pH probe in a plastic soaking bottle.

The original pH electrodes were made of silver/silver chloride (Ag/AgCl) half-cells inside of glass bulbs filled with a strong electrolyte, and silver wire that made contact with the external solution.

Although the basic operation of pH electrodes has not changed significantly, combination electrodes and double junction electrodes are now more often utilised.

COMBINATION ELECTRODE

The most typical electrode found in pH probes is a combination electrode, which measures both surfaces of a glass electrode. The pH metre, the external solution being measured, and the internal solutions (for example, potassium chloride) of the electrodes must all be connected in a closed circuit for pH probes to detect potentials.

The internal electrode receives the signal when the electrode is immersed in the test solution and detects the positive charge of the hydrogen ions, measured in millivolts (mV). The electrode cable that is attached to the pH metre receives the electrical signal from the electrode cable through the silver wire within the pH probe.

COMPONENTS OF A pH PROBE

The majority of pH probes available today, termed as combination electrodes as previously indicated, include both a glass hydrogen ion-sensitive electrode and a reference electrode.

ELECTRODE BODY

"Glass electrode" it refers to the membrane material rather than the exterior electrode body because the electrode body can either be plastic or glass.

Extruded epoxy body of the laboratory-grade pH probe gives it exceptional resistance to strong acids and bases. Industrial pH probe: Ryton body, highly unbreakable and unaffected by chemicals.

GlASS ELECTRODE

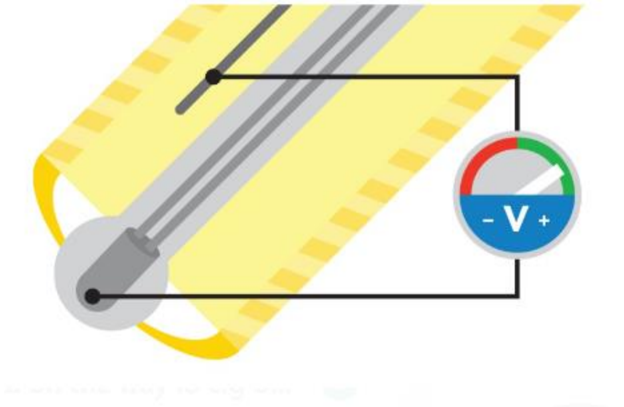


Fig. 3.14 Electropotential difference of reference electrode and glass electrode

Inside the glass electrode of the pH probe's glass membrane, a pH-sensitive membrane containing a buffer solution is present.

While the glass membrane's exterior portion is exposed to the test material, the membrane permits the continual binding of hydrogen ions inside the membrane. The voltage potential is generated by the variation of hydrogen ions across the membrane.

Depending on the use, the membrane's form can change. A pH probe with a spear tip or other specific membrane that may be used to puncture into semi-solid material is required for some applications.

A hydrogen ion exchange that results in an electrical voltage is essential to the operation of a pH probe. The pH electrode and the solution you want to test have different pH values, which are measured by the glass electrode inside the pH probe. By comparing the voltages of the hydrogen ions created in the electrode and the solution, the electrode can measure the differences. This voltage is transformed into a legible pH value by the pH metre.

