**RMIT UNIVERSITY VIETNAM**
**SCHOOL OF SCIENCE AND TECHNOLOGY**

**OENG1183 – ENGINEERING CAPSTONE PROJECT PART A**

# Portable-Handheld Weather Station
# Progress Report

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# 1 EXECUTIVE SUMMARY

Measurement of weather conditions is important for adapting to severe climate changes and global warming, occurred as a result of extreme weather conditions. There are numerous ways to observe and predict weather conditions used in a wide range of applications ranging from fishery and marine transportation to military operations and aviation industry. Nevertheless, most of them are non-portable and require regular maintenance, higher product costs and skilled labour.

Consequently, it is important to find a solution to overcome these issues, since real-time meteorological data logging is vital in various industries to make important decisions and predictions.

This solution presents an ergonomically designed, rechargeable and portable-handheld weather station which can obtain instantaneous meteorological measurements and broadcast them in real-time. Integration of several advanced and economical IoT drivers support this to stand out from existing solutions as a low-cost device and enhance its business value.

Current progress of the project is recorded here up to this date, supported by a market and literature review to analyse the technology used in existing solutions in the market and their weaknesses. More insightful explanation about the project deliverables and required resources is provided by the statement of work and solution design sections. Changes in several features and the underlying reasons for the changes are discussed with preliminary findings in the progress demonstration section. And a detailed work plan for the second semester is presented including current accomplishments of the team according to the proposed timeline towards the end of this report.

# 2 PROBLEM STATEMENT

## 2.1 What is the problem to be solved?

Demand for a solution to overcome the issues in conventional weather stations(sites) and automatic weather stations (AWS) occurs since a far greater time. And the voids are still available in industrial meteorology and several other industries that utilize meteorological weather measurements such as fishery, farming industry, marine transportation, aviation industry and military operations. Following section categorizes some key problems of conventional and automatic weather stations which has influenced this project.

- **Overall cost**
  - Contains large capital investments.
  - Requires high maintenance costs.
  - Requires high human labour costs.
  - Consists of high recurrent and execution costs due to lack of modern technology and IoT integration.
- **Requirement of resources require,**
  - Advanced equipment for execution.
  - Expensive tools and labour for maintenance.
  - Regular maintenance.
- **Functionality**
  - Non-portable conventional systems.
  - Non-handheld automatic weather stations (AWS).
  - Non-rechargeable and requires high and constant electrical power.
  - Less-ergonomically designed systems available in the market.
  - Less-user friendly products available in the market.
- **Reliability of weather data**
  - Conventional systems cannot provide entirely reliable weather data because weather conditions change rapidly.
  - Manned systems are vulnerable to fail in severe weather conditions.
- **Real-time weather measuring and cloud storage**
  - Inability to store real-time weather data in cloud databases.
  - Inability to access weather data in real-time anywhere possible.
  - Automatic systems require human intervention for saving measured data.

## 2.2 Conventional weather stations

Technically advanced automated weather measuring devices (Personal weather stations) were not familiar in the earlier eras. Instead, there were large buildings that consisted of large equipment and stations to measure atmospheric conditions and weather forecasting[1].

A conventional weather station consists of separate weather measuring instruments and parameters such as listed follows.

a) Thermometer - surface temperature of air and sea
b) Barometer - atmospheric pressure
c) Anemometer - wind speed and determine wind direction
d) Rain gauge - precipitation
e) Hygrometer - relative humidity/amount of water vapor in the air

Even though, conventional weather stations can measure a larger number of weather parameters as categorized above, they require regular maintenance with skilled labour. Hence, the execution cost, maintenance cost and other relative costs were high compared to modern systems. A comparative discussion of advantages and disadvantages of conventional weather stations with AWS is carried out in table 1[2].

## 2.3 Modern weather stations

Addressing the issues of conventional weather stations, modern technology involved to upgrade them into more simple and advanced systems without damaging the quality of measurements and other advantages. As key aspects, sensors and transducers could be mentioned which have mainly guided this transition from CWS to AWS.

Following are some key technologies which assisted this process[3-5].

- Smart sensors

- MEMS
- Wireless Sensors
- Nano sensors and generators

Main objective of introducing modern weather stations was to obtain more reliable weather data with a good accuracy and less human intervention. Portable weather stations (PWS) are a significant type of modern weather stations which were established to test the experiments which were performed by researchers and scientists to apply newly developed sensor technology to them[6]. Primarily, a PWS can measure following weather parameters[6].

a) Rainfall
b) Wind speed and Direction
c) Indoor/Outdoor humidity
d) Indoor/ Outdoor atmospheric pressure
e) Soil moisture/ Temperature
f) Solar radiation

PWS do not rely on constant human intervention as conventional and automatic weather stations. But a human hand might be needed to upload measured data to a database or to a data distribution system. PWS can be fully customized with preferred measurements according to customer preferences and PWS also relates to AWS systems as well.

Even though, modern weather stations are equipped with intelligent sensors and capable of measuring greater number of weather parameters compared to conventional weather stations, there are still some existing drawbacks in them which could be reduced/ eliminated with further research and development. Following table compares the advantages and disadvantages between CWS and AWS in a general overview[1, 3-5].

*Table 1: Comparison between advantages and disadvantages of CWS and AWS[1, 4, 5]*

| Weather station type | Advantages | Disadvantages |
|---|---|---|
| **Conventional weather stations (CWS)** | Can obtain detailed weather data. | Required intensive and complex resources. |
| | Simple to conduct. | High risk in safety. |
| | No required capital cost. | Weather data can be not entirely reliable. |
| | Can predict weather forecasts. | Required expertise labour to operate. |
| | High accuracy results. | Weather predictions rely on large datasets. |
| | | Instant weather changes cannot be monitored/ measured. |
| | | Estimations might be wrong due to severe weather conditions. |
| | | Require high recurrent and maintenance costs. |
| | | |
| **Automatic weather stations (AWS)** | Can obtain large data quantities. | Required large capital investment/ contract fee. |
| | Can obtain multiple data types. | Human labour required for data logging and fetching. |
| | Can graphically present data. | Several weather parameters are too complex to capture. |
| | Comparatively convenient. | Non-portable and non-handheld. |
| | | Considerable maintenance costs required. |
| | | Limitations occur due to different sensor specifications. |

It is observed that, conventional weather stations might not require a large capital investment/ contract fee compared to AWS from the table above. Yet they consist of higher maintenance and recurrent costs due to large scale measurement equipment included and constant maintenance procedures carried out. As a main disadvantage of CWS, the requirement of high skilled/expertise labour for data logging and operating could be identified and AWS has reduced that requirement up to a certain limit by wanting human labour for data logging only. But still, a considerable maintenance cost is required for both stations and none of them are neither portable nor handheld. Moreover, saving logged weather data in cloud servers and giving access to anyone who prefer is not a visible advantage in both stations. Hence, the need of a solution to eliminated/ reduce disadvantages of currently existing weather stations (CWS, PWS, AWS) is clearly highlighted.

## 2.4 Stakeholders and key values of the product

This product could be used in several applications as a personal-automatic weather stations (Relating to PWS and AWS concurrently). Applications of a general weather measuring station could be also applied to this device as well. The speciality of this devise is being able to be used on the way[1].

Accordingly, there are many applications of this product in various industries for weather measuring and forecasting purposes. Following are some highlighted key stakeholders of this product.

a) Industrial workshops and its personnel.
b) Construction sites.
c) Home/ personal use.
d) Researchers
e) Government authorities and workstations.

This could be used as a day-to-day necessity in life due to its ergonomic/miniature design, simplicity and ease of carrying in hands. Addition to those characteristics, this product stands out from other existing weather stations for its relative low cost for manufacture, maintenance and repair. Also, this overcomes the issue of hugeness which is commonly existed in Remotely Automated Weather Stations (RAWS) as the overall design of this product is comparatively small compared to existing RAWS in the market. Focusing on the system architecture of RAWS, this solution could be applied as a mediator between the primary weather station and the meteobridge to measure weather data and give certain alerts of severe weather conditions.

# 3 MARKET AND LITERATURE REVIEW

Weather is an important atmospheric phenomenon that includes conditions of the temperature, humidity, pressure, precipitation and direction and speed of wind in the atmosphere. Extreme weather can make natural disasters such as floods, landslides, and subsidence. Hence monitoring weather parameters are extremely important. Over decades, many stationary weather stations were developed to measure and monitor ambient weather parameters. But such instruments are costly and not portable. More importantly such commercial stations can measure only few parameters and can do any modifications [7]. Therefore, development of a low cost, handheld type weather monitoring station that capable of transferring and collecting data using various techniques is important for the modern society. Such systems are important for acquiring real-time data required for farmers, researchers, and disaster managers. Particularly such smart system can be effectively used in faming activities.

Major challenges faced by the portable weather device developers are obtaining suitable sensors, high response time of sensors, designing the device ergonomically, and quick transferring data to a server, the accuracy of the measurements and power consumptions. Last few years, much attention was made by developers to fabricate portable weather stations and in this chapter, previous attempts on fabricating portable weather devices are reviewed.

## 3.1 Recent developments of portable weather stations

Portable weather stations need to offer versatility and mobility, compared to any other weather stations. Fang et al. [8] developed a micro weather station which has the capability to measure ambient temperature, humidity, wind speed and atmospheric pressure. The main advantage of this system is that it consisted of Micro Electro-Mechanical System (MEMS) with a multi sensor chip. Sensing material for both pressure and temperature were fabricated using a platinum layer whereas the humidity sensor has three layers, as meshed upper electrode, polyamide and an electrode. Two perpendicularly encapsulating cells have been used to fabricate the wind sensor which measures the velocity of the wind. The sensors of this device were fabricated from scratch, and these sensors have been not subjected to quality test compared to commercially available sensor. Due to this drawback, this device causes errors in measurements than the sensors developed for commercial purposes. Further, this weather station consists of a charging circuit and a touch screen LCD display (Figure 1).

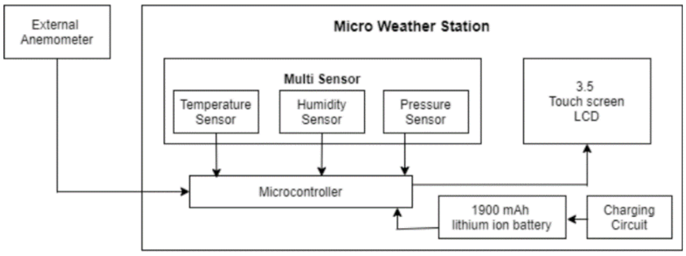



*Figure 1: Micro weather station developed by Fang et al.*

Similar system was also developed by Haque et al. [9], but this system uses renewable energy to charge the batteries. The system is capable of measuring temperature, humidity, atmospheric pressure, raindrops, altitude and air quality which includes the amount of carbon monoxide, smoke and the liquid petroleum gas (LPG) in the ambient environment. A GSM module was used to send the collected meteorological data to end user via SMS to mobile phones on the request. Hence the output of the data was displaced both in a LCD display and a mobile phone. The main speciality of this device is that the use of a solar panel to charge batteries. Moreover, DHT22 module has been included in this device to measure the temperature and humidity, while BMP180 sensor to measure the barometric pressure whereas gases were detected by MQ2 (Figure 2).

