DEVELOPMENT OF AUTOMATIC CUPPING SUCTION SYSTEM

(SOFTWARE AND CIRCUIT)

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DEVELOPMENT OF AUTOMATIC CUPPING SUCTION SYSTEM (SOFTWARE AND CIRCUIT)

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ABSTRAK

Terapi bekam adalah rawatan penyembuhan tradisional. Ia adalah bentuk perubatan alternatif kuno yang boleh meningkatkan peredaran darah ke alam di mana cawan diletakkan. Secara tradisinya, cawan dipanaskan dengan api sebelum bahagian terbuka terus digunakan pada kulit. Beberapa pengamal bekam moden telah memodenkan cara bekam dengan menggunakan pam getah untuk menghasilkan sedutan pada kulit. Dua kategori utama bekam telah dilakukan pada masa ini iaitu bekam kering dan bekam basah. Tekanan negatif dikenakan pada kulit melalui cawan sedutan untuk kedua-dua kaedah bekam tetapi tekanan tidak terkawal yang dilakukan semasa kedua-dua kaedah bekam boleh menyebabkan lepuh atau vesikel pada kulit. Ciptaan alat bekam elektrik terkini membolehkan seseorang melakukan terapi bekam tanpa sijil perubatan. Walau bagaimanapun, ia tidak menyokong bekam di kawasan kulit berbulu. Oleh itu, sistem sedutan bekam automatik diciptakan dalam projek ini sebagai sistem automatik yang berkesan, cekap dan menjimatkan untuk kehidupan yang lebih baik dan sihat. Sistem bekam automatik 3 diasingkan ditimbulkan untuk memastikan proses bekam berganda dapat dikendalikan pada masa yang sama dan ia mampu diaktifkan pada kawasan kulit berbulu. Dalam mereka bentuk sistem, papan Arduino digunakan untuk membangunkan sistem automatik yang membolehkan pengguna menggunakan terapi bekam dengan menetapkan masa yang diperlukan. Pengawal Logik Fuzzy (FLC) menggunakan kod program untuk memastikan kestabilan tekanan semasa proses bekam. Sistem automatik dicipta dan diperiksa untuk memastikan sistem dapat berfungsi secara automatik dan untuk mengurangkan bahaya mendapat lepuh atau vesikel. Akhirnya, sistem automatik disahkan untuk menggunakan terapi bekam kepada pesakit dengan berkesan.

ABSTRACT

Cupping therapy is a traditional healing treatment. It is an ancient form of alternative medicine that can increase blood circulation to the realm where the cup is placed. Traditionally the cups were heated with fire before the open side directly applied to the skin. Some modern cupping practitioners have modernized the way of cupping by using the rubber pumps to create suction on the skin. There are only two main categories of cupping performed today which are dry cupping and wet cupping. A negative pressure is applied on the skin through the suction cup for both cupping method but unregulated pressure that occurred during both methods of cupping might cause blisters or vesicles on the skin. The latest invention of the electric cupping device allows one to perform cupping therapy without a medical certificate. However, it does not support cupping in the hairy skin area. Therefore, an automatic cupping suction system is developed in this project as an effective, efficient and economical automatic system for a better and healthier life. 3 separated automatic cupping system is developed to ensure that multiple cupping process can be handled at the same time and it is able to be activated on the hairy skin area. In designing system, the Arduino board is utilized to develop the automatic system that allows the user to apply cupping therapy by setting the time required. A Fuzzy Logic Controller (FLC) is applying to the program code to ensure the stability of the pressure during the cupping process. The automatic system is created and examined to ensure the system are able to work automatically and to reduce the hazard of getting blister or vesicle. Finally, the automatic system is verified to apply the cupping therapy to the patient effectively.

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LIST OF SYMBOLS

mmHg	Millimeter of mercury columns
kPa	Kilopascal
Pa	Pascal
°C	Degree Celcius

LIST OF ABBREVIATIONS

CAM	Complementary and Alternative Medicine
A.D.	Anno Domini
B.C.	Before Christ (British Columbia)
TCM	Traditional Chinese Medicine
TIM	Traditional Iranian Medicine
P_{abs}	Absolute Pressure
P_{atm}	Atmospheric Pressure
P_v	Vacuum Pressure
MPX5100DP	Monolithic Silicon Pressure Sensor
LCD	Liquid Crystal Display
USB	Universal Serial Bus
V	Voltage
Vin	Voltage input
Vout	Voltage output
GND	Ground
I/O	Input or Output
L/min	Litres per minute
DC	Direct Current
AC	Alternating Current
A	Ampere
mA	Milliampere

PWM	Pulse-Width Modulation
W	Watts
FLC	Fuzzy Logic Controller

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CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

This thesis is mainly focus on the development of an automatic cupping suction system. The negative pressure (vacuum) in the suction cup is produced by a pump and it is tested by using a differentiate pressure sensor, MPX5100DP to get the real-time pressure value. The Arduino Nano will receive the programming of this system from the Arduino IDE software and transfer it to the components that connected to it. When the system is executed, the sucking process (suction) is created by placing the suction cup on the desired skin area. This process is generally called as cupping therapy.

Cupping therapy was first mentioned in the medical literature of Eber's Papyrus (1550 BC) in Ancient Egypt. This medical treatment is also a prevalent historical treatment among the Arabic and Islamic countries. It is frequently used by people to increase their blood flow, relieve local ache and get relaxation to their muscles. Basically, suction is recognized as creating a partial vacuum by removing air. The suction is created in the suction cup or sucker and it is applied on the skin surface to perform the cupping treatment. There are several techniques are used to perform the cupping therapy process. Among these techniques, wet cupping and dry cupping are two most famous techniques to perform the cupping therapy. Traditionally, the cupping therapy is performed by using mouth directly or placing a leech, animal horns, bamboo, glass or plastic cup on the desired skin area for several minutes. However, there would be a risk after undergoing the cupping therapy which an unregulated pressure might occur when the negative pressure is applied on human's skin. The unregulated pressure might cause blister or vesicles on the skin. The scar may last from a few days to a few weeks before recovers.

Figure 1.1 shows the cause of blister or vesicles when there is an uncontrolled pressure applied to the skin surface.

Figure 1.1 Blister or Vesicles

1.2 PROBLEM STATEMNET

Cupping therapy is a safe and easy clinical technique that has been widely used since Ancient Egypt. The latest invention allows one to perform cupping therapy without a medical certificate. However, despite the gradual development of cupping equipment, current cupping therapy for hairy part can only be performed by manual machines and an individual requires experience to control pressure by operating the machine manually. Since every human being has different pressure in their body and each body part also has different air pressure, therefore, a manual control of the pressure in the cup is required. Besides, according to the present invention, there is no automatic cupping suction system available and there is only one output available thus only one cupping process can be applied at a time. In order to solve the problems mentioned above, an automatic cupping suction system is developed to allow the cupping therapy process to run automatically by pressing buttons.

1.3 OBJECTIVE

There are a few objectives that focus on this project. The main objectives of the development of automatic cupping suction system are:

1. To develop an automatic suction mechanism.
2. To develop 3 separated system of automated cupping suction control system.
3. To test the automatic cupping system by using dry cupping methods in the clear skin area as well as in the hairy skin area.

1.4 PROJECT SCOPE

There are several factors that need to be considered before starting this project. The purpose of this project is to test the development of an automatic cupping suction system in different selected skin conditions. The scope of the project is stated below.

1. This project required a development of hardware mechanism that consist of pump, pressure sensor, filter and cupping hose.
2. This project also needs to develop a complete machine source by AC.
3. The MPX5100DP KKT 19421 differential pressure sensor is selected to measure the pressure with suitable suction pressure.
4. This project also develops a prototype of 3 separated automated cupping suctions control machine including 2 automated system for body part and 1 automated system for head (hairy area).

1.5 THESIS ORGANISATION

The goal of this project are to develop an automatic suction mechanism which include 3 separated system of automated cupping suction to control the machine and to test the automatic cupping system by using dry cupping methods in the clear skin area as well as in the hairy skin area. A few steps are executed to achieve the goal of this project. The activation of the air pump needs to be done at the beginning of this project to ensure the pump is controllable. The proposed system utilizes MPX5100DP the pressure sensor to detect the negative pressure in the suction cup. It is connected to the manual pump before attached to the vacuum air pump to ensure it is functional. The pressure value is then displayed in the graphic LCD. Next, the digital value of MPX5100DP is calibrated by using a manometer. After calibration, fuzzy logic controller is used in the program code to automatically control the speed of the air pump based on the detected pressure value.

The methodology to reach the objectives of this project is presented in the Chapter 3. The organization of the remaining part of this technical report is stated as follows. In Chapter 2, the related work of the cupping therapy will be discussed. The procedure to reach the final result of this project are given in Chapter 3. Chapter 4 contains the simulation result as well as the experimental result of this project and Chapter 5 is the conclusion for this project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The literature review of the cupping therapy including its definition, history of cupping therapy, the disease that can be cure by applying the cupping therapy, equipment or tools used to perform cupping therapy, process or steps to apply the cupping therapy, and the concepts of the pressure in cupping will be discussed in this chapter. Generally, the cupping therapy is performed by placing the suction cup or a sucker to the desired skin area of the body. The negative pressure or the vacuum inside each suction cup is produced by using flames, manual suction tool or a mechanical suction equipment. The types of cupping tools that used in the cupping therapy process are leech, animal horns, bamboo cups, glass cups and plastic cups. Besides that, the level of negative pressure inside the cups has also been discussed in this chapter. There are a few types of pressure sensor can be used to measure the real-time pressure in the cup. In this project, the monolithic silicon differential pressure sensor (MPX5100DP) is selected to detect the pressure inside the suction cup as it can measure large range of pressure which from 0Pa to 100kPa. Moreover, the microcontroller and some main component that used to develop the automatic cupping suction system would be discussed in this chapter. The components consist of Arduino Nano, Graphical Liquid Crystal Display (ST7920 Graphical LCD) and vacuum air pump.

2.2 CUPPING THERAPY

Complementary and Alternative Medicine (CAM) is widely recognized throughout the world and even popular in every culture. CAM is also known as "bǔ chōng yǔ tì dài yī xué" (補充與替代醫學) in Chinese culture. It is a term that accommodates a large number of treatment options that complement conventional therapies to help relieve symptoms. Cupping therapy is one of the CAM therapies. It is well known of its significant potential for treating various disease. Cupping therapy is also known as "bá guàn" (拔罐) in Chinese term and the Arabic civilization had named it as "Al-Hijamah".(Medicine, 2005) The Chinese term "bá" means to pull out or pluck while "guan" refers to a can or a pot (Nielsen et al., 2012). "Al-hijamah" means to restore to original size in Arabic root word (El Sayed et al., 2013) "bá guàn" and "Al-hijamah" are both involves application of a suction cup that applied negative pressure or vacuum on the skin surface. In Chinese medicine, cupping is generally defined as a treatment in which a heated glass cup is placed on the person's skin along the meridians of the body and creating a sucking process (suction). The main function of this treatment is to extract the toxic substances or undergo detoxification from body tissue and organs by creating negative pressure in the suction cup (Elsubai et al., 2017). In Chinese cultural, this treatment is believed to restore the flow of energy or "qì" (氣) in human body (Medicine, 2005).

There are various of methods can produce the sucking effect on human body including oral suctioning (suck directly on the cut or wound with the mouth in the case of poisonous bites), use leeches for bloodletting, the use of animal horns as cupping instrument in ancient China, or using modern instruments such as bamboo cup, glass cup and plastic cup. These instruments are used either with fire or with pump mechanisms.

Figure 2.1 Leech Cupping

The leech or Hirudo therapy (Irsale Alaq) is a therapy that undergo blood sucking process by using medicinal leeches. The Hirudo medicinalis is a European medicinal leech with medical properties and it can help to maintain the blood circulation in tissue during the replantation. During the blood sucking process, these medicinal leeches will release their saliva containing natural anticoagulant enzymes, anaesthetic and analgesic compounds which can effectively restore blood flow. The experimental studies conducted globally have proved that leeching is very beneficial for microsurgery and different types of arthritis. Some cupping clinics used medicinal leeches as it is a safer and preferred option, which also leaves fewer scars on the skin (Lone et al., 2011).

Figure 2.2 Animal Horns Cupping

Cupping therapy was once called Jiao Fa (角法) which means horn method as hollowed animal horns were used as cupping instrument in ancient China (Lin et al., 2018). It is originally used to treat boils and suck out toxins from snake bites. The wider end of the animal horn is placed on the skin and the vacuum is formed by orally sucking the air through the narrow end of the animal horn (Nayab et al., 2011).

Figure 2.3 Bamboo cups

Apart from the animal horns, the bamboo cup was developed for the cupping therapy in ancient times. This type of cups is easy to obtain, light and inexpensive. Some practitioners prefer to use bamboo cups as they can be infused with herbal decoction before applying suctioning process on desired skin area. However, it is not suitable for wet cupping as it is impossible to observe the blood sucking process and it is difficult to sterilize (Lin et al., 2018).

Figure 2.4 Glass cups

Glass cups are the favourite cupping instrument of most practitioners in clinical practice as they are easy to sterilize, convenient use and the suction progress in the cup can be observe. However, it breaks easily while dropped and it is difficult to replace as they are normally selling in set (Lin et al., 2018).

Figure 2.5 Plastic cups

Plastic cup or fibres made cups are similar to the function of glass cups. It is also popular among the practitioners as it is affordable and not easy to break while dropped. However, they need to be disposed after the cupping progress as the valve mechanism cannot be fully sterilized (Lin et al., 2018).

Figure 2.6 (a) Dry Cupping (b) Wet Cupping

There are a few cupping techniques that can be applied including dry cupping, wet cupping, flash cupping and massage cupping (Al-Bedah et al., 2016). Among these cupping techniques, dry cupping and wet cupping are the most common techniques to apply cupping therapy.

Dry cupping is also known as static cupping or retained cupping(El-Hassan & Supervisor, 2017). In this technique, the suction cup will be placed on the desired skin area and a vacuum (negative pressure) is created through several methods including flame, manual suction pump or electrical suction device. The skin will be dragged into the cup when cupping progress is undergoing. The cup is left for a few minutes before being removed. The patients might suffer the risk of burn, redness, swelling and heat on the affected area, scar formation and dermatitis if there is an uncontrolled pressure during the cupping progress (Al-Bedah et al., 2016).

Wet cupping is also referred to as Hijama, full cupping, bloodletting cupping or bleeding cupping. A small incision is made by using a surgical instrument before placing the cup on the skin to suck blood. This technique would also apply when there is a wound on the skin to remove static blood and toxins from the body. There will be a risk of infection, scar formation and vasovagal attack when applying this technique (Al-Bedah et al., 2016).

Flash cupping is also called empty cupping. This technique is employed when several medium to light pressure cupping are performed several times in rapid succession on the desired skin area that needs stimulation. The cups are applied and reapplied on the skin of the next area before 30 seconds with repeated application of cups. This technique helps in reducing local congestion and stimulates local circulation. It is applied when dry cupping is not indicated (Al-Bedah et al., 2016).

Massage cupping, also known as sliding cupping, moving cupping, dynamic cupping or gliding cupping is a technique where the oil is applied to the skin to provide frictionless movement on the cups with a fixed pressure on the body and can be moved through the area that requires massage (Al-Bedah et al., 2016).

2.2.1 CUPPING HISTORY

Cupping therapy is a type of alternative therapy that widely applied in China and Middle East. It was first known to the world in the world-famous medical documents Eber’s papyrus which written approximately 1536 B.C and published in 1875 by Georg Moritz Ebers (Al-Bedah et al., 2016). Back to 1550 B.C, cup was the Egyptian glyph used to refer to a doctor. During the Jin Dynasty in Asia, a chinese physician, Ge Hong (281-341 A.D.) had mentioned the use of animal horns as a means of expelling fluids from the body. The use of a cup (Hijama) for the treatment of menstrual conditions is also recommended in Arab and Islamic countries in the Medical Classics' Al-Qanun Fi'l-Tibb in 1025 CE (Anna Dinallo, 2019).

5500 years ago (3500 B.C.), the first Arab population that used animal horns and bamboo wood as the primitive tools for cupping therapy is Assyrians in the middle east and Jee Hong (381 – 281 B.C.), the Chinese physician was one of the leaders in that art (El Sayed et al., 2013). A Greek historian, Herodotus had recorded that the use of suction cups on the body with both dry and wet cupping therapy are recommended by the ancient Egyptian physicians in 400 B.C.. The conditions that being treated with the use of cupping therapy including headache, loss of appetite, indigestion, fainting, abscess discharge, narcolepsy (repeated sleepiness), and more (Turk & Allen, 1983).

The use of cupping therapy and other types of complementary medicines has gradually increased in the United States (Eisenberg et al., 1998). The authors of medical report from Harvard Medical School reported that cupping and acupuncture treatments were pleasant and effective in pain management (Kemper et al., 2000).

Cupping therapy is currently most popular in China. According to the Chinese scientists, cupping therapy has been used in tradisional Chinese medicine (TCM) at least 2000 years ago. It is adpoted as a formal treatment modality since 1950 by the Chinese hospitals (Cao et al., 2012). Cupping is currently being used by doctors in China and Mongolia to treat high blood pressure, neck pain, headaches, chronic hepatitis, eye disease, skin disease, and infectious diseases (Kim et al., 2011).

In the early state of classification of cupping therapy, it is only being categorized in to 2 cupping which is dry and wet cupping. In 2013, a new classification was developed and 5 categories of cupping is categorized. An updated was made in 2016 that another category is added into the previous classification. The first classification named “technical types”, including dry, wet, massage and flash cupping while the second classification is the “power of scution” that consists of the level of negative pressure which is light, medium, strong and pulsatile cupping. Thrid classification is related to the method of suction that consists of fire, manual vacuum and electrical vacuum cupping therapy. Next classification is classified according to the materials inside the suction cups, including herbal, water, ozone, moxa, needle and magnetic cupping. Fifth classification is the “area treated” that includes facial, abdominal, female, male and orthopedic cupping. The last classification is other cupping types category, including sports, cosmetic, and aquatic cupping (El-Hassan & Supervisor, 2017).

2.2.2 CUPPING FOR COMMON DISEASE

In recent years, people have paid more and more attention to their own health and cupping therapy has become one of the most important treatments for human health. The Unani-Tibb, Traditional Chinese Medicine (TCM) and Traaditional Iranian Medicine (TIM) are the most detailed in understanding why and how cupping therapy maintains health and treats disease within the paradigm of traditional medicine (Osman-Latib, 2019).

Unani-Tibb is a form of traditional medicine that widely practiced by Muslim in the Graeco-Arab region based on the guidance of the Greek physician, Hippocrates and a Roman physicain Galen. In Hijamah (phlebotomy), the act of bloodletting is to remove the contaimination in the blood, relief excessive heat from the body, rebalance the humors and draws inflammation and pressure away from the organs. The Unani practitioners believed that the Hijamah had facilitates this as the healing process (Osman-Latib, 2019).

TCM is a form of traditional medicine that widely practiced in the Asian region and other practitioners all over the world. It is believed when the blood and the flow of "qi" in the body is smooth, the health is maintained. However, the existing of stagnation or stasis resulting in disease that can be systemic, affecting the whole body or particular organ or part of the body. Hijamah is believed can invigorates the flow of "qi" and blood as well as release the blockages inside the blood vessel. Excess heat and fire from the outer parts of the body and also the inner side of the organs would also be drain when Hijamah is applied. Moreover, it would also stimulates the blood production and eliminate toxins from body. In summarize, the impurities in the blood will be removed and toxins and harmful impurities in the vital organs would also be transferred and expelled (Osman-Latib, 2019).

TIM is a branch of so-called Arabic-Unani Medicine cited by the British medical historian Cyril Elgood. It is more advanced than the medicine of Assyria and further claimed that it is firstly created in ancient Persia before being transferred to Greek during the period of Islamic-Arab civilization and thus developed worldwide (Reza et al., 2012).

2.2.3 CUPPING EQUIPMENT

There is several basic equipment required before applied cupping therapy. Nine basic cupping would be introduced in this subtitle. The basic equipment are suction cup, rubber glove, alcohol swab, blade, tissue paper, pen, needle and olive oil.

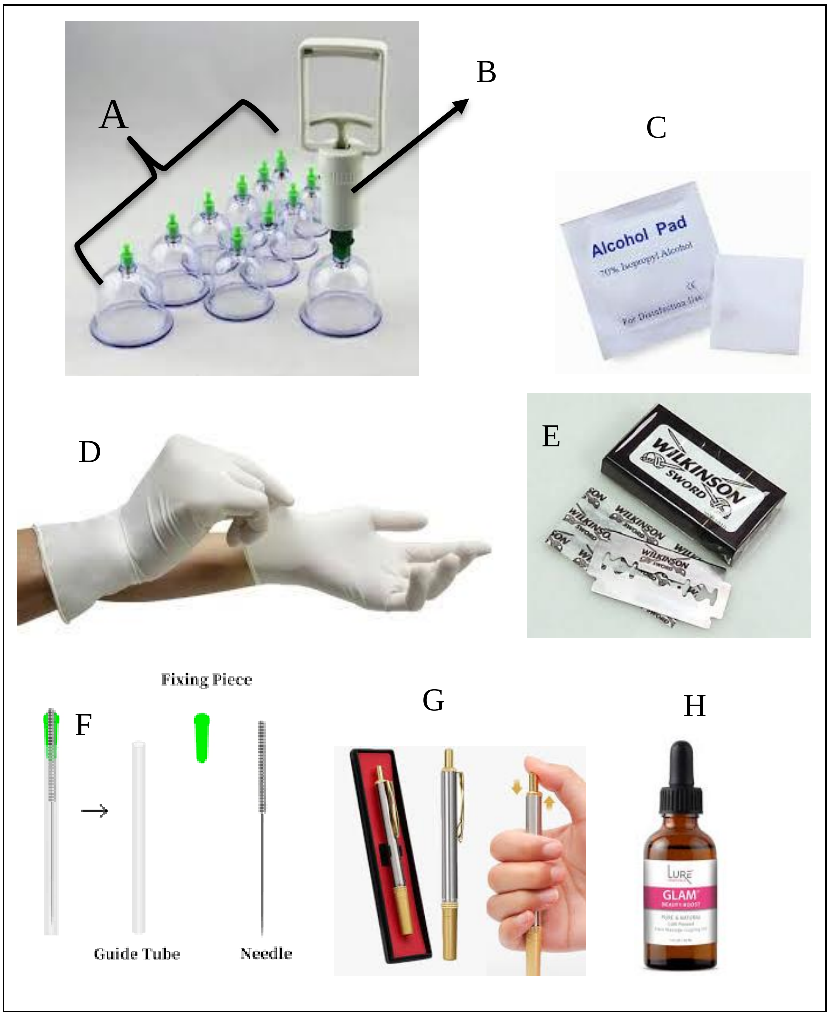

Figure 2.7 Equipment of cupping

Table 2.1 List and description of equipment

Items	Name	Description
A	Suction Cups	It is placed on the desired skin area and is pumped manually to create vacuum under the skin.
B	Manual Suction Tool	It is used to suck the air in the suction cup to create vacuum in the suction cup.
C	Alcohol Pad	It is used for the cupping with flames.
D	Surgical Glove	It must be worn by the practitioners to prevent the spread of germs.
E	Surgical Blade	It is used to make small incisions on the body to apply the wet cupping.
F	Acupuncture Needles	It is used in the needle cupping or dry needling technique. It can initiate the natural healing process of body by creating tiny, microscopic injury to the body.
G	Lancing Pen	It also known as a needle prick cupping device that can apply consistent puncture depth to the patient.
H	Essential Oil / Olive Oil	It is applied to the skin surface before applying cupping process. It help to decrease the risk of bruising and also can become a better seal for the suction cup to prevent leakage of the negative pressure.