3.6 CIRCUIT DIAGRAM

3.6.1 CIRCUIT

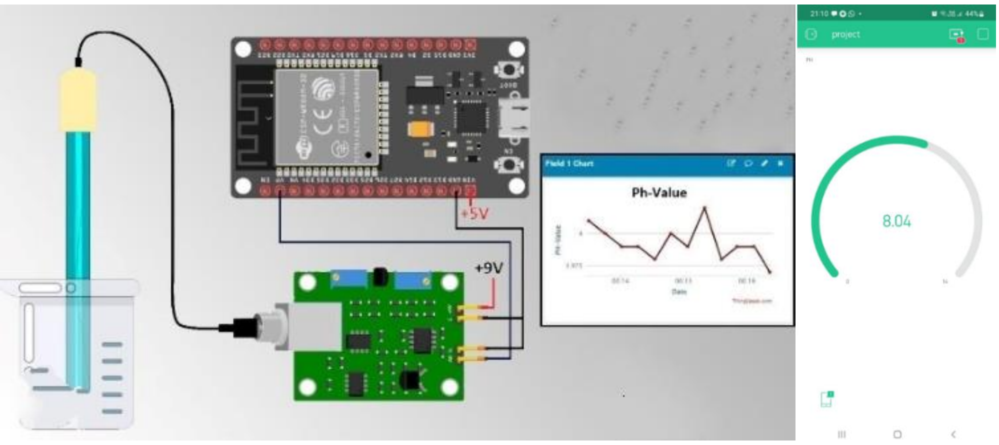


Fig.3.15 reference circuit diagram showing IoT application thingspeak and blynk

Fig. 3.16 circuit set up

The glass electrode present in the pH electrode probe collects the electric signal and is processed in the analog pH sensor which gives an analog output or the electro potential difference. The analog pH sensor is driven with 5V power supply. The output of PH4502C in given to Vp of the ESP32 and Vin is supplied 5V and both microcontrollers are grounded to complete the circuit.

CHAPTER-4

COMMUNICATION TO THE USER THROUGH APPLICATION

It is essential for the necessary results to transmit hassle-free to the user after processing at ESP32.

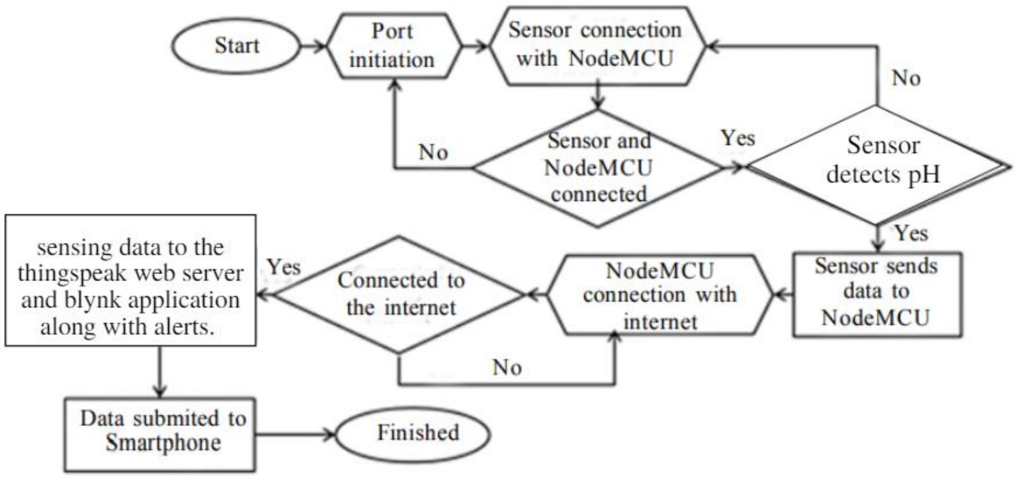


Fig. 4.1 Flowchart of software implementation

From the above flowchart, we understand after the port initiation takes place, analog pH sensor processes to the ESP32. If the connection is successful the sensor detects pH, otherwise the port reinitiating has to take place. Once the sensor detects pH, sensor sends data to the ESP32 with the connection of the internet, otherwise the further transmission of data to the blynk and Thingspeak cannot take place. Data is submitted furtherly on the smartphone.

One has to note that NodeMCU in the above flowchart is also referred to ESP32. "NodeMCU" is the name of a firmware originally for the ESP8266 microcontroller, with support for the ESP32 microcontroller added more recently, that allows you to program these microcontrollers using the Lua programming language.

4.1 IOT CLOUD

In today's environment, technology has brought about enormous change. IoT, also known as the Internet of Things, is a 4th Industrial Revolution characterized by a dramatic growth in the prevalence of the Internet of Things. The Internet of Things Revolution has had an influence not only on technology but also on health and medicine. Because of IoT, the term, Smart Devices has entered the business. IoT can help you achieve real-time data transfer from devices used in the health industry to your smartphone platforms.

