Design and Development of Breathing Air Level Transmitter by using Arduino

By

Benjamin Chen Wee Kiat
16494

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Approved by,

____

(AP Ir. Dr. Nursyarizal Bin Mohd Nor)

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

BENJAMIN CHEN WEE KIAT

Abstract

Firefighters risk their own lives while performing their required tasks, which is rescuing under dangerous and hazardous environment. There have been numerous amount of cases in which the firefighters themselves were not able to survive and died before they even managed to carry out their duties. Therefore, a mechanism or system to monitor the condition of a firefighter on duty is very much needed and must be implemented. This system should be able to allow another personnel who is not on duty to monitor the condition of the firefighter throughout the whole period when he or she is on duty under dangerous environment. Through this, fast and immediate actions can be taken whenever there is an emergency or accident that occur and thus fatalities involving firefighters while carrying out their mission can be prevented. With the digital air flow sensor used, it will be able to transmit real time data to the monitoring system and indicate the control centre whenever the oxygen level in the tank is low.

Acknowledgement

I would like to take this opportunity to express my deepest gratitude to all individuals who have given their endless amount of precious time to assist me in completing the project. The cooperation that they have given proved to be completely useful and relevant and I would have faced many difficulties without all this.

Special thanks goes out to my project supervisor, AP Ir Dr, Nursyarizal Bin Mohd Nor for his guidance and assistance during the entire period of my project. The amount of information and knowledge that he has shared with me has strengthened my ability in this field in order to complete the project within the timeframe given. Thanks also to the Final Year Project Coordinators and Committees for their information and guidance regarding this project.

Lastly, I would like to express my gratitude to my parents and friends around me as well, for their endless support and advice throughout the entire period of this project.

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List of Abbreviations

EMS	Emergency Medical Services
I2C	Inter-Intergrated Circuit
PASS	Personal Alert Safety System
SCAMP	Supercritical Air Mobility Pack
ADD	Aerospace Design and Development
LCD	Liquid Crystal Display
MEMS	Microelectromechanical System
SCL	Serial Clock Line
SDA	Serial Data Line
SLPM	Standard Litre Per Minute
PWM	Pulse Width Modulation
UART	Universal Asynchronous Receiver/Transmitter

CHAPTER 1
INTRODUCTION

1.1 Background Study

Firefighters play a vital role in our everyday lives in the human society. They are made up of a group of people who are very well trained in firefighting, essentially in a situation where there are hazardous fires that may possess harm to property, civilians or natural populations [1]. In addition to being a firefighter, this group of experienced individuals is also trained to rescue people out of any sort of emergency situations, such as people who are trapped in collapsed buildings, burning buildings or vehicles.

Firefighters around the world go through very specific and intensive training and in some countries, they are also trained in Emergency Medical Services (EMS) [1] in which they also assist the medical officers and ambulances in addition to being a firefighter. Other than that, they might be required to collaborate trainings with other specialized organizations too, such as the police, navy or military forces. They are considered as one of the three main emergency services in the world, which would respond to any incidents or accidents immediately at any given point of time.

Different countries in the world have different rescue team division and their own specific responsibilities. In Malaysia, the firefighting division will be managed by Jabatan Bomba dan Penyelamat (Department of Rescue and Firefighting) [2].

1.2 Problem Statement

While carrying out their duties, firefighters will be exposed to hazardous, unsafe and risky environments all the time. For example, a male volunteer firefighter on duty died on 6th September, 2010 after inhaling sewer gases and experiencing low oxygen problem while on his way climbing down into a sewer manhole in an attempt to rescue a village utility worker who was trapped underneath [3]. Besides that, there are several other incidents, which took away lives of the firefighters as well due to this issue. Hence, monitoring the conditions of these firefighters in duty becomes crucial in order to prevent more accidents from happening, especially their breathing air level in benchmarking the condition of the firefighter themselves. Once this data is available to be monitored by authorized personnel, they are able to take fast and responsive actions immediately.

Figure 1 shows the firefighter fatalities statistics in 2014 in Malaysia. As it is shown, fireground operations contribute to the most amounts of fatalities involving firefighters. This operation involves all the operations carried out in the ground such as firefighting and rescuing activities. No immediate response can be taken when a firefighter on duty is in danger because their conditions are not monitored which led to so many of the incidents above, and air breathing level is one of the main factors.

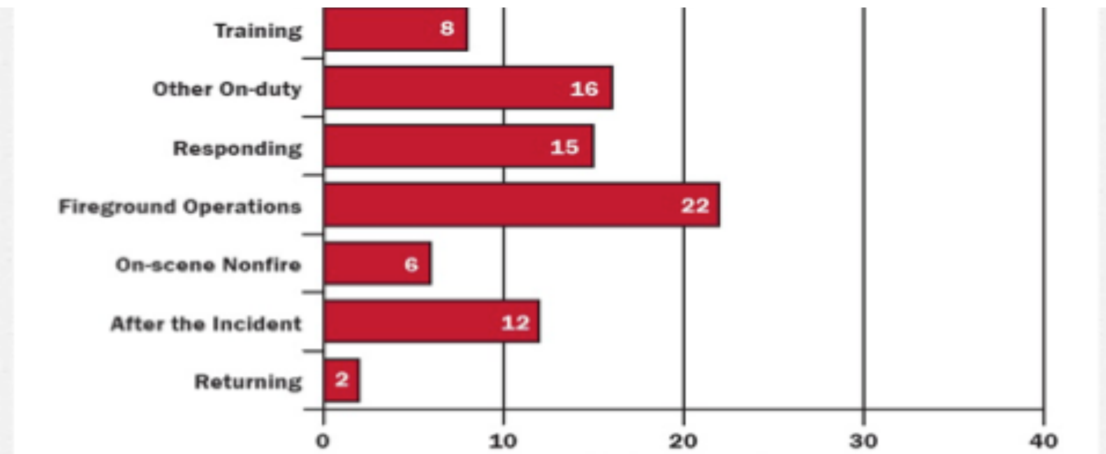

Figure 1: Firefighters fatalities statistics in 2014

1.3 Objectives

The main objective of this project is to monitor the air breathing level of a firefighter on duty. In order to achieve this, a digital air flow sensor will be attached in between the oxygen tank and the breathing mask of the firefighter. An Arduino microcontroller will be used to read the reading of the sensor and display it on a monitor for the officers who stay outside of the accident area to interpret and determine the condition of the firefighters.

The objectives of the project are:

- To monitor the air breathing level in the oxygen tank of the firefighter and give out alert when the oxygen level is low
- To transmit real-time oxygen level data from the tank to the monitoring system wirelessly
- To develop a new oxygen monitoring product while maintaining the design of the oxygen tank

1.4 Scope of Study

The project starts by conducting a study on the digital air flow sensor and its working principle, as it will be the main component used in this project. Some other components that are used are laptop, batteries and the Arduino microcontroller.

The system will be setup using both software and hardware. The software involved in this project is the Arduino IDE. Therefore, the scope of study will cover the working fundamentals of the Arduino microcontroller.

For the digital air flow sensor, the main function of it in this project is to measure the oxygen level in the oxygen tank of the firefighters. In order to achieve this, this sensor will be integrated with the Arduino microcontroller to display the air breathing level on a monitor or laptop. If the level of oxygen is below a certain threshold which may be dangerous to the firefighters, alert will be sent out to them to notify them and increase their awareness to their situation. Therefore, this involves the interfacing on Inter-Integrated Circuit (I2C) programming between the air flow sensor and the Arduino microcontroller.

Besides that, further study is done on the use of I2C programming library for the digital air flow sensor and the codings involved in order to successfully display the correct data on the laptop for monitoring purposes. Finally, the digital air flow sensor will be tested on the functionality in real life situations.