Among the cupping equipment, the suction cup and manual suction tool are two most important equipment. Figure below show the structure of the suction cup and the manual suction tool. The suction cup is the combination of vent valve, rubber ring, cupping body and cupping mouth while the manual suction tool consists of 5 part which are plug, spring, plastic tube, draw bar and handle.

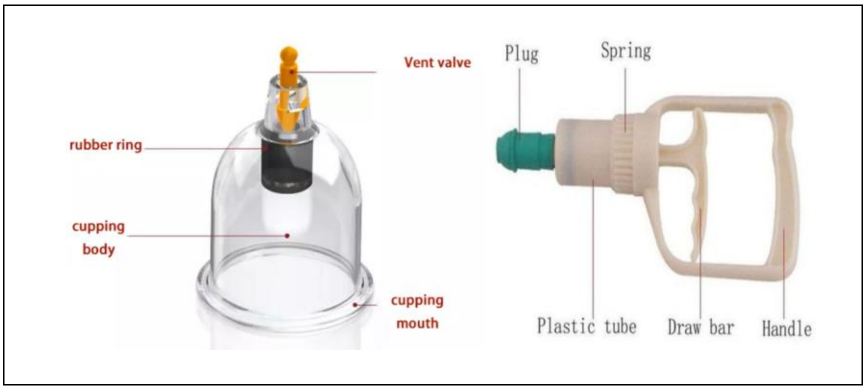

Figure 2.8 Structure of suction cup and manual suction tool

All modern suction cups have a vent valve on top it. It is usually can be attached to the plug or muzzle which is at the end of the suction handle (pikestaff). The air in the suction cup will be extracted when the draw bar is pulled after placing the cup on the surface of the skin. The skin will then be draw into the suction cup when a vacuum is occurred in the suction cup or negative pressure is applied to the suction cup. The rubber ring is designed to release the pressure in the cupping body. The cupping body will hold the blood when blood is draw during the wet cupping.

2.2.4 CUPPING PROCEDURE

Dry Cupping is the most common method to apply the cupping therapy. It is works without making any incisions on the body. First, with the help of the suction tool, the suction cups are placed on the desired skin area, for example back of the body or the other painful area. There is a total of 3 types of tensions can be made during the cupping therapy which are light tension, medium tension and strong tension.. The tensions can be made according to the strength of the suction and the patient’s affordability. After that, the cups are left of a few minutes before the practitioners released the pressure in the suction cups.

Wet Cupping is a type of cupping therapy method that is related to the dry cupping. In this cupping method, the cups will be placed on the skin with negative pressure applied to the suction cups. The suction cups are removed after two to three minutes. Then, a scalpel or surgical blade, for example a 26-gauge disposable lancet will be used to pierce the skin to a depth of 2 mm within the cupping site. Thereafter, a second times of the vacuum will be performed to drain three to five cm^3 of blood from each cupping site. A sterile pad will be used to cover up the application sites to prevent the risk of infection (Tagil et al., 2014).

Flash cupping is a most common type of cupping therapy used in clinical practice. It can be used to apply in the places where the skin is numb, the body is weak, the muscles are sagging, and it is difficult to generate suction and keep the cup. In this technique, the cups are removed immediately after they are placed onto the skin. This procedure is repeated until the cupping area is flushed (Lin et al., 2018). It only takes less than 30 seconds for the cups to be removed and applied again to the skin (Al-Bedah et al., 2016).

Massage cupping is the only type of cupping method that applied with the existing of oil. In this type of cupping therapy, olive oil, peppermint oil or lavender oil can be used to apply to the skin and a weak suction is applied to the massaged area by moving the suction cups. It is suitable for all ages, including children and the elderly (Al-Bedah et al., 2016).

2.2.5 CONCEPT OF PRESSURE IN CUPPING

Modern suction cup consist of a valve bar. The air would be extracted from the suction cup when suction is occurred and the valve bar remained tight. In this state, the skin is pulled into the suction cup as the vacuum condition is occurred while the atmospheric pressure in the suction cup is reduced.

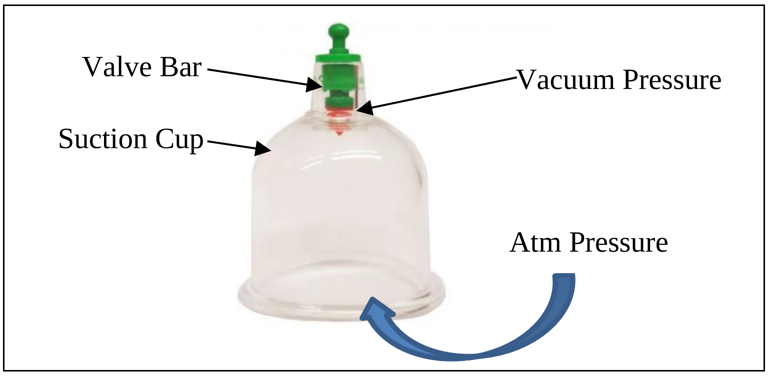

Figure 2.9 Overview of Pressure

Equation below show the relationship of the absolute pressure (P_{abs}), atmospheric pressure (P_{atm}) and vacuum pressure (P_v). Therefore, it can be said that the P_{abs} is the combination of P_{atm} outside the suction cup and P_v inside the suction cup.

$$P_{abs} = P_{atm} + P_v \quad (1)$$

2.2.6 POWER OF SUCTION

This subtitle is focus on the level of the negative pressure of cupping therapy inside the suction cups. There are 4 type of classification incluing light (weak), medium, strong (Aldallal, 2009) and pulsatile cupping (Teut et al., 2012).

1. Light (weak) cupping

This category of cupping is mainly used when the blood and energy are sluggish or stagnant. Its intention is to break the stagnation while replenishing weak energy. The most important factor to select the weak cupping is depends on patient’s current energetic state. This method of cupping can be used almost anywhere on the body and may cause minor skin reddening. Weak cupping is also an ideal cupping method for elderly patients, frail adults, and young children, especially children under seven (Hasan, 2018).

2. Medium cupping

This cupping method is the most commonly used for patient. It is safe for the patient above 7-year-old. The suction is stronger during moderate cupping. It will pressed the skin deeply into the cup and causing slight redness. Medium cupping can also be safely used in anywhere on the body (Hasan, 2018).

3. Strong cupping

Strong cupping is the most exhausting method among other cupping methods. Therefore, before deciding on this treatment, practitioners must confirm the suitability of the patient. Tiredness and exhaustive may appear after using this procedure. A strong pulling feeling is occurred during this procedure and the powerful pulling motion will turned the skin inside the cup into red colour and then purple colour, and erythema may appear on the skin around the cup. Imprinting is unavoidable when using strong cupping for the first time and may take 15 to 20 days to fully fade. Wet cupping is often combined with strong cupping (Hasan, 2018).

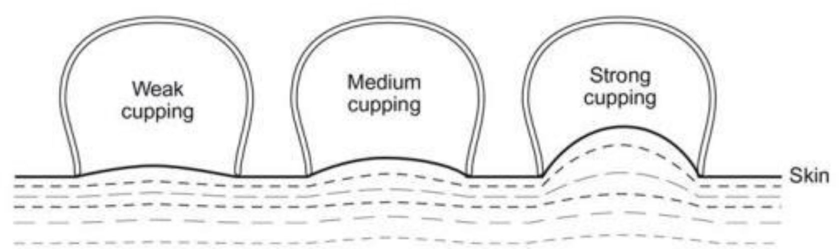

FIGURE 9-4 Section of the skin showing the effects of Weak, Medium and Strong cupping.

Figure 2.10 Effect of Cupping

4. Pulsatile cupping

In this type of cupping, the pressure inside the suction cups is variable and not constant. It is used in randomised clinical trials to assess the effectiveness of cupping therapy in the treatment of osteoarthritis. A mechanical cupping device with flexible silicone and plastic cups is used to administer pulsatile cupping based on the treatment area. A pulsating (variable) negative pressure is created inside the suction cups by using the device. The range of the negative pressure is between 100 to 200 mbar every 2 second. When compared to no intervention, this method was found to relieve symptoms of knee osteoarthritis (Teut et al., 2012).

2.3 CURRENT AVAIABLE CUPPING SUCTION DEVICE

The subtitle below discussed the current available cupping suction device in today's world. There is only 2 type of devices which are manual cupping tool and electronic cupping device.

2.3.1 MANUAL CUPPING TOOL

The ME17 set is the most popular manual cupping tool in recent year. It is an upgrade to the 10-piece set and the addition of a wider range of cup sizes and styles making the cupping tool more versatile. It is suitable for self-cupping by using the supplied extension tube. No cream or oil is needed for cupping treatment.

Figure 2.11 Manual Cupping Tool Set (ME17)

2.3.2 ELECTRONIC CUPPING DEVICE

The electronic suction device is available high pressure for patient to apply the cupping therapy which is up to -550 mmHg pressure. However, there is no value displayed, thus there patient might face to unknown pressure which will lead to blister of vesicles.

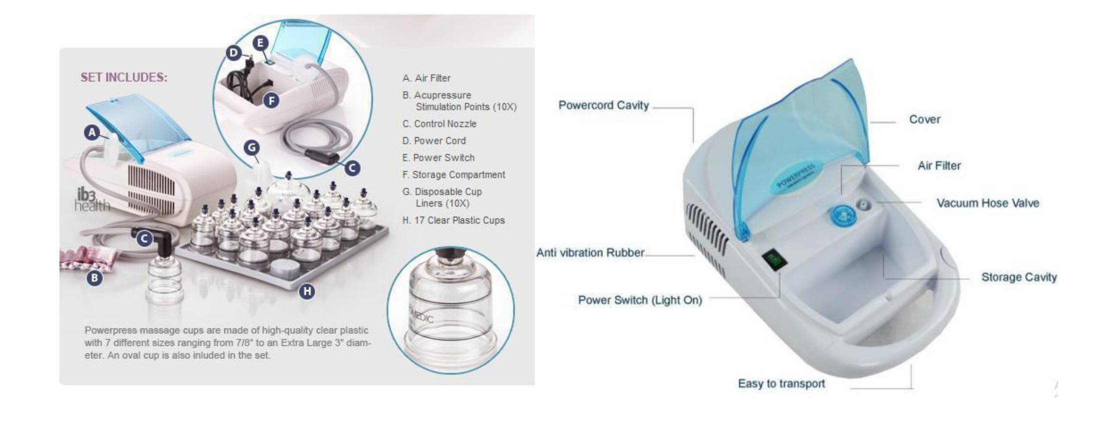

Figure 2.12 Electronic Suction Equipment

The electric vacuum cupping device is adopting the vacuum principle to keep the suction cup in the vacuum state. It is more effective than the manual suction tool in terms of strength and profession. The patient can change the rate of suction from lower to higher by pressing the manual button provided.

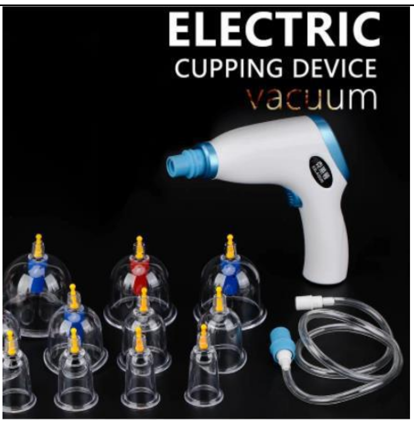

Figure 2.13 Electronic Cupping Device

2.4 MICROCONTROLLER

A microcontroller is an electric equipment that integrates several components of a microprocessor system onto a unitary microchip and optimises them to interact with the outside world through an onboard interface. Arduino board have fast processing speed and simple interface. It can be function as a minicomputer by accepting the inputs and controlling the output of several type of electronic devices. It is also a type of microcontroller that can be used as a quick tool for developing Integrated Circuit (IC) or VLSI test benches, especially for sensors (Louis, 2018). In this project, the microcontroller is mainly used to verify the detecting value of the pressure sensor, sending the instructions to the air pump and receiving the data value of pressure value before displayed on the graphical LCD.

2.4.1 ARDUINO UNO

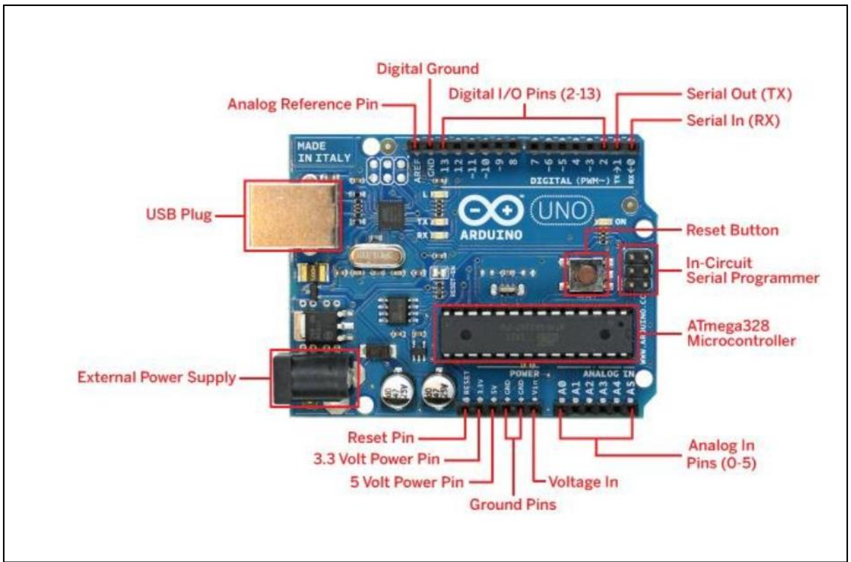

Figure 2.14 Arduino Uno

The detail pinouts of Arduino Uno are show in Figure 2.14. The Arduino Uno is used as a microcontroller board based on the 8-bit ATmega328P processor during the trial of this project. This microcontroller board has fourteen digital input or output pins which included six PWM output pins, six analog input pins (A0 to A5), a sixteen MHz ceramic resonator, a Universal Serial Bus (USB) plug, an external power supply, an In-Circuit Serial Programming (ICSP) header and a reset button.

The Arduino Uno board can be activated by simply connect it to a computer or laptop with a USB cable or connect the microcontroller with an external power supply. The external power supply can be either an AC-to DC adapter or battery. An Arduino Uno board can be operated on an external supply from six volts to 20 volts. However, when the external supply supplied over twelve volts, the voltage regulator may be overheated and the board will be damaged. Thus, the recommended range of the external supply is seven volts to twelve volts.

By selecting the “Arduino Uno” from “Tools” > “Board” menu in the Arduino software (Arduino IDE), it can be used to programme the Arduino Uno board. The Arduino Uno should be connected to a computer or a laptop to receive the Arduino sketch from the Arduino IDE. An extra layer of protection, resettable polyfused is consist in the Arduino Uno to protect the USB port from a computer or a laptop from shorts or overcurrent.

2.4.2 ARDUINO NANO

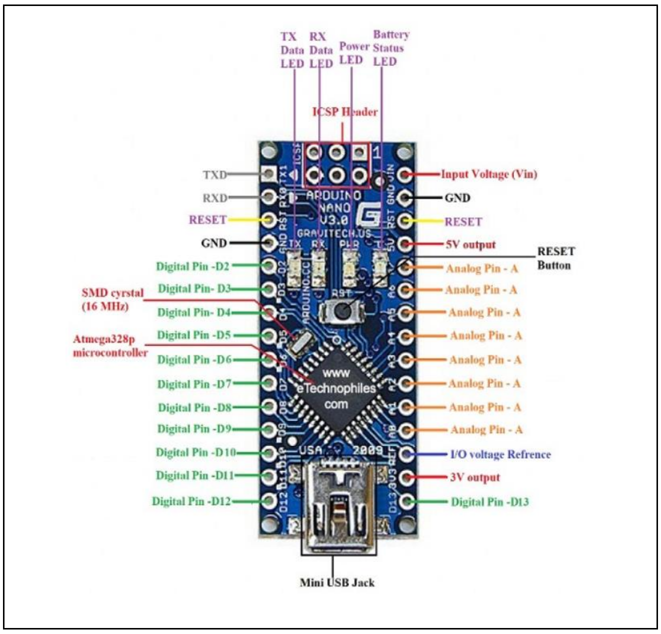

Figure 2.15 Arduino Nano

Figure above show detail pinouts of Arduino Nano. The Arduino Nano is selected to use in the end of the project due to its smaller size, breadboard friendly and more analog pin than the Arduino Uno board. The breadboard friendly function makes the Nano board very easy when handling the connections. It is also an ideal microcontroller for most of the applications where the size of electronic components is a great concern. On the other hand, same as the Arduino Uno, the Arduino Nano is also used as a microcontroller board based on the ATmega328P processor. Thus, both microcontrollers can share same program.

There is a total of fourteen digital pins which included six PWM output pins, eight analog pins (A0 to A7), two reset pins and six power pins on the Arduino Nano board where the digital pins can be used as an input or output pins. Similar to the Arduino Uno board, the recommended input voltage for the Vin pin is seven volts to twelve volts. The operating voltage of the Arduino Nano board is five volts but its upper end of the range can be change by using the analogReference() function in the Arduino IDE. However, the Arduino Nano board only works with a Mini-B USB cable instead of a standard USB cable like Arduino Uno. It also lacks with a DC power jack which means no external power supply can be used through a battery.

2.5 SOFTWARE PROGRAMMING

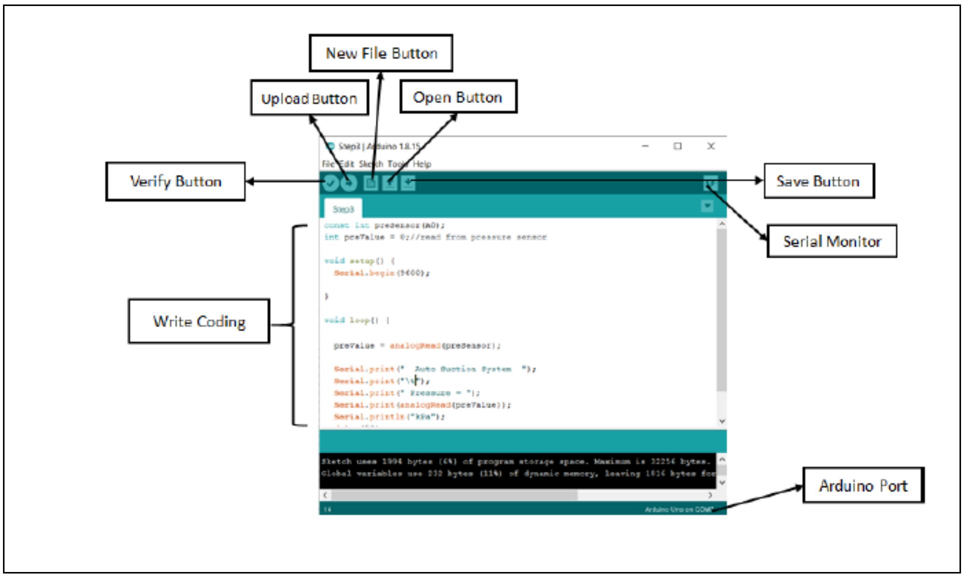

Figure 2.16 Arduino Sketch

In order to activate the Arduino controller, the Arduino IDE (Integrated Development Environment) 1.8.15 software is downloaded from the Arduino Software Download page. Figure above shows each of the functions of each button in the software. Based on the instruction from the Arduino software official net, the code that is written in the space provided is uploaded to the Arduino board by connecting it to the computer with a USB cable. However, if a quotation is short, in text quotation should be used.

Figure below shows the output result of the program at the Serial Monitor. Before uploading the programming code to the Arduino board, the coding needs to be verified to ensure that there is no error in the programming code. Once the verification of the coding is done, the coding is ready to upload. The Arduino port is selected and the program is allowed to upload to the Arduino board that connects to the computer. Thus, the output of the program will display at the Serial Monitor of the Arduino IDE.

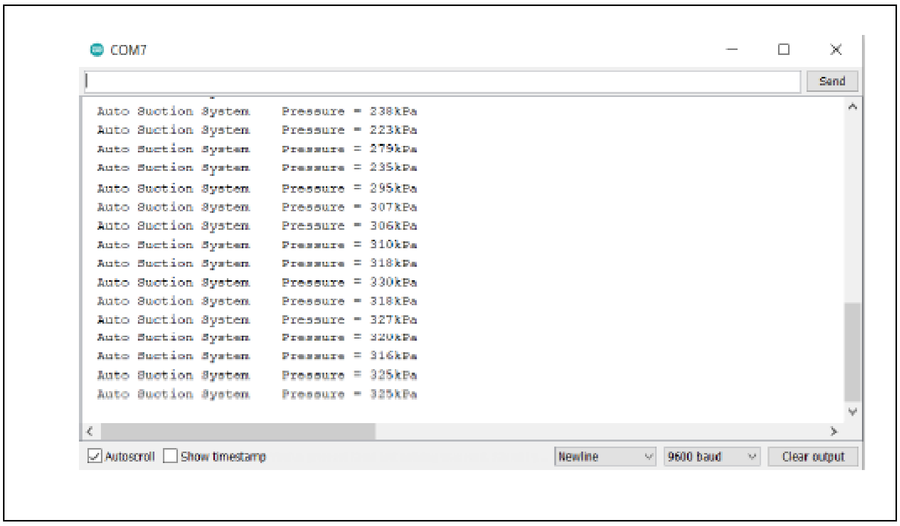

Figure 2.17 Output at Serial Monitor

2.6 GRAPHICAL LIQUID CRYSTAL DISPLAY (ST7920)

Figure 2.18 ST7920 Graphic LCD

A graphical liquid crystal display (Graphical LCD) which is also known as a monochrome graphics LCD displays or a dot matrix LCD display is a controller that is used to display either alphabets, number or character (Eric Hawkins, 2017). In this project ST7920 graphical LCD is selected to display the output result. According to the datasheet from Sitronix (2002), ST7920 graphical LCD controller or driver can not only display like a common LCD, but it also able to display Chinese fonts as it includes the character ROM with eight thousand one hundred and ninety-two16 x 16 dots of Chinese fonts and one hundred and twenty-six16 x 8 dots of half-height alphanumerical fonts. It supports 3 kinds of bus interface and all the functions including display the RAM, character generator ROM, LCD display drivers and control circuits are all in a one-chip solution. Thus, a Chinese character display system can be easily achieved. The operating voltage of ST7920 is wide which is from 2.7V to 5.5V. It is also a device that is suitable for battery power portable devices as it has low power consumption. ST7920 graphical LCD controller consists of 33 common and 64 segments. When it connects with the segment driver ST7921, it can support up to 33 common x 256 segments display.