On the other hand, the advancement of internet technology has enabled intelligent devices to transition from local networks to Internet networks. The user may monitor their health condition via the Internet Network from anywhere as long as they have internet connectivity. Many intelligent applications are built with HTTP technology, REST API, and web 2.0. Many device interconnections are employed in Service-Oriented Architecture and Internet of Things technologies to construct a smart application.

With the fast development of technology and device and sensor cost reductions, Smart Applications have become simple, economical, and capable of real-time application.

4.1.1 BLYNK IOT CLOUD

Blynk is a complete software package for prototyping, deploying, and remotely managing linked electrical devices at any size, ranging from personal IoT projects to millions of commercial connected items.

With Blynk, anybody can connect their gear to the cloud and create no-code iOS, Android, and web applications to analyse real-time and historical data from devices, remotely operate them from anywhere in the world, get vital notifications, and much more...

Blynk is a multi-tenant solution. Setting roles and establishing permissions allow you to control how users get access to data.

Applications created using Blynk are now available to end users. Whether it's a family member, an employee, or a customer, they'll be able to download the app, connect the device, and begin using it.

Blynk also provides a white-label option (as part of the Business Plan), which allows you to add your company logo, app icon, theme, and colours, as well as publish the app to the App Store and Google Play under your own name. These applications are compatible with your devices.

4.1.2 HARDWARE AND BLYNK INTERACTION

Blynk makes it simple and quick to connect your gadget to your embedded system. For that we need to first login so that it makes the communication between your gadget and your hardware easier.

Blynk uses MQTT(Message Queue Telemetry Support) for front-end builder and signalling relay and lets quickly create control and display your IoT. MQTT is a low bandwidth consumption machine protocol for WebSockets and use HTTP POST for push notification.

4.1.3 TRANSFER OF DATA BETWEEN HARDWARE AND BLYNK

You may submit raw or processed data from any sensor or actuator attached to the MCU board using Blynk.

When you transmit data to Blynk, it goes through a Datastream and is processed using the Blynk protocol. The values are then automatically timestamped and saved in the Blynk.Cloud database.

Datastream is a channel that informs Blynk about the sort of data that is passing via it.

VIRTUAL PIN DATASTREAM

Virtual Pins are a Blynk abstraction that allows any data to be exchanged between your hardware and Blynk. Everything you connect to your hardware will be able to communicate with Blynk. With Virtual Pins, you can transfer data from the app to the microcontroller and then back to the smartphone. Functions may be triggered, I2C devices read, values converted, servo and DC motors controlled, and so forth.

Virtual Pins can be used to communicate with external libraries (Servo, LCD, and so on) and to develop bespoke functionality.

SENDING AND STORING DATA

The data can be saved as-is (Raw data) or averaged to a one-minute average, depending on the plan you select. Averaging implies that even if you send 60 values every minute, Blynk will only save one. The data is still coming in in real time.

Before you begin transmitting data, we must first create a location to store and view it. In Blynk, let's use the Chart Widget. For that, use the console and plot the noise coming in from Analog Pin A0 on the device.