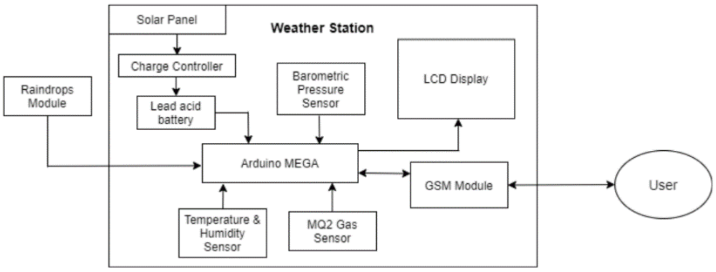



*Figure 2: Weather station developed by Harque et al.*

In a recent research done by Warnakulasorriya et al [10], developed a low cost mobile weather station which used GPRS technology for web access facility. The advantage of this design is that the system was able to measure eight weather parameters including soil moisture, wind vane and the precipitation. Similar to the model developed by Haque et al, this system also has the capability of interpret data in two platforms, that is by using a LCD display and 'slpiot', which is an open source platform used for visualize the data using GPRS technology. Further, this system consisted of a micro SD card to store data in case of data could not be able to transfer to the server. The power consumption of the weather station is about 100 mAh, and this system consists rechargeable batteries, where it can be recharged by using either external Li-Po charger or solar power (Figure 3).

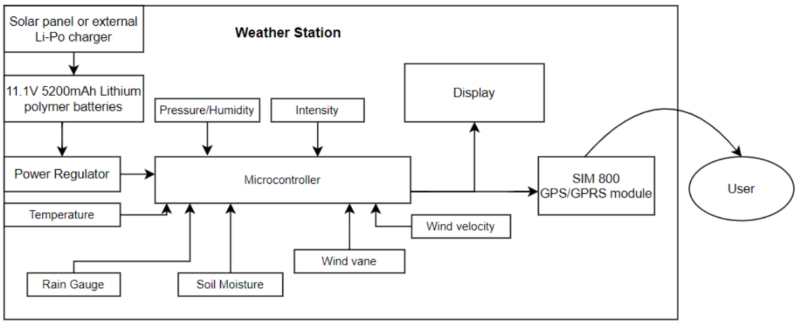



*Figure 3: Weather station developed by Warnakulasooriya et al.*

A weather station developed by Kapoor et al. [11] is capable of measuring temperature, humidity, barometric pressure and rainfall. It was a cloud-based system that uses IoT devices for data uploading. This system compromises of two stations, as remote station and base station. Data were collected from the remote station and then transferred and analysed in the base station. The purpose of this weather station was to analyse meteorological parameters, stored in a cloud network and then to predict the future weather. Schematic diagram of this system is given in figure 4.

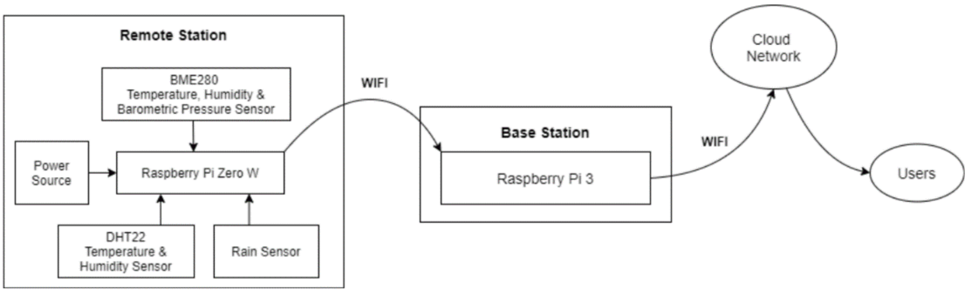



*Figure 4: Weather station developed by Kapoor et al.*

Another attempt to fabricate a portable weather station was made by Kusriyanto and Putra [12]. They have fabricated a weather station that can be accessed via a website as it used IoT platform. Then, the people can directly obtain the weather parameters easily from any location. Their system consists of an Arduino Mega 2560 microcontroller. DHT -22 and FC 37 sensors were used to measure the temperature, humidity and rain while BMP180 sensor was used for air pressure measurements. The data were stored in a SD card and it is also displayed in an LCD panel while ESP8266 module was used for WIFI transfer. However, they have obtained errors of 3.74% for temperature, 2.14 % for humidity and 0.32% hPa for air pressure (Figure 5).

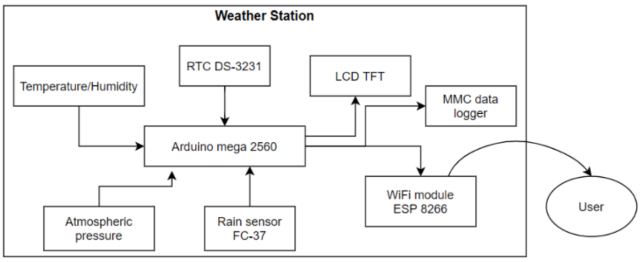



*Figure 5:Weather station developed by Kusriyanto et al.*

In the view of providing services to the agriculture sector, Tenzin et al. [13] developed a real time weather monitoring device to determine and provide climatic data, particularly to farming community. Many farmers are always facing the problem of getting real time data on the weather conditions that is important for their activities. The weather monitoring system introduced by Tenzin et al. consists of a data collector and a transmitter unit and it is powered by using solar energy. It used PIC 24FJ64 microchip as the controlling system with cloud storage facility. This system is similar to the weather station developed by Kapoor et al, however in this system the data transfer from the remote station to base station is done by Xbee router and a coordinator. They have compared the data obtained from the smart weather system with a commercially available device in which both were installed in a same agricultural field. An equivalent data was obtained from the portable smart weather station and compared with the data obtained from the commercial weather station. A major disadvantage of this system based weather stations is not being portable (Figure 6).

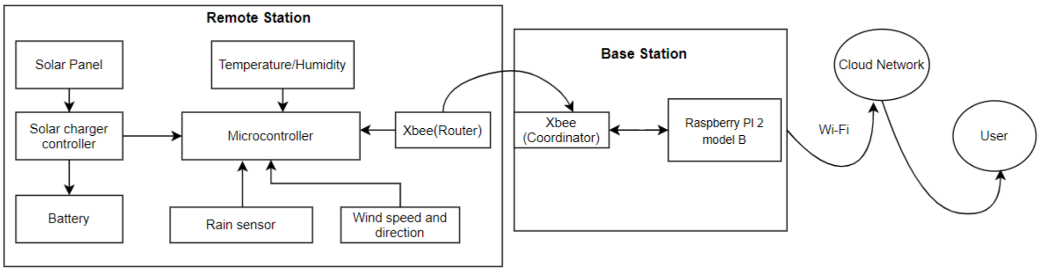



*Figure 6: Weather station developed by Tenzin et al.*

Developing an ergonomically handheld device will be mainly beneficial to farmers and researchers who mainly involved in field of agriculture. Although the existing weather stations are highly accurate and able to predict the data, these devices are not ergonomically handheld devices. Therefore, it is necessary to develop a cost effective handheld weather station which able to measure weather parameters such as temperature, humidity, barometric pressure, air quality, soil moisture, luminosity and wind speed with higher accuracy and low response time. According to the analysis done on the above developed weather stations, temperature, humidity and the atmospheric pressure of the environment are foremost important weather parameters that should include in a weather station. DHT22, BMP180 and BMP280 are the most common sensors available to measure the temperature, pressure and barometric pressure. [11]. From among these, DHT22 is a low cost sensor which uses to measure temperature and humidity, where BMP180 can measure temperature and barometric pressure, however, BMP280 sensor is able to measure the temperature, humidity and barometric pressure in the ambient environment.

DHT22 works with a thermistor and capacitive moisture sensor where the accuracy of humidity measurements lies between 3-5% and the accuracy of temperature lies between ±0.5 ºC [11]. However, the percentage deviation of measurements taken from DHT22 and BMP180 of temperature, humidity and barometric pressure were 1%, 5% and 8% respectively [9]. Carranco et al. [14] also noted the accuracy of the BME280 sensor. They have compared data obtained from a BME280 sensor which was integrated in a low-cost weather station, with the data obtained from an automatic meteorological station. The results indicated the similarity of measurements of 95% accurate.

## 3.2 Technical research to obtain meteorological measurements from real world

**Research question:** How to communicate with natural environment using Atmega2560 microcontroller?
**Requirement:** A technique to convert natural meteorological measurements into binary data

### 3.2.1 ADC Principle of Atmel Atmega2560 in depth

ADC is a subsystem which is equipped with most microcontrollers to communicate with the natural world and perform systemized processes. ADC is associated with three important processes namely[15],

1) Sampling
2) Quantization
3) Encoding

Sampling is the process of obtaining snapshots of a signal over time. It is important, in representing an analog signal in a digital form such as in a computer, the appropriate sapling rate should be determined to capture analog signals to represent in a digital system accurately. This sampling rate could be referred to as the frequency of the microcontroller's ADC which is normally represented in "Hz" and kHz" units[16].Following figure depicts a generalized A/D conversion with sampling and quantization procedures[17].

Techniques to represent the obtained samples could be termed as "quantization". It is performed in several levels in accordance with the number of bits captured in the sampling process. Whereas all the possible combinations which the captured sample signal could be represented as, could be defined as "quantization levels"[16]. Moreover, a measurement of "resolution" is also utilized in quantization of sampled analog signal to quantize an analog signal. And the number of bits used in quantization is directly proportional to the measurement of resolution of the system. So that, the resolution would increase when the number of bits are increased and vice versa[16].

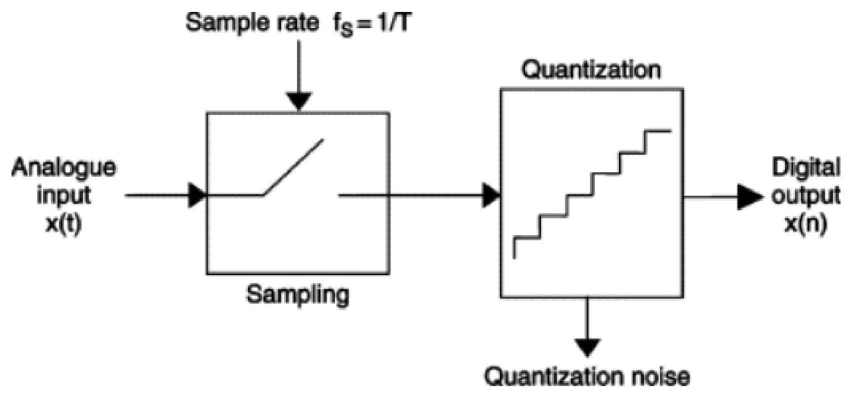



*Figure 7: Generalized A/D conversion[17]*

The encoding process represents the quantization level with the available bits after the sampled signal is quantized. As a result, the sampled analog signals are represented in binary numbers throughout the encoding process. Therefore, the encoding process is considered as the last necessary and important step in representing a sampled analog signal in its corresponding digital format[16].

Following the principles mentioned above, ADCs vary between different microcontrollers. As an example, Atmega microcontrollers comprise a 10-bit ADC which could capture 1024(2^10) discrete analog levels. Some controllers might capture 2^8 or 2^16 levels and so on.

#### 3.2.1.1 The Atmel Atmega2560 ADC sub system specifications

*Table 2: Atmega2560 ADC sub system specifications[15]*

| Feature | Specification |
|---|---|
| Resolution | 10-bit |
| Least Significant Bit (LSB) absolute accuracy | ±2 |
| ADC clock cycle conversion time | 13 |
| Input channels | 16 multiplexed single ended |
| Results justification | Left or Right (selectable) |

#### 3.2.1.2 ADC system – working principle

There are more complex different ways that an ADC system operates to capture analog signals and output a digital value. A general technique uses the analog signal obtained from sensors to charge an internal capacitor. The time to discharge the capacitor is measured afterwards through the internal resistor. Microcontroller counts the number of clock cycles which pass until the capacitor is fully discharged. Returning digital value will be the number of clock cycles which is counted by the microcontroller[15, 16].