2.7 MONOLITHIC SILICON PRESSURE SENSOR (MPX5100DP KKT 19421)

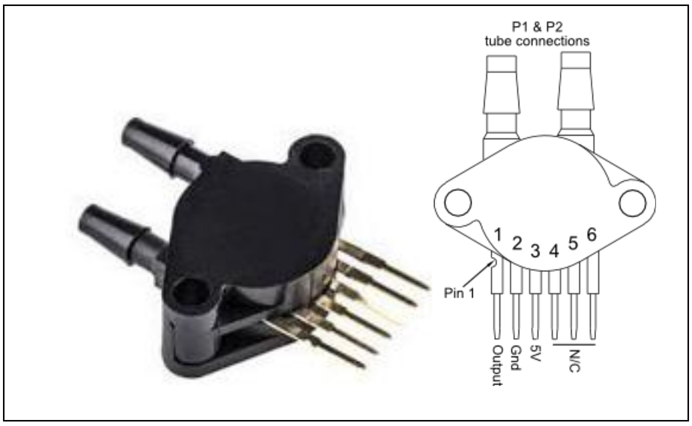

Figure 2.19 MPX5100DP pressure sensor

Generally, a pressure sensor is a device that is used to measure the pressure of gases or liquid. The pressure sensor that is selected for this project is MPX5100DP KKT19421. According to the datasheet of the Freescale Semiconductor, the MPX5100DP series is a state-of-the-art monolithic silicon pressure sensor that is designed for employing a microcontroller or a microprocessor with Analog to Digital inputs. It also known as a patented piezoresistive transducer which combine the advances micromachining techniques, thin film metallization and bipolar processing in the system to provide an accurate and high-level analog output signal proportional to the applied pressure.

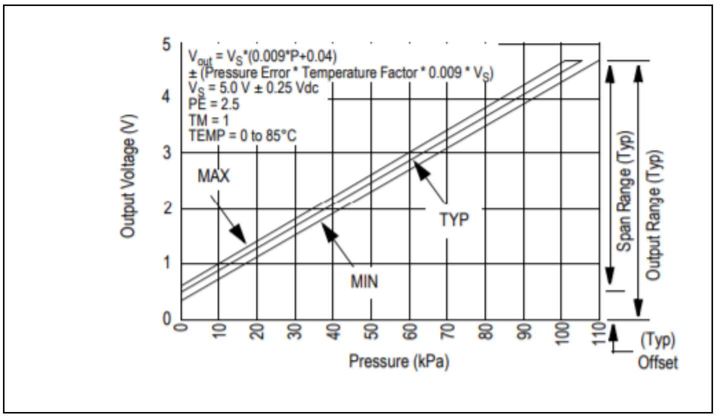

Figure 2.20 Graph of Output Voltage vs. Pressure Differential

This type of pressure sensor is able to measure the pressure difference between the sources when the pressure is applied on the sensor and the atmospheric pressure which is also known as gauge pressure. Based on the same datasheet of MPX5100DP, the port closes to the Pin 1 is the positive pressure while the other port is the vacuum port. Pin 1 represents the VOUT, Pin 2 is the pin that connects to the ground, Pin 3 is the VCC pin, Pin 4 is V1, Pin 5 is V2 and the last pin, Pin 6 is the V EX pin. Its typical applications are patient monitoring, process control, pump or motor Control and pressure switching. Figure 2.20 show the output signal of the sensor is related to the input pressure. By referring to it, the maximum I/O voltage is 5V which certify that the pressure sensor is harmless to the human body. The fundamental reason for choosing this pressure sensor is that its pressure range is from 0 kPa to 100 kPa.

2.8 VACUUM AIR PUMP

Figure 2.21 Vacuum Air Pump

Vacuum air pump is a suction device that will draw gas from an impenetrable volume to create a partial vacuum. This type of air pump is also known as a dc motor that coated with absorbing sponge. It has 3.2 L/min flow rate and it also can withstand high pressure range. The maximum positive pressure is 100kPa while the negative pressure is -60 kPa. The rated voltage of this air pump is DC 12V and it can load at least 400 mA current. Two 10cm wire are welded at the bottom of the air pump to eliminate the difficulty of wiring. In this project, the air pump will generate a relative vacuum from the suction cup that placed on the body through a tube. The speed of the pump will be control by the detected pressure where the higher the pressure, the lower the speed of the pump to prevent the risk of blister or vesicles occurred during the cupping process.

2.9 MOTOR DRIVER (L298N)

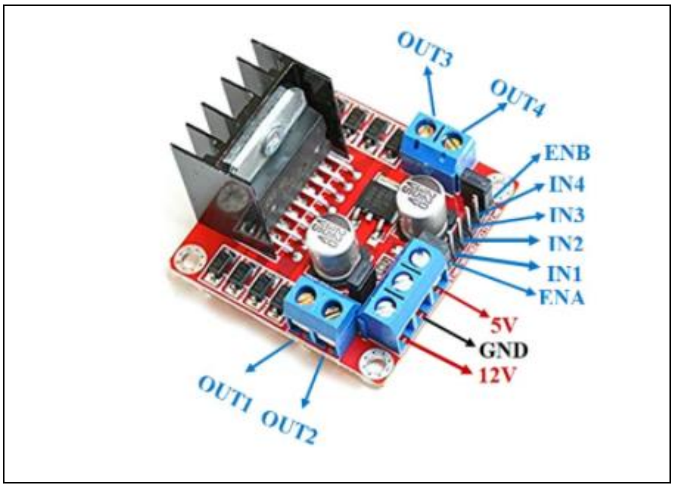

Figure 2.22 Motor Driver L298N

L298N motor driver is a dual bidirectional motor driver that provide simple control for up to 2 DC motors at the same time. The basis of this motor driver is L298 Dual H-Bridge Motor Driver. Its design allows the user to control 2 motors independently in both directions. The input voltage of this motor driver is between 3.2 volts to 40 volts. Its peak current is 2 A while the operating current range is between 0 to 36 mA. It can be stored between -25 °C up to 130 °C. When the temperature is at 75 °C, it has maximum power consumption up to 20 W. In this project, only one output is used which are output A. The 12 volts 10 mA power supply will connect to the +12 V and GND pins of the motor driver to supply power. The +5 V pin will connect to the Vin pin and the GND pin will again connect to the GND pin on the Arduino board. The Enable A pin will connect to the PWM pins (digital 10 pin) on the Arduino board while the logic input pins 1 and 2 will connect to digital pin 8 and pin 9 on the Arduino board respectively.

2.10 DISPOSABLE HYDROPHOBIC BACTERIA FILTER

Figure 2.23 Disposable hydrophobic bacteria filter

The disposable hydrophobic bacteria filter can be operated about three hours on full power battery at maximum vacuum. The vacuum range of -25mmHg to 550mmHg coupled with a flow rate that is greater than 30 lpm at the open flow will provides a more powerful suction for a faster power of suction. It is made of high-quality engineering thermoplastics that are impact resistant and long-lasting. Generally, this bacterial filter can be used with most type of portable suction system and it must be located between the suction header and the portable air pump. When there is an overflow occurred, it will help to prevent the contamination of the suction pump as it helps in preventing the spillage to reach to the pump. In this project, this type of filter is used to prevent the blood flow into the pressure sensor as well as the air pump.

2.11 SWITCH MODE POWER SUPPLY

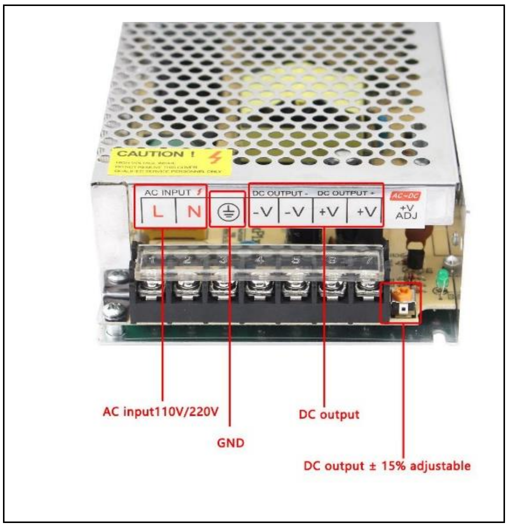

Figure 2.24 Switch Mode Power Supply

The switch mode power supply has a safe design with overload and overvoltage protection. It is made from aluminium. The input voltage of this power supply is between 110 volts to 220 volts AC and its output voltage is 12 volts DC. Its input current is 3A and has a leakage current that less than 0.5mA. It also has an output current of 10 A with 120 W output power. The DC output of this power supply has an error of ±15% and this error can be adjusted manually. This power supply can work under -10 °C to 60 °C. This power supply is suitable for most of the devices included CCTV, LED lights, fans and etc. In this project, a 12V and 10mA power supply adapter is selected.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this chapter, the sequence to conduct this project is discussed. The general flow and the process of the mechanism and system are written. The focus of this project is started on the literature review about the cupping therapy, concepts of pressure in cupping and the components that used for this project. A most suitable differential pressure sensor is selected based on its characteristics. The selected sensor is monolithic silicon pressure sensor, MPX5100DP that able to detect high pressure up to 100 kPa. To ensure the reading from the pressure sensor is valid, its value will be compared and calibrated with the manometer value by using the manometer. Besides, Arduino Uno is used to conduct the activities before developing the single suction mechanism as well as the 3 separated system of automatic cupping suction system. In the end of this project, the complete system will be activated by using the Arduino Nano as it is more suitable to use in a machine due to its small size. Then, the pressure value and the time remaining for a cupping process will be display on the graphical LCD. All the system and mechanism are designed before the development. After completing, an experiment of dry cupping method at the hairy skin part is conducted to test the automated machine is function on human body.

3.2 GENERAL PROJECT FLOWCHART

There are a few flowcharts are created to give a clearer understanding about this project. Same as the process mentioned above, this project is started by studying and understanding the literature review on cupping. By using the knowledge, a simple design of the suction mechanism is built and a system to control the pressure is created. Both mechanism and system are tested before designing the complete system.

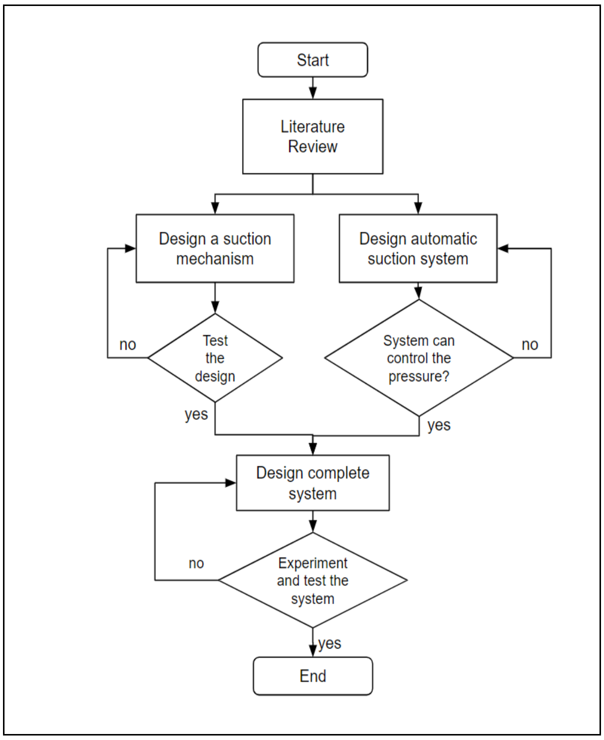

Figure 3.1 General Flowchart

3.3 SUCTION MECHANISM

The suction mechanism is designed to test the system before developing the complete 3 separated automatic cupping suction system. There are 5 small subtitles consist in this part which are flowchart, selection of components, prototype of single cupping suction mechanism, prototype of automatic cupping suction machine and prototype of 3 separated automatic cupping suction mechanism.

3.3.1 FLOWCHART OF SUCTION MECHANISM

Figure below shows the flowchart on design a suction mechanism. This flowchart is created to give the general information on the process of design a suction mechanism. A closed loop system shows in Figure 3.3 is the system of single suction mechanism. The system is consisting of 3 main elements which are Fuzzy Logic Controller (FLC), pump or cupping process and the differential pressure sensor.

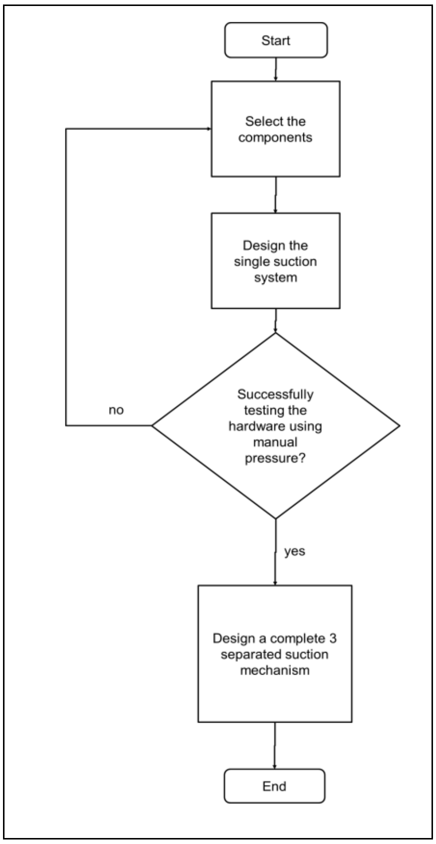

Figure 3.2 General Mechanism Flowchart

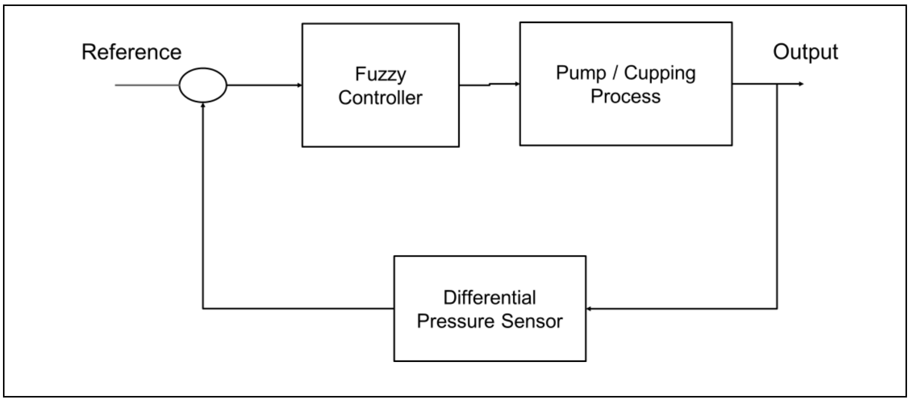

Figure 3.3 Closed loop system of this project

3.4 SELECTION OF COMPONENT

In this part, the selection of the hardware components is display. The components are cupping hose, pump, motor driver, filter, T-junction, cup and bottle. The cupping hose is used to transfer the suction pressure from the pump to the cup in order to apply the cupping therapy. The pump is activated to transmit the air pressure to the cup through the cupping hose while the motor driver is used to activate the air pump. The filter is used to prevent the blood flow into the pressure sensor and inside the machine. The T-junction is used to connect 3 components which are the pump, pressure sensor and filter through the cupping hose. The cup will be placed on the user's desired treatment area to apply the cupping therapy and if the cup is full of blood when the wet cupping method is used, the bottle will collect excess blood.

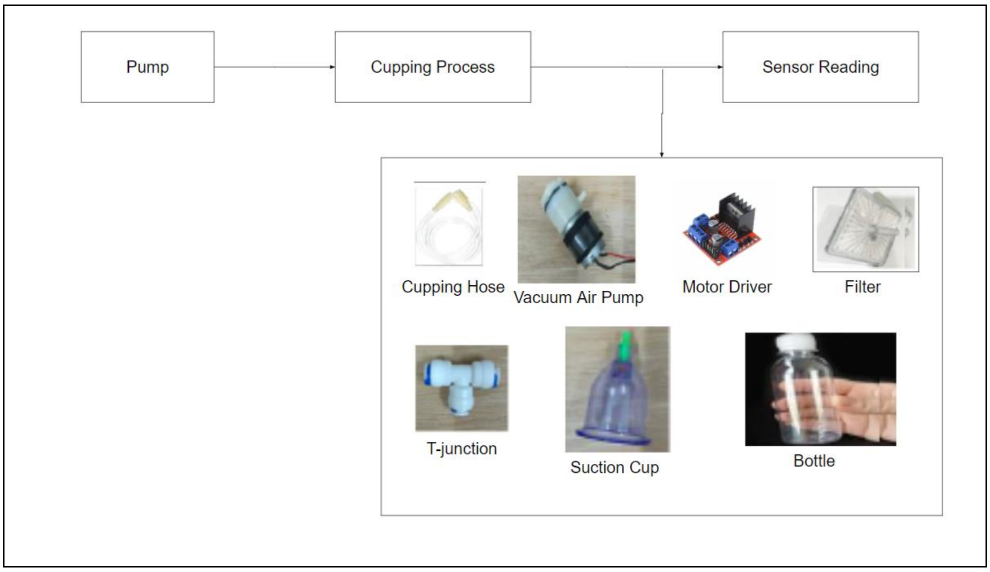

Figure 3.4 Selection of components

3.4.1 PROTOTYPE OF SINGLE CUPPING SUCTION MECHANISM

Figures 3.5 and 3.6 show the prototype of the single cupping suction mechanism. Based on the figures below, the arrangement of the differential pressure sensor is behind the filter while the bottle is placed in front of the filter. The layout of this prototype is for double protection of the differential pressure sensor. This is because when using the wet cupping method, the overflowing blood will flow into the bottle and if the bottle is full, the filter will work and this can prevent the blood for conducting with the differential pressure sensor. This arrangement would also give benefit to the differential pressure sensor which make it last longer.

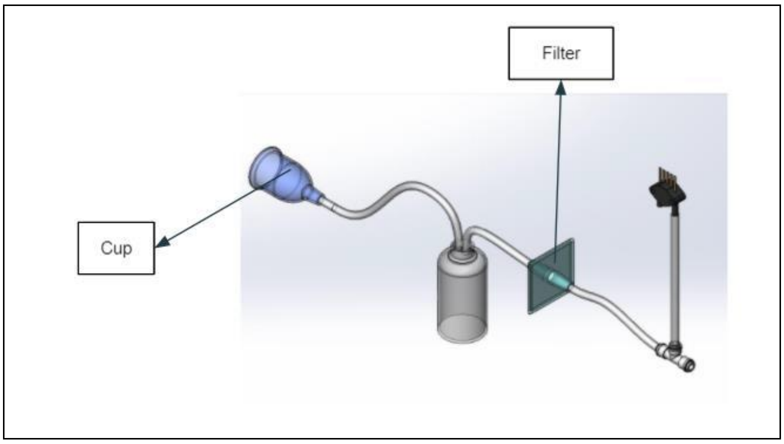

Figure 3.5 Side view of prototype of the single cupping suction mechanism

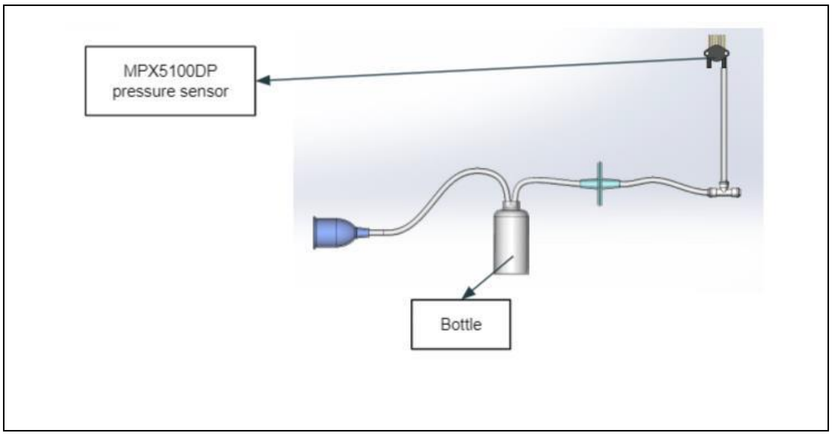

Figure 3.6 Front view of prototype of the single cupping suction mechanism

3.4.2 PROTOTYPE OF AUTOMATIC CUPPING SUCTION MACHINE

Figures below show the side and top view of the prototype of the completed automatic cupping suction machine. This machine will consist of a power switch, an emergency switch, a graphical LCD, an alarm or buzzer, 3 LEDs and 12 reset button. The power switch is used to control the ON or OFF of the machine while the emergency switch is used to stop the machine immediately when there is a risk of injury. The graphical LCD will separately display the pressure value of a cupping process and the time remaining of each cupping system. The alarm will be activated and LED will light up when the cupping process has left 1 minute. A single automatic cupping suction system is used 4 reset buttons to set the activation time for the cupping process. Two reset buttons in the middle are used to increase or decrease the time required for a cupping process as each body part required different pressure for cupping therapy while the mode is change by pressing the first button. The last reset button that located on the bottom corner of the graphic LCD is used to cancel the cupping process. It is designed for a double safety purpose. There will be a hole at the side of the machine which is used to connect the wire from the switch mode power supply to the socket.

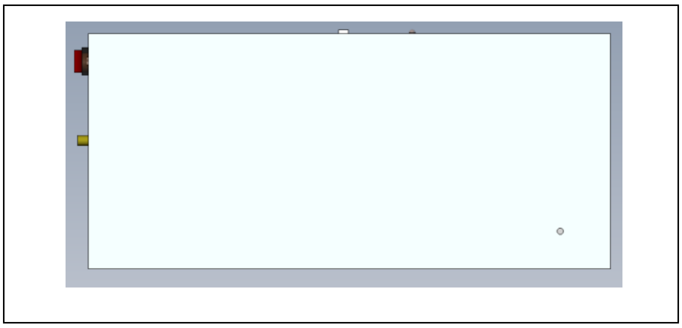

Figure 3.7 Side view of prototype of the automatic cupping suction machine

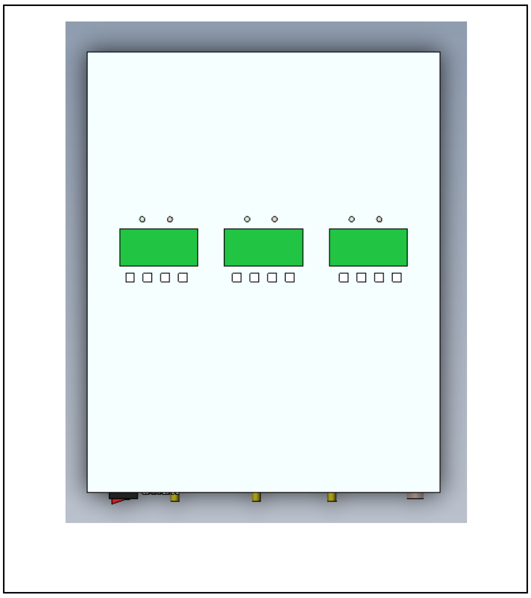

Figure 3.8 Top view of prototype of the automatic cupping suction machine

3.4.3 PROTOTYPE OF 3 SEPARATE AUTOMATIC CUPPING SUCTION MACHINE

Figure below illustrates the prototype for the 3 separate automatic cupping suction machine. The components consist inside the machine are 3 MPX5100DP pressure sensor, 3 motor driver, 3 Arduino Nano, 3 T-junction, a power supply and 3 vacuum air pump. On the outer casing there will have 3 LCDs, a power switch, 3 alarms, a total of 12 reset button, 3 filters, 3 bottles and 3 cups. Besides, there will be an emergency switch placed at the side corner on the left of the power switch to provide immediate stop when there is a risk of injury.