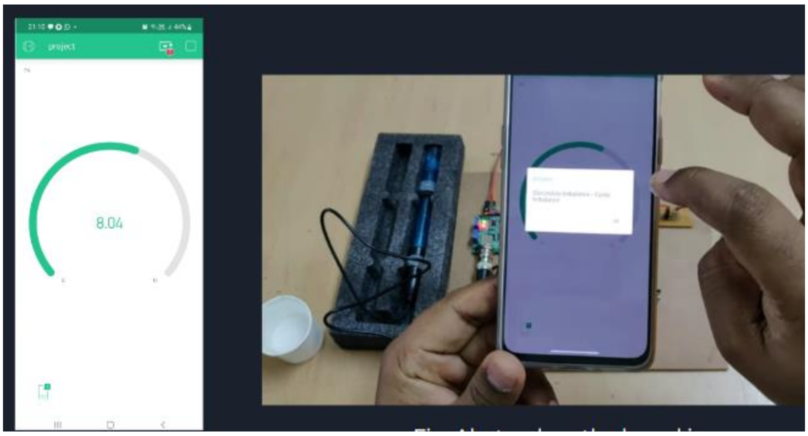


Fig. 4.2 A gauge and alert system on Blynk

4.1.4 NOTIFICATION ALERT

Fig.4.3 Notification alert based on the pH value

Notifications/Alerts are an essential component of any IoT system. Blynk provides a wide range of tools for sending and receiving in-app (push), email, and SMS alerts from devices.

This is the most straightforward method of sending alerts prompted by user-defined criteria. Blynk, you don't even need to write any code on the device. Blynk and Apps Console provides a simple user interface for configuring it. The remainder will be handled by Blynk.Cloud.

4.2 THINGSPEAK

ThingSpeak is an Internet - of - things analytics platform service that enables you to collect, view, and analyse live data streams in the cloud. You may submit data to ThingSpeak from your devices, generate rapid visualisations of live data, and send alerts using web services such as Twitter and Twilio. You may use MATLAB analytics within ThingSpeak to create and execute MATLAB code to conduct pre-processing, visualisations, and analysis. ThingSpeak allows engineers and scientists to experiment and design IoT solutions without having to establish up servers or write web applications.

4.2.1 SYSTEM REQUIREMENTS

Sensor data may be supplied to ThingSpeak from Arduino, Espressif ESP32 & ESP8266, Raspberry Pi, BeagleBone Black, and other hardware. Devices must support the MQTT protocols in order to interact with ThingSpeak. Secure communications are encouraged, and your device must support TLS 1.2. Your firewall must enable access to the normal ports for these protocols.

4.2.2 CONFIGURING CHANNELS AND ACCOUNTS

To read and write to a ThingSpeak channel, your application sends HTTP requests, MQTT messages, or MATLAB functions to the ThingSpeak server. Each ThingSpeak channel can contain up to eight fields of 255 characters in numeric or alphanumeric format. A channel also includes location information and a section for status updates. Each channel data entry is timestamped and date stamped. You can access saved data by date or by entry ID.

To handle numeric data, use the ThingSpeak API, which supports timescaling, average, median, summing, and rounding. You may build and update a ThingSpeak channel by sending an HTTP POST feed including your API key and data.

4.2.3 READ AND WRITE DATA TO CHANNEL

ThingSpeak is an Application platform that stores data delivered from apps or devices via channels. You may write data to your ThingSpeak channels using numerous methods, including HTTP requests from the REST API, the MQTT Publish method, and the MATLAB thingSpeakWrite function. You may read data from your channel using HTTP requests and the REST API. ThinspeakRead is also used to read data from your channels in desktop MATLAB.

4.2.4 DATA ANALYSIS AND VISUALIZATION

Data from a ThingSpeak channel is prepared, filtered, and analysed. ThingSpeak lets you understand and interpret your data using MATLAB. The analysis and visualization applications include template code to let you perform simple operations on either historical or live data. Use the applications to convert between units, compare distinct or comparable data on the same plot, and display your data's statistical distribution.

In static infographics, you may see and study data using interactive visualizations like as an area plot, line plot, or scatter plot, as well as additional MATLAB plots. You may also make infographics public and use the URL to embed them on websites. ThingSpeak also allows you to examine your data with MATLAB. The MATLAB Analysis and MATLAB Visualizations applications include code templates to help you perform simple operations on your historical or live data

Data is monitored in thingspeak for the user to self-analyse. Data need not entered in the thingspeak it is directly transmitted to the thingspeak and Blynk app sends the alert notification simultaneously. An illustration of a specimen's data display is as follows.

Thingspeak uses MQTT protocol. MQTT is a communication protocol that uses TCP/ IP sockets.