CHAPTER 2
LITERATURE REVIEW

A small research and survey has been done, showing that there were some similar products developed before this in order to ensure the safety of a firefighter on duty. The first one is Personal Alert Safety System (PASS) device while the second one is Supercritical Air Mobility Pack (SCAMP) and they will be discussed further in this chapter.

2.1 Personal Alert Safety System (PASS) Device

A PASS device is a personal safety device used by firefighters around the world in the event of entering a precarious building such as a burning or collapsing building [5]. In a situation where a firefighter is in distress, this PASS device sends a loud alert to notify others in the surrounding.

Figure 2 shows the PASS device which is usually attached and used together with the breathing mask of a firefighter. When it does not detect any motion for 30 seconds, it will assume that the firefighter is either trapped or seriously injured and it will therefore produce a very loud beep to alert the people nearby. Hence, this device can also be activated manually, in the event where a firefighter is lost among the pack or get trapped by collapsing buildings.

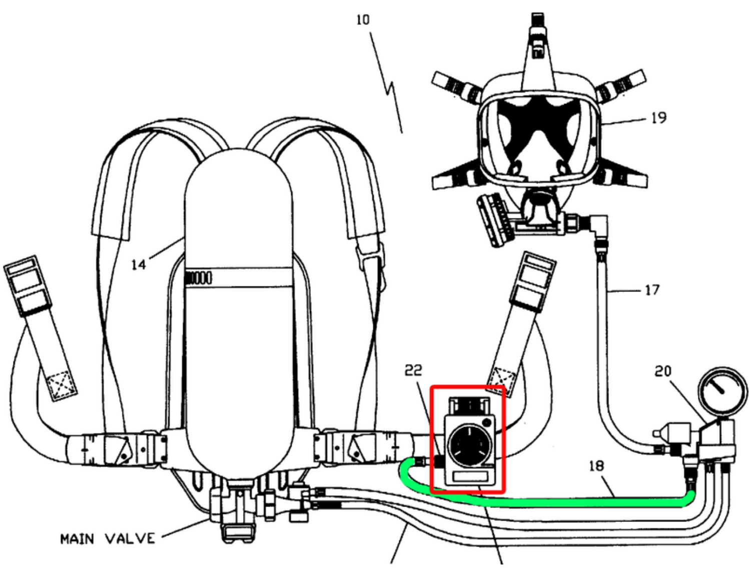

Figure 2: A PASS device together with a SCBA unit

Several experiments has been done to show that this PASS device is able to sustain itself in an extreme condition, in this case referring to high temperature. In this experiment, three types of tests were carried out, mainly the Static Oven Test, Flow Loop Test and Mannequin Test. For the first test which is the Static Oven Test, the PASS device will be placed inside an electric oven as shown in Figure. The range of the temperature of this oven varies from 18° C to 250° C [10].

Next, for the Flow Loop Test, the PASS device will be placed inside a flow loop. In this flow loop, a specific temperature of the gases will be maintained by the heat produced by the resistance heater. A blower will also be inside the flow loop to blow the heat produced. The range of the gas temperature varies from 18° C to 150° C [10].

For the third and final test which is the Mannequin Test, the PASS devices are attached on to the body of the mannequins to monitor the device condition under different exposures of fire [10].

Even though this device has been produced, the firefighters' safety is still in harm due to unexpected conditions and environment. Therefore, a way to improvise this system is to come out with a mechanism, which enables the firefighters on duty to be monitored outside the rescue scene so that immediate actions can be taken whenever there is an accident.

2.2 Supercritical Air Mobility Pack (SCAMP)

SCAMP was first developed by Aerospace Design and Development (ADD). The function of this system, as shown in Figure 3 is to provide cooling and also breathing from supercritical cooled (cryogenic) compressed air. A vacuum bottle called dewar is used to store this air. When the human body produces heat, it will be used to warm the cold air to a temperature 50-60° F at the backpack, which consists of a heat exchanger. An undergarment laced with tubes consisting antifreeze mixture and a flowing water will be worn by the rescuer and the liquid will be pumped to the rescuer's body. This particular liquid will be heated again by the rescuer's body, which is eventually pumped to the heat exchanger and then being cooled by the cold air from dewar. The same source provides the cooling and breathing air.

When compared to the conventional SCBA equipment, this system is slightly smaller and lighter. Besides being more convenient to carry, it also provides longer operating period of time. This is because of the high fluid density and also low pressure in the dewar. The density of the air inside the tank will be measured by a capacitor and the remaining air left will be calculated by a computer. In order for the rescuer to be informed, they will be notified through a beeper alarm and a LCD display mounted in the mask [11].

This system is considered quite practical, but still it lacks of a monitoring mechanism. The condition of a firefighter on duty is unknown once they are inside a building and they might be involved in any accidents but no one is aware of it. Therefore, a monitoring mechanism is strongly recommended to be implemented in this system.

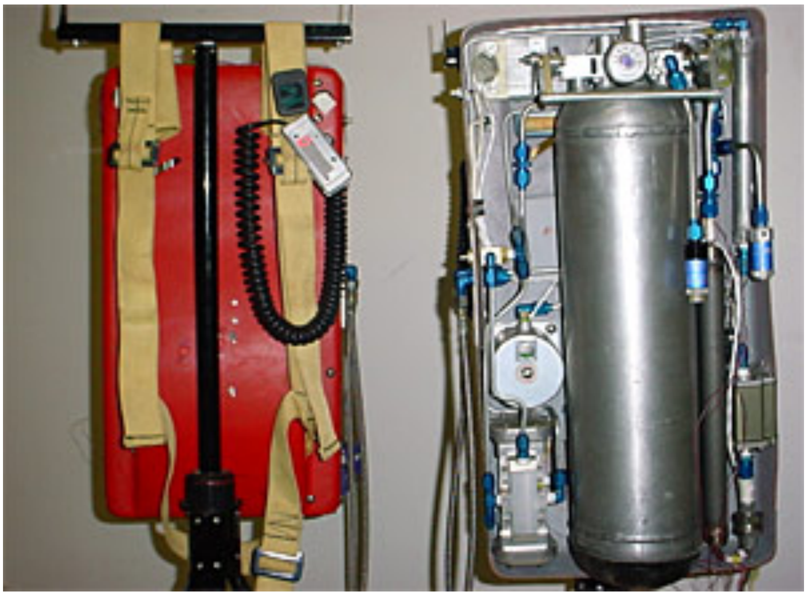

Figure 3: SCAMP System

2.3 Oxygen Monitoring Technique

Oxygen level monitoring is one of the critical systems, which is being tested in order to assist firefighters in performing their duties successfully while reducing the amount of casualties. This research has been conducted actively all around the world in order to come out with a most practical system to be used and implemented in real life situations.

Besides the search and rescue industry, there have been statistics showing that researches have been done even in the medical industry on this oxygen monitoring technique. For example, in hospitals, the pressure of the oxygen cylinders are being tested and measured using the MEMS pressure sensor. This particular sensor will transmit real-time pressure data from the oxygen cylinders to a monitoring system located nearby [12].

Other than that, another oxygen monitoring technique that is available currently is to monitor the oxygen level in a patient's oxygen tank. The pressure released by the oxygen tank will be able to generate an audible alarm and as a result, the patients or doctors will be notified when the pressure inside the oxygen tank is low [13]. This system functions using a spring that opens and closes a hole in the adapter, depending on the spring's constant and pressure applied.

MacDermott [14] developed another technology which is more complicated, where detachable monitoring systems can be connected to the outlet of the oxygen cylinder to the pressure regulator in order to monitor the oxygen level inside the cylinder. Electronic pressure sensor is used in this system to monitor the oxygen level and also to notify the control centre if the level drops below a warning level. Visual and verbal alarms can both be produced [14].

All of the systems mentioned above use an external power supply or source to power up the circuit of the monitoring system. This is because the system requires continuous reading of the pressure in order to notify the end user when the oxygen level is low. Therefore, a high efficiency battery is essential in order to power up the system continuously without any disruptions.