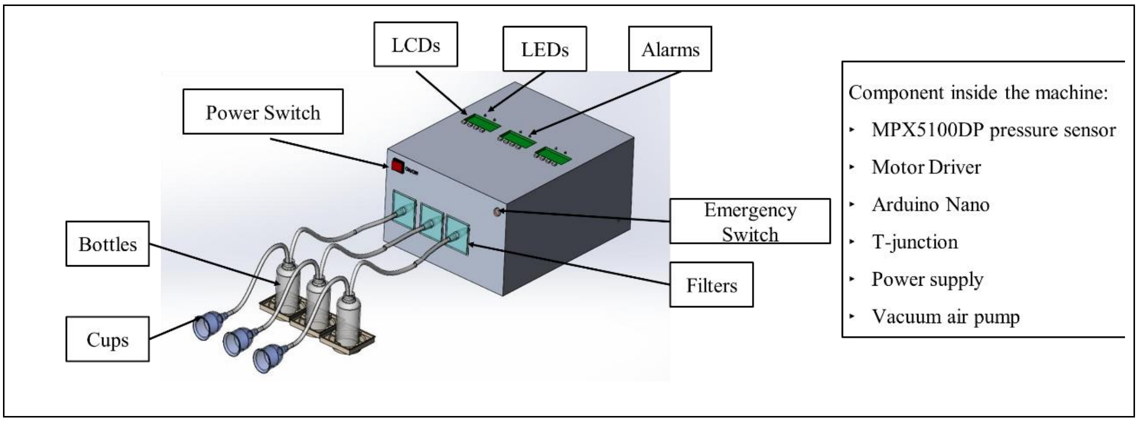

Figure 3.9 Prototype of 3 separate automatic cupping suction machine

3.5 AUTOMATIC SUCTION SYSTEM

The program code to activate the automatic suction system is created by using the Arduino IDE. There are 2 small subtitles consist in this part which are flowchart and the block diagram of automatic suction system. Each experiment procedure is represented by the block diagrams that connected by arrow.

3.5.1 FLOWCHART OF AUTOMATIC SUCTION SYSTEM

Figure below shows the flowchart on design an automatic suction system. This flowchart is created to give the general information on the process of design an automatic suction system. Once the experiment procedure of Step1 to Step 4 are completed, the verification for the validity of the MPX5100DP KKT 19421 differential pressure sensor will conducted. The process is called calibration. If the calibration is failed then the experiment procedure will be developed again but if it is success, thus, a complete 3 separate automatic suction system will be designed.

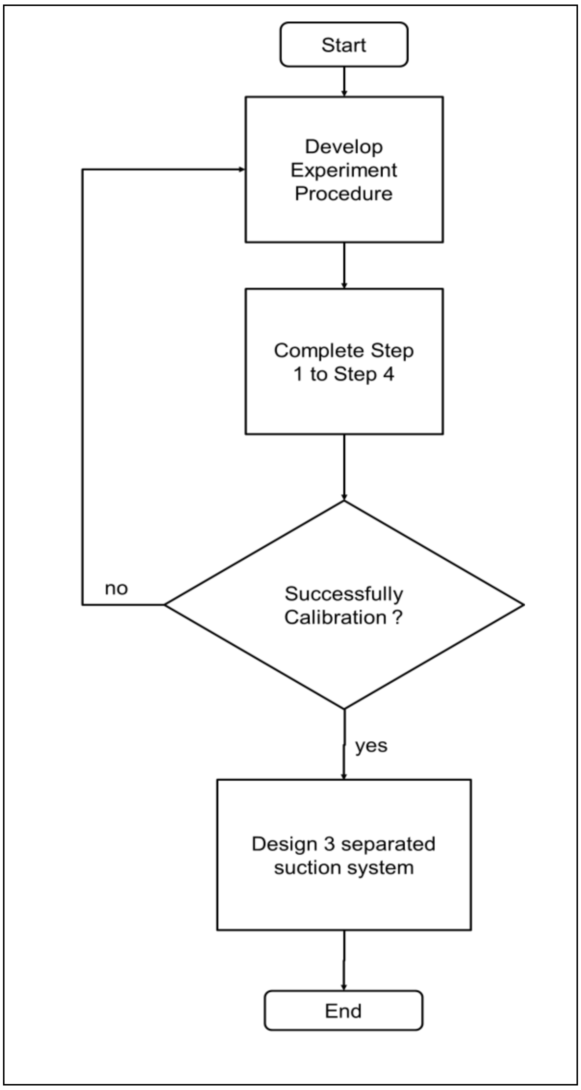

Figure 3.10 General System Flowchart

3.5.2 PROCEDURE FOR AUTOMATIC SUCTION SYSTEM

The experiment procedure of the automatic suction system is showed below. Each step is annotated with a block diagram and flowchart. Besides, the steps are tested in hardware component to ensure there is no mistake or error appear in the complete system. A simple connection circuit will also be displayed in each part of the steps. The program code for each step will be displayed in the Appendix session in the end of this thesis.

3.5.2.1 STEP 1 – CONTROL THE SPEED OF PUMP

The first step of this project is to control the speed of the air pump. A motor driver is required to connect to the air pump and the Arduino Uno. In this step, the speed of the pump is inserted in the Arduino coding. If the speed is higher than 0 and lower or equal to 255, the air pump will be activated and the motor is in start condition while if the speed in the coding is exceed 255, the air pump will be deactivated and the motor will in stop condition. Figures below displayed the block diagram, flowchart, hardware installation and circuit connection for Step 1. The program code for Step 1 is attached in the Appendix part.

i. Block diagram for Step 1:

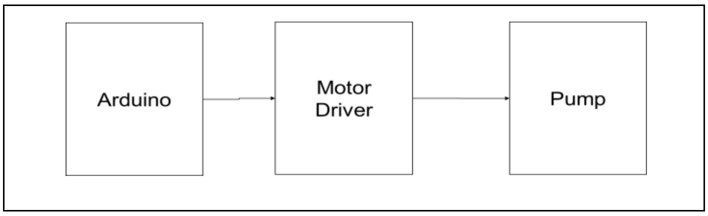

Figure 3.11 Block Diagram for Step 1

ii. Flowchart for Step 1:

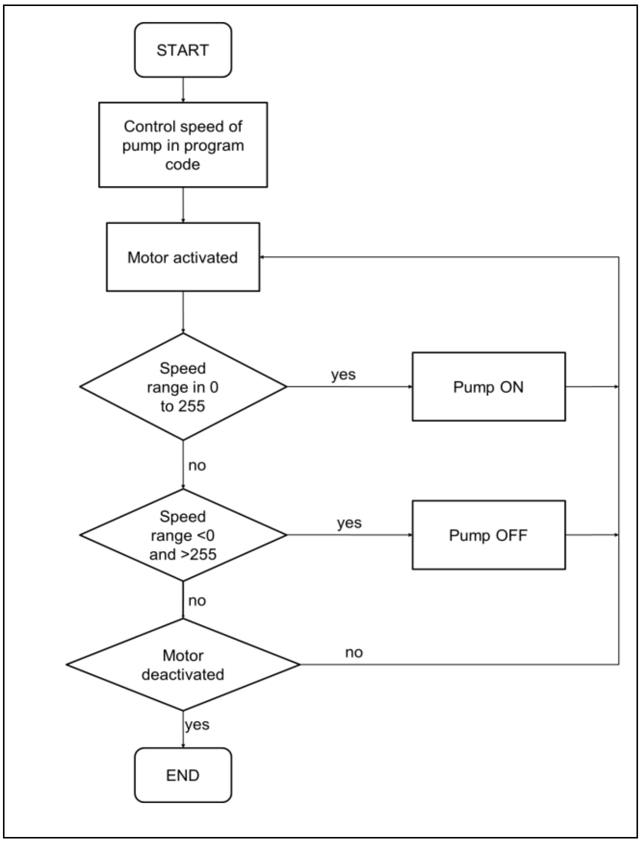

Figure 3.12 Flowchart for Step 1

iii. Hardware installation for Step 1:

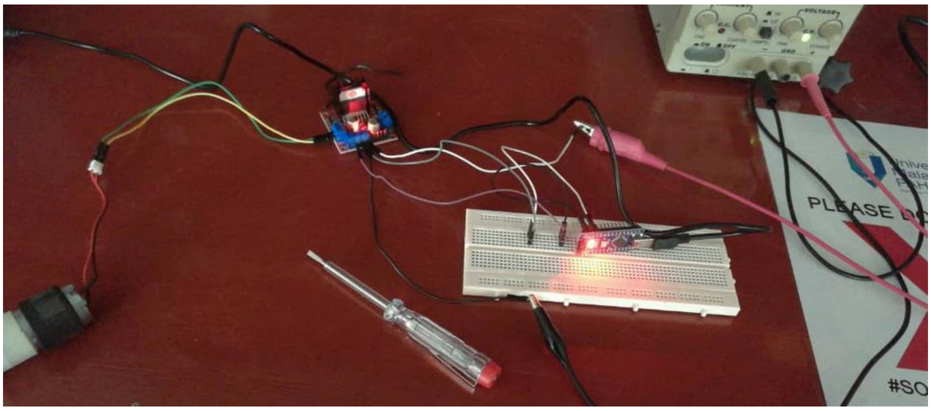

Figure 3.13 Hardware Installation for Step 1

iv. Circuit connection for Step 1:

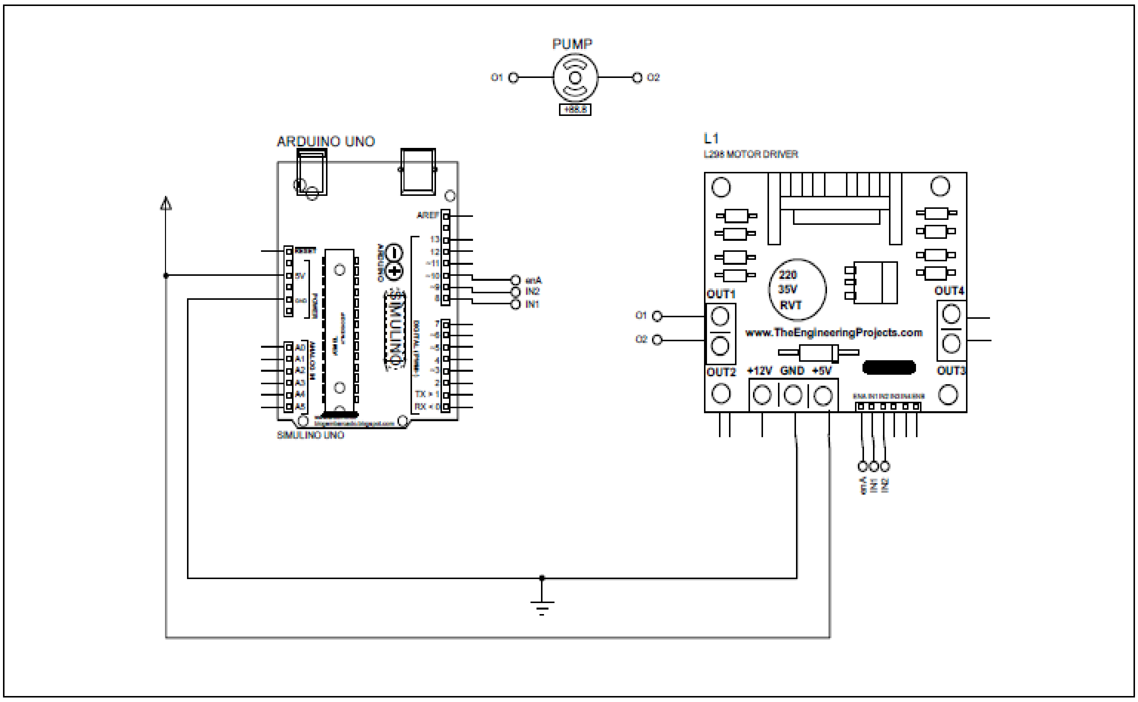

Figure 3.14 Circuit Connection for Step 1

v. Programming for Step 1:

*Refer to Appendix A (1)

3.5.2.2 STEP 2 – CONTROL THE SPEED OF PUMP WITH A POTENTIOMETER

The second step for this project a potentiometer is added in the connection in Step 1. In this step, the speed of the pump will be control by the potentiometer. The purpose of this step is to make sure that the speed of the pump is not only can control by changing the value of speed in the program code. Figures below showed the block diagram, flowchart, hardware installation and circuit connection for Step 2. The program code for Step 2 is attached in the Appendix part.

i. Block diagram for Step 2:

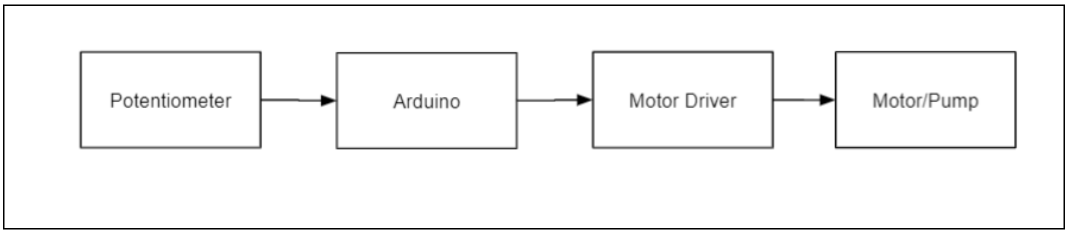

Figure 3.15 Block Diagram for Step 2

ii. Flowchart for Step 2:

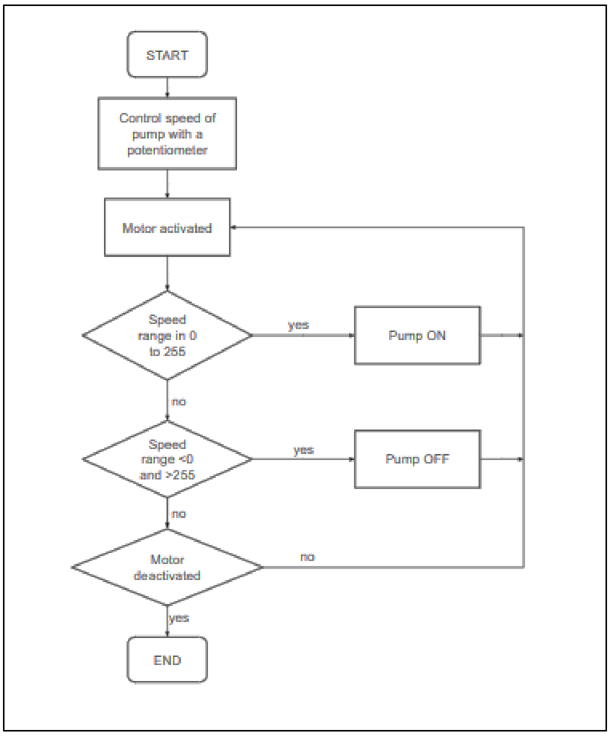

Figure 3.16 Flowchart for Step 2

iii. Hardware installation for Step 2:

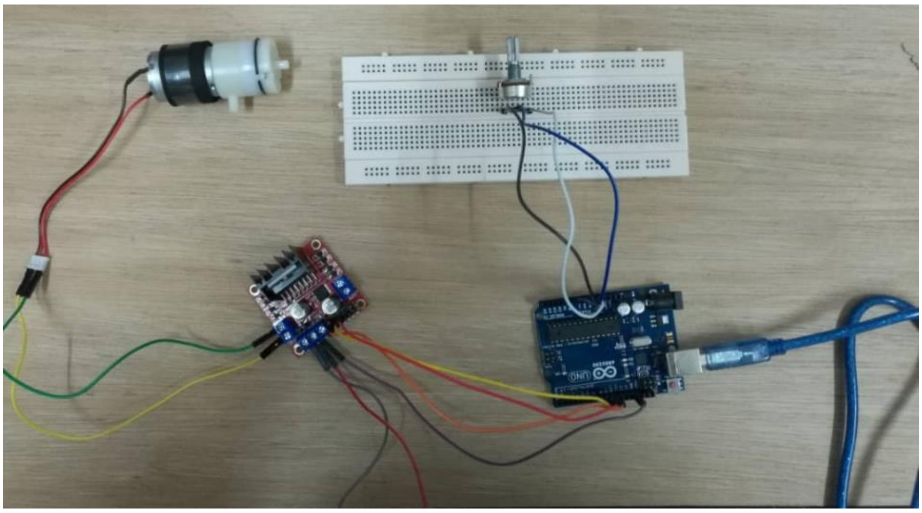

Figure 3.17 Hardware Installation for Step 2

iv. Circuit connection for Step 2:

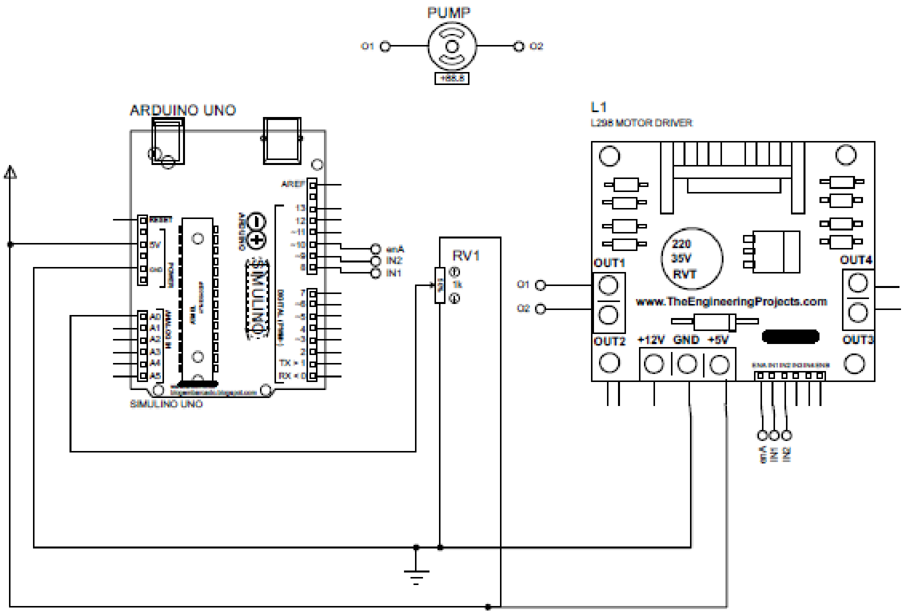

Figure 3.18 Circuit Connection for Step 2

v. Programming for Step 2:

*Refer to Appendix A (2)

3.5.2.3 STEP 3 – DETECT PRESSURE WITH MPX5100DP SENSOR AND DISPLAY IN SERIAL MONITOR

In the third step for this project, the microcontroller, Arduino Uno is used to receive the detected data from the pressure sensor. The pressure of the manual suction tool is measured by using the differential pressure sensor, MPX5100DP. The output result is received by the Arduino Uno and displayed in the Serial Monitor. The block diagram, flowchart, hardware installation and circuit connection this step are displayed below while its program code is attached in the Appendix part.

i. Block diagram for Step 3:

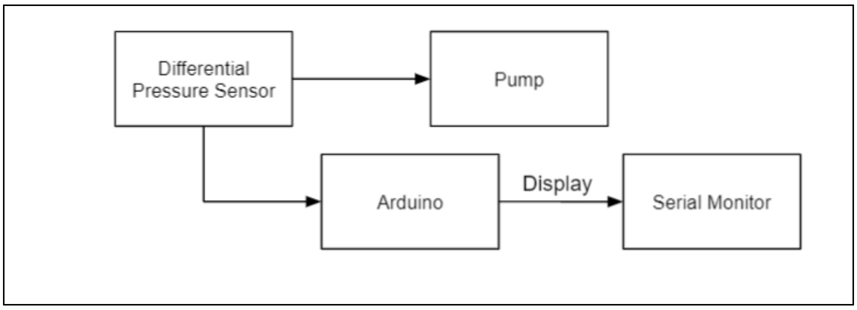

Figure 3.19 Block Diagram for Step 3

ii. Flowchart for Step 3:

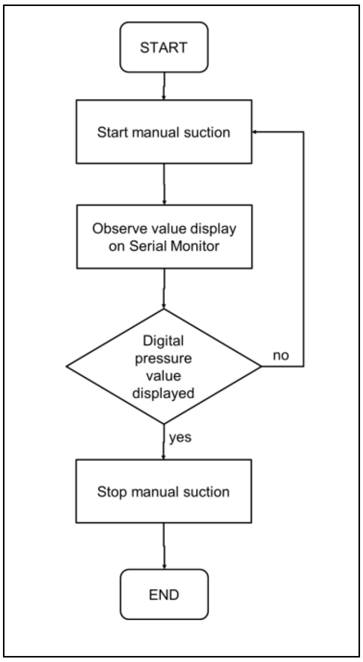

Figure 3.20 Flowchart for Step 3

iii. Hardware installation for Step 3:

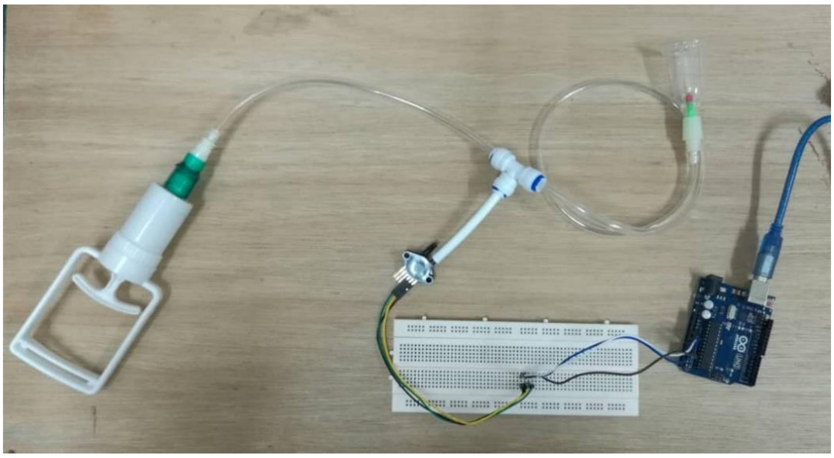

Figure 3.21 Hardware Installation for Step 3

iv. Circuit connection for Step 3:

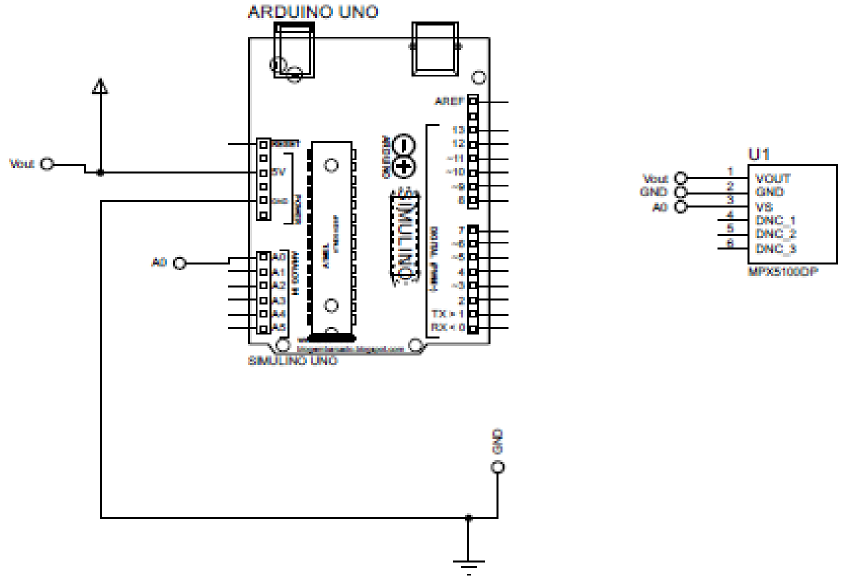

Figure 3.22 Circuit Connection for Step 3

v. Programming for Step 3:

*Refer to Appendix A (3)

3.5.2.4 STEP 4 - DETECT PRESSURE WITH MPX5100DP SENSOR AND DISPLAY IN GRAPHICAL LCD

The connection in Step 3 is added with a graphic LCD as shown in Step 4. In this step, the pressure of the manual suction tool is also measured by using the differential pressure sensor, MPX5100DP and the output result is displayed in the Serial Monitor and at the same time it also displayed on the graphic LCD. Same as previous step, the pressure detected is also applied by using the manual suction tool. The block diagram, flowchart, hardware installation and circuit connection this step are arranged below while its program code is attached in the Appendix part.

i. Block diagram for Step 4:

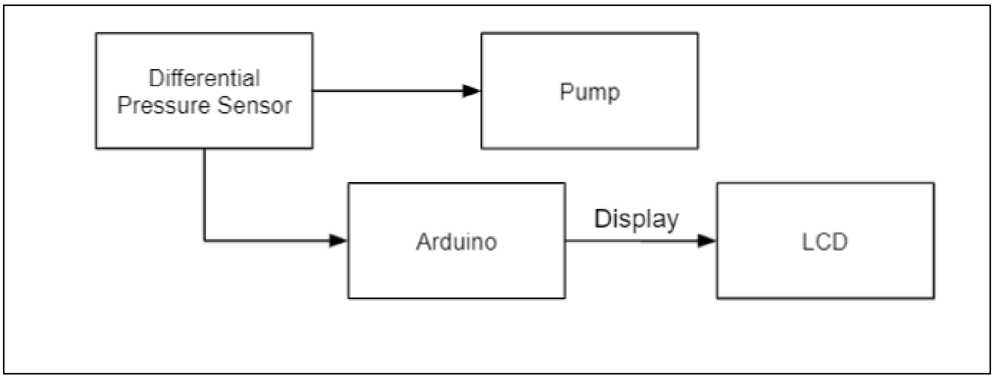

Figure 3.23 Block Diagram for Step 4

ii. Flowchart for Step 4:

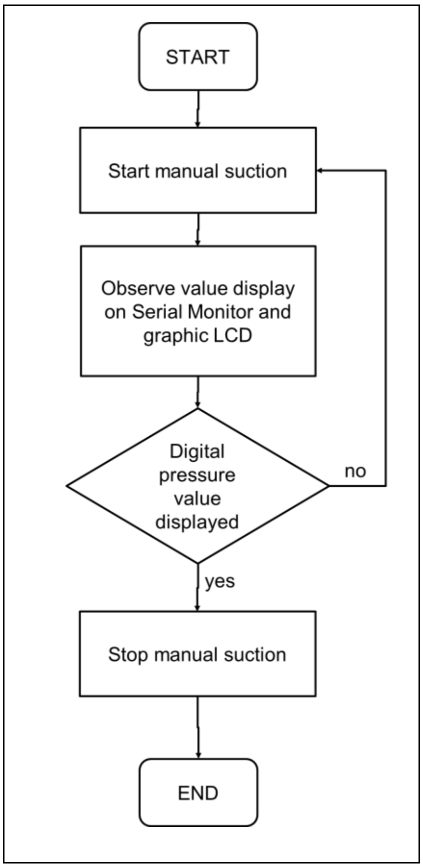

Figure 3.24 Flowchart for Step 4

iii. Hardware installation for Step 4:

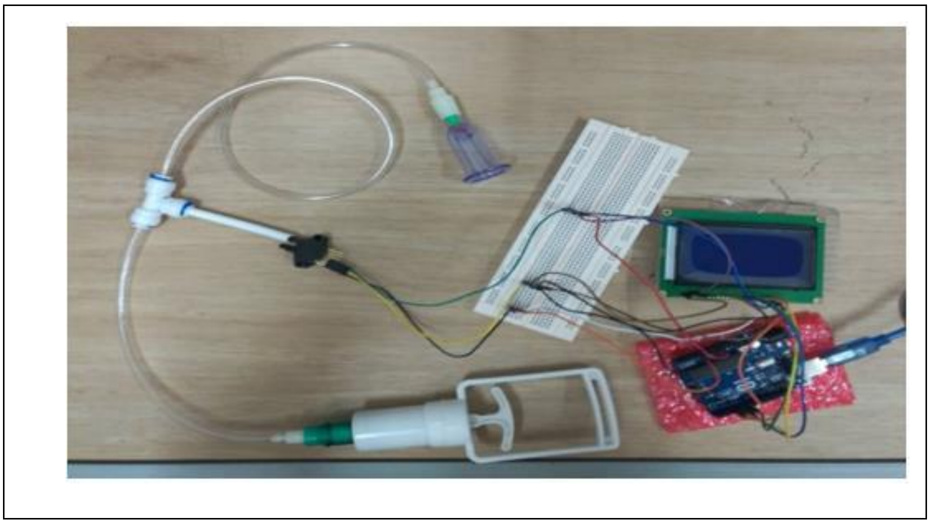

Figure 3.25 Hardware Installation for Step 4

iv. Circuit connection for Step 4:

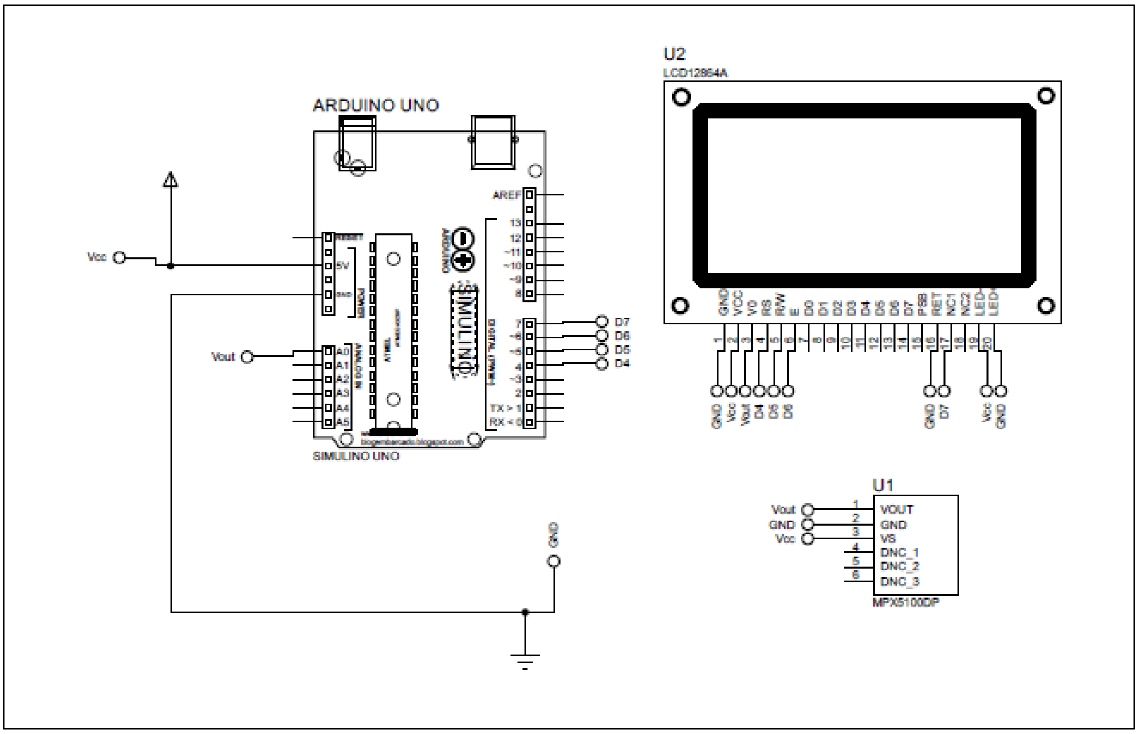

Figure 3.26 Circuit Connection for Step 4

v. Programming for Step 4:

*Refer to Appendix A (4)

3.5.2.5 STEP 5 – CALIBRATION WITH MANOMETER

This step is executed to verify the validity of the pressure value by using a manometer. The detail procedure will be present in subtitle 3.6. This step is necessary as the reference pressure is -40kPa which is not digital value that detect and display by the MPX5100DP pressure sensor. The block diagram, flowchart, hardware installation and circuit connection that can be used to explain this step are present in the below part. The program code of calibration is attached in the Appendix part.

i. Block diagram for Step 5:

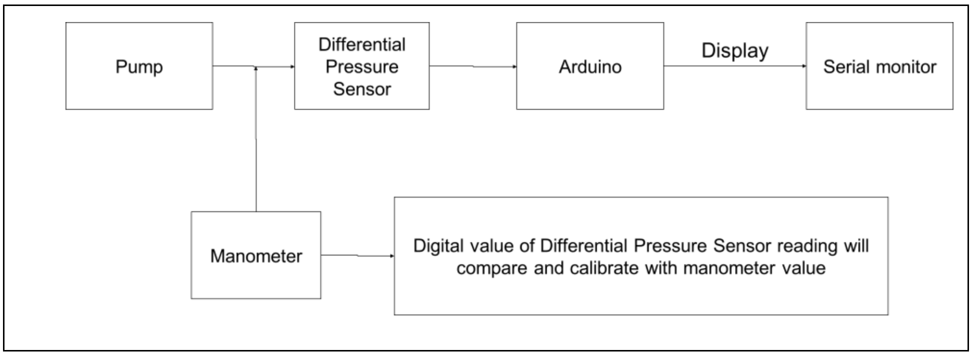

Figure 3.27 Block Diagram for Step 5

ii. Flowchart for Step 5:

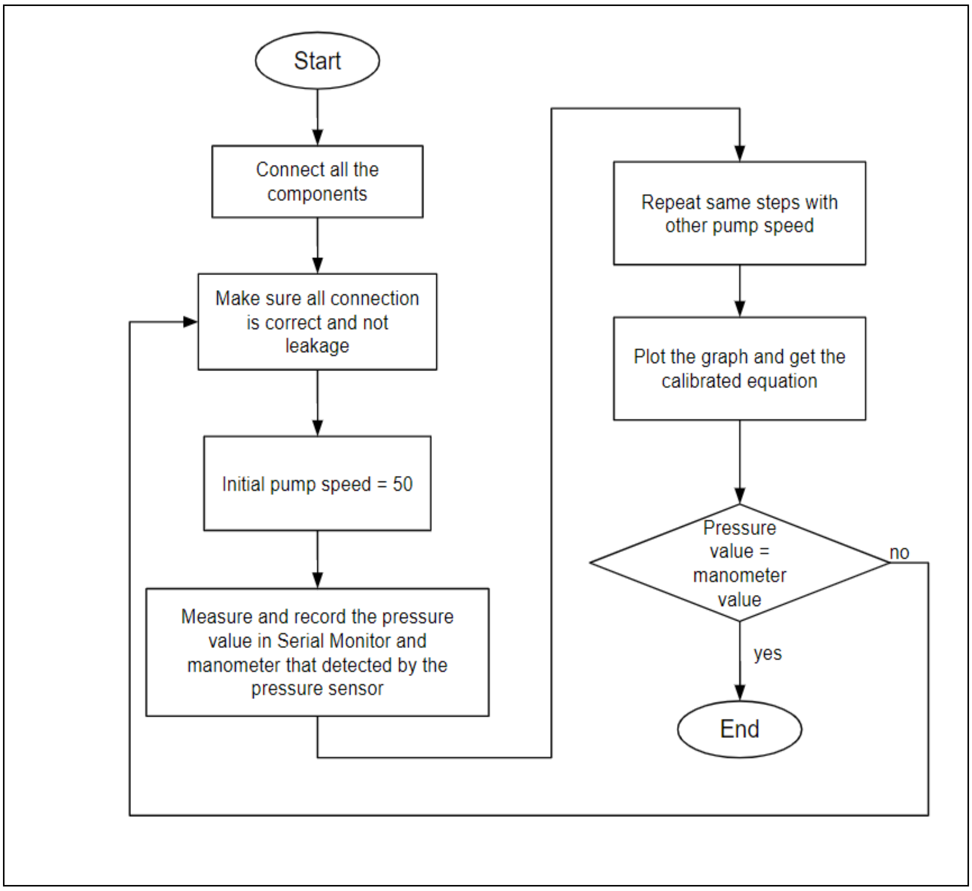

Figure 3.28 Flowchart for Step 5

iii. Hardware installation for Step 5:

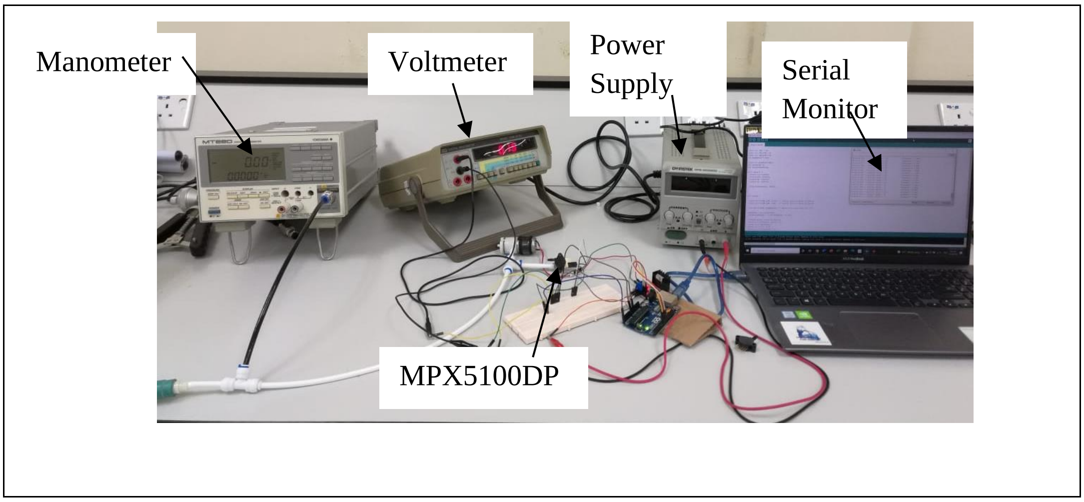

Figure 3.29 Hardware Installation for Step 5

iv. Circuit connection for Step 5:

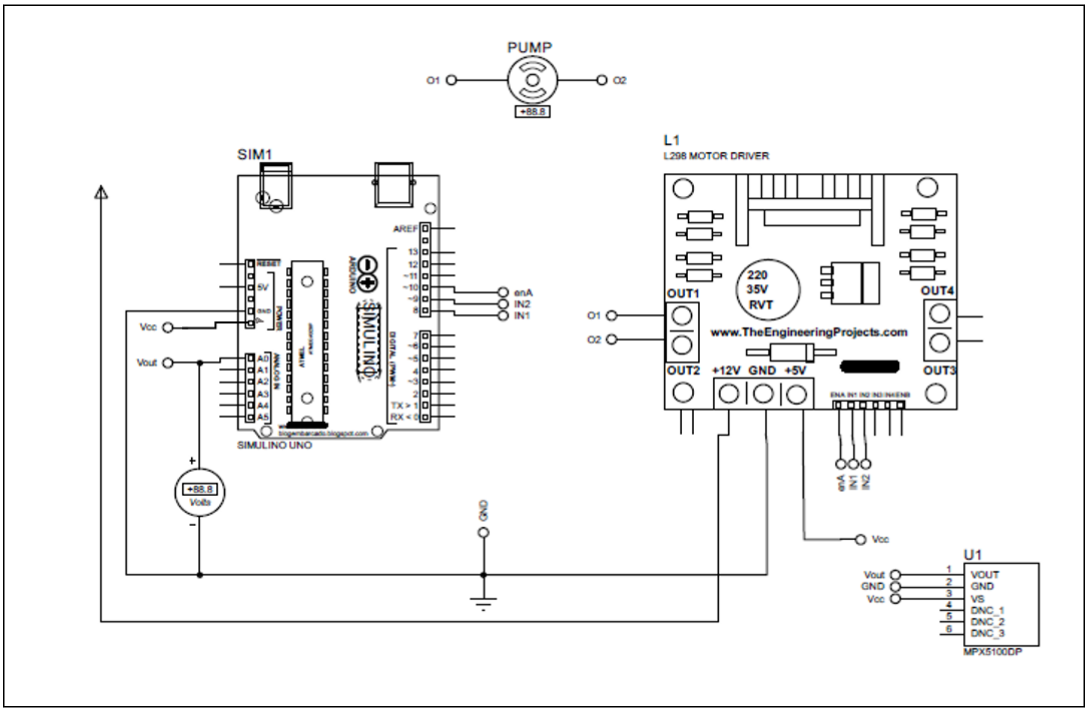

Figure 3.30 Circuit Connection for Step 5

v. Programming for Step 5:

*Refer to Appendix A (5)

3.5.2.6 STEP 6 – COMBINATION OF STEP 1 TO STEP 5

Next, the knowledge learns from Step 1 to Step 5 are shown in Step 6 which the system can be execute after calibration and the pressure value is successfully display on the graphic LCD. Same as previous steps, below give a clear understand explanation of Step 6 by using the block diagram, flowchart, hardware installation and its circuit connection. The program code is appended in the Appendix part.

i. Block diagram for Step 6:

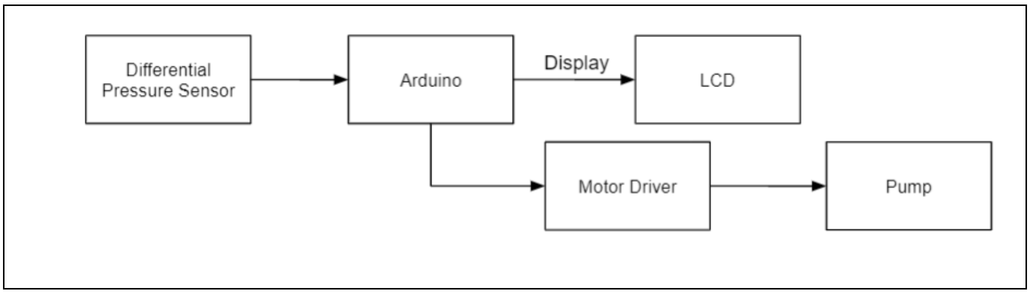

Figure 3.31 Block Diagram for Step 6

ii. Flowchart for Step 6:

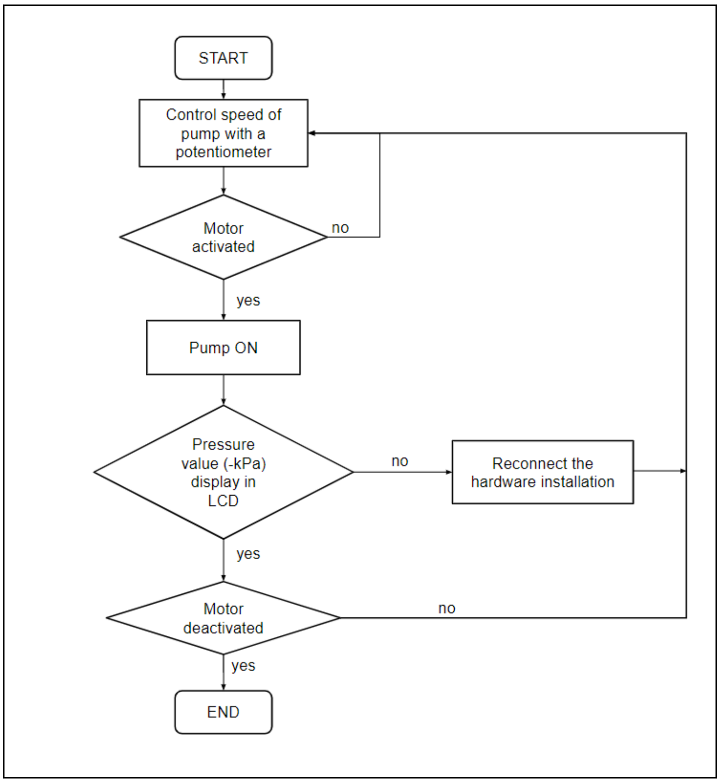

Figure 3.32 Flowchart for Step 6

iii. Hardware installation for Step 6:

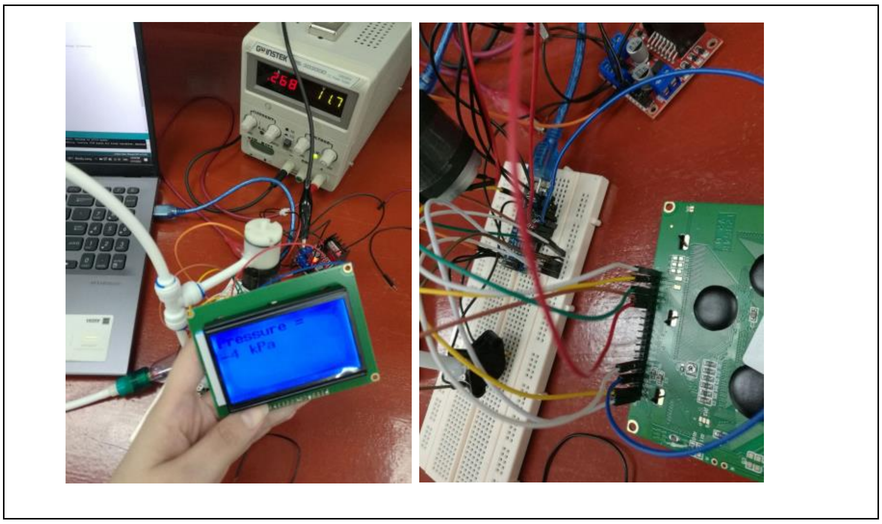

Figure 3.33 Hardware Installation for Step 6

iv. Circuit connection for Step 6:

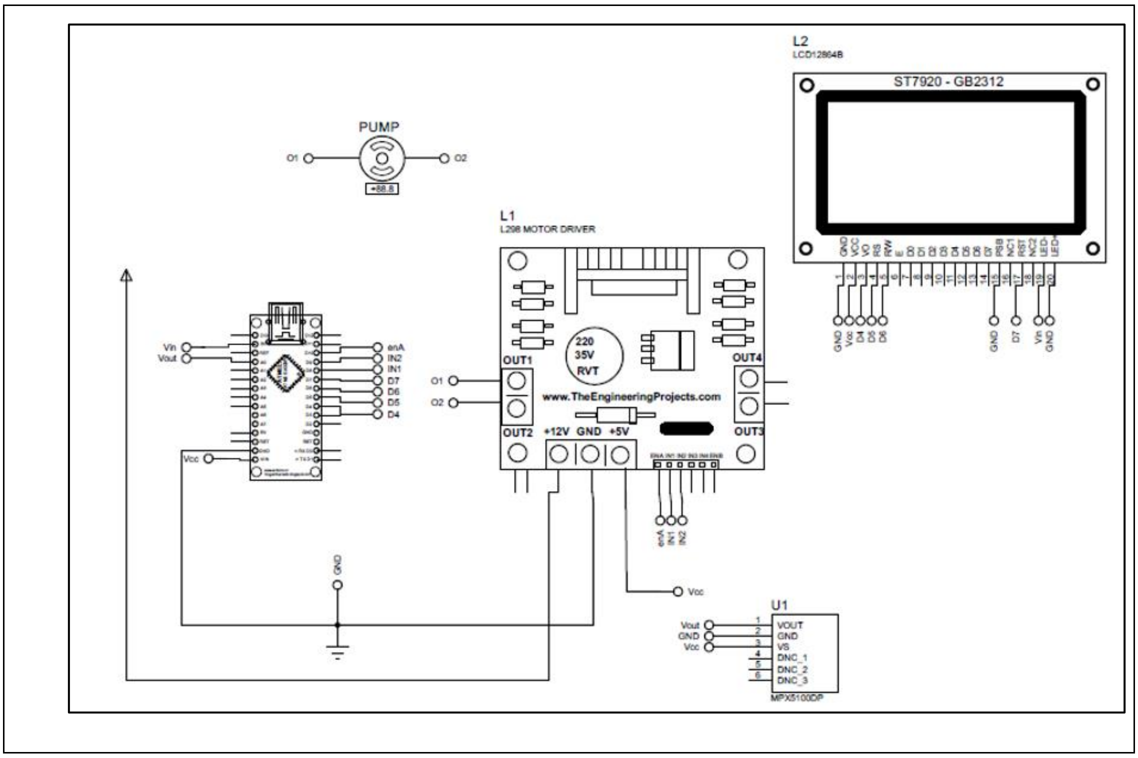

Figure 3.34 Circuit Connection for Step 6

v. Programming for Step 6:

*Refer to Appendix A (6)

3.5.2.7 STEP 7 – APPLY FUZZY LOGIC CONTROLLER SYSTEM

The seventh step is important as the Fuzzy Logic Controller (FLC) will allow the system to run automatically without adjusting the pressure value. The result of the FLC will be discussed in detail in Chapter 4. The briefing explanation for the FLC is shown in below part by dispose the block diagram, flowchart, hardware installation and circuit connection respectively. Same as the previous step, the program code for Step 7 is enclosed in the Appendix part.

i. Block diagram for Step 7:

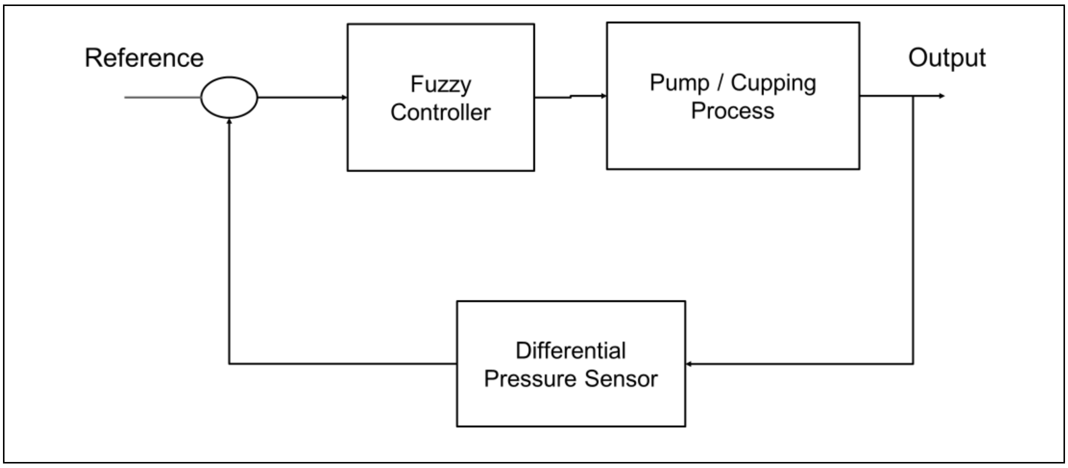

Figure 3.35 Block Diagram for Step 7

ii. Flowchart for Step 7:

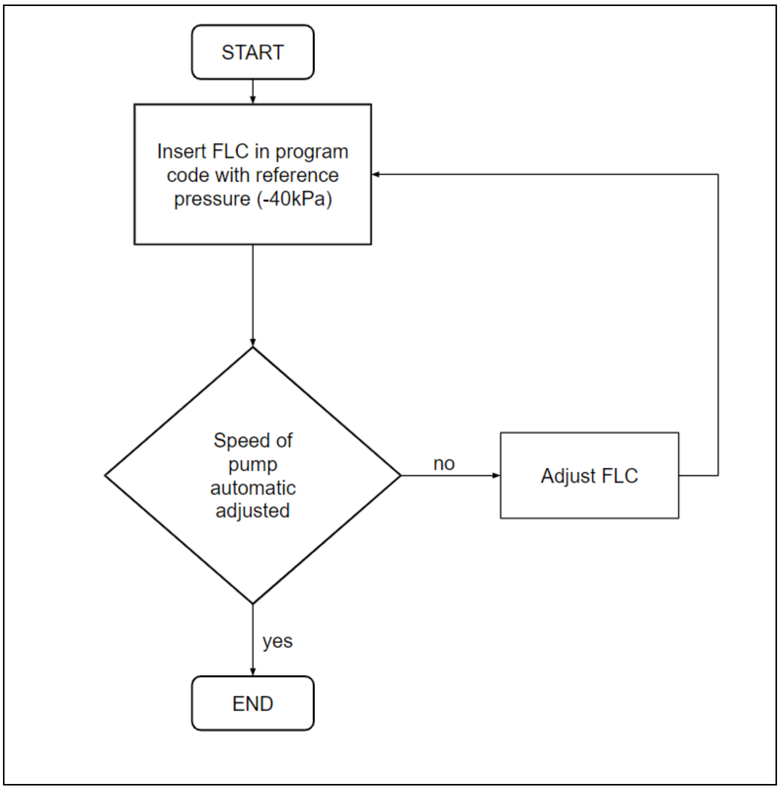

Figure 3.36 Flowchart of Step 7

iii. Hardware installation for Step 7:

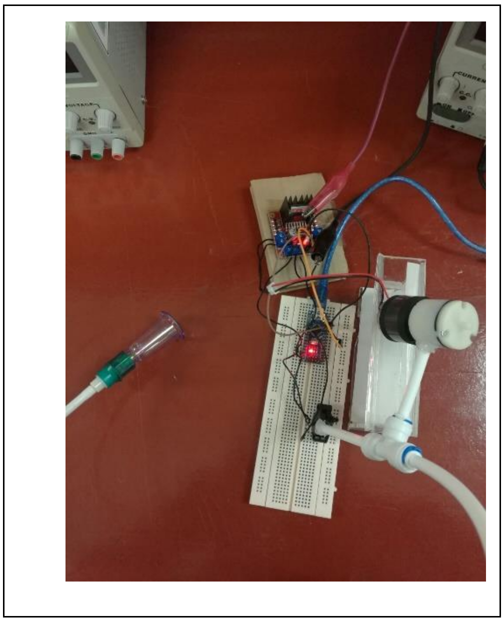

Figure 3.37 Hardware Installation for Step 7

iv. Circuit connection for Step 7:

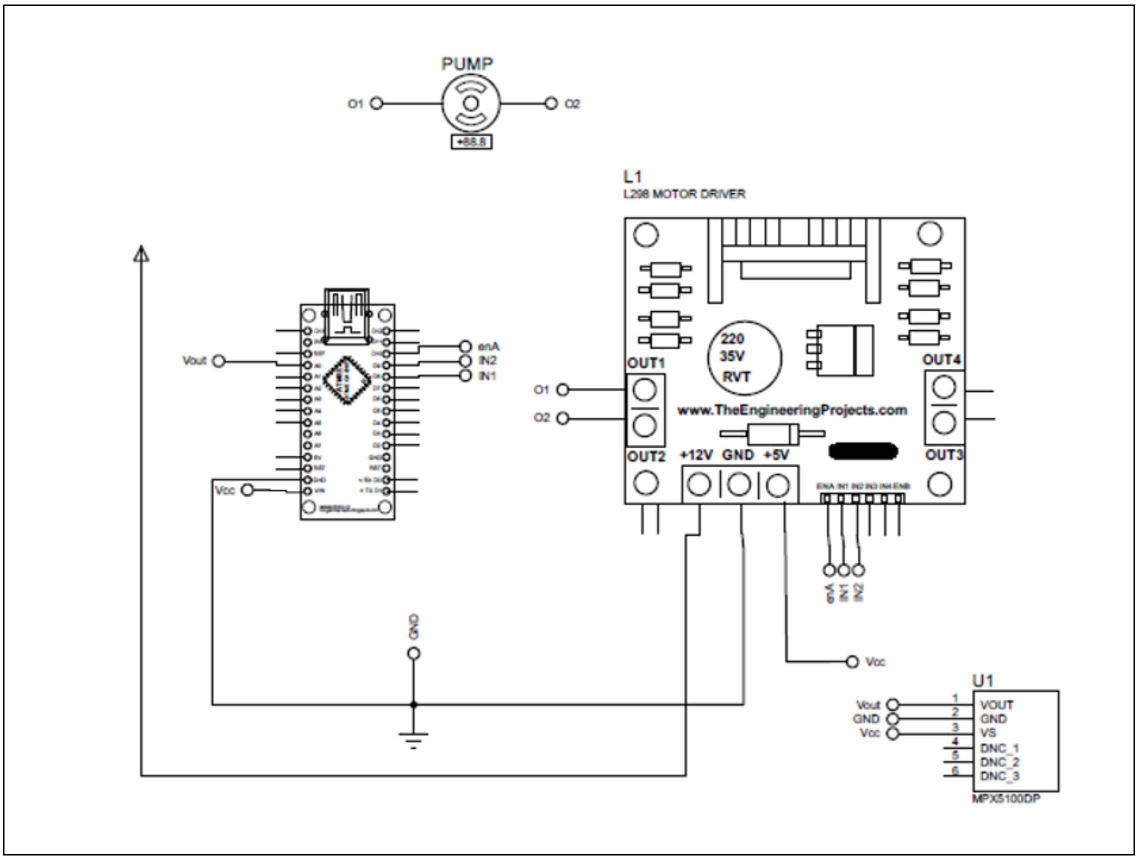

Figure 3.38 Circuit Connection for Step 7

v. Programming for Step 7:

*Refer to Appendix A (7)

3.5.2.8 STEP 8 – CONNECTION FOR A FULL SYSTEM

In the last step before developing the final product, a single automatic suction system is connected. This is to ensure no error mistake will be make in the final product. External component like buzzer and LED light is added in the system. Activated LED light indicate that the system is ready to use and the buzzer will activate when the remaining time is equal to 1 minute. The buttons that connected to the analog pin on the Arduino Nano are used to control the time setting for the system to be executed. There are 4 buttons used for a complete automatic cupping system. The first button is used to switch the condition of the arduino to state 1 or remain in state 0. In state 1, button 2 is used to increase the time required by 1 minute while button 3 is used to decrease the time required by 1 minute. When the time show 0 but button 3 is clicked, the time will equal to the maximum time for the minutes which is 60 minutes and vice verse. In state 0, button 2 is used to start the time countdown and cupping process while button 3 is used to pause the time and the cupping process. When button 4 is clicked, the whole system will be reset and switch to the initial condion in both state. The air pump will only activate when the pressure is higher or equal to -40 kPa after the time is set. The pressure will be control automatically by using the FLC. Below part is arranged by the block diagram, flowchart, hardware installation and circuit connection for Step 8. The program code for Step 8 is appended in the Appendix part.

i. Block diagram for Step 8:

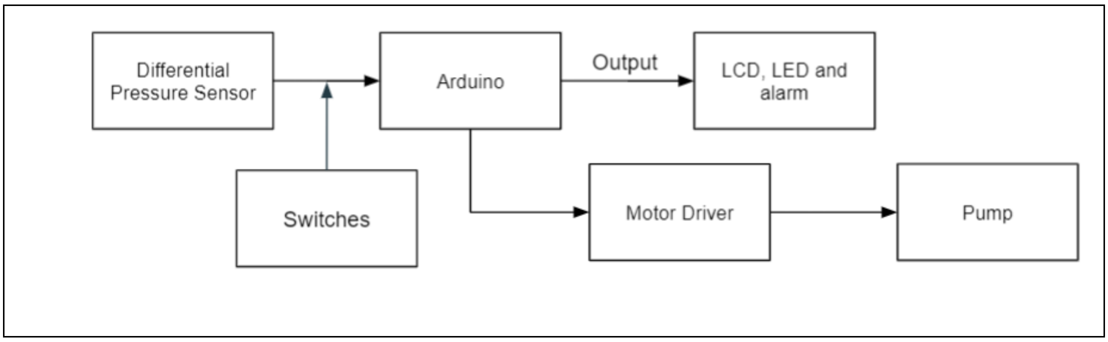

Figure 3.39 Block Diagram for Step 8

ii. Flowchart for Step 8:

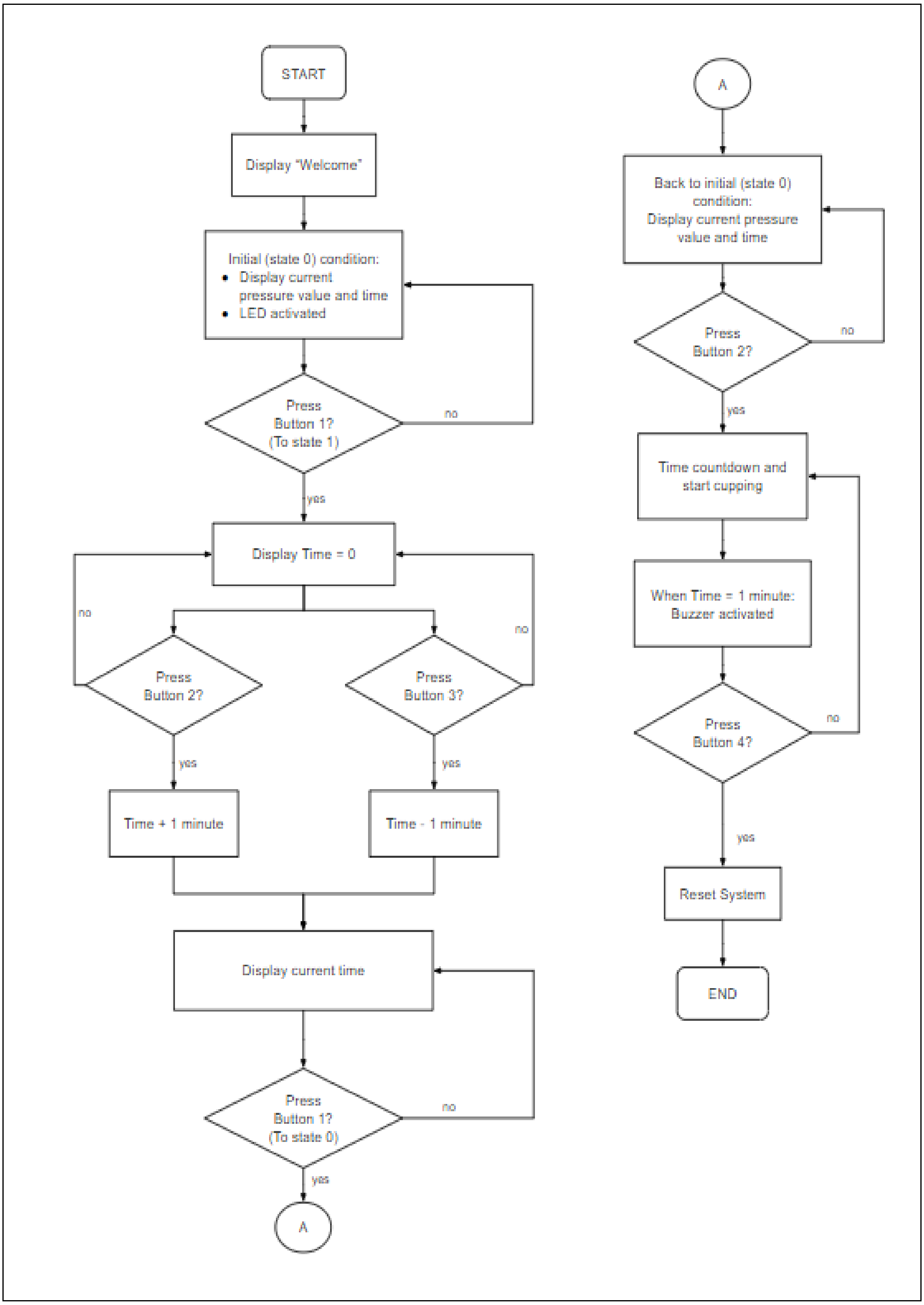

Figure 3.40 Flowchart for Step 8

iii. Hardware installation for Step 8:

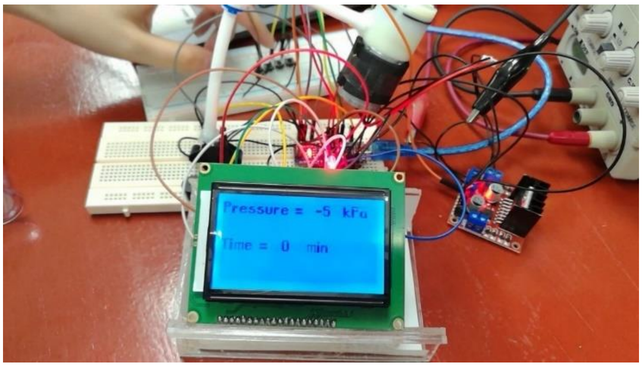

Figure 3.41 Hardware Installation for Step 8

iv. Circuit connection for Step 8:

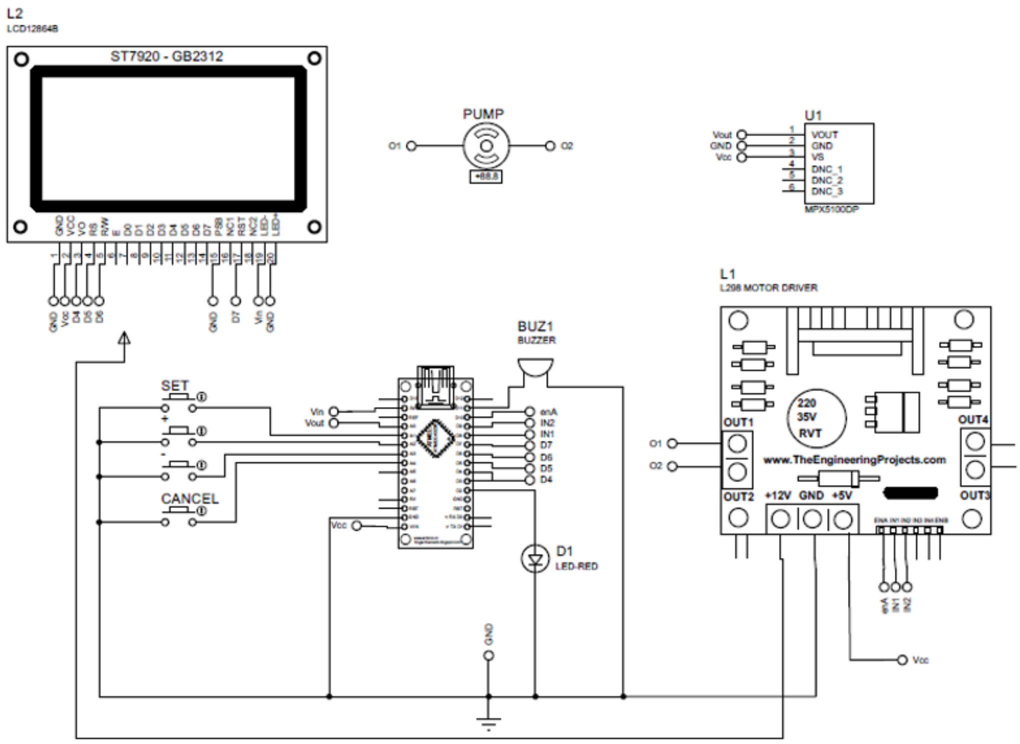

Figure 3.42 Circuit Connection for Step 8

v. Programming for Step 8:

*Refer to Appendix A (8)

3.6 CALIBRATION OF MPX5100DP WITH MANOMETER

Generally, calibration is the process or act of comparing, checking or validating the sample result of an instrument with a standard reference of known measurement. Negligible ambiguities are not allowed with regard to obtain the accuracy of calibration(Phillips et al., 2001). In this project, calibration is necessary to ensure that the reading from the MPX5100DP pressure sensor is accurate. Manometer is a pressure measuring device that is used in this section to compare the digital pressure value detected by the MPX5100DP pressure sensor. The procedure to set up the component for calibration is written in the subtitle 3.6.1 and the flowchart is generated in the subtitle 3.6.2.. In addition, the result of calibration will display in the subtitle 3.6.3.. In the end of this section, the pressure value detected by the MPX5100DP pressure sensor is exactly same as the value detected by the manometer.

3.6.1 CALIBRATION PROCEDURE

1. All the components are set up as shown in Fig.
2. An Arduino Uno is connected to a motor driver with an air pump.
3. The 12 V and ground pin of the motor driver is connected to a power supply.
4. A pressure sensor is connected to the Arduino Uno to read the digital pressure value and display in the Serial Monitor.
5. The pressure sensor is placed between the pump and the suction cup.
6. A multimeter is connected to the pressure sensor to measure the voltage during the process.
7. A manometer is also placed between the pump and the suction cup to measure the pressure value inside the tube based on standard of known accuracy.
8. The range of the speed of the pump is 0 to 255 and it is set to 50 at the beginning of the calibration process.

9. The reading on the manometer and sensor is observed and recorded in table.
10. The calibration process is stopped when the speed of the pump reached to 255.
11. A graph is plotted.

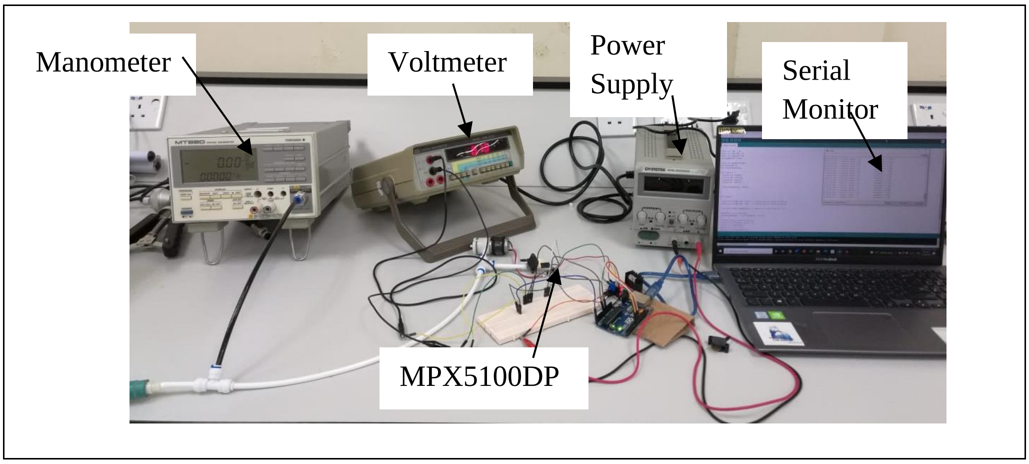

Figure 3.43 Hardware Installation for Calibration

3.6.2 CALIBRATION FLOWCHART

Flowchart below show the steps that required to complete the calibration by using the manometer provided in the laboratory.