Fig. 4.4 showing data transmitted to thingspeak (and blynk notification is displayed from notification)

CHAPTER – 5

RESULTS

To test our module, we approached a group of people who voluntarily came forward to give their sweat samples as an outcome of various activities, like strength training, cross fit, cricket, basket ball, badminton etc., based on their interests. While in some cases a higher room temperature was also an added factor to the activity like Gym environment.

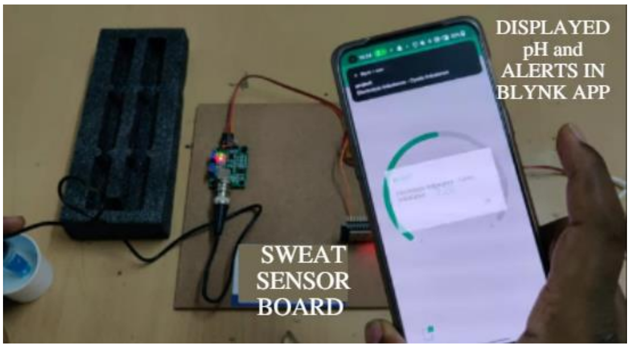


Fig. 5.1 Results post sweat sample processing is displayed on IoT Cloud Blynk

The user can also monitor his/her own pH levels from Thingspeak if they desire to store to see the pH levels falling or rising from the previous time of test. One such instance is below.

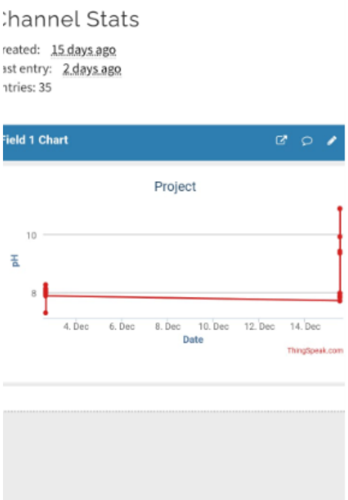


Fig. 5.2 Thingspeak representation graphically

Last entry 2 days ago and the progress is available pictorially or the data can be downloaded in an excel sheet as per one's convenience in fig. 5.2.

The data samples collected from certain volunteers and their pH values measured are briefly described below,

Name	Gender	Age	Activity	pH Value
Rohan	Male	20	Cricket	6.8
Saryu	Female	21	Workout	6.1
Vamsi Alla	Male	21	Workout	5.5
Dharma Teja	Male	19	Running	5.9
Lasya	Female	20	Brisk Walking	6.3
Tanishq	Male	21	Basketball	6.7
Manidhar	Male	20	Running	6.2
Tanu	Female	21	Gym	6.4
Raghunath	Male	23	Basketball	6.4
Himanshu	Male	19	Cricket	6.9
Tejaswi	Female	20	Badminton	5.8
Rohith	Male	21	Badminton	5.6

Table. 5.1(a) Samples taken from our college students

Name	Gender	Age	Activity	pH Value
Prithvi	Male	21	Basketball	6.3
Vidya	Female	20	Badminton	5.4
Nikitha	Female	21	Strength Training	6.8
Rishi	Male	20	Strength Training	5.9
Venkatesh	Male	19	Workout	6.3
Kailash	Male	18	Cross-Fit	6.4
Rama Rao	Male	18	Basketball	6.9
Lalitha	Female	19	Badminton	6
Alekya	Female	21	Running	5.7
Rajesh	Male	22	Brisk Walking	5.7
Rushitha	Female	21	Workout	6.5
Esha Janvey	Female	21	Workout	5.7
Bhuvan	Male	23	Strength Training	5.3
Ashish	Male	24	Cross-Fit	6.1
Sharanya	Female	22	Brisk Walking	5.8

Table 5.1(b) Samples taken from outside the college

Name	Gender	Age	Activity	pH Value
Dharma Teja	Male	19	Running	5.9
Lasya	Female	20	Brisk Walking	6.3
Manidhar	Male	20	Running	6.2
Tanishq	Male	21	Basketball	6.7
Vidya	Female	20	Badminton	5.4
Nikitha	Female	21	Strength Training	6.8
Esha Janvey	Female	21	Workout	5.7
Himanshu	Male	19	Cricket	6.9
Prithvi	Male	21	Basketball	6.3
Raghunath	Male	23	Basketball	6.4