The ADC determines a ratio-metric value. When MCU is powered with 5V, it captures a signal of 0V as a binary 0 and 5V as binary 1023. Any value less than 5V will be a ratio between 5V and 1023. Relation between measured analog voltage and ADC value could be demonstrated as follows for a 10-bit microcontroller[15-18].

$$\frac{Resolution\ of\ the\ ADC}{System\ voltage} = \frac{ADC\ reading\ from\ the\ sensor}{Measured\ Analog\ Voltage}$$

*Equation 1: Relationship between measured analogue voltage and ADC value[15-18]*

Assume the measure analog voltage to be 3.33V and system voltage to be 5V. The value reported by the ADC will be as follows,

$$\frac{1023}{5} = \frac{ADC\ reading\ from\ the\ sensor}{Measured\ Analog\ Voltage}$$

$$\frac{1023}{5} = \frac{ADC\ reading\ from\ the\ sensor}{3.33}$$

$$\frac{1023 \times 3.33}{5} = ADC\ reading\ from\ the\ sensor$$

$$ADC\ reading\ from\ the\ sensor = \frac{1023 \times 3.33}{5} = 681.318$$

The basic arrangement of a successive-approximation ADC is depicted in the following figure. In this, the input signal is single-ended, and all the voltages referenced to a common node[15, 17].

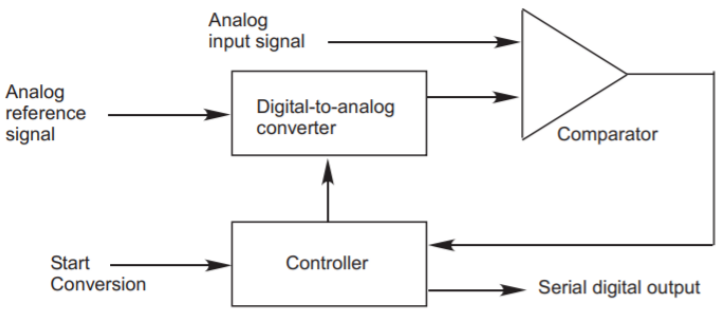



*Figure 8: The basic arrangement of a successive-approximation ADC[15, 17]*

### 3.2.2 I2C Protocol communication

The I2C (Inter-integrated circuit) communication protocol is a very popular protocol among electronic devices since it helps one device communicate with multiple systems. The reason for the easy implementation is that the I2C bus only requires 2 wires to transmit data to all systems. Miscommunication between devices is prevented because each device can be set with an unique address for each modules with the master/ slave relationship[19]. The master device will synchronize the data transfer between the devices and manage the address of all devices during the communication[20].In this project, the micro controller will be set as the master device and the sensors will be set as slave devices.

There are 2 wires on the I2C bus. The SCL line is the clock signal that will synchronize the data transfer and the SDA lines is the data carrier[19]. In this project, the SCL pin is pin 21 of the Arduino Mega2560 and SDA pin is pin 20.

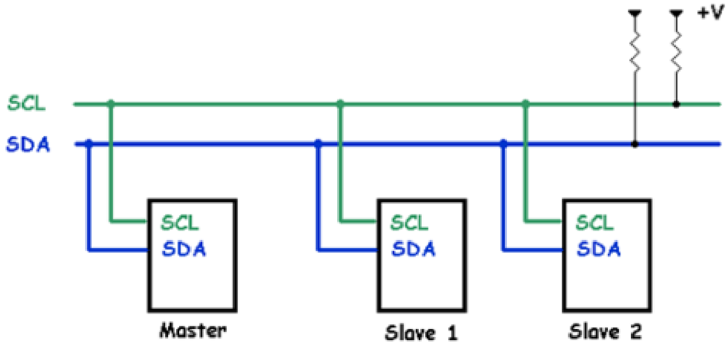



*Figure 9:Communication between devices with the I2C protocol[19]*

There are multiple sensors that requires I2C communication in this project. For example, the BME280 which consists of temperature and humidity sensor, the CCS811, which contains CO2 and TVOC sensor are used. Therefore, to avoid error in the implementation, we need to know the unique address of each module. The unique address can be found by referencing the datasheet of each module or using the I2Cscanner code from IDE.

### 3.2.2.1 Working Principle of I2C

The I2C bus works by transfer multiple frames in one message. Each message contains an address frame, data frame (that includes data being transmitted), start and stop condition, read/write bit and ACK/NACK bit. The function of each frame is discussed following Figure below

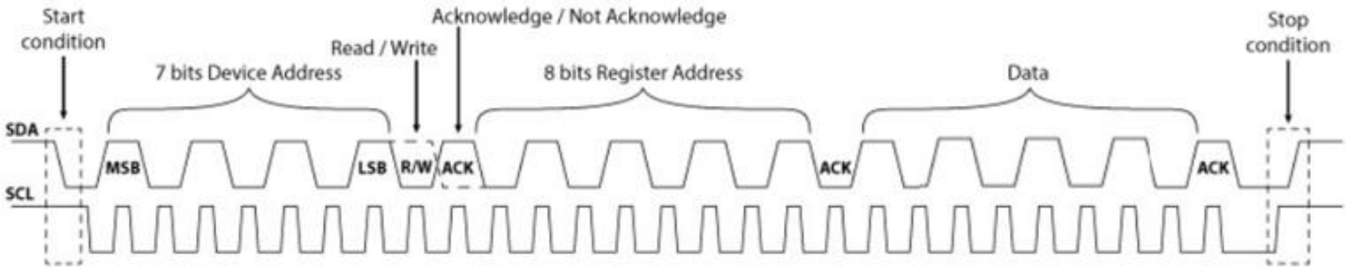



*Figure 10: I2C device addressing[19]*

- **Start condition**: SDA line switches from high voltage level to low voltage level before SCL switches from high voltage level to low voltage level.
- **7 Bit Device Address**: Identify the slave device (sensor) that the master device (microcontroller) wants to communicate with.
- **Read/Write bit**: A single bit was programmed at low voltage level if the master wants to send the data to the slave devices and high level if the master requests data from slave device.
- **8 Bit Register Address**: Identify the specific internal register that the master device needs to read the data from.
- **ACK/NACK**: A single bit which is used to indicate whether the address frame or data frame successfully receive the data from the master device. It will pull down the SDA line if it succeeds.
- **Data Frame**: Only ready to be sent if the ACK bits was detected by the master devices, the data frame is the 8 bit long which starts from the Most Significant Bit and ends with the Least Significant Bit. The Data Frame is used to transfer data either from Master or Slave devices depend on the Read/Write bit.
- **Stop Condition**: SDA line switches from low voltage level to high voltage level after SCL switches from low voltage level to high voltage level.

# 4 MEASUREMENT OF SUCCESS

Project performance and outcomes are evaluated after every milestone marked in the project timeline over several success measures. These criteria are outlined by the team considering the standout features proposed to address the issues in existing solutions towards the successful completion of the project and to analyse the overall success of the team up to which far are they met.

Following are the success criteria of this project. Note that, all criteria are categorized based on three main aspects namely, technical, product specified and achievement of proposed milestones. Also, measurement specifications of the success criteria are set according to annual meteorological information since 2016 in Vietnam and Sri Lanka where no seasonal variation exist throughout a regular year and several other weather parameters measuring devices. Therefore, they might vary when another country is considered as reference.

*Table 3: Measurements of success criteria*

| Category | Specification | | Success Criteria | Success measurement /Units |
|---|---|---|---|---|
| **Technical aspects** | Sensor accuracy | Temperature | Measurement of average room temperature | 16ºC ± 2ºC to 27ºC ±2ºC |
| | | Humidity | Measurement of average atmospheric humidity | 80% ± 8% |
| | | Atmospheric pressure | Atmospheric pressure at an altitude of 78.7” | 100.5kPa ± 0.5kPa |
| | | Air quality | TVOC level – in the range of excellent to moderate | (5 ppb ± 5 ppb) to (40 ppb ± 10 ppb) |
| | | | eCO2 level – in the range of excellent to fair | (400 ppm ± 50 ppm) to (700 ppm ± 50 ppm) |
| | | UV Index | Measurement of moderate UV index | 4 ± 1 |
| | | Soil moisture | O-Horizon moisture level | 30.5% ± 0.5% |
| | | | A-Horizon moisture level | 30 % ± 1% |
| | | | B-Horizon moisture level | 28.5% ± 0.5% |
| | | Altitude | Measurement of altitude at 78.7” | 80” ± 2” |
| | | Dew point | Dew point measured at an altitude of 78.7” | 25ºC ± 2ºC |
| | Power | Input power to MCU | Measured input power does not exceed the required amount for MCU | 10V ± 2V |
| **Product specified aspects** | portability | | Device being able to hand carried (miniature design dimensions LxWxH) | (16cm ± 3cm) x (4cm ± 2cm) x (20cm ± 3cm) |
| | Safety | | Not vulnerable to electrical shocks/ burns | |
| | | | No sharp edges existed | |
| | Cost | | Be comparatively low cost | 3,000,000 VND ± 1,000,000 VND |
| | Weight | | Light weight and easy to carry | 150g ± 40g |
| **Achievement of milestones** | Prototype development | | Start to build the prototype at the end of week 4 and run adequate development | Start by 27th July and continue |
| | Proposal | | Finish submitting by end of week 2 | Finish by 13th July |
| | Progress Report | | Finish submitting by end of week 12 | Finish by 20th July |
| | Presentation | | Finish submitting by end of week 12 | Finish by 20th July |

# 5 STATEMENT OF WORK

## 5.1 Project Deliverables

This project is mainly concerned about the standout features which were proposed to be included in the final product. Consequently, the project deliverables lie parallel to the product specifications and proposed features. Following are the key project deliverables which were proposed. They have been marked delivered/ not with respect to the current progress of the project.

*Table 4: Evaluation of project deliverables*

| Feature | Dedicated function | Performed by | Delivered | Remarks |
|---|---|---|---|---|
| **Temperature sensor** | Measurement of atmospheric temperature | BME280 | ✓ | Delivered |
| **Humidity sensor** | Measurement of relative humidity | | ✓ | Delivered |
| **Pressure sensor** | Measurement of atmospheric pressure | | ✓ | Delivered |
| **Air Quality sensor** | Measurement of Air Quality Index (AQI) | CCS811 | - | Cannot measure AQI from CCS811 |
| | Measurement of TVOC & eCO2 | | ✓ | Delivered |
| **Soil moisture sensor** | Measurement of soil moisture level | FC-28 | ✓ | Delivered. Switched to HW-390 v1.2 due to drawbacks |
| | | SKU: Sen0193 | ✓ | Delivered |
| **Dew point** | Measurement of dew point | BME280 | - | Not delivered yet |
| **Altitude** | Measurement of altitude | | - | Not delivered yet |
| **UV sensor** | Measurement of UV Index (UVI) | ML8511 | - | Not delivered yet |
| **Flame sensor** | Measurement of radiation/fire | Generic flame sensor | ✓ | Delivered. Eliminated due to sensitivity limitations |
| **Wind Speed & Direction** | Measurement of wind speed & direction | Anemometer | - | Not delivered yet |
| **Cloud Integration** | Fetch obtained data to a cloud database | SIM800L | ✓ | Delivered |
| **Local storage data logging** | Fetch obtained data to a micro SD card | Micro SD | ✓ | Delivered |

# 6 SOLUTION DESIGN AND REQUIRED RESOURCES

The design of the weather station includes consolidating multiple subcomponents which each serve a designated purpose and contribute to the overall success of the project. These subcomponents are mainly as follows.

1. Sensory Input Array - Consist of the numerous electronic sensor apparatus capable of measuring certain meteorological aspects of the immediate environment such as temperature, pressure etc.
2. Assistive Apparatus - Consist of other modules such as GPS or GSM which enable geo-location and data logging to the cloud.
3. User Interface - Mainly consist of the LCD display and the tactile buttons located externally on the device
4. Power Management - Batteries, buck converters and charging connectors responsible for supplying power to the device safely

Furthermore, the overall physical structure of the device, the shape and form of the device and other aesthetic aspects are other important features in the final solution design.