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

The complete flow of the project is in Figure 4. In this case, an airflow sensor will be attached in between the fullface mask and the SCBA unit worn by firefighters on duty. The purpose of this sensor is to read the amount of oxygen that is left in the high-pressure tank, in which the data is then transferred to the Arduino microcontroller, before being sent wirelessly to a host PC/Laptop to be monitored by the Arduino software.

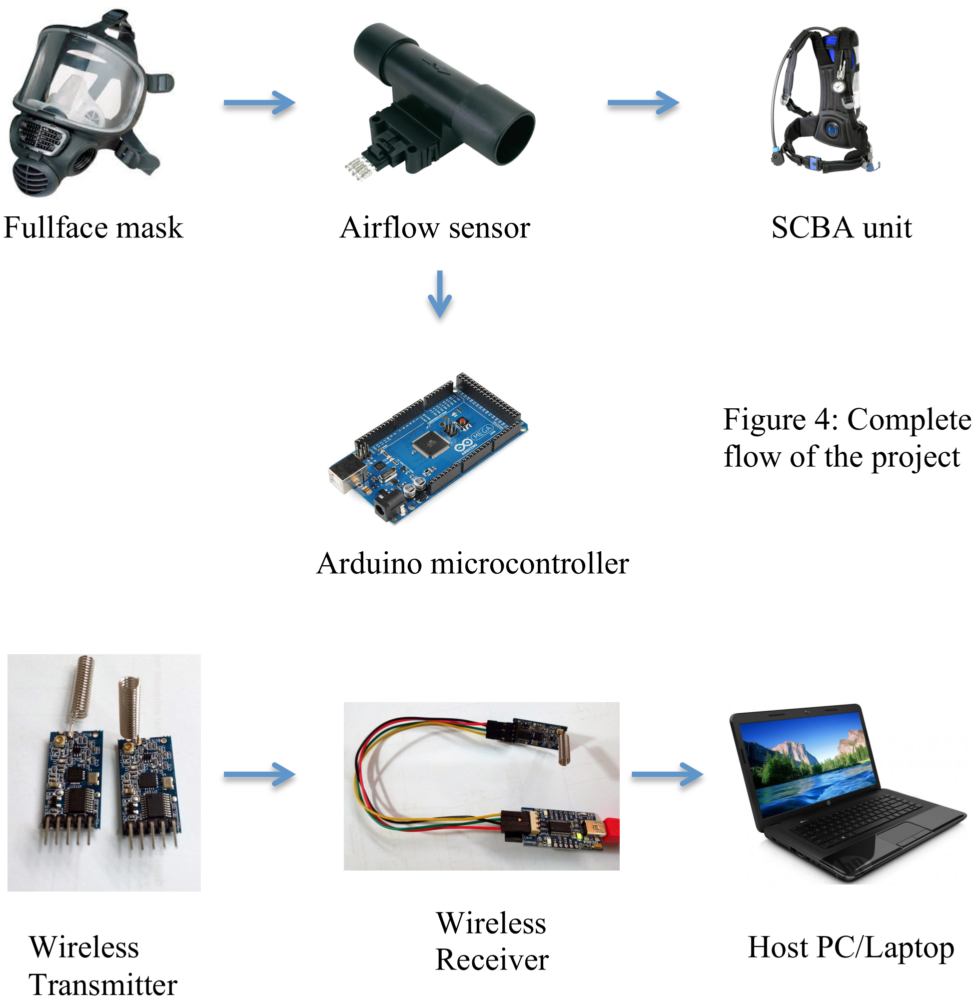

Figure 4: Complete flow of the project

3.2 Project Phases

There are two main phases in this project, mainly hardware implementation and software interfacing. However, there are several other phases as well in order to complete the project on time and also achieving all the objectives.

Phase 1: Project Planning

In this phase, the project is planned and all the aspects involved are being considered carefully before the start of all the other activities. The project has to be ensured to prove the functionality and novelty of it to the people who are directly involved with it.

Phase 2: Design Approach

In this phase, the entire design of the project will be discussed before coming up to a final conclusion. Many considerations has to be done including the components to be used, hardware to be purchased in order to complete the prototype and also which software to be used for interfacing with the monitoring system.

Phase 3: Market Research

The purpose of doing this market research is to find out the most suitable types of components or tools available, with reference to the budget of this project given. Before purchasing, the tools or components are being compared with different models before finally coming to a decision.

Phase 4: Hardware Implementation

This phase involves one of the important phase in this project, which is to implement all the hardware purchased together. A prototype will be completed in order for further testing to be done.

Phase 5: Software Interfacing

Besides hardware implementation, software interfacing is also one of the crucial part of this project. The sensor has to be integrated successfully with the laptop using the microcontroller in order for the whole monitoring system to work.

Phase 6: Testing and results

The last phase of this project will be testing and results. Multiple testing has been done during the project period in order to confirm and certify that this project is viable to be implemented when finished.

3.3 Project Activities

Based on the research methodology, Figure 5 shows the description of the project activities.