Table 5.1(c) Samples taken from people who workout regularly

Name	Gender	Age	Activity	pH Value
Rohan	Male	23	Cricket	6.8
Saryu	Female	21	Workout	6.1
Vamsi Alla	Male	20	Workout	5.5
Tanu	Female	21	Gym	6.4
Tejaswi	Female	21	Badminton	5.8
Rohith	Male	21	Badminton	5.6
Rishi	Male	20	Strength Training	5.9
Venkatesh	Male	22	Workout	6.3
Kailash	Male	18	Cross-Fit	6.4
Rama Rao	Male	18	Basketball	6.9
Lalitha	Female	19	Badminton	6
Alekya	Female	21	Running	5.7
Rajesh	Male	22	Brisk Walking	5.7
Rushitha	Female	21	Workout	6.5
Bhuvan	Male	23	Strength Training	5.3
Ashish	Male	24	Cross-Fit	6.1
Sharanya	Female	22	Brisk Walking	5.8

Table 5.1(d) Samples taken from people who workout rarely

It was observed that the people whose sweat was almost a pH of value less than 5, genuinely had acne, skin breakouts. Some even had rashes on their skin. While the sweat pH value greater than 7, were very dehydrated, some experienced fatigue and urge to take breaks while working out.

CONCLUSION AND FUTURE ASPECTS

CONCLUSION

Our research and analysis revolves around the health of a person or detection of disorders like electrolyte imbalance, cystic fibrosis, acidosis or so. Cystic fibrosis is an imbalance caused due to Na^+ ions in the body. For diagnosis of even basic and non-hazardous disorders, one has to approach for a diagnosis, based on the blood or urine sample collection. Both of them are inconvenient, and moreover blood collection is excruciating and invasive. Utilisation of the simple combination of devices or components that come together to provide a diagnosis of health of the person based on the pH of the sweat and health is a great modification to the normal pH meter connection. The research has included the comprehensive study of the electrochemistry, pH of skin & sweat, sweat v/s health relations, biofluids, internet of things and also applications that are user-friendly with an easy alert system.

The objective of this research and project, Sweat sensor, is to utilise the least number of components and connecting it to the internet using the emerging technology of IoT and making a straightforward and uncomplicated application for the user.

The advantages and disadvantages are discussed below,

ADVANTAGES

The pH levels are continuously monitored as an advantage, Data monitoring through the Thingspeak cloud, Use the Blynk app to alert in unusual circumstances, Manual work is done away with, It Is Possible to Monitor.

Cost-effective and efficient design, Minimal power usage, Future improvements are simple to implement.

There is no requirement of visiting the diagnostic centres for basic and non-hazardous conditions of the body. They can be easily rectified with the basic knowledge of the body health.

It is a non-invasive, convenient method without any cumbersome collection of biofluids like blood and urine samples.

DISADVANTAGES

The project needed a Wi-Fi network, pH meter calibration has to be updated

FUTURE ASPECTS

Post pandemic and unpredictable situations of everyone for the past 2 years, it has become essential for good health and it's self-diagnosis, and also emphasising on convenient methods.

A digital pH sensor can be introduced that might overcome the challenges of requirement of calibration of the electrodes at regular intervals.

Using of the ion sensitive electrodes for a specific electrolyte can separately detect the specific electrolyte imbalance. For example, Na^+ ion sensitive electrode can be used to understand the saturated and insufficient conditions of the same in the body.

Making wearable patches or wrist-bands for a comprehensive hardware plus software display of the health of the person by collecting the droplets of the sweat, processing and displaying on the wrist band and other IoT devices.

As discussed in the relationship between sweat and health, this technology can be extended to the determination of Immune system, metabolic systems along with the sweat electrolyte imbalance.