## 6.1 Block diagram of current hardware implementation

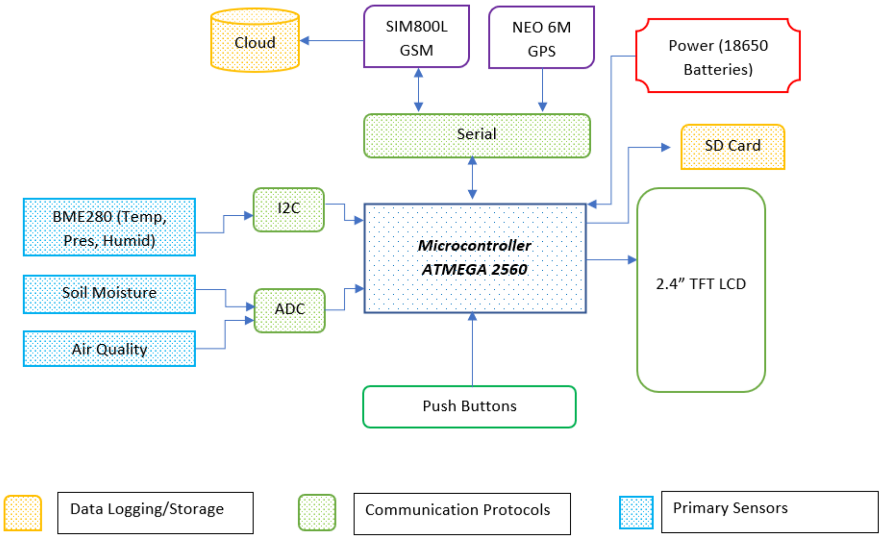



*Figure 11: Hardware implementation of the current prototype*

## 6.2 Schematic drawing

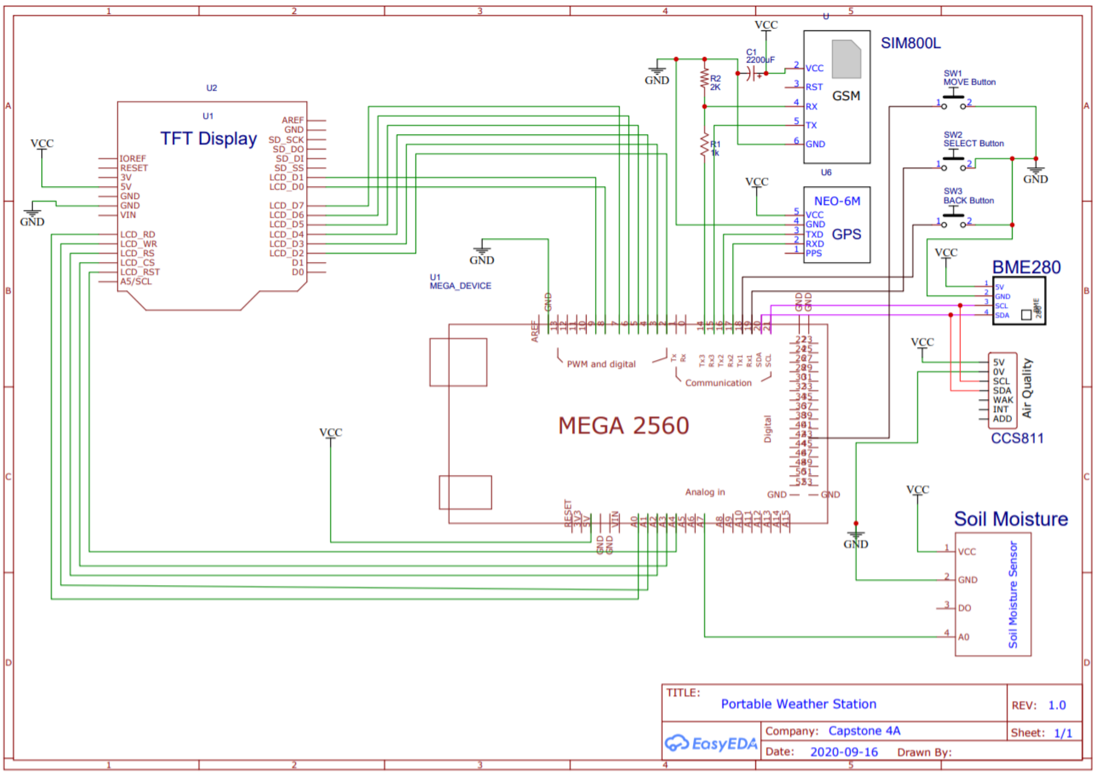



*Figure 12: Schematic design*

The solution design of the device is an ergonomically handheld system, which can operate from a single hand. The size of the device is approximately 180 x 94 x 25 mm in size. This device will have the capability of measuring weather parameters such as temperature, humidity, atmospheric pressure, soil moisture level, luminosity, UV index, air quality, and wind speed. The collected data of the solution design will be expected to display in a LCD display, store in a SD card and sent to cloud storage where everyone can access the collected data. The design consists of a hard-plastic cover. The power will be supplied by two rechargeable batteries while a charging port is also included in the bottom of the device. A hard-plastic enclosure with wrapped rubber around the device will be employed to prevent the damage for the device. Further, the device will be with a user-friendly interface with five keys to control the device. Such keys are for power on/off, swipe right, swipe left, enter and back button to direct it to the main menu. The complete solution designed was modelled by using SOLIDWORKS is indicated in figure 13.

## 6.3 3D Drawing of the design


*Figure 13: 3D design of the product*

## 6.4 Required resources

Required resources for this project are supplied according to their availability with time. Mandatory resources such as time, human resources and financials either storable or non-storable, depend on the team members and course delivery methods as well. Following lists down some important resources of requirement.

1) **Software resources required for,**
   a. Data acquisition – Arduino IDE, LabVIEW, National Instruments (NI) software and tools.
   b. 3D modelling – Solidworks or AutoCAD.
   c. Documentation – MS word, MS PowerPoint and MS SharePoint.
2) **Hardware resources**
   a. Machine tools and equipment – Multimeters, soldering station, oscilloscope and necessary probes.
   b. Components – Sensors, MCU, wires, batteries, push buttons and other electrical components.
   c. Safety equipment
3) **Office supplies**
   a. Tools – laptops, notebooks and other stationery.
   b. Workspaces – laboratories and office rooms.
4) **Financial resources required for,**
   a. Purchasing components.
   b. Fabrication processes.
   c. Other mandatory tasks.
5) **Intellectual resources**
   a. Knowledge in project related subjects.
   b. Skills to complete project tasks.
6) **Human resources**
   a. Project working personnel as a team.
   b. Project supervisor to provide necessary advices on project performance.
   c. Project coordinator to provide the outline for coursework.
7) **Time**
   a. Necessary and enough time to run the project.

# 7 TIMELINE

## 7.1 Current accomplishments

### 7.1.1 Temperature, Humidity & Pressure

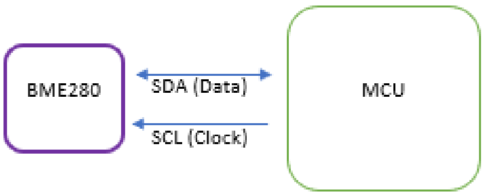
The primary mode of gathering information about the ambient quality of the environment is via the BME280 sensor. It communicates to the microcontroller via the I2C line and provides rich data gathering capabilities.

The BME sensor transmits an actual readout of the temperature, humidity and pressure according to its onboard microcontroller. This means proper ASCII based character byte data can be obtained instead of simple PWM voltages. This process increases accuracy and reduces dependence on further calibration (via potentiometers etc.) generally required in analogue sensors whose output depends on the supply voltage.

*Table 5: BME280 sensor pin-out and specifications*

| Pin-Out [BME280 → ATMEGA2560] | | |
|---|---|---|
| VCC | | +5V |
| GND | | GND |
| SCL (Clock Line) | I2C | D21 |
| SDA (Data Line) | | D22 |

| Specifications | |
|---|---|
| Current Draw | 3.6 µA @ 1 Hz (H, P, T) |
| Weight: | Weight: 1 g |
| Temperature Range | -40 - 85°C |
| Pressure: | 300 - 1100 hPa |




#### *7.1.1.1 Hardware implementation*

The BME280 sensor is the primary method for recording the following measurements.

a) Temperature
b) Humidity
c) Atmospheric Pressure

The sensor is capable of reading values at a rate of approximately 1Hz and has a precision of ±0.1 °C. One main feature of the BME280 sensor when compared to other temperature sensors is the ability to directly get an accurate reading without further processing of the incoming data. This means the incoming readouts do not need to be divided or multiplied to obtain a proper temperature/ pressure etc. reading. This process is facilitated via the I2C protocol. The MCU can act as a master and calls data directly from the BME280 sensor (which acts as the slave). The MCU calls the sensor at the address 0x76 and awaits the incoming reply from the BME280 sensor. Depending on the type of call each measurement type (Temperature, Pressure, etc) can be obtained independently.

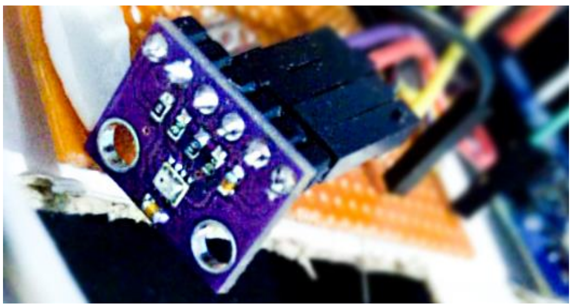
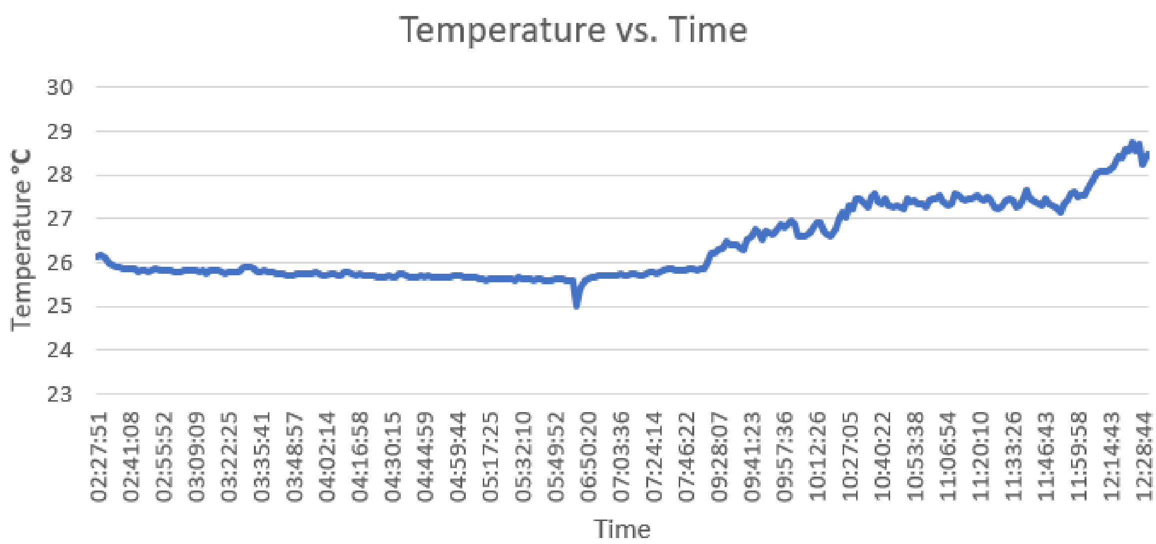


*Figure 14: BME280 sensor*

#### *7.1.1.2 Software Implementation*

The BME280 sensor is controlled by a set of custom functions and methods which work alongside a library known as the BMx280 library. This library has the capability of controlling both BMP and BME type sensors, the primary difference being the **inability** of measuring humidity in the BMP type sensor. Unfortunately, due to incorrect component supply by the retailer a BMP sensor was provided instead of the BME sensor. Hence, humidity values are yet to be obtained.