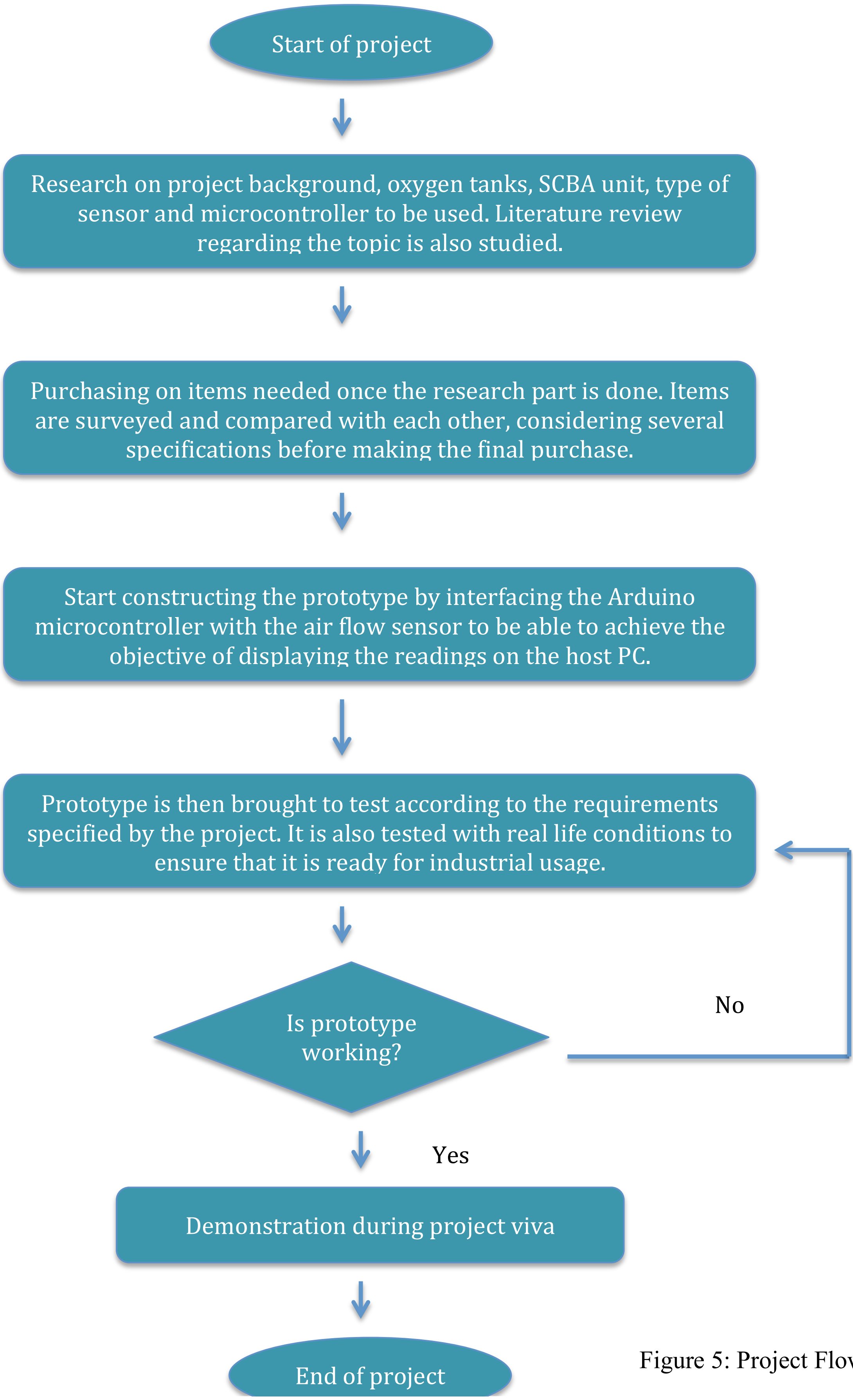

Figure 5: Project Flow Chart

3.4 Key Milestones

Figure 6 shows the key milestones of this project that highlights the important datelines. The very first milestone that has to be completed is the submission of progress report on week 8. On week 11, there will be a pre-SEDEX / poster presentation on the project itself to two internal examiners which will evaluate the project. The third milestone of the project is the submission of draft final report to the project supervisors in order to allow them to review and give comments on the report, before submitting the final report on week 14 together with the technical paper. Finally, the project VIVA will be done on week 15 in front of supervisors and examiners, both internal and external.

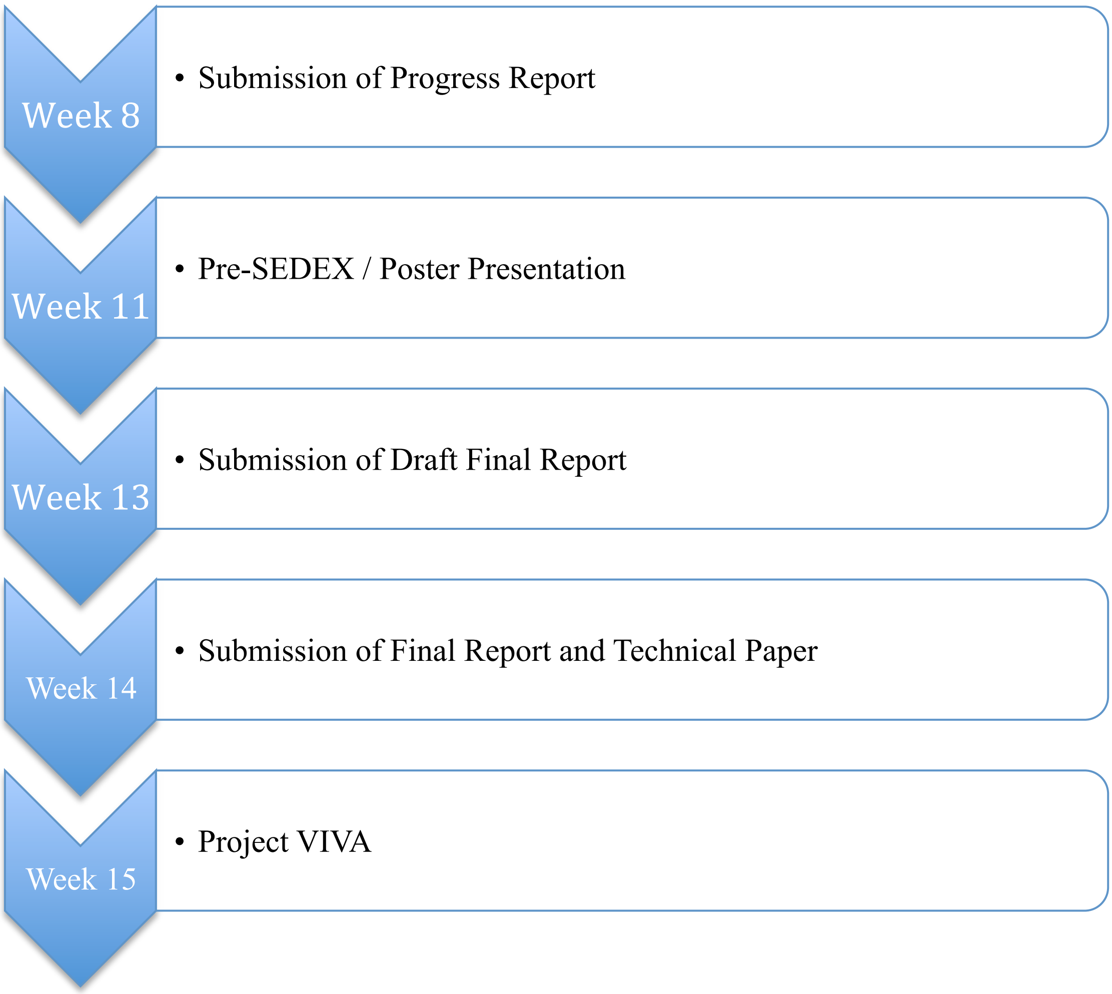

Figure 6: Project Key Milestones

3.5 Gantt Chart

The Gantt chart shows the flow of datelines that needs to be met in order to fully achieve all the objectives in this project. The project is separated into FYP 1 and FYP 2. The Gantt chart for FYP 1 is shown in Table 1:

Table 1: Gantt Chart for FYP 1

Details	Week												
	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Title selection	■	■											
2. Preparation of Extended Proposal			■	■	■								
3. Submission of Extended Proposal						■							
4. Preparation for Proposal Defense							■	■					
5. Proposal Defense and Progress Evaluation									■				
6. Preparation of Interim Report										■	■		
7. Draft Interim Report Submission												■	
8. Modifications done to Interim Report													■
9. Submission of Interim Report													■

The Gantt chart of FYP 2 is shown in Table 2.

Table 2: Gantt Chart for FYP 2

Details	Week														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Development of prototype	■	■	■	■											
2. Analysis of data					■	■	■	■							
3. Finalization of prototype									■	■	■				
4. Pre-SEDEX / Poster presentation											■	■			
5. Submission of Draft final report													■		
6. Submission of Final Report														■	
7. Project VIVA															■

3.6 Tools and software required

3.6.1 Digital Air Flow Sensor

Air flow sensors function in such a way that they provide a digital interface for reading airflow over specified full-scale flow and compensated temperature ranges. Thermally isolated heater and temperature sensing elements are usually paired up with the sensors to provide an immediate response to air flow in a given situation [4]. These sensors are also designed to measure mass flow of air and other non-corrosive gases, and come with standard flow ranges such as 10 Standard Litre Per Minute (SLPM), 20 SLPM, 30 SLPM and so on. Besides that, the sensors are carefully calibrated and temperature compensated with an on board circuit.

Heat transfer principle measures mass air flow of these sensors. The sensors are made up of a microbridge system with temperature-sensitive resistors deposited with thin films of platinum and silicon nitride. To grant repeatable accurate and systematic response to the flow, the system is located in a precise and carefully designed airflow channel, as shown in Figure 7.

Figure 7: Digital air flow sensor

3.6.2 Arduino Mega microcontroller

The Mega 2560, as shown in Figure 8 is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins, of which 15 can be used as PWM outputs, 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller. It is connected to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. In this project, this microcontroller is used to interface it between the air flow sensor and the laptop in order to monitor the level of oxygen left in the oxygen tank.