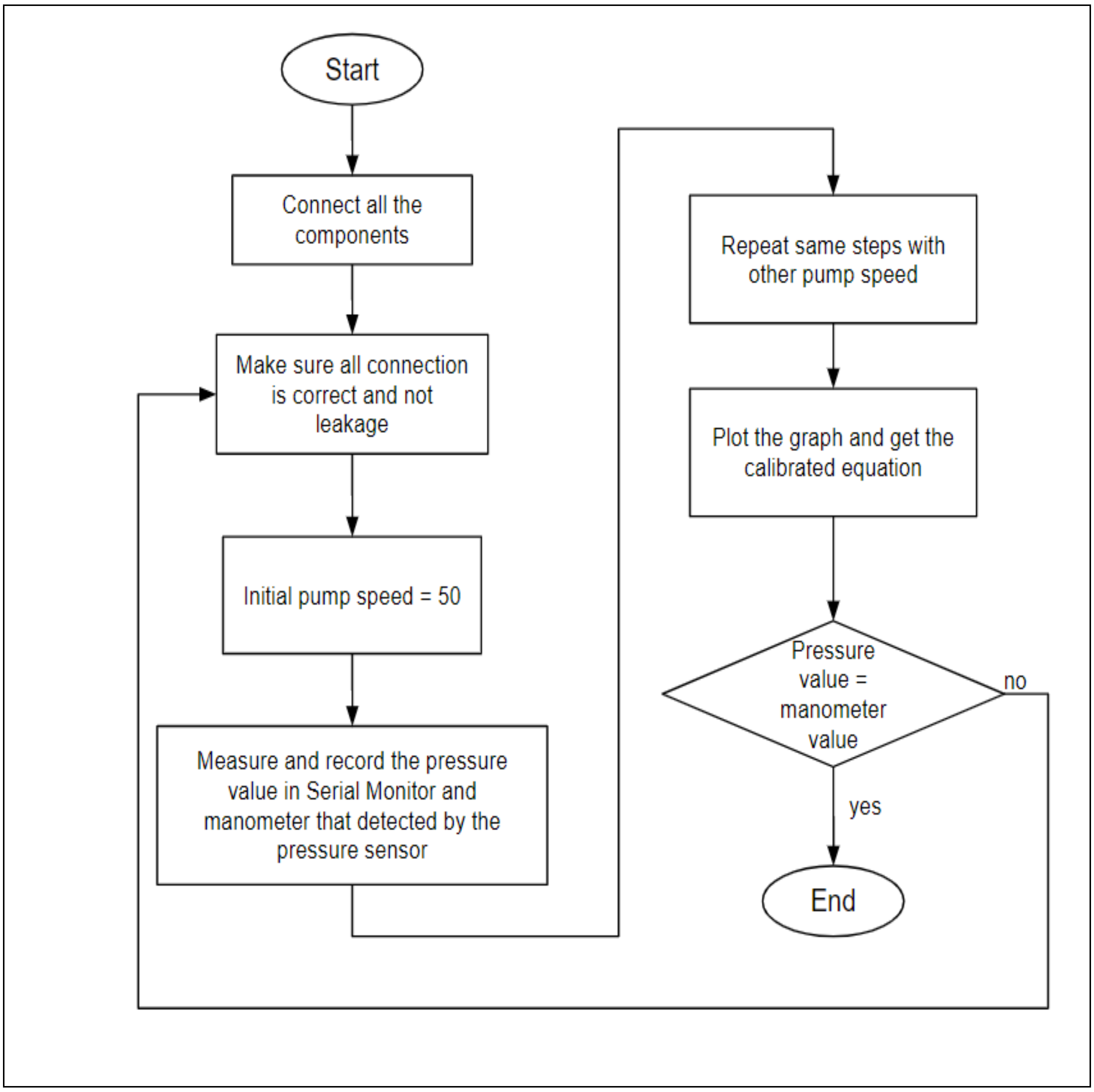

Figure 3.44 Flowchart for Calibration

3.6.3 CALIBRATION RESULT

Table below record the value detected during the calibration process.

Table 3.1 Calibration Result

Speed of motor	Voltage (V)	Digital Value on Serial Monitor	Manometer (-kPa)
50	0.31	74	-4.34
60	0.46	104	-7.45
70	0.56	140	-11.25
80	0.70	174	-15.22
90	0.84	225	-20.51
100	1.00	310	-29.61
120	1.31	486	-50.03
140	1.62	563	-56.66
160	1.91	585	-58.81
180	2.21	595	-59.83
200	2.34	600	-60.75
220	2.51	610	-61.31
240	2.69	613	-61.91
255	2.80	615	-62.18

A curve is generated to determine an equation that makes the value of the manometer and the sensor the same. The graph for calibration result is displayed in Figure 3.45 in the next page.

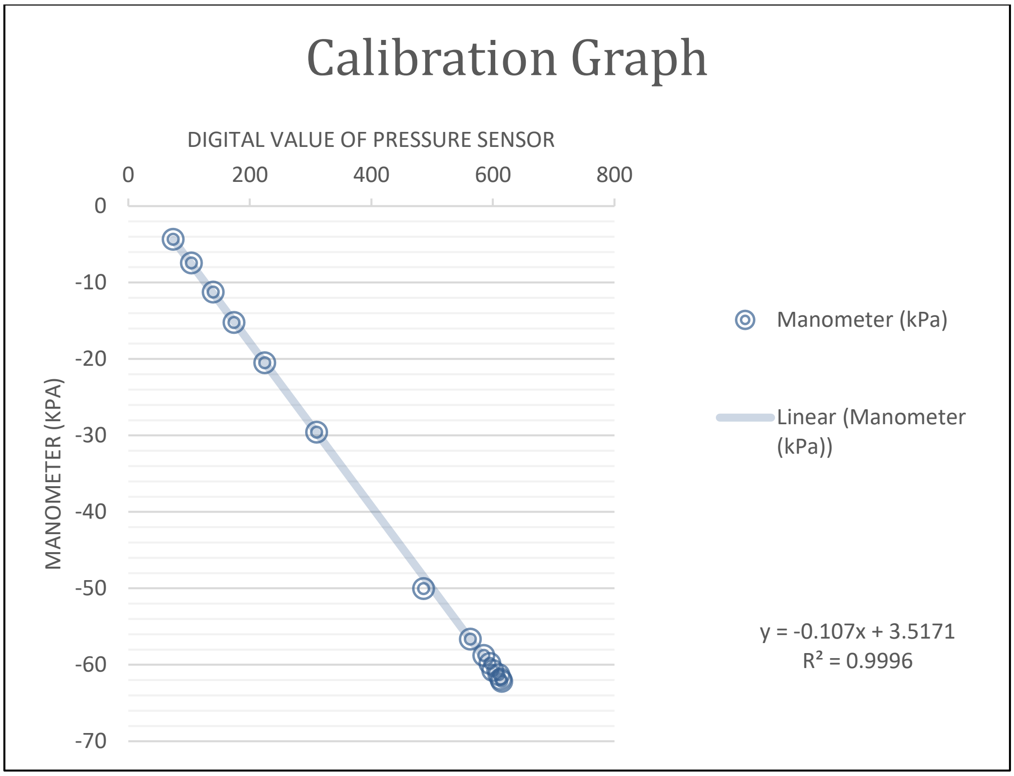

Figure 3.45 Graph of Calibration

The graph is generated based on the digital value on Serial Monitor and the value of manometer. Thus, this graph is indicated the relationship or connection between the digital value and the manometer value. The graph has a negative slope as the straight line on the graph move from left to right. The equation that determined based on the graph shows that the appropriate pressure value in the suction cup will be negative.

The following equation determined by the graph is:

$$y = -0.107x + 3.5171 \tag{2}$$

The unknown x in the equation represented the digital pressure value from the sensor. Then this equation is inserted into the Arduino programming code. Thus, the pressure reading on the Serial Monitor and manometer were the same.

3.7 SYSTEM ARCHITECTURE

The overall system architecture of the development of automatic cupping suction system is presented below. The Arduino Nano is used as a microcontroller to receive data and upload data to the output of this system which is the graphical LCD, LED light and buzzer. The finalize design is a 3 separated system of automated cupping suction system which indicate that if one system is spoil it will not affect to the other system.

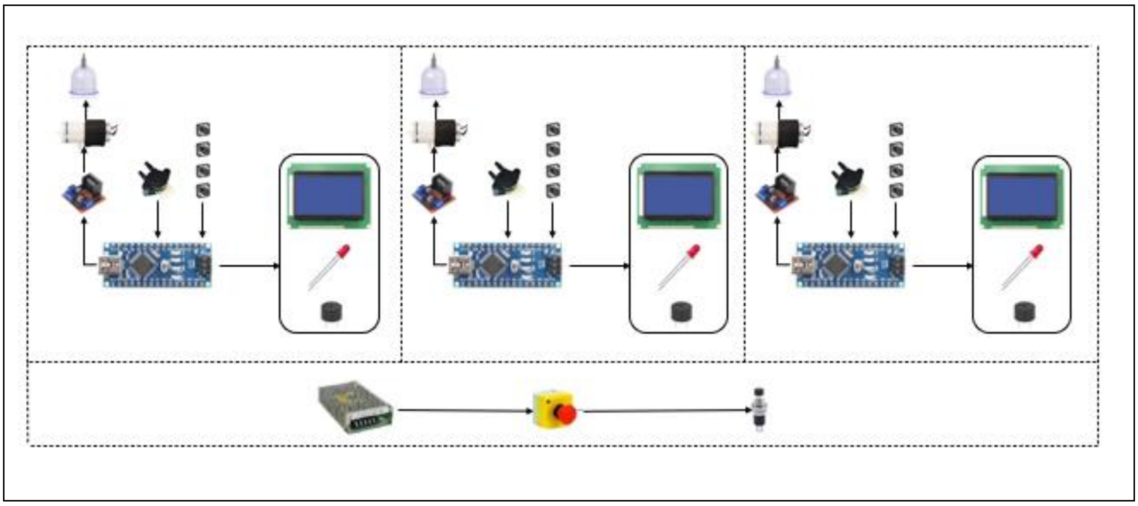

Figure 3.46 System Architecture

The system architecture consists of the vacuum air pump stop automatically when the pressure level is lower than -40kPa in the clear skin area according to the pressure sensor. In addition, the pump will automatically turn on when the pressure is higher than -40kPa. Based on this system, the patient can enjoy the cupping process without manually adjusting the pressure value.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

In chapter 4, the result for the cupping process that applied on the clear skin area and hairy skin area is obtained. All of the experiment are undergoing after the fuzzy control is successfully applied in the system. The duration of each experiment is 15 seconds with a reference negative pressure of -40kPa. All of the result are experimented and tested after the calibration is verified as the testing involved the detected value by the differentiate pressure sensor. On the other hand, the development of software system will be discussed in this chapter as well as the complete design of the hardware mechanism.

The detail of the analysis and discussion for each part of the result will be elaborated in this chapter. All elucidation based on the data collection and transforming to the graphs in order to evaluate the efficiency, stability and effectiveness of the developed system.

4.2 HARDWARE CONNECTION

For the purpose of developing a complete single automated suction system, the Fuzzy Logic Controller (FLC) is inserted in the program code of this system. Subtitle below show the compared data of the pressure when the system is not using FLC and when FLC is applied.

4.2.1 HARDWARE CONNECTION FOR FLC

FLC is designed for the development of controllers without a system model. A suitable FLC can overcome the environmental changes when the control system is operated (Palanisamy, 2016). The connection show in figure below consists of a suction cup, a power supply, a MPX5100DP pressure sensor, a vacuum air pump, a motor driver and a microcontroller, Arduino Nano. The MPX5100DP pressure sensor is located in between the vacuum air pump and the suction cup through a long white tube and a T-junction. It is used to detect the pressure in the suction cup and the value will be displayed in the Serial monitor. This part focuses on the results of stabilizing the speed of the vacuum air pump in order to bring the negative pressure in the suction cup close to the reference pressure of -40kPa.

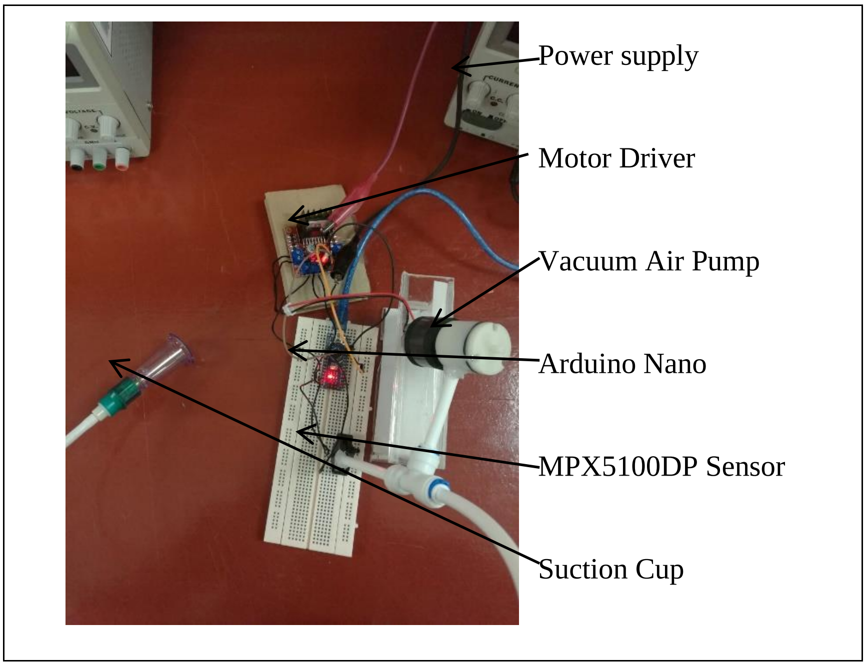

Figure 4.1 Hardware Installation for FLC Testing

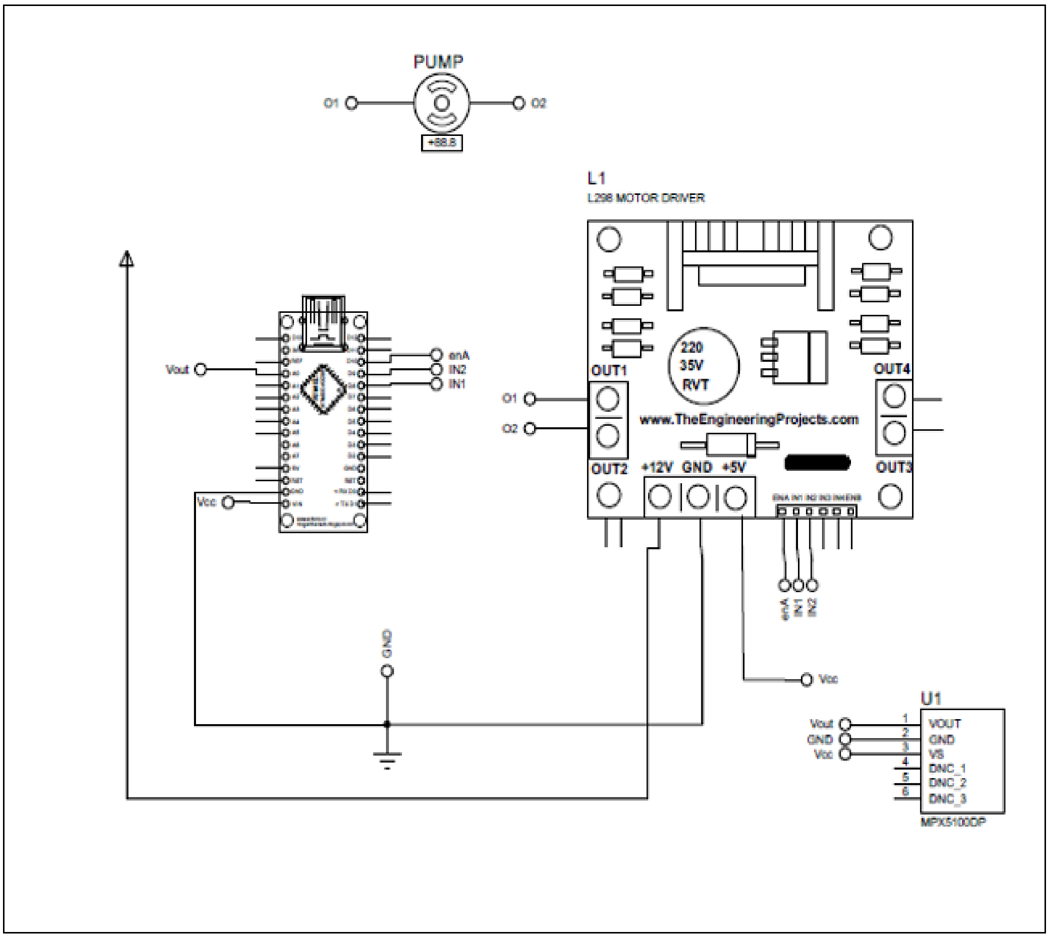

Figure 4.2 Circuit Connection for FLC Testing

4.2.1.1 CONNECTION WITH BASIC CONDITION

The experiment is compared with the program code with basic condition and the program code with FLC by using the same connection as shown above. Basic condition is the program code with a single comparison with the reference pressure by using the if else statement and a fixed speed in the beginning of the program code. The left side of the table recorded in the next page show the pressure in the suction cup when the speed of the vacuum air pump is 115.001 in 15 seconds while right side of the table below show the pressure in the suction cup when the speed of the vacuum air pump is 200 in 15 seconds. The graph for both speeds are displayed in the following page.

Table 4.1 Pressure value with basic condition

Speed / Time (s)	115.001	200
	Pressure (kPa)	Pressure (kPa)
0.25	-3	-6
0.5	-7	-7
0.75	-25	-13
1	-37	-34
1.25	-44	-41
1.5	-45	-52
1.75	-44	-52
2	-43	-51
2.25	-41	-51
2.5	-40	-51
2.75	-39	-51
3	-38	-50
3.25	-42	-48
3.5	-46	-47
3.75	-45	-46
4	-43	-45
4.25	-42	-44
4.5	-41	-43
4.75	-40	-42
5	-39	-41
5.25	-38	-40
5.5	-42	-40
5.75	-46	-39
6	-46	-38
6.25	-44	-46
6.5	-43	-54
6.75	-42	-55
7	-41	-53
7.25	-39	-52
7.5	-38	-51
7.75	-43	-49
8	-47	-49
8.25	-46	-48
8.5	-44	-47
8.75	-43	-46
9	-42	-45
9.25	-41	-44
9.5	-40	-43
9.75	-38	-42
10	-37	-41

10.25	-42	-40
10.5	-47	-39
10.75	-46	-38
11	-45	-47
11.25	-43	-55
11.5	-42	-55
11.75	-41	-54
12	-40	-53
12.25	-39	-51
12.5	-38	-50
12.75	-41	-50
13	-45	-49
13.25	-44	-48
13.5	-42	-47
13.75	-41	-46
14	-40	-45
14.25	-39	-44
14.5	-37	-43
14.75	-42	-42
15	-47	-41

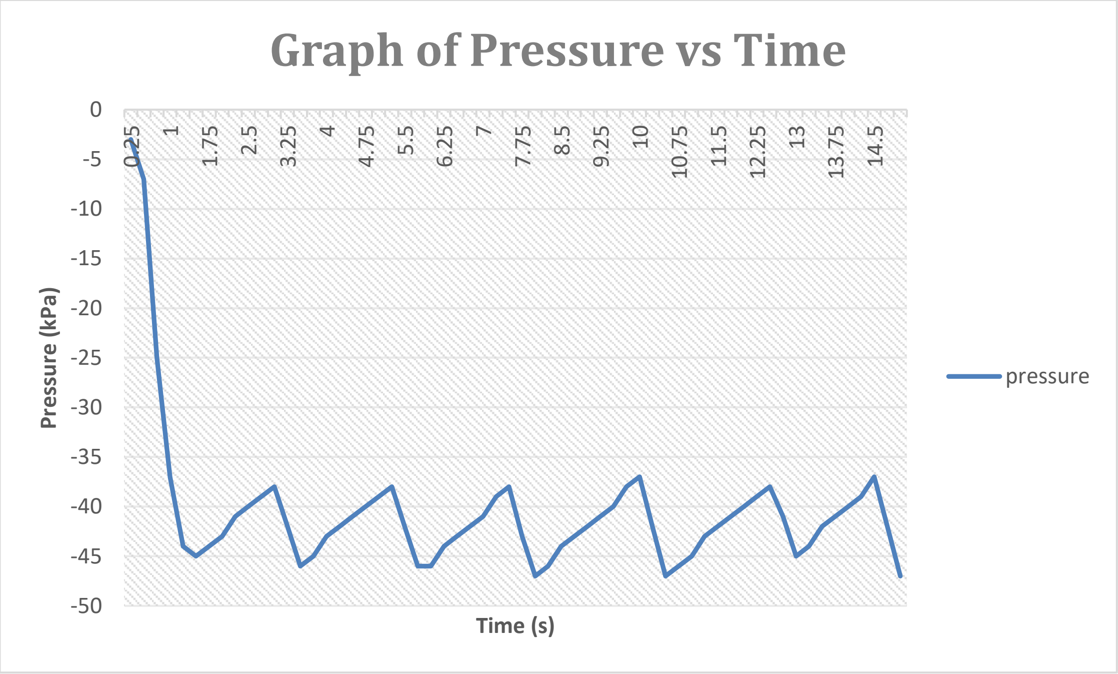

Figure 4.3 Graph of Pressure vs Time velocity = 115.001

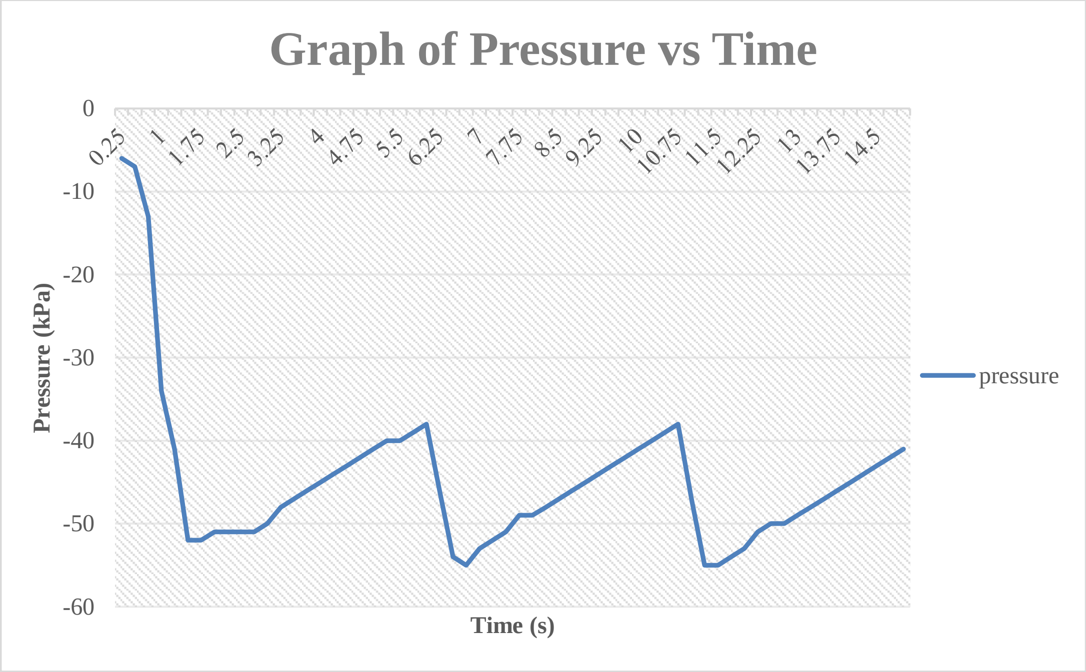

Figure 4.4 Graph of Pressure vs Time with velocity = 200

a. Programming for experiment on clear skin area with velocity = 115.001
   *Refer to Appendix A (9)

b. Programming for experiment on clear skin area with velocity = 200
   *Refer to Appendix A (10)

4.2.1.2 CONNECTION WITH FLC

1. Reference point: -40 kPa

Program code that insert with the FLC is the code that consists of a few of if else statement without setting a fixed speed in the beginning of the program code. Then, the FLC is added in the program code with the reference pressure of -40kPa. This reference pressure is suitable in applying the cupping therapy on the clear skin surface. The graph showed in Figure 4.6 is the pressure value of the suction cup in 15 seconds on the clear skin area. The program code used is same as the program code state in the subtitile 3.5.2.7.