The obtained values of the sensor are read as floating-point numbers which are converted to char arrays (string) to display on the LCD. Additionally, during this stage data can either be written to the SD card or to the cloud for logging purposes. A sample of such data which was written to the cloud can be seen in the figure below.




Data acquisition was done for a period of about 10 hours at a rate of around one reading every 2 minutes. The variation of temperature can be observed gradually rising as expected due to the sun rising. The temperature was recorded indoors in a semi-ventilated room with no other heat sources and data was logged onto thingspeak.com via the SIM800L module.

### 7.1.2 Air Quality

For measuring Air Quality Index, the microcontroller will gather information about the Total Volatile Organic Compound (TVOC) and an equivalent carbon dioxide reading (eCO2) over standard I2C digital interface [21].

Total Volatile Organic Compound (TVOC) is the combination of gases and indoor volatile substances emitted from many toxins and chemical found in everyday products like candles, fragrances, cooking fumes, cleaning products and craft products[22]. In this project, the level of Total Volatile Organic Compound will be measured in ppb (part per billion). The level of TVOC will show Indoor Air Quality situation[22]. In this project, the level of TVOC will be measured by CCS811 gas sensor with the concentration from 0 to 1187 ppb.

*Table 6: TVOC level explained[22]*

| Air Quality | IAQ | TVOC (mg/m3_) | TVOC (ppb) | Air Information |
|---|---|---|---|---|
| Excellent | ≤ 1.99 | ≤ 0.3 | 0 - 65 | Clean Hygienic Air (Target value) |
| Good | 2.00 - 2.99 | 0.3 - 1.0 | 65 - 220 | Good Air Quality (If no threshold value is exceeded) |
| Moderate | 3.00 - 3.99 | 1.0 - 3.0 | 220 - 660 | Noticeable Comfort Concerns (Not recommended for exposure > 12 months) |
| Poor | 4.00 - 4.99 | 3.0 - 10.0 | 660 - 2200 | Significant Comfort Issues (Not recommended for exposure > 1 month) |
| Bad | ≥ 5.00 | ≥ 10.0 | 2200 - 5500 | Unacceptable Conditions (Not recommended) |

Equivalent carbon dioxide (eCO2): The total level of emissions from various greenhouse gases, converted into equivalent amount of carbon dioxide with the same global warning potential (SWP)[23].

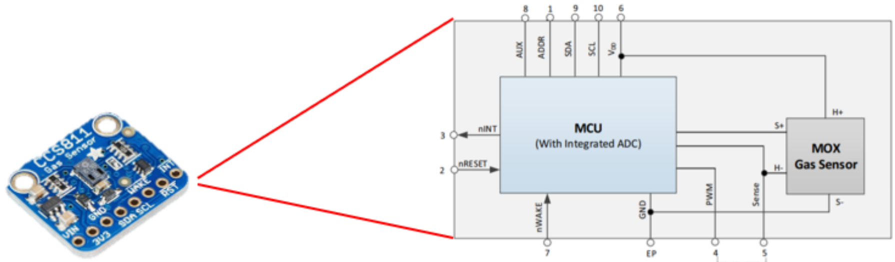
In this project, the eCO2 level is measured by CCS811 with the concentration of 400 to 8192 part per million (ppm)[21]. For example, when the sensor detects one ppm Methane with 25 GWP, it will add 25 ppm to Equivalent Carbon Dioxide. The higher the level of the eCO2, the worse the Indoor Air Quality, the Indoor Air Quality level can be determined as the table below.

*Table 7: eCO2 level explained[21]*

| Level of eCO2 (PPM) | Indoor Air Quality situation |
|---|---|
| 0 - 600 | Excellent |
| 600 - 800 | Good |
| 800 - 1500 | Fair |
| 1500 - 1800 | Bad |
| More than 1800 | Inadequate |

The CCS811 sensor has the ability of transmitting raw ASCII byte data through its data lines as compared to typical analogue sensors which simply give a readout of a voltage. This increases accuracy of the sensor and prevents changes due to voltage variation in the main circuit of the device.

To increase the accuracy of the measurement, it is strongly required that the sensors run for 20 minutes in desired mode per use.




| Pin Name | Description |
|---|---|
| VDD | Supply Voltage |
| GND | Ground |
| SDA | Pin 20 (I2C Communication) |
| SCL | Pin 21 (I2C Communication) |
| WAK | Wake (Active low) |
| ADD | Single address bit. Allows to select alternate address |

*Figure 15: CCS811 sensor interior structure and pinout*

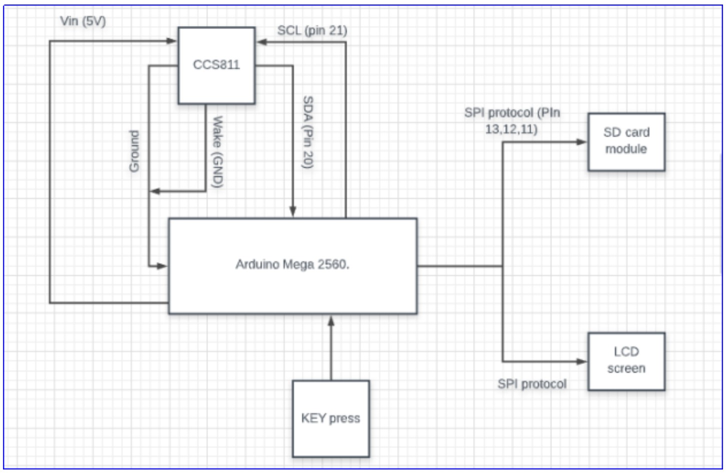
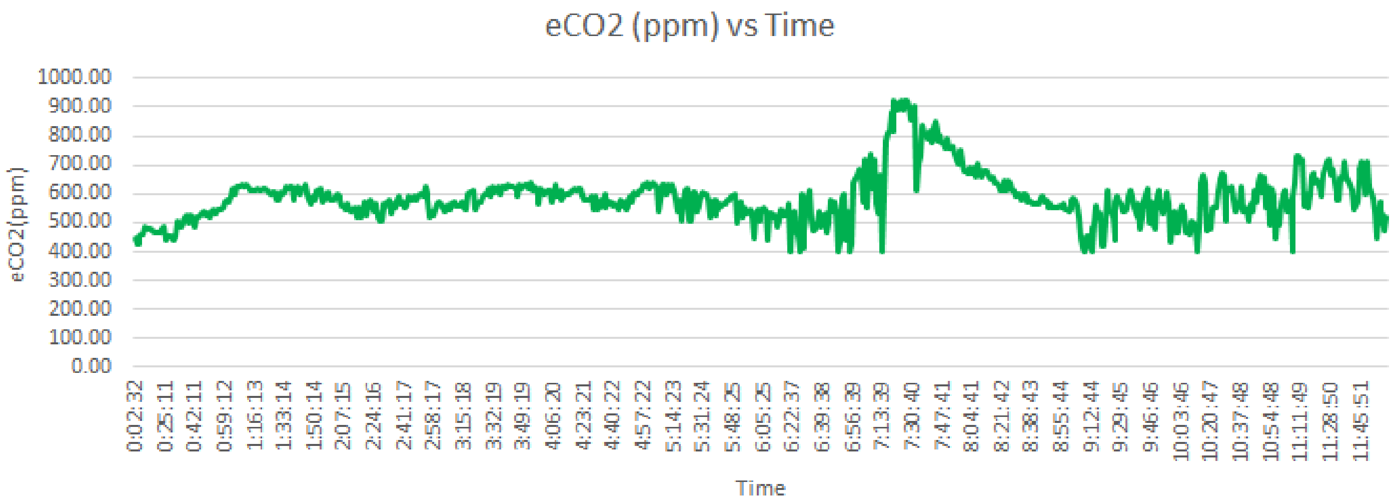



*Figure 16: Block Diagram of Air Quality Sensor systems.*

The device communicates with the microcontroller via the I2C protocol, with requires connection between the sensors with SCL (pin 21) and SDA (pin 20) of the Arduino Mega 2560[21]. Once the Clock signal from SCL pin (21) is synchronized, data transfer between Master device (Arduino Mega2560) and slave device (CCS811) begins. The Arduino will read data from CCS811 via SDA wires (pin 20). Consequently, the signal will transfer to LCD screen to display the value of TVOC and eCO2. In addition, the value from CCS811 will be saved in a .csv file named “Air Quality” in the module SD card. A sample of such data which was written to the cloud can be seen in the figure below.




The CCS811 sensor has measured the Equivalent carbon dioxide for a period of about 12 hours at a rate of around one reading every one minute in Ho Chi Minh City. The level of eCO2 was recorded indoors in a semi-ventilated room during the operation. The data shows that the level of eCO2 was between 400 and 600 part per million from 00:00 AM to 06:00 AM, which means the Indoor Air Quality was “Excellent” and “Good” during nighttime. From 07:00 AM, the value increases significantly up to 950 ppm because there was an increment of other sources that affect the record value such as human, fragrances or cooking fumes in the morning. However, it was just temporary, and the value was decrease steadily back to around 700 ppm during daytime.

### 7.1.3 Soil moisture level

The soil moisture sensor consists of two conducting plates which acts as a probe and a variable resistor in obtaining sensor measurements. Soil moisture content and resistance between two conducting plates are inversely proportional to each other and proportional to the Dielectric Permittivity Constant (DPC). Following section describes the working principle of soil moisture sensor[24-28].

- Soil moisture content is measured based on the change in resistance between two conducting plates.
- First plate connects to +5V through a series of 10kΩ resistance.
- Second plate connects directly to the ground (0V).

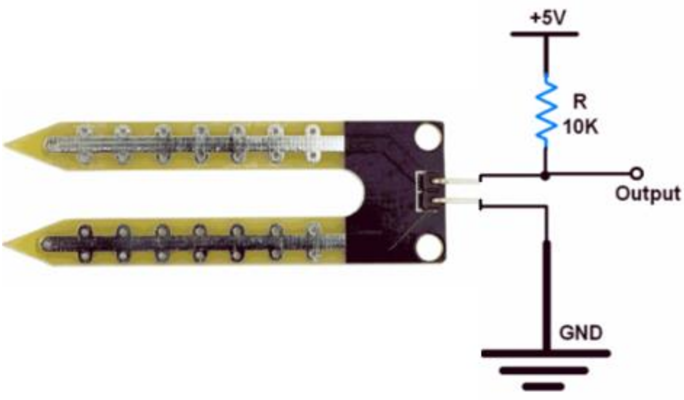



*Figure 17: voltage divider circuit in FC-28 sensor*

- This system acts as a simple voltage divider network as depicted in figure 8.
- Output is obtained through the first terminal of the sensor pin as shown in figure 8.
- Output changes in the range of 0-5V proportionally to the moisture content in coil.
- As an ideal case, when the moisture level is null, the system acts as an open circuit (contains infinite resistance) and the output will be same as the input (+5V).

#### *7.1.3.1 Replacing FC-28 with HW-390 v1.2 capacitive soil moisture sensor*

Through experiments it was determined that two conducting plates of FC-28 sensor tends to corrode and the provide inaccurate soil moisture data when immersed into soil for a long time. Hence, it was replaced by HW-390 v1.2 – a capacitive soil moisture sensor to eliminate errors in data logging over time. Systematically, FC-28 and HW-390 v1.2 both has the same operation in soil moisture measurement as they both measured the DPC and outputs an ADC value accordingly. Two conducting plated capacitive sensor is covered with a rubber layer to protect them from corrosion. Compared to FC-28, this replacement helped to obtain more reliable and accurate soil moisture measurements.