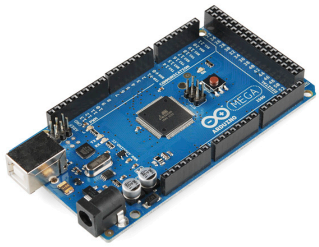

Figure 8: Arduino Mega microcontroller

3.6.3 Wireless Universal Asynchronous Receiver/Transmitter (UART)

This wireless serial port communication module shown in Figure 9 is a new-generation multi-channel embedded wireless data transmission module. Serial transceiver module is a low cost, high performance transparent FSK transceiver with operating frequency at 434 MHz. It features small size, XBee form factor, high output power, high sensitivity, long transmission distance and high communication data rate with auto setup for communication change and data receiving and transmission control. With UART interface, it is easy to realize the wireless data transmission with only providing the UART data.

Figure 9: Wireless UART module

In this project, this wireless module is used to transmit real time data wirelessly from the sensor to the monitoring station.

3.6.4 Fullface mask

The fullface masks of breathing apparatus designed for use out of water are sometimes designed in a way that makes them unsuitable for scuba diving as shown in Figure 10. However, some some may allow very shallow submersion for emergency purposes.

Figure 10: Fullface mask

This fullface mask used by firefighters has a seal at the edge which is a wide tube with thin, flexible walls running around the edge of the mask, full of air at atmospheric pressure.

3.6.5 SCBA unit

In firefighting, a SCBA unit as shown in Figure 11 is a device worn by firefighters to provide breathable air in an atmosphere where there is an oxygen deficit or when extremely toxic chemicals are present [6]. In other words, they are generally used in emergency situations during an incident or accident.

A unit of SCBA consists of high-pressure tank, a pressure regulator and an inhalation connection. All these components are connected together and mounted to a carrying frame. There are two types of SCBA used around the world now, which is the closed-circuit type and also the open-circuit type. However, the more commonly used type of SCBA is the open-circuit type, in which they are breathing sets filled with compressed air rather than pure oxygen [7]. Normally, an open-circuit system consists of two different separated regulators, a first stage to reduce the pressure of air to allow it to be carried to the mask, and a second stage to reduce it further to match the level above standard atmospheric pressure. The system is then connected to a fullface mask to be used by a firefighter on duty.

Figure 11: SCBA unit

3.7 Wireless module selection

A few options were considered before finally deciding on the wireless protocol to be used in this project. Table 3 shows the comparison done by focusing on a few important features of the protocols.

Table 3: Wireless module comparison

Wireless Protocol	Operating range (m)	Price (RM)	Flexibility
Bluetooth	100	40 – 100	Built in networking protocol
Zigbee	50	69	Built in networking protocol
Wi-fi	46 (indoors) and 92 (outdoors)	200	Built in networking protocol
Wireless UART	100	60	Self developed protocol

Therefore, according to the table of comparison, Wireless UART module is selected as the wireless protocol for this project because of its operating range, price and also flexibility.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Hardware Setup

For the testing of this prototype, it was done on a normal circuit breadboard. The digital air flow sensor has 6 pins attached to it, and the pin configuration is shown in Table 4.

Table 4: Pin configuration of the sensor

Pin number	Function
1	Not connected (NC)
2	Serial Clock Line (SCL)
3	Supply Voltage (VDD)
4	Ground (GND)
5	Serial Data Line (SDA)
6	Not connected (NC)

As the sensor interfaces with I2C programming, its Serial Clock Line (SCL) and Serial Data Line (SDA) pins are connected to pins 20 and 21 on the Arduino Mega respectively. The sensor is then supplied with a 5 V voltage, coming from the 5 V output pin on the microcontroller itself as its range of voltage supply is from 3 V to 10 V DC. The current itself can also be obtained from the microcontroller pin as the sensor only requires 20 mA maximum supply current. The other two pins, which are 1 and 6, are not connected and can be neglected in this situation.

The maximum sink current on the SCL and SDA pins are both 2mA. Therefore, pull-up resistors with a typical value of 4.7 k ohms must be connected in between the SCL and SDA pins and the positive power supply voltage to ensure that the signal will be a valid logic level if external devices are disconnected or high-impedance is introduced. The microcontroller itself is powered by the USB supply from the laptop. However, the system can also be powered up by a battery for convenience. The schematic diagram of the project is shown in Figure 12.

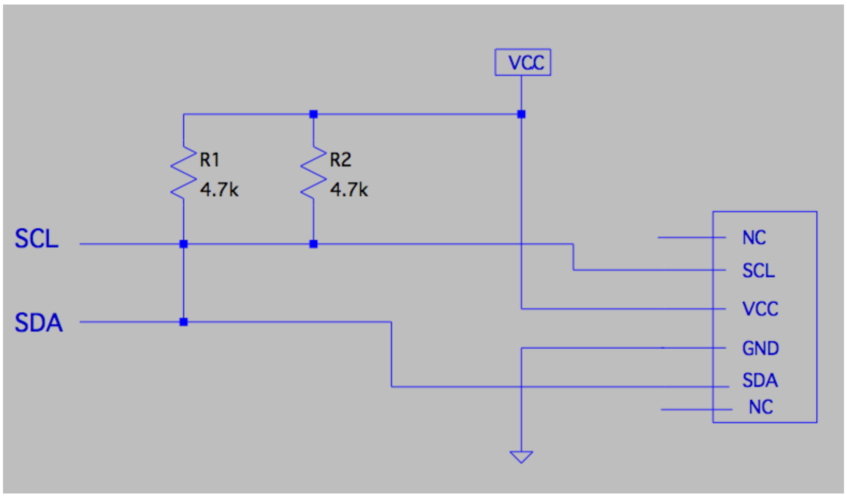

Figure 12: Schematic diagram of the project

In Figure 13, the actual prototype A is shown and it is done on a breadboard for initial testing and easier troubleshooting. Modifications can also be done easily when this breadboard is used.

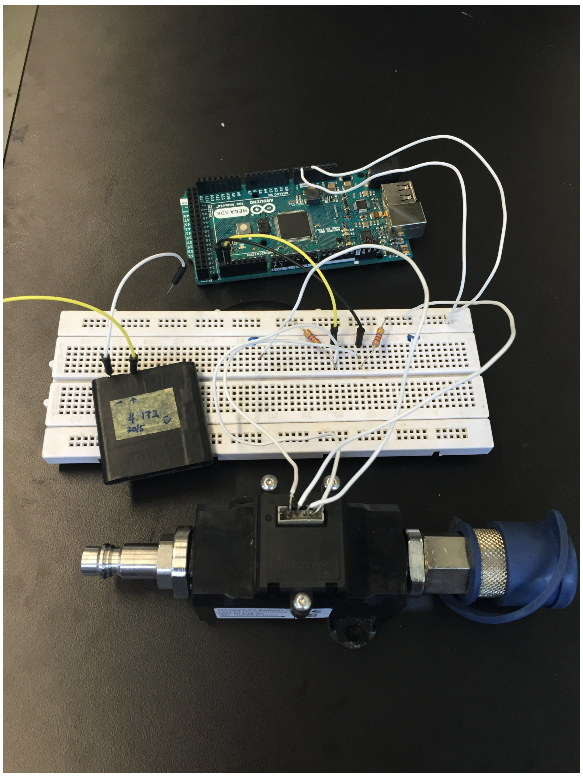

Figure 13: Prototype A of the project

4.2 Software Setup

Arduino Programming Software

To establish the interfacing between the digital air flow sensor and the microcontroller, an Arduino software with coding must be established. The I2C protocol is used in this case using the existing library available from the software itself. Figure 14 shows the Arduino IDE and programming codes can be written here to integrate between the air flow sensor and serial monitor.