APPENDIX – A

SOFTWARE SIMULATION USING PROTEUS

Before setting up with the apparatus physically, it is essential to look for the working of code, idea alignment, components relevant to work on, by simulating the thoughts through Software simulation.
For one such verification, **PROTEUS** was used.

Proteus board and Logo

PROTEUS

Proteus is used to simulate, design and drawing of electronic circuits. It was invented by the Labcenter electronic.By using proteus you can make two-dimensional circuits designs as well. With the use of this engineering software, you can construct and simulate different electrical and electronic circuits on your personal computers or laptops.

There are numerous benefits to simulate circuits on proteus before make them practically.

Designing of circuits on the proteus takes less time than practical construction of the circuit.

The possibility of error is less in software simulation such as loose connection that takes a lot of time to find out connections problems in a practical circuit.

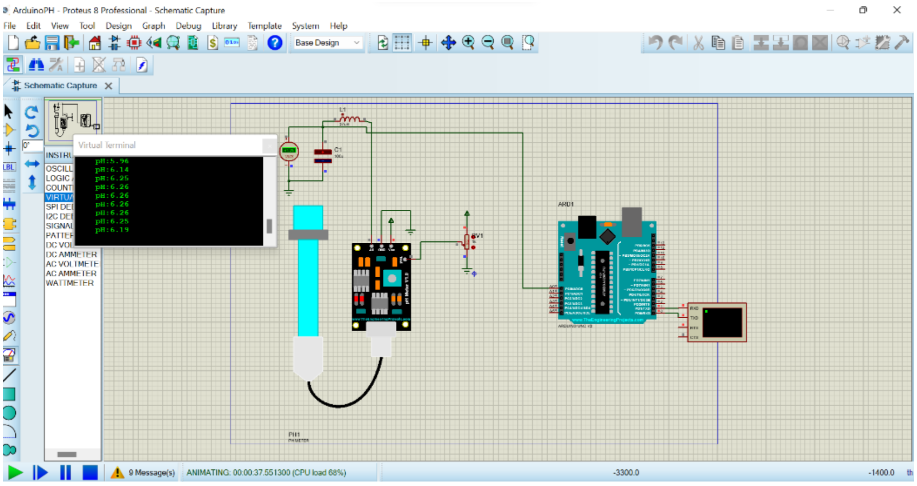
Circuit simulations provide the main feature that some components of circuits are not practical then you can construct your circuit on proteus.

There is zero possibility of burning and damaging of any electronic component in proteus.

The electronic tools that are very expensive can easily get in proteus such as an oscilloscope.

Using proteus you can find different parents of circuits such as current, a voltage value of any component and resistance at any instant which is very difficult in a practical circuit.

SET UP IN PROTEUS FROM THE AVAILABLE COMPONENTS IN LIBRARIES



Proteus Simulation

In the above figure, the pH is displayed on the serial terminal. The electrode potential is varied at the pot HG. The pH sensor gives the analog output which is given to the Microcontroller input and the output is taken at the terminal. As the electrode potential probe is adjusted, the electro potential difference also varies and the pH value at the serial monitor also varies proportionately.

.hex file is generated in the Arduino IDE and it is uploaded to the 2D circuit of Arduino containing in the proteus software.

APPENDIX-B

CALIBRATION METHOD FOLLOWED

PROGRAM CODE:

```
const int potPin=A0;// the pH meter Analog output is
connected with the Arduino’s Analog
float avgValue;  //Store the average value of the sensor
feedback
float b;
int buf[10],temp;

void setup()
{
  pinMode(13,OUTPUT);
  Serial.begin(9600);
  Serial.println("Ready");    //Test the serial monitor
}
void loop()
{
  for(int i=0;i<10;i++)       //Get 10 sample value from the
sensor for smooth the value
  {
    buf[i]=analogRead(potPin);
    delay(10);
  }
  for(int i=0;i<9;i++)        //sort the analog from small to
large
  {
     if(buf[i]>buf[j])
      {
        temp=buf[i];
        buf[i]=buf[j];
        buf[j]=temp;
      }
o
  }
  avgValue=0;
  for(int i=2;i<8;i++)                      //take the
average value of 6 center sample
    avgValue+=buf[i];
```

```
  float milliVolt=(float)avgValue; //convert the analog into
millivolt
  //Serial.println();
  float phValue;
  phValue=(0.00164)*milliVolt-9.23;
 //convert the millivolt into pH value
  Serial.print("    pH:");
  Serial.print(phValue,4);
  Serial.println(" ");
  digitalWrite(13, HIGH);
  delay(800);
  digitalWrite(13, LOW);

}
```