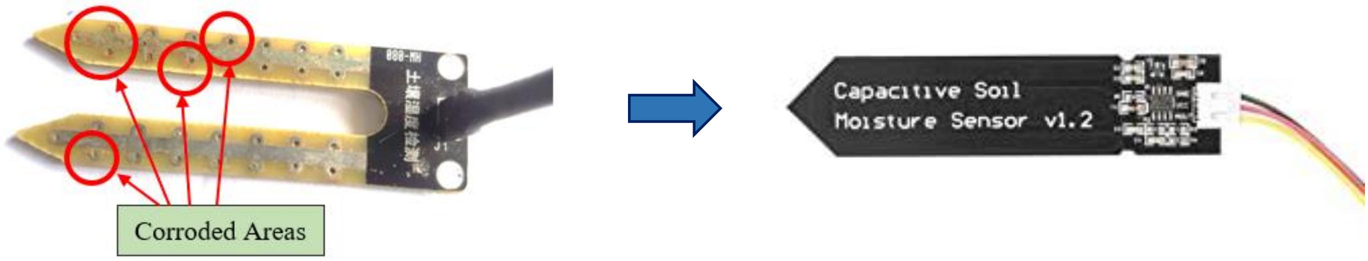



*Figure 18: Corroded areas in FC-28 (Left) and replaced capacitive soil moisture sensor (Right)*

#### *7.1.3.2 Determination of soil moisture content in percentage*

Usually, the sensor reading is treated as an analog reading, as the sensor determines a characteristic in the nature and models it into a voltage signal using ADC principles to obtain the percentage of moisture in soil in a quantized form. ADC processes the analog output of the soil moisture sensor and the moisture content could be displayed in terms of percentage or any other form which is preferred. In accordance with the Atmel Atmega microcontroller specifications (in table 2), sensor output varies in the range of 0-1023 bytes. Following representation provides the way it is processed to obtain the moisture content as a percentage with reference to ADC voltage measurements and advancing equation 1[15-18, 29].

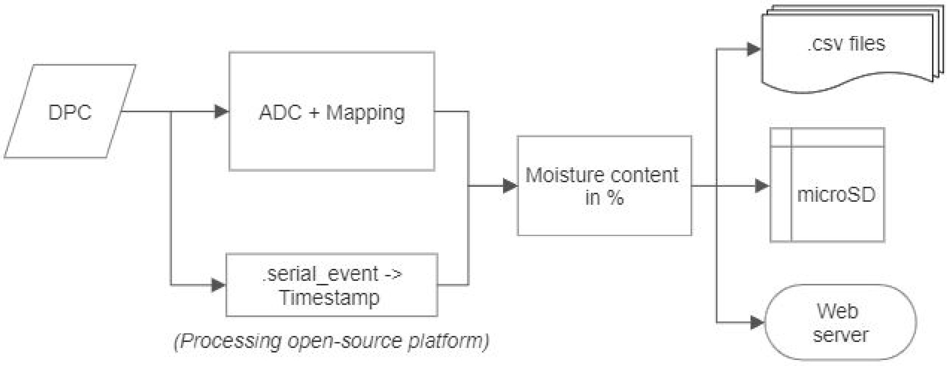
$$Analog\ Output = \frac{Measured\ ADC\ reading\ from\ the\ sensor}{1023}$$

Soil moisture in percentage,

$$\boxed{Soil\ mosture\ content\ in\ percentage(\%) = \big(100 - (Analog\ output \times 100)\big)\%}$$

### *7.1.3.3 Real time data logging and storage*

Soil moisture level (%) is recorded real time in three ways with three different storage principles. Primary storage method is to fetch recorded data to a microSD card. Alternative methods could be mentioned as saving to a .csv file in PC or saving record history in a web server. Following figure depicts the functions used in real-time data logging and storage process.




| | A | B |
|---|---|---|
| 1 | Time | Moisture_Level |
| 2 | 00:03:59 | 25 |
| 3 | 00:08:59 | 24 |
| 4 | 00:13:59 | 25 |
| 5 | 00:18:59 | 25 |
| 6 | 00:23:58 | 25 |
| 7 | 00:28:58 | 27 |
| 8 | 00:33:58 | 26 |
| 9 | 00:38:58 | 24 |
| 10 | 00:43:58 | 25 |

*Figure 19: Real time data logging and storage process with a sample dataset*

As input, DPC of soil in the surrounding area of the sensor will be fed to this system. Thereafter, ADC process will take place with the help of MCU and a timestamp for recorded data is added through processing sketchbook parallel to the MCU operation. Finally, the recorded data are stored in either way among three methods mentioned above. A sample dataset will be as shown as in the figure above.

### *7.1.3.4 Experimental data acquisition*

To measure the accuracy of HW-390 v1.2soil moisture sensor, several datasets were obtained considering three layers of soil. Then the average values were obtained between them to output a validated sensor reading as the soil moisture level for a specific timestamp of the MCU clock. Three levels which were examined using the sensor are namely,

1) O-Horizon (Humus layer) – 5cm deep from ground level.
2) A-Horizon (Topsoil layer) – 18cm deep from ground level.
3) B-Horizon (Subsoil layer) - 50cm deep from ground level.

Following figure 10 depicts those three layers and figure 11, figure 12, and figure 13 depict the positioning of the sensor for data acquisition.

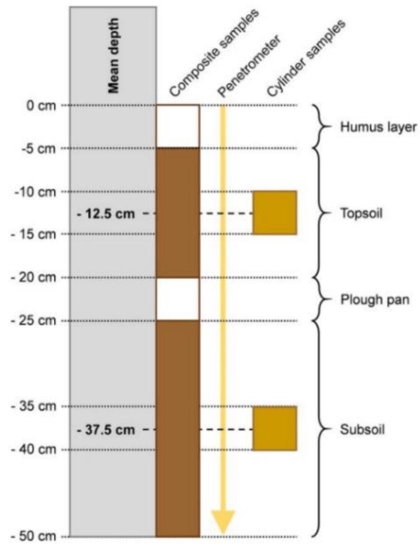



*Figure 20: Schematic overview indicating soil layers and respective depths [13-15*

*Figure 21: Sensor positioned at O-Horizon (Humus layer)(left), A-Horizon (Topsoil layer)(middle), B-Horizon (Subsoil layer)(right)*

### 7.1.4 Analysis of obtained soil moisture data

From the obtained measurements for separate layers, linear regression models were determined to analyse the behavior of soil moisture content over 24 hours. Following are linear regression model graphs obtained for each soil layer with different adjusted root mean squared values.

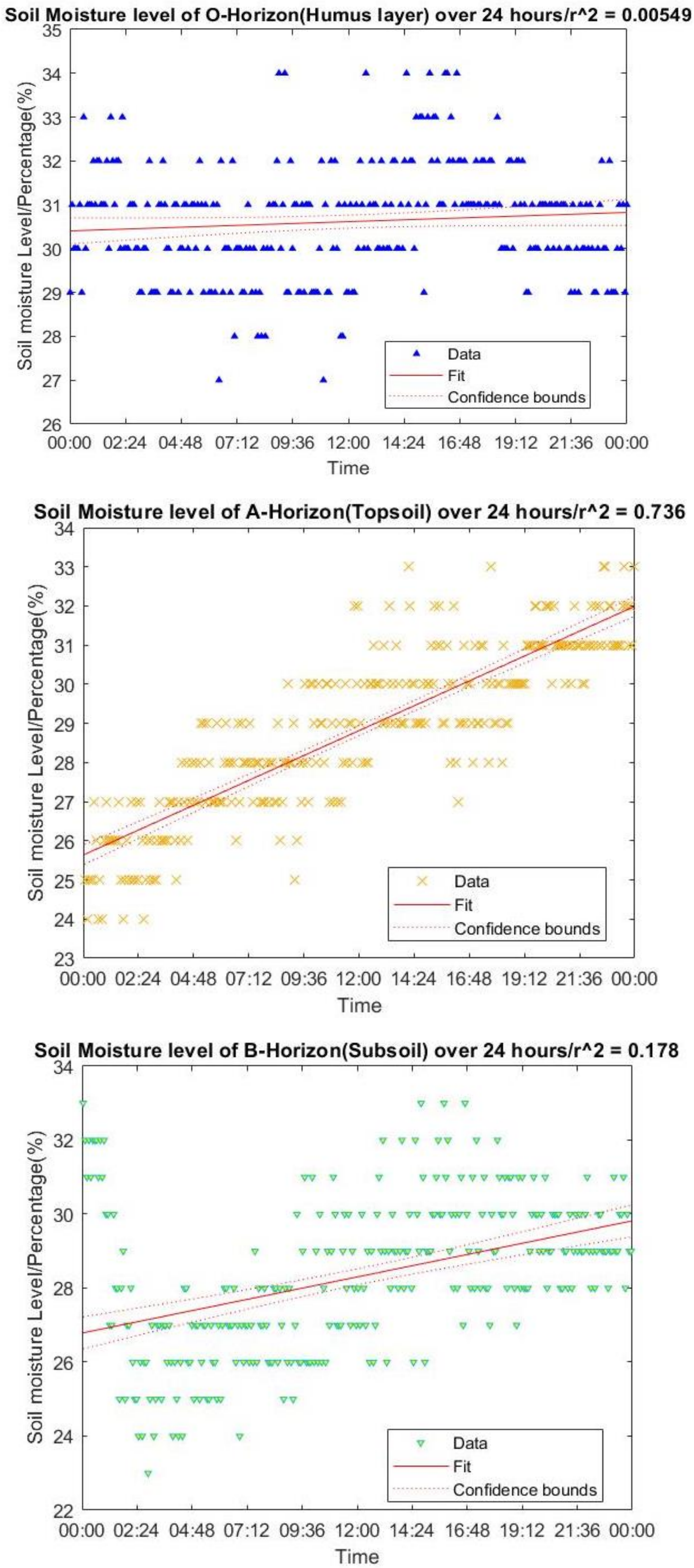



*Figure 22: Linear regression analysis of statistical soil moisture data*

First graph represents the linear regression model with 289 observations for each five minutes of time from 00:00h to 23:59h for the soil moisture percentage of O-Horizon (Humus layer) nearly 8cm-10cm deep from the ground level. The root mean squared error is obtained as 1.29 with $r^2$ value being 0.0894 and the adjusted $r^2$ value being 0.00549. The fit line shows a positive correlation of the soil moisture percentage with time. It has a comparatively small gradient, which could be considered as almost static over a given short period (for 2 or 3 hours in a regular day). And the whole moisture percentage data are varied between 26% and 35% while the fit line is drawn between 30% and 31% of soil moisture percentage. Standard deviation of the soil moisture percentage is being 1.2915 and the average soil moisture level is determined as 30.6159% for the set of data logged in the considered period and the soil layer (O-Horizon/Humus).

In the second graph, the variation of soil moisture percentage is plotted during the same period for the A-Horizon (Topsoil) to the depth of 10cm-25cm from the ground level. The linear regression model shows a positive correlation of the soil moisture percentage with time. Therefore, the soil moisture level could be defined as a variable that is linearly decreased over time in the specific layer. Average soil moisture percentage is obtained as 28.8194% and the standard deviation of 288 observations is obtained as 2.1386 for this layer. Comparatively, both parameters are much larger than the values in O-Horizon layer. The root mean squared error is obtained as 1.1 with the $r^2$ value and the adjusted $r^2$ values being 0.737 and 0.736.