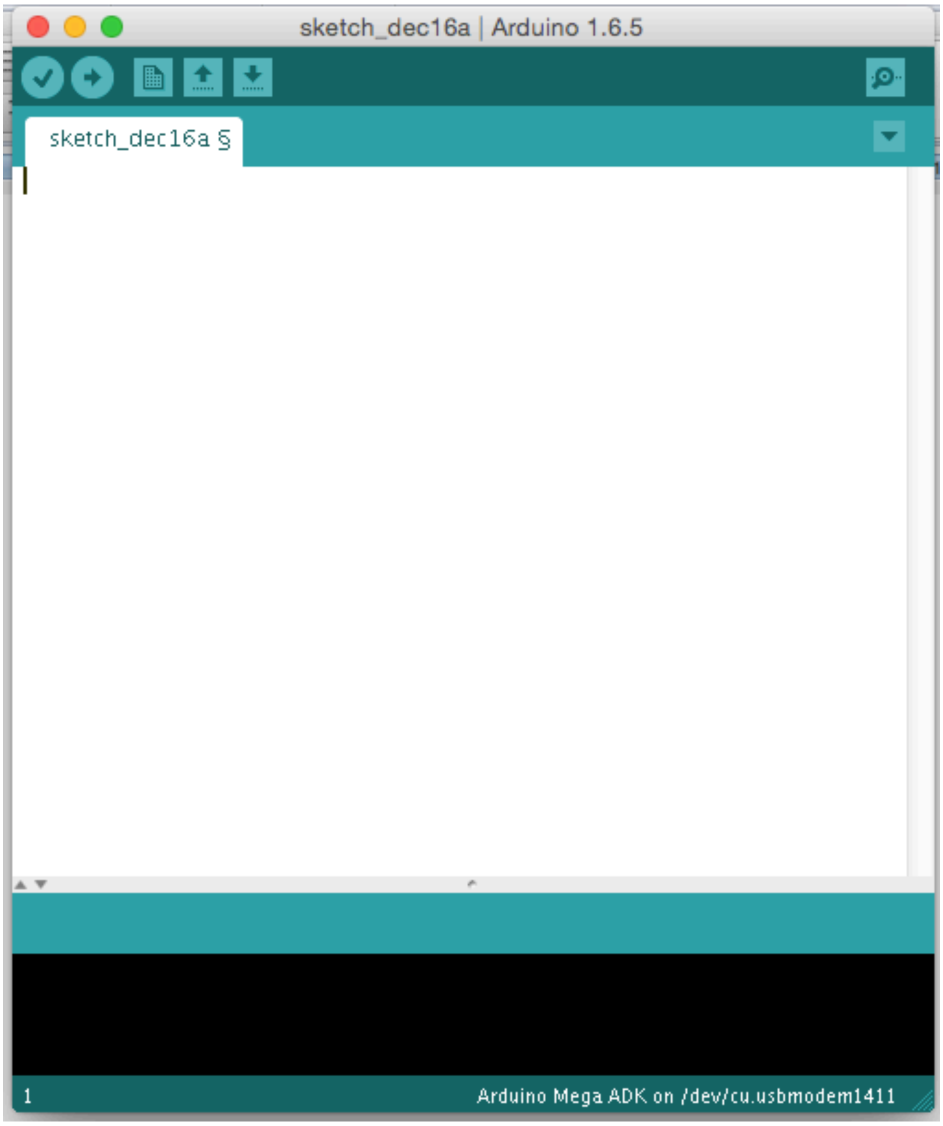

Figure 14: Arduino programming software

In order to set the connection between the sensor and the microcontroller, a few steps need to be taken. From the software itself, the serial port of the USB connecting the microcontroller to the laptop must be selected in order to allow communication and also supply from the USB.

As for the ideal transfer function of the digital air flow sensor, it has two equations to calculate two different items, which are the digital output code and also the flow applied. The first will be the Digital Output Code, with the equation as follows:

$$16384 \text{ x } [\, 0.1 + 0.8 \text{ x } \left(\frac{\text{Flow Applied}}{\text{Full Scale Flow}}\right)]$$

Next, the flow applied can be calculated with the formula below:

$$\text{Full Scale Flow x} \frac{\left[\left(\frac{\text{Digital Output Code}}{16384}\right) - \ 0.1\right]}{0.8}$$

Therefore, in the programming source code later on, the formula for these two equations will be entered in order to obtain the final output to be displayed on the serial monitor.

The sensor uses the I2C standard for digital communication with a slave address specified in the datasheet that comes along with it. Following sensor power-up, each of the first two read sequences will respond with 2 bytes of unique 4-byte Serial Number. The first after the power-up will respond with the two most significant bytes of the Serial Number while the second read will will respond with the two least significant bytes. Therefore, for reliable performance, the sensor must be allowed to be powered for the sensor startup time before performing the first read and then allowed a 10 ms command response time before performing the second read.

The programming coding used for the interaction between the flow sensor and the arduino can be found in the Appendices section of this report. In the coding, wire library is used as wire library allows communication between I2C devices and arduino. On the Arduino Mega board used, SDA (data line) and SCL (clock line) are the 2 pins used for this I2C communication.

4.3 Functionality Test

In order to get the flow reading coming out from the tank, the flow sensor is connected to the output valve of the oxygen tank. Figure 15 shows the setup of the prototype B involved in this testing. In this prototype, the circuit connections are soldered on to a miniaturized circuit board for easy testing.

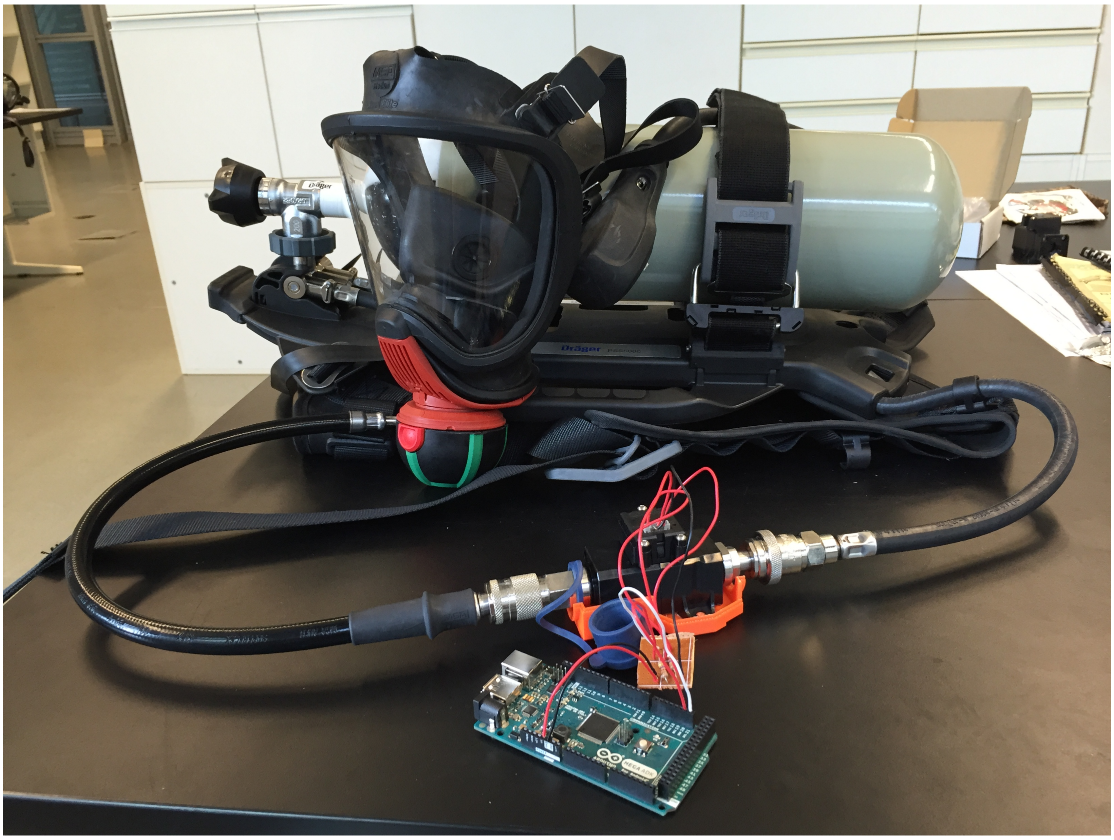

Figure 15: Prototype B of the project

The first test was conducted with the oxygen tank level of 200 bars (full) and the results are shown in the Figure 16.