APPENDIX-C

SOURCE CODE, COMPILATION AND UPLOADING

```
#define BLYNK_PRINT Serial
#include <BlynkSimpleEsp32.h>
#include "ThingSpeak.h"
#include <WiFi.h>
const char* auth ="LWzANJiIVE3qmg_jjg1ETpvnBsFKSlxJ";
char  ssid[]  =  "project5610";     //  your  network  SSID
(name)
char pass[] = "123456789";   // your network password
int keyIndex = 0              // your network key Index
number (needed only for WEP)
WiFiClient  client;


unsigned long myChannelNumber = 1966729;
const char * myWriteAPIKey = "UQKIONEDFLAHKS8Z";


float calibration_value = 20.24 - 0.7;
int phval = 0;
unsigned long int avgval;
int buffer_arr[10],temp;
float phact;
void setup() {
  Serial.begin(9600);  // Initialize serial
```

```
  Blynk.being(auth, ssid, pass);
  ThingSpeak.begin(client);  // Initialize ThingSpeak

}
void loop()
{
  Blynk.run();

    int Value= analogRead(A0);
    float voltage=Value*(3.3/4095.0);
    ph_act=(3.3*voltage);

  if ((ph_act > 4.5) && (ph_act < 6.3))
  {
    Blynk.notify("Healthy");
  }
  if (ph_act < 4.5)
  {
    Blynk.notify("Acidosis");
  }
  if (ph_act < 6.5)
  {
    Blynk.notify("Electrolyte   Imbalance   -   Cystic
Imbalance");
  }
```

```
if(tcount > 20)
{
  tcount = 0;
  ThingSpeak.setField(1, ph_act);
  ThingSpeak.setStatus(myStatus);
}
tcount++;
```

CODE EXPLANATION

The code starts by initializing the serial port. The Blynk library is then initialized with the network credentials and ThingSpeak API key. Then, analog readings are taken from A0 to calculate ph_act which is then used to set a virtual write on V0 of Blynk. If ph_act is between 4.5 and 6.3, it will notify "Healthy". If it's below 4.5 or above 6.3, it will notify "Acidosis" or "Electrolyte Imbalance - Cystic Imbalance", respectively The code is a simple example of how to connect to the ThingSpeak API. The code above will print out "Healthy" if the pH value is between 4.5 and 6.3, otherwise it will print out "Acidosis"

REFERENCES

1. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5548369/
2. https://journals.physiology.org/doi/full/10.1152/jappl.1997.82.1.336
3. **Temperature and pH Monitoring System Design in the Fermentation of Cocoa Beans Based on Android** - Lukito Hasta Pratopo1*), Ahmad Thoriq1), Eko Heri Purwanto2), and Daffa Afian Wiradwinanda1)
4. https://cdn.awsli.com.br/969/969921/arquivos/ph-sensor-ph-4502c.pdf
5. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4369929/#:~:text=Sweat%20is%20normally%20a%20transparent,acidic%20than%20blood%20%5B2%5D.
6. https://www.ece.iastate.edu/pandey/files/2020/10/Sweat-Sensors.pdf
7. **Sweat sensing in the smart wearables era: Towards integrative, multifunctional and body-compliant perspiration analysis** - Christopher Legner, Upender Kalwa, Vishal Patel, Austin Chesmore, Santosh Pandey
8. **Feasibility Study of Wearable Sweat Sodium Sensor** By Tianchi Zhang