Third graph represents the linear regression model with 288 observations for each five minutes of time from 00:00h to 23:59h for the soil moisture percentage of B-Horizon (Subsoil) nearly 25cm-50cm deep from the ground level. Overall trend of the soil moisture percentage is positive with respect to the time. Soil moisture percentage data are spread between 22% and 34%. Average soil moisture percentage is obtained as 28.3021% which is close to that of topsoil, compared to the O-Horizon layer soil moisture average value. And the standard deviation of the data is recorded as 2.0624 where the root mean squared error is 1.87, $r^2$ and adjusted $r^2$ values being 0.181 and 0.178.

Accompanying the analyzed experimental results, the top layer of soil maintains almost a static moisture level compared to topsoil and subsoil layers. And with the time, all three layers show a linear increment (a positive correlation) of the soil moisture percentage regardless of the gradients of them.

This is an experiment performed to observe the behaviour of soil moisture content over a whole day from 00:00h to 23:59h to predict the soil moisture content in percentages with real-time data logging in a cloud database. Turning back to the portable smart weather measuring device, determination of these experimental analyses in large scale would help to record, analyse, and predict the daily, weekly, monthly, and yearly soil moisture content for numerous applications. i.e. business purposes, large scale experiments, research purposes.

Moreover, the external soil moisture sensor probe would be able to attach and detach from the weather measuring station which would count as a good portability feature besides the ability to log large scale data in real-time.

### 7.1.5 Geo - Location - Neo 6M GPS Sensor

Since weather differs regionally a rough estimation of the user's location (at the time of measurement) while data logging allows much more enhanced data gathering capabilities and provides a richer dataset. The ability of logging the longitude and latitude of the data allows post visualization of data on a map to see where the user has travelled while taking measurements.

#### 7.1.5.1 Hardware Implementation

The GPS module consists of two main components which are the actual module itself and the accompanying u.fl ceramic antenna. This antenna is capable of receiving GPS satellite signals when the device is outdoors. In addition to having an antenna the module also has a backup reserve battery for the task of saving UTC time and the last known GPS fix. This enables quick acquisition of the GPS signal in subsequent power-ups of the device (known as hot-fixing). The time taken for a hot fix in adequate conditions is around **1s** whereas a cold start would require around **28s**. The saved UTC time and last fix location are recorded on the inbuilt EEPROM chip located on the module.

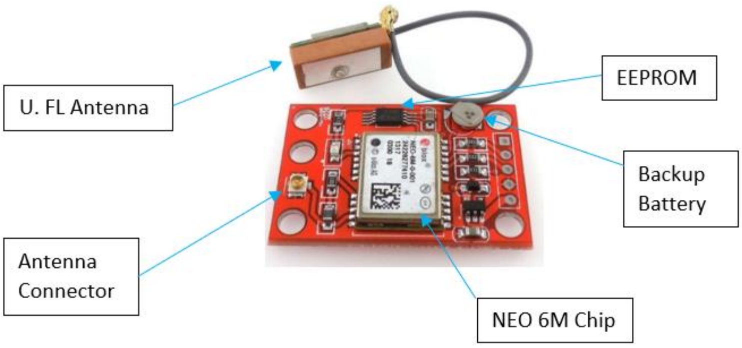



*Figure 23: Neo6M GPS sensor*

*Table 8: Neo6M GPS sensor pinout and specifications*

| Pin-Out [NEO 6M → ATMEGA2560] | |
|---|---|
| VCC | +5V |
| GND | GND |
| TXD | D16 (Serial 2) |
| RXD | D17 (Serial 2) |

| Specifications | |
|---|---|
| Position Update Rate | 1Hz |
| Position Accuracy | 2.5m |
| Current Draw | 30 - 60 mA |
| Time to acquire signal | 1s - Hot / 26s cold start |
| Power source | VCC or backup battery for UTC time backup |

#### 7.1.5.2 Software Implementation

To facilitate the task of fixing a GPS signal the NEO 6M GPS module was utilized. The module provides a serial communication interface which uses the typical serial standard of the atmega2560 to provide an output which adheres to the National Marine Electronics Association (NMEA) standard.

The generated output is provided in the form of NMEA sentences. These can be utilized to obtain the geo-location, altitude and UTC time of the device. Additionally, the relative ground speed, heading and no. of satellites connected can be obtained.

A typical example of a NMEA sentence is shown below.

**$GPRMC, 123519, A, 4807.038, N, 01131.000, E,022.4, 084.4, 230394, 003.1, W*6A**

| | | |
|---|---|---|
| 1 | GPRMC | Global Positioning Recommended Minimum Coordinates |
| 2 | 154127 | Current time in UTC – 15:41:27 |
| 3 | 0609.035 | Latitude 06 deg 09.035′ N |
| 4 | 07931.000 | Longitude 79 deg 31.000′ E |
| 5 | 016.4 | Ground Speed in knots |
| 6 | 240820 | Current Date – 24th of July 2020 |
| 7 | W*6A | Checksum Data |

To assist with interpreting the following data the library TinyGPS++ was used. This simplifies reading the generated serial output of the module and enables direct access to desired data points such as.

1. Longitude & Latitude
2. Ground Speed
3. UTC Time and Date
4. Heading Angle

The outputs are read and displayed on the LCD to show the users current location or ground speed. Additionally, the data can be tagged alongside the other measurements to obtain a geo-tagged data. Using this method, the corresponding temperature/ soil moisture etc values can be linked to places on a map. This enables a much richer form of data acquisition.

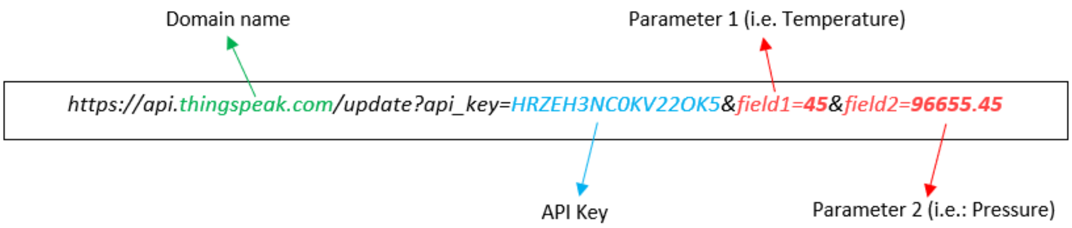
### 7.1.6 Cloud Integration

In the modern world all sufficiently equipped elctroinc devices are expected to have some sort of wireless connection to the internet. The pricnicples of IoT have been added to the device to facilitate this process by utilizing the SIM800L module. This module provides access to both GSM and GPRS signals for both SMS and online capabilities. The mechanism which the device uses to trasmit data to the network is carried out via standard AT commands.

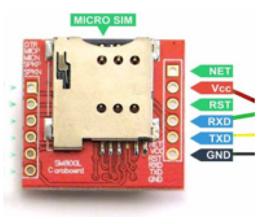
After the prilimanary setup commands have been instruced to the module, namely,

1. Allocate APN to network (Access Point Name)
2. Power on GPRS
3. Retrive current IP address
4. Initiate HTTP request parameters

The instruction to initate a simple GET request to the thingsspeak server can be intiated after these steps. During this process the device trasmits data in the form of a GET request with sensor information encoded into the URL. The example below depicts how this process is accomplished.




Additional parameters can be included to the above string by joining them at the end with "*&field**n***" where n (n =1,2,3,4…) is the parameter identifier as set by *thingspeak.com*. Furthermore, the pinout diagram of the module is depicted below




| Pin-Out [SIM800L → ATMEGA2560] | |
|---|---|
| VCC | +4V |
| GND | GND |
| TXD | D15 (Serial 3) |
| RXD | D14 (Serial 3) |

| Power Consumption | |
|---|---|
| Idle | < 7mA |
| GSM Transmit (avg) | 350mA |
| GSM Transmit (peak) | 2000mA |

Due to certain discrepancies between the advertised SIM800L and the one received a 2200 μF capacitor was added parallelly to the power line in order to meet rapid current surge requirements.

### 7.1.7 User Interface Development

The system which links the hardware and the software and allows the user to control the device is the user interface. The primary mode of displaying information and status of the device is via the 2.4" TFT Panel. The panel works via 8 data lines and 5 control lines. The combination of these connections allows displaying coloured images of up to 320 x 240 pixels. However, to minimize unnecessary distractions a minimalistic approach was taken when implementing the UI of the device. (This however, is subject to change in the final product)


*Figure 24: Current Design for Prototype & Proposed End Design*

The home page of the device roughly resembles the "app-like" design model of modern-day cellular devices and as such displays two columns of "apps" which the user can jump into depending on the feature of the environment they would like to measure.

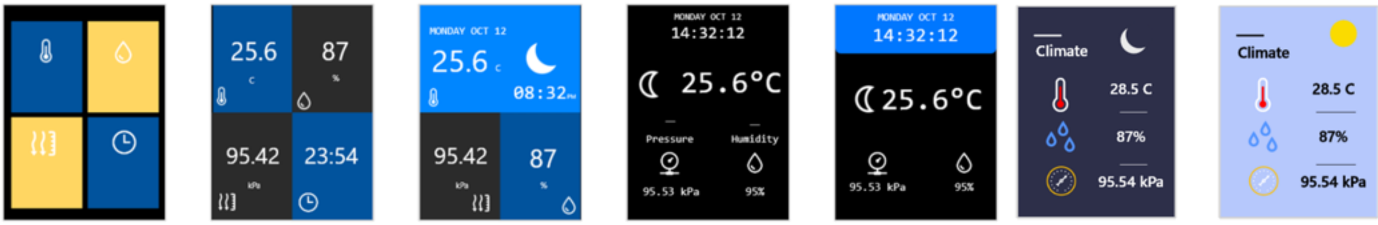



*Figure 25: Further Preliminary Designs*

#### 7.1.7.1 UI Testing on Actual LCD Hardware

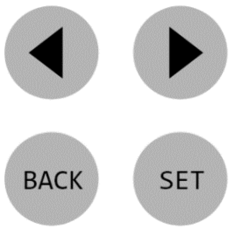
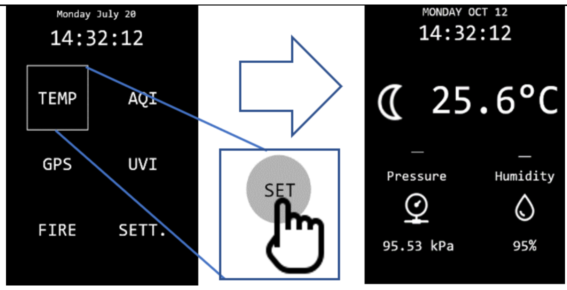
The current LCD consists of a 2.4" display with a resolution of 320x 240 pixels. It is primarily driven by 8 data lines, 5 control lines and 2 power (VCC, GND) lines, for a total of 15 connections. Since the display does not operate using modern communication protocols such as SPI or I2C the number of connections is considerably high. For programming the display and interfacing the Adafruit GFX library is used to display text, symbols and other features on the display.


*Figure 26: UI functions in current prototype*

#### 7.1.7.2 Navigation

Primary navigation through the interfaces is currently done using tactile buttons. Most functions are capable of being performed via the following layout. For example, navigation through the home screen can be performed by clicking the "LEFT" or "RIGHT" buttons and selecting the desired "app" can be performed by pressing "SET". To return to the previous page "BACK" button can be used.

*Table 9: Navigation button functions*

| Primary Navigation | Demo of Pressing SET at Home Screen |
|---|---|
|   |   |

### 7.1.8 Power Management

The primary power supply of the device is two 18650 batteries in series which generate a combined voltage of 8.4V when fully charged. To properly power these batteries a BMS module is connected which prevents battery over/undercharging and greatly enhances safety. Additionally, a buck converter is used to lower the voltage of the supply to 5V so other components such as the sensors and LCD display can be directly connected to a common rail.