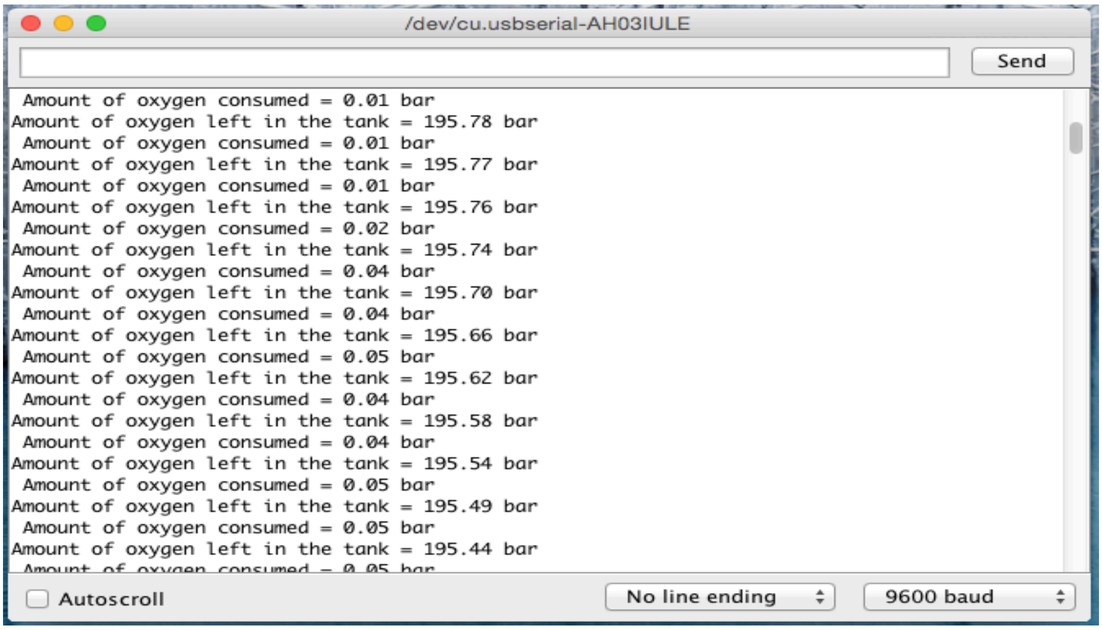

Figure 16: Results of testing with 200 bars of oxygen

The results were obtained by using wired connection between the Arduino microcontroller and the laptop. As it is shown, the amount of oxygen consumed is measured by the air flow sensor, and the remaining oxygen left in the tank is shown on the display monitor. A second test was done when there is less than 50 bars of oxygen left in the tank, and the results are shown again in Figure 17.

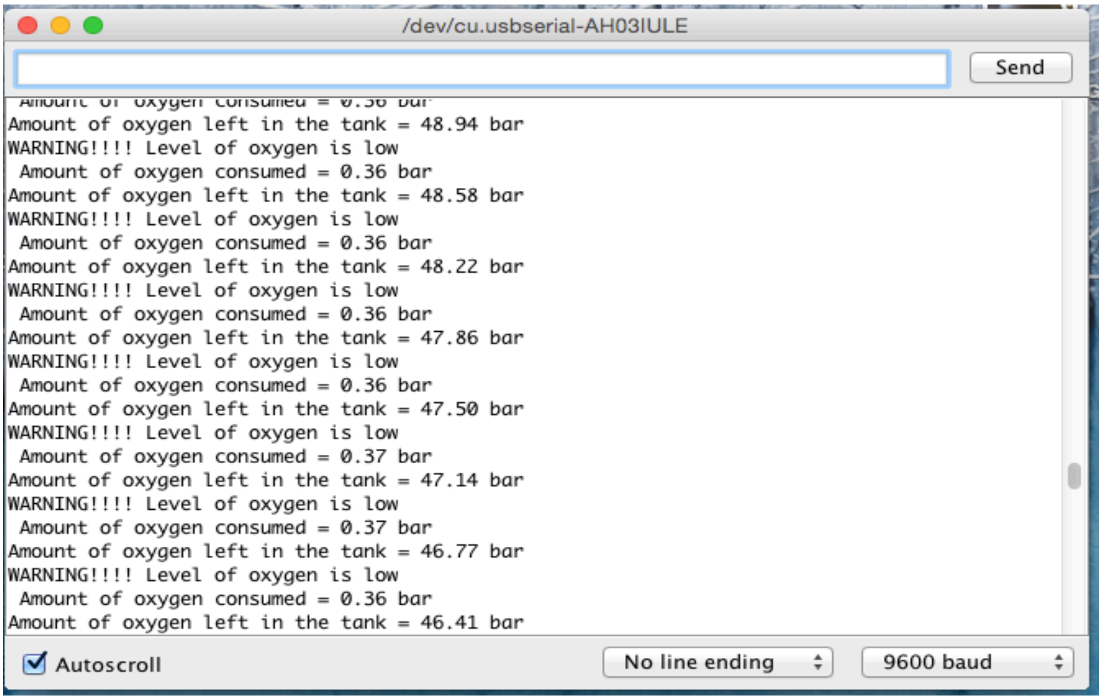

Figure 17: Results of testing with less than 50 bars of oxygen

As it is shown, there will be an alert appearing on the display monitor when the oxygen level in the tank is low, in this case which is less than 50 bars. Therefore, the warning signs will be sent out to the firefighters and they will be expected to evacuate immediately.

A more specific schematics diagram shown in Figure 18 has been drawn in order to clarify more on the circuit connections of the entire system. As it is shown, in order for the system to become more practical to be implemented in real-life situations, the Arduino microcontroller is to be replaced by a Microchip PIC18F4550 instead, which has the same functions as the Arduino.

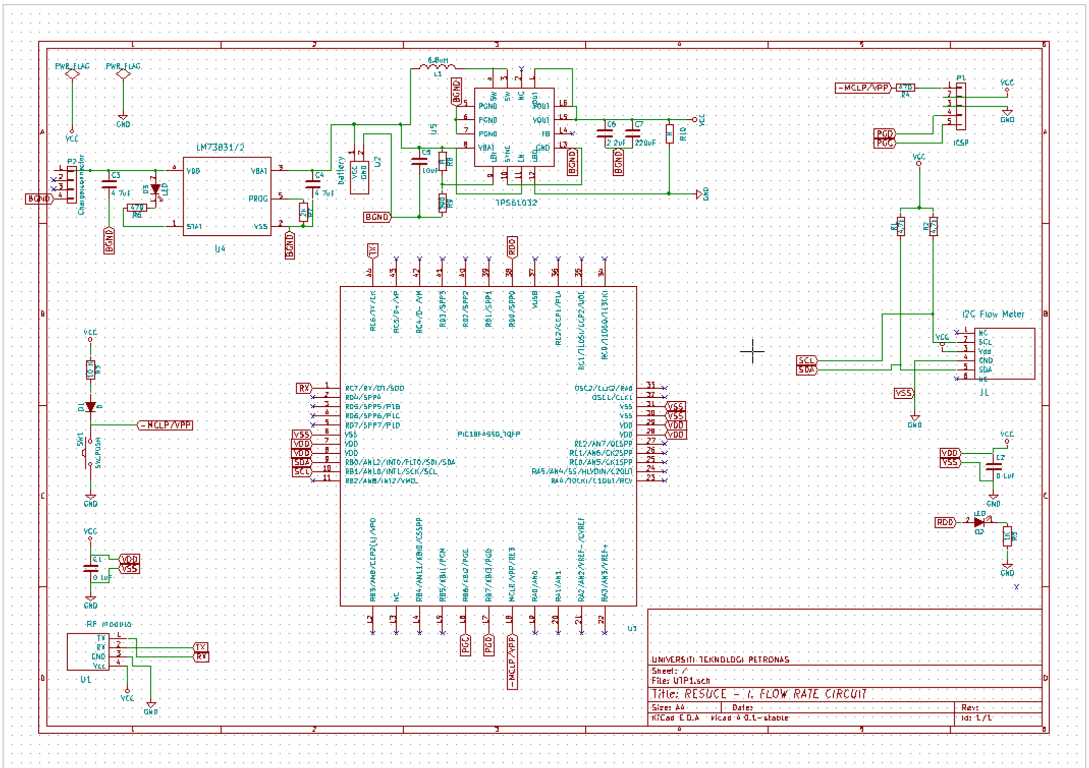

Figure 18: Schematic diagram of the entire system

Besides that, a 3D model of the system as shown in Figure 19 is also sketched, to have a clearer view on how the system will look like when being implemented later on. The considerations when doing this sketch will be the size of the printed circuit board (PCB) and how it will fit in to the existing design of the oxygen tank without modifying it. After finalizing on the design, it will be sent to Cytron Penang for fabrication.

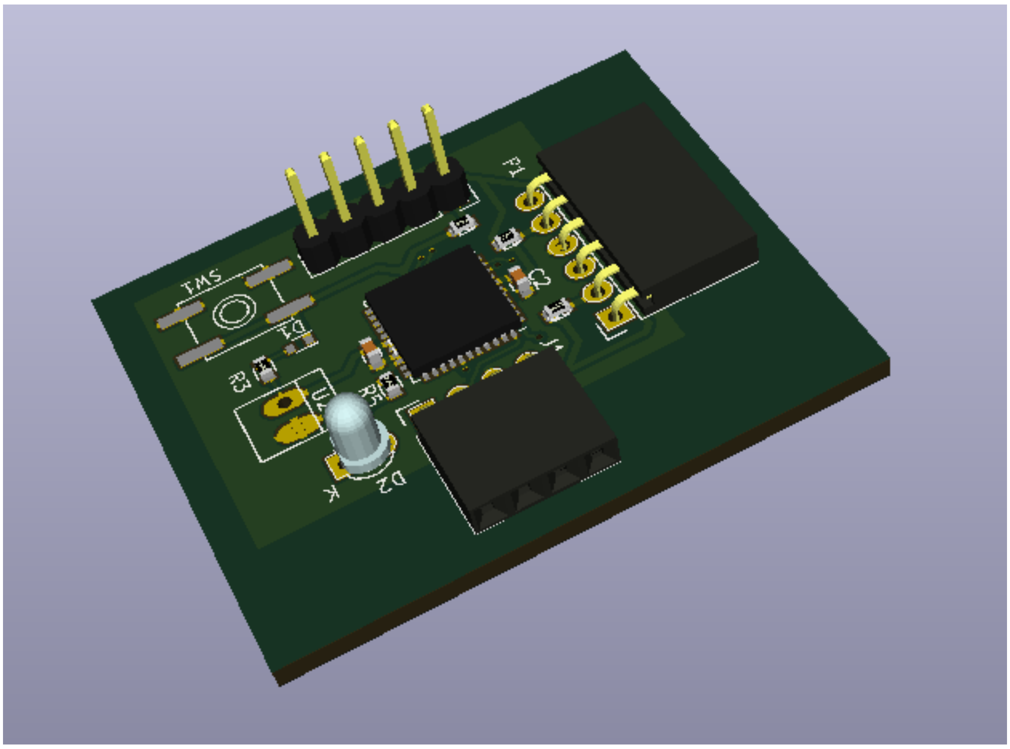

Figure 19: 3D model of the PCB

4.4 Power Consumption of the system

The flow sensor attached to the firefighter will be powered using a battery while functioning. Therefore, the power consumption has to be calculated. Table 5 shows the results of calculation.

Table 5: Total power consumption of the system

Component	Power consumed	Quantity	Total power
Digital Air flow sensor	100 mW	1	100 mW
Microchip PIC18F4550	175 mW	1	175 mW
Wireless UART	72.6 mW	1	72.6 mW
Total power consumption			347.6 mW

Based on the total power consumption of the system calculated, the capacity of the battery to be used in milli-amp hour can also be calculated. The size of the battery must be considered as well, in order to reduce the amount of space taken up and to fit in the casing to be used.

4.5 Cost Analysis

A cost analysis on the project has also been done to ensure that the project is within the budget limit given by the FYP coordinator and committees of RM 500. Therefore, the components that have been used are broken down and listed individually to calculate the total cost in Table 6.

Table 6: Cost Analysis of the project

Item	**Quantity**	**Price (RM)**	**Subtotal (RM)**
Honeywell Digital air flow sensor	1	325.00	325.00
Arduino	1	60.00	60.00
Sensor connector	1 set	20.00	20.00
Wireless UART	1 pair	61.48	61.48
Total			466.48

Based on the calculations done, the total cost of the project is still within the budget limit and is acceptable.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

In conclusion, this project can be very useful and beneficial in the effort to increase the safety of firefighters while they are carrying out their duties in their search and rescue missions. This breathing air level design and development using Arduino will always enable the firefighters' colleagues to monitor their oxygen level all the time and send out cautioning alerts when the air level is too low. The air breathing level will also be able to be displayed on a serial monitor, which will be located at a distance away from the firefighters. More importantly, this oxygen monitoring technique will be developed to maintain the original design of the oxygen tank. Other than that, in a case when a firefighter on duty is still unable to respond to the alert, the others who are on backup will have to respond immediately to assist their colleagues. The type of sensor chosen in this project is also very versatile, and can be modified to fit all different types of oxygen tank used by firefighters all over the world.

In order to further improve the project in the future, other aspects of the prototype can be considered such as the oxygen tanks can be modified to add more sensors. The reason of this is to collect more accurate readings. Besides that, a the alert system can be improved in order to communicate with the firefighters more effectively.

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APPENDICES

Arduino coding for air flow sensor

```
#include <Wire.h>
float oxygentank;

void setup()
{
  // put your setup code here, to run once:

  Wire.begin();
  Serial.begin(9600);

  Serial.println("Initializing");
  oxygentank = 50;
  Serial.println(oxygentank);
}

void loop() {
  // put your main code here, to run repeatedly:

  Wire.requestFrom(0x49, 2); //sensor address, number of bytes
/*
  Serial.print(Wire.read(), DEC);
  Serial.print("   ");
  Serial.println(Wire.read(), DEC);
  float readFlow(){
  // Now take a Flow Reading
  Wire.requestFrom(HAF_Address,numOfBytes);  // Address the flow sensor and set
number of bytes to receive*/
  byte MostSigByte = Wire.read();              // Read the first byte this is the MSB
  byte LeastSigByte = Wire.read();             // Now Read the second byte this is the
LSB
```

```
  // Being a 12 bit integer use 2's compliment for negative temperature values
  unsigned int PressSum = (((MostSigByte << 8) + LeastSigByte));
  // From Datasheet the TMP75 has a quantisation value of 0.0625 degreesC per bit
  float flow = 20*((PressSum/16384.0)-.1)/.8;
  //Serial.println(MostSigByte, BIN);   // Uncomment for debug of binary data from
Sensor
  //Serial.println(LeastSigByte, BIN);  // Uncomment for debug  of Binary data from
Sensor
                    // Return the temperature value
  float flow1 = flow/2;

  oxygentank = oxygentank - flow1;
  if(oxygentank<=50)
  Serial.println("WARNING!!!! Level of oxygen is low");
  Serial.print(" ");
  Serial.print("Amount of oxygen consumed = ");
  Serial.print(flow1);
  Serial.println(" bar");
  Serial.print("Amount of oxygen left in the tank = ");
  Serial.print(oxygentank);
  Serial.println(" bar");
  delay(1000);

}
```