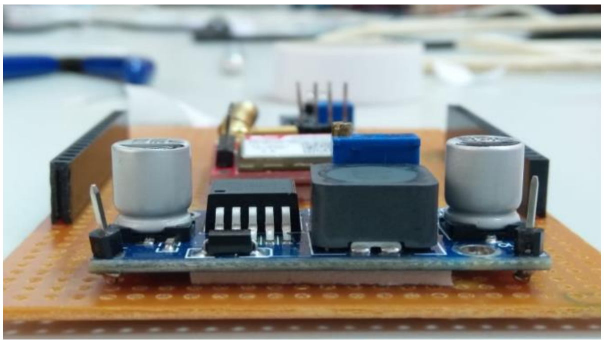


*Figure 27: Power supply circuit of current prototype*

## 7.2 Demonstration of progress

The progress of the project can be monitored by comparing the achieved milestones and outcomes with the proposed milestones. The proposed milestones of the project and the completed milestones are indicated in the table 11.

*Table 10: Progress versus proposed milestones*

| Task | Proposed semester: Capstone | Proposed sub tasks | Status |
|---|---|---|---|
| Literature Review | 4A | Research on existing weather stations and sensors | Completed |
| | | Developments for the portable weather stations | Completed |
| | 4B | Further developments for the portable weather stations | Not commenced |
| Testing | 4A | Testing the functionality of the sensors. | Completed |
| | 4B | Power Consumption of the device | Not commenced |
| | | Response time of the device | Not commenced |
| | | Accuracy level of the device | Not commenced |
| Designing | 4A | Device architecture | Completed |
| | | Electrical and electronic design of the system | Partially completed |
| | | Modelling CAD drawing | Completed |
| | 4B | Device frame designing | Partially completed |
| | | PCB | Not commenced |
| Programming | 4A | Software implementation of the prototype. | Completed |
| | | Testing and error correction of the program of prototype | Completed |
| | 4A | Software implementation of final design | Not commenced |

| | | | |
|---|---|---|---|
| | | Testing and error correction of the program of final product | Not commenced |
| Fabrication | 4A | Prototype fabrication | Completed |
| | 4B | PCB fabrication. | Not commenced |
| | | Device fabrication. | Not commenced |
| Documentation | 4A | Project proposal. | Completed |
| | | Project Presentation. | Completed |
| | | Progress Report for Capstone A | Completed |
| | 4B | Completion Plan for Capstone B | Not commenced |
| | | Final presentation | Not commenced |
| | | Final Report | Not commenced |

Literature review was done throughout the Capstone part A regarding the existing portable weather station and different types of sensors used in these weather stations. The testing of sensors was almost completed, however, due to COVID-19 pandemic it was difficult to find sensors such as ML8511 which is used to measure the luminosity. Device architecture, electrical and electronic system design and a CAD drawing of the device was proposed to complete in Capstone part A. The team was able to complete both device architecture and CAD drawing of the device in capstone part A, however the electrical and electronic design was partially completed, due to lack of sensors. Although the device frame is expected to complete in Capstone Part B, the team managed to complete the designing section of the device frame. Furthermore, team managed to fabricate a prototype of the proposed weather station as proposed. Software implementation of the weather station was successfully done with several trial and error modifications for the fabricated prototype.

## 7.3 Future works and a detailed workplan for the second semester

Following milestones have been accomplished by the group upon current progress of the project throughout capstone phase 4A.

a. Proposal submission.
b. Presentation (4A) submission.
c. Progress report submission.
d. Prototyping and development

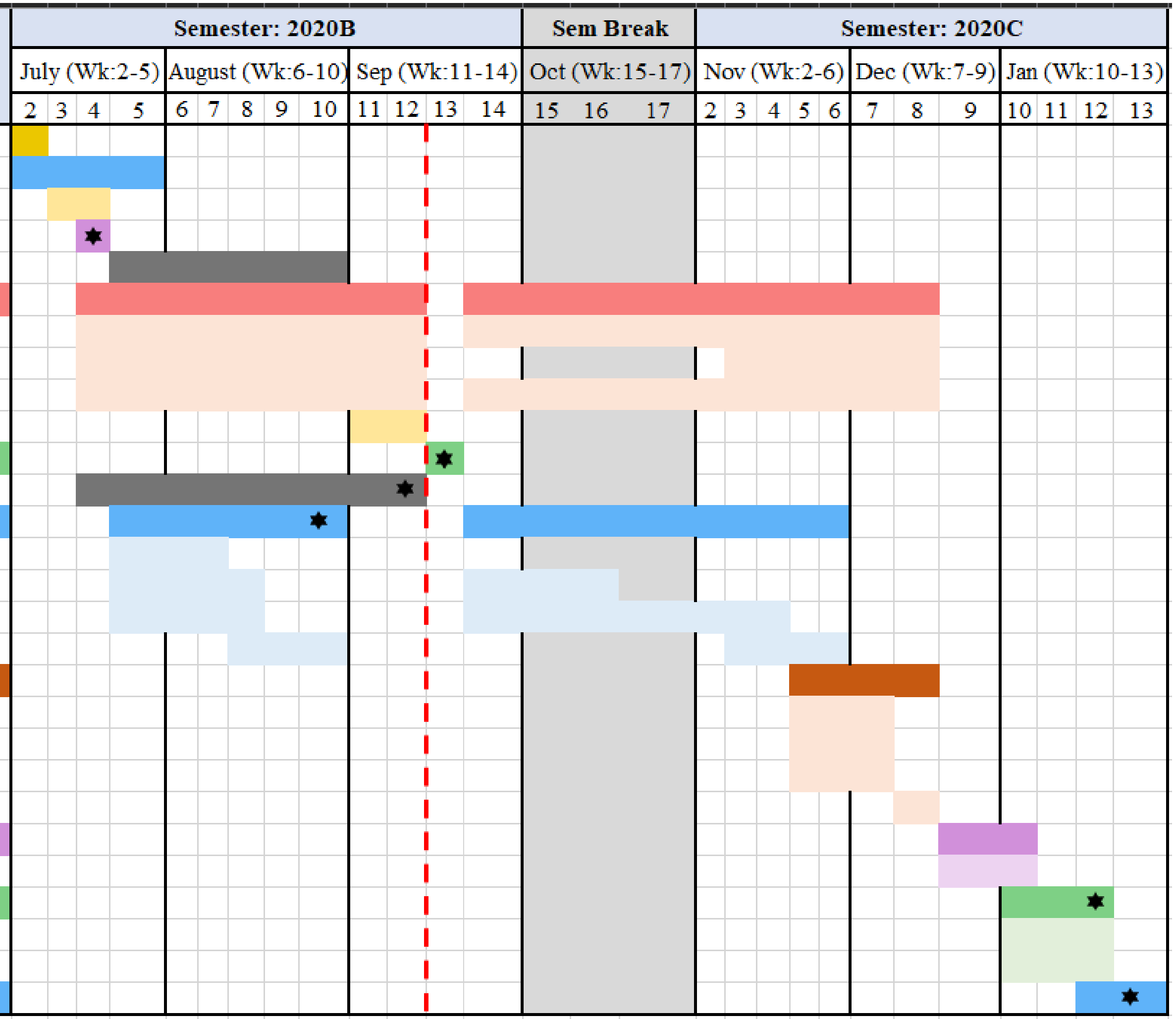
The team managed to build and develop a functional prototype of the product and meet the success criteria set forth. Moreover, there are several features to be included to the product towards the development and fabrication of the final product design. After completion of Capstone phase 4A in semester 2020B, following main tasks are set to be completed during the semester break and by the end of upcoming semester 2020C (Note: there are sub tasks under each main task).

a. Performing further research.
b. Prototyping and development.
c. Testing and evaluation.
d. Finalizing project.
e. Final documentation and presentation.

Among the main tasks mentioned above, final documentation presentation is marked as project milestones. More detailed plan including sub tasks under main tasks could be presented in the project timeline as follows.

## 8 WORK PLAN AND PROJECT TIMELINE

| | Risk | Task Name | Status | % Progress |
|---|---|---|---|---|
| ✓ | | **Kick off meeting** | **Completed** | **100%** |
| ✓ | | **Preliminary Research** | **Completed** | **100%** |
| ✓ | | **Proposal Writing** | **Completed** | **100%** |
| ✓ | | **Proposal Submission** | **Completed** | **100%** |
| ✓ | | **Proposal Approval** | **Completed** | **100%** |
| | | **Further Research** | **In Progress** | **85%** |
| | | Research on Developments | In Progress | 80% |
| | | Literature Review | In Progress | 75% |
| | | Project Planning | In Progress | 80% |
| ✓ | | **Prepare Presentation** | **Completed** | **100%** |
| | | **Project Presentation (4A)** | **In Progress** | **90%** |
| ✓ | | **Progress Report** | **Completed** | **100%** |
| | | **Prototyping & Development** | **In Progress** | **60%** |
| | | Test the sensors | In Progress | 70% |
| | | Design Hardware | In Progress | 55% |
| | | Design software | In Progress | 45% |
| | | Alteration | In Progress | 50% |
| | | **Testing & Evaluation** | | |
| | | System model evaluation | | |
| | | Record sample data | | |
| | | Trial & Error modifications | | |
| | | Finalize the design | | |
| | | **Finalizing Project** | | |
| | | Manufacturing(PCB, 3D print etc.) | | |
| | | **Final documentation** | | |
| | | Final report writing | | |
| | | Submission | | |
| | | **Final Presentation (4B)** | | |




- Red Dashed line ( ) indicates the current Week
- = Project milestones
- = Low Risk, = Moderate Risk, = High Risk

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## 10 APPENDICES

1) **Appendix A -** Data Acquisition files
    a. Full stack: https://rmiteduau-my.sharepoint.com/:f:/g/personal/s3765778_rmit_edu_vn/Ei7m68o914NOq-5HFkKtS2kBg6TRf76eq9UcoX1SLVLzyg?e=wgTfWv
    b. Flame Detection: https://rmiteduau-my.sharepoint.com/:f:/g/personal/s3765778_rmit_edu_vn/EqvTsuGfWVxDh6NviGWFYEkB5Rf9S3bALypiI9ls15i_Ow?e=cdc74w
    c. Soil Moisture Detection: https://rmiteduau-my.sharepoint.com/:f:/g/personal/s3765778_rmit_edu_vn/Eop7_0Az7c9FuT_gTDaDDZYBOXALDRqcklUtPjXrWYsJQw?e=Kahrlt
    d. Air Quality Detection: https://rmiteduau-my.sharepoint.com/:f:/g/personal/s3765778_rmit_edu_vn/EvXIJOgQhFdGhRASHUDN8_UBc5nVdHwRqslz5JD-V0JgmQ?e=Rnn4kV
2) **Appendix B -** Sensor Readings
    a. Link: https://rmiteduau-my.sharepoint.com/:f:/g/personal/s3765778_rmit_edu_vn/EiEJsCzUWG5LlCQJYDgWXooB3d-R_CtGHwQby_J5cIDl6A?e=CmNt7B
3) **Appendix C -** Data Analysis files
    a. Link: https://rmiteduau-my.sharepoint.com/:f:/g/personal/s3765778_rmit_edu_vn/ElChmg0UB6lAstUY5Ji9EJwBo5r9pYPvbp5-6z1ptHlTCg?e=t5plgP
4) **Appendix D -** 3D Solidworks Drawing files
    b. Link: https://rmiteduau-my.sharepoint.com/:u:/g/personal/s3765778_rmit_edu_vn/ESqNrcoklLNMquYJrsVbVtYB1QKC60r4ZutsrjlVkczwUA?e=e2J16g