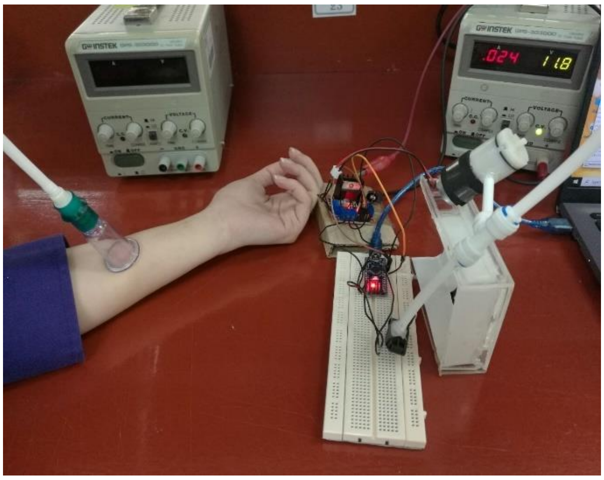

Figure 4.5 Experiment in Clear Skin Area

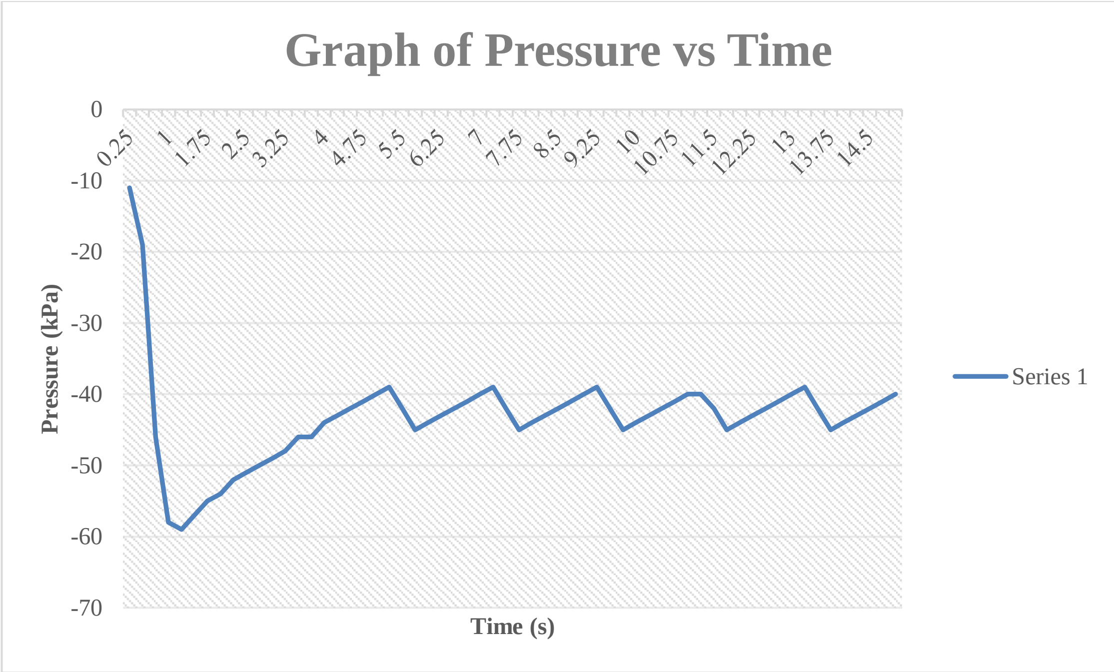

Figure 4.6 Graph of Pressure vs Time with FLC on Clear Skin Area

c. Programming for experiment on clear skin area
*Refer to Appendix A (7)

2. Reference point: -50 kPa

Then, the FLC is added in the program code with the reference pressure of -50kPa. This reference pressure is suitable in applying the cupping therapy on the hairy skin surface like head. The graph showed in Figure 4.8 is the pressure value of the suction cup in 15 seconds on the hairy skin area.

Figure 4.7 Experiment in Hairy Skin Area

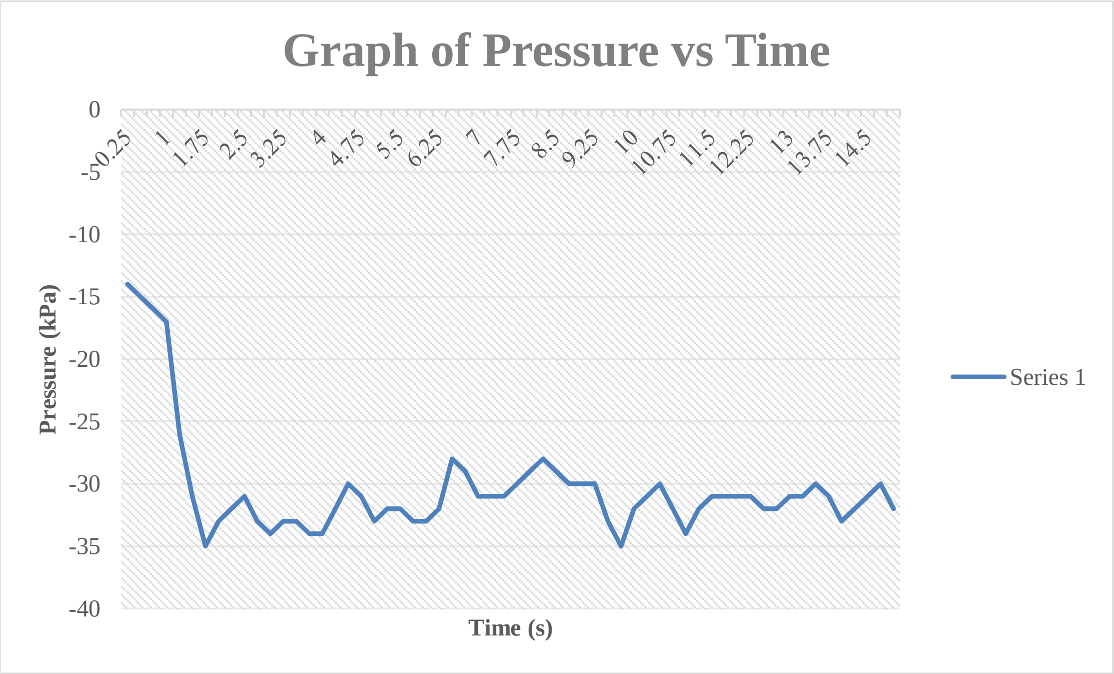

Figure 4.8 Graph of Pressure vs Time with FLC on Hairy Skin Area

d. Programming for experiment on hairy skin area
*Refer to Appendix A (9)

4.3 DISCUSSION

According to the graph obtained in Figure 4.6, the preesure value can move smother to reach the reference point compare to the graph in Figure 4.3 and Figure 4.4 after utilization of the fuzzy logic controller. Based on Figure 4.8, the value is not maintaining to its reference point, -50kPa. This occurrence may due to the obstruction of the hair but it is still successfully applying the cupping therapy automatically without adjusting the value of pressure. It is clearly state that the pressure value inside the suction cup will be very unstable and large oscillation will occurred if the program code only consist of basic condition which compare the detected pressure value with the reference pressure.

Nevertheless, the pressure value may not be able to have a smoother straight line detection in despite of the FLC has been inserted to the program code. This occurrence is due to the lack of number of comparison between various pressure value with the speed of pump by using the if else statement and the limitation on the FLC. A large amount of testing is required for the automated system to obtain a better straight line detection and high data acquistion accurancy.

Below listed out some of the detail issues that may affect the straight line detection of the automated system.

- Sensitivity of the MPX5100DP pressure sensor
- Tolerance of the breadboard
- Inadequate layout
- Landing pattern errors on the PCB board
- Wrong connection of the switch mode power supply
- No PID algorithm in the program code

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

Conclusion is the final section of this thesis. It is mainly focus on the solution or answer of the problem statement of this project, summarizing and reflect on the research of this project and provide annotation and recommendation upon the implication of the previous chapter. All testing and analytical guidance at each stage is key to ensuring and determining the successful development of robot functionality and operation. Some of the point will also be elaborate in this section. In the subtitle of recommendation, some suggestion will be introduced to minimize the issue that the next researcher will encounter when continuing to develop the project in the future.

5.2 CONCLUSION

In the conclusion section, all the objectives that stated in the beginning of this thesis has been achieved. An automatic suction mechanism is successfully developed in the end of this project. The automatic suction mechanism is managed to work automatically in the simulation of software application and hardware parts and the requirements of this project is met. In this state, the electrical and the mechanical hardware part of this project is successfully combined to constuct a automatic suction machine to a satisfactory stage.

Three separated system of the automatic cupping suction control system is also completed in which two system are suitable for clear skin area while the remaining system suitable for the hairy skin area especially on the head. A few test is execute to confirm the developed system is meeting the requirement. The experiment obtained in Chapter 4 proof that the system is successfully applied on the clear skin area as well as on the hairy skin area by using dry cupping methods.

This project is a closed loop system that consist of Arduino Nano, MPX100DP pressure sensor and graphic LCD. The sensor is selected to measure the pressure value in the suction cup as it can detect up to 100kPa. Thus, it is suitable to use as the reference pressure is between -30kPa to -40kPa on clear skin area. In addition to the features of the automatic system, the buzzer will be activated in the last minute to ensure that the user is aware that the cupping time is only a minute left.

5.3 RECOMMENDATION AND IMPROVEMENT

There are some issue found in this project. The development of the straight line detecction for the automatic suction system is recommended to use another controller which is the Proportional, Integral and Derivative (PID) controller instead of the FLC. This is because PID controller can be used to act as an intelligent controller that will provide suitable algorithm to maintain the pressure value always above a certain line. Therefore, the constant of K_P, K_I and K_D must be tuned correctly until system reaches the corresponding values to reduce the number of oscillation during the straight line detection to the desired set point (pressure).

Another issue that being found in this project is the experiment is only tested by using the dry cupping method on the clear skin area and hairy skin area. However, there are 3 more methods that can be used to apply the cupping therapy. The investigation of the automatic cupping suction system on the clear skin area and hairy skin area for 3 other methods are recommended for next researchers in the future. It is recommended to determine the ideal pressure for the other 3 cupping methods recommended by most cupping practitioners to prevent blisters or blisters.

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APPENDIX

Program Source Code

Appendix A (1): Program Code for Step 1

```
const int enA = 10;
const int IN1_PIN = 8;
const int IN2_PIN = 9;
int speedV = 50;

void setup() {
  Serial.begin(9600);
  pinMode(10, OUTPUT);
  pinMode(8, OUTPUT);
  pinMode(9, OUTPUT);

}

void loop() {

    digitalWrite(IN1_PIN, HIGH); // control motor A spins clockwise
    digitalWrite(IN2_PIN, LOW);  // control motor A spins clockwise


    analogWrite(enA, speedV); // speed is a value from 0 to 255

  //Result print in Serial Monitor
  Serial.print("Pump speed = ");
  Serial.println(speedV);
  delay(1000);

}
```

Appendix A (2): Program Code for Step 2

```
const int enA = 10;
const int in1 = 8;
const int in2 = 9;
int speedValue = A0;

void setup() {
  Serial.begin(9600);

  pinMode(10, OUTPUT);  //PWM Di/Do
  pinMode(8, OUTPUT);
  pinMode(9, OUTPUT);
}
```

```
void TurnPot(){
  digitalWrite(in1, LOW);//Switch between this HIGH and LOW to change direction
  digitalWrite(in2, HIGH);

  speedValue = analogRead(A0);
  speedValue = speedValue*0.2492668622;//1023*255
  analogWrite(enA,speedValue);
}

void loop() {

  TurnPot();
  //Print output
  Serial.print(" Speed = ");
  Serial.println(speedValue);
  delay(100);
}
```

Appendix A (3): Program Code for Step 3

```
const int preSensor(A0);
int preValue = 0;//read from pressure sensor

void setup() {
  Serial.begin(9600);

}

void loop() {

  preValue = analogRead(preSensor);

  Serial.print("  Auto Suction System  ");
  Serial.print("\t");
  Serial.print(" Pressure = ");
  Serial.print(analogRead(preValue));
  Serial.println("kPa");
  delay(50);

}
```

Appendix A (4): Program Code for Step 4

```
#include "U8glib.h"

U8GLIB_ST7920_128X64 u8g(6,5,4,7);//En, Rw, Rs, Reset

const int preSensor(A0);
int preValue= 0;

void setV(void) {

  u8g.setFont(u8g_font_9x15B);
  //u8g.setFont(u8g_font_unifont);
  u8g.drawStr(0, 10,"Pressure1= ");
  u8g.setPrintPos(0, 20);
  u8g.print(preValue);
  u8g.drawStr(20, 20," kPa");
}

void setup() {

  Serial.begin(9600);

  pinMode(preSensor, INPUT);
  //u8g.setColorIndex(1);
}

void loop() {

  Serial.print("  Auto Suction System  ");
  Serial.print("\t");
  Serial.print(" Pressure = ");
  Serial.print(analogRead(preValue));
  Serial.println(" kPa ");

  preValue = analogRead(A0);

  delay(100);

  u8g.firstPage();
  do{
    setV();
  }while(u8g.nextPage());

}
```

Appendix A (5): Program Code for Step 5

```
const int enA = 10;
const int IN1_PIN = 8;
const int IN2_PIN = 9;
int pumpspeed = 50;// initial speed = 50

const int preSensor(A1);
int preValue= 0;
int calibratedValue;

void setup() {
  Serial.begin(9600);
  pinMode(10, OUTPUT);
  pinMode(8, OUTPUT);
  pinMode(9, OUTPUT);

  pinMode(preSensor, INPUT);

}

void loop() {

  digitalWrite(IN1_PIN, HIGH); // control motor A spins clockwise
  digitalWrite(IN2_PIN, LOW);  // control motor A spins clockwise

  analogWrite(enA, pumpspeed); // speed is a value from 0 to 255

  preValue = analogRead(A1);
  calibratedValue = -0.107*preValue + 3.5171;

  //Result print in Serial Monitor
  Serial.print("Digital value = ");
  Serial.print(preValue);
  Serial.print("\t \t");
  Serial.print("Pressure = ");
  Serial.print(calibratedValue);
  Serial.println(" kPa");

  delay(1000);


}
```

Appendix A (6): Program Code for Step 6

```
#include "U8glib.h"

U8GLIB_ST7920_128X64 u8g(6,5,4,7);//En, Rw, Rs, Reset

const int enA = 10;//PWM DI/DO
const int in1 = 9;
const int in2 = 8;
int pumpspeed = 150;

//int speedValue = A0;//connected to L298n

const int preSensor(A0);
int preValue= 0;
int calibratedValue;

void setV(void) {

  u8g.setFont(u8g_font_9x15B);
  //u8g.setFont(u8g_font_unifont);
  u8g.drawStr(0, 10,"Pressure = ");
  u8g.setPrintPos(0, 25);
  u8g.print(calibratedValue);
  u8g.drawStr(20, 25," kPa");
}

void setup() {

  Serial.begin(9600);

  pinMode(10, OUTPUT);
  pinMode(9, OUTPUT);
  pinMode(8, OUTPUT);

  pinMode(preSensor, INPUT);
}

void TurnPot(){

  digitalWrite(in1, HIGH);
  digitalWrite(in1, LOW);

  digitalWrite(in1, LOW);//Switch between this HIGH and LOW to change
direction
  digitalWrite(in2, HIGH);
```

```
  //speedValue = analogRead(A0);
  //speedValue = speedValue*0.2492668622;//255/1023
  //analogWrite(enA,speedValue);

  analogWrite(enA,pumpspeed);
}

void loop() {

  //Serial.print("  Auto Suction System  ");

  preValue = analogRead(A0);
  calibratedValue = -0.107*preValue + 3.5171;

  TurnPot();
  //Result print in Serial Monitor
  Serial.print("Pump speed = ");
  Serial.println(pumpspeed);

  Serial.print("Pressure = ");
  Serial.print(calibratedValue);
  Serial.println(" kPa");

  delay(100);

  u8g.firstPage();
  do{
    setV();
  }while(u8g.nextPage());

  delay(100);


}
```

Appendix A (7): Program Code for Step 7/ Programming for experiment on clear skin area

```
#include "U8glib.h"
U8GLIB_ST7920_128X64 u8g(6,5,4,7);//En, Rw, Rs, Reset



const int enA = 10;
const int IN1_PIN = 8;
const int IN2_PIN = 9;
```

```
int pumpspeed = 255;//initialize speed

const int preSensor(A1);
int preValue= 0;
int calibratedValue;

void setup() {
  Serial.begin(9600);
  pinMode(10, OUTPUT);
  pinMode(8, OUTPUT);
  pinMode(9, OUTPUT);

  pinMode(preSensor, INPUT);

}

void loop() {

  digitalWrite(IN1_PIN, HIGH); // control motor A spins clockwise
  digitalWrite(IN2_PIN, LOW);  // control motor A spins clockwise

  analogWrite(enA, pumpspeed); // speed is a value from 0 to 255

  preValue = analogRead(A1);
  calibratedValue = -0.107*preValue + 3.5171;

  //Result print in Serial Monitor
  Serial.print("Digital value = ");
  Serial.print(preValue);
  Serial.print("\t \t");
  Serial.print("Pressure = ");
  Serial.print(calibratedValue);
  Serial.println(" kPa");

  delay(200);

  //Mannual controller to prevent blister
  if(calibratedValue >= -25 ){
    pumpspeed = 255;
  }

  else if(-25 > calibratedValue && calibratedValue >= -35){
     pumpspeed = 200;
  }

  else if(-35 > calibratedValue && calibratedValue >= -40){
     pumpspeed = 115.001;
  }
```

```
 else if(calibratedValue < -40){
    pumpspeed = 0;
  }

 else{
   pumpspeed = 0;
  }

 u8g.firstPage();
     do{
       setV();//Display pressure value in LCD

     }while(u8g.nextPage());
}

//Display the pressure value from MPX5100DP
void setV(void) {
  u8g.setFont(u8g_font_tpssb);//u8g.setFont(u8g_font_8x13B);
  u8g.setColorIndex(1);
  //u8g.setFont(u8g_font_unifont);
  u8g.drawStr(0, 10,"Pressure = ");
  u8g.setPrintPos(75, 10);
  u8g.print(calibratedValue);
  u8g.drawStr(95, 10," kPa");
}
```

Appendix A (8): Program Code for Step 8

```
#include "U8glib.h"
U8GLIB_ST7920_128X64 u8g(6,5,4,7);//En, Rw, Rs, Reset

int buzzer = 11;
int ledPin = 2;

#define bt_set     digitalRead(A1)== 0//button to set the display in pressure value
or time setting
#define bt_in      digitalRead(A2)== 0//button to increase time by 1
#define bt_de      digitalRead(A3)== 0//button to decrease time by 1
#define bt_cancel  digitalRead(A4)== 0//button to cancel time setting

int minutes; //in ms
unsigned long  previousTime = 0;
int startCountdown = 0;
```

```
char buttonState;

const int enA = 10;//EN of motor driver
const int IN1_PIN = 8;//IN1 of motor driver
const int IN2_PIN = 9;//IN2 of motor driver
int pumpspeed = 0;// range: 0 - 255, initial speed = 255

const int preSensor(A0);
int preValue= 0;
int calibratedValue;

void setup() {
  Serial.begin(9600);

  pinMode(11, OUTPUT); //buzzer
  pinMode(2, OUTPUT); //led

  pinMode(A1, INPUT_PULLUP);//button
  pinMode(A2, INPUT_PULLUP);
  pinMode(A3, INPUT_PULLUP);
  pinMode(A4, INPUT_PULLUP);

  //Below are the pin connect to the motor driver
  pinMode(10, OUTPUT);
  pinMode(8, OUTPUT);
  pinMode(9, OUTPUT);

  pinMode(A0, INPUT);//pressure sensor

  //Display the opening
  u8g.setFont(u8g_font_tpssb);
  u8g.setColorIndex(1);

  u8g.firstPage();
  do {
    loading();
  } while( u8g.nextPage() );
  delay(1000);//delay 1000
  clearLCD();

  u8g.firstPage();
  do {
    opening();
  } while( u8g.nextPage() );
  delay(1000);//delay 1000
  clearLCD();
}
```

```
void loop() {

  digitalWrite(IN1_PIN, HIGH); // motor spins clockwise
  digitalWrite(IN2_PIN, LOW);  // motor spins clockwise

  analogWrite(enA, pumpspeed); // speed is a value from 0 to 255

  preValue = analogRead(A0);
  calibratedValue = -0.107*preValue + 3.5171;

  delay(100);

  //TIMER SETTING
  //set 0 = pressure, set1 = time setting
  //if bt_set not pressed, pressure value will be displayed only and pump is not
activate (state = 0)
  //if bt_set is pressed, time setting is choosen (state = 1)
  //in state 0: if bt_in is pressed time will start countdown while the pressure value
is displayed and the pump is activated.
  //         : if bt_de is pressed time deducted for 1 minute
  //in state 1: if bt_in is pressed time added for 1 minute
  //         : if bt_de is pressed time deducted for 1 minute
  //if bt_cancel is pressed, the time == 0

  if(millis() > previousTime + 60000){//in ms 60000 = 1 minutes
  previousTime = millis();
  if(startCountdown == 1){
    minutes--;
    clearLCD();
    fuzzycontrol();
    Serial.println("   ");

    if(minutes == 0){
      startCountdown = 0;
      pumpspeed = 0;
     }
   }
  }

  switch(buttonState){
    case 0:
      u8g.firstPage();
      do{
        setV();//Display pressure value in LCD
        //delay(200);
        //Display remaining time
        u8g.drawStr(0, 40,"Time = ");
```

```
      u8g.setPrintPos(49, 40);
      u8g.print(minutes);
      u8g.setPrintPos(65, 40);
      u8g.print(" min");
    }while(u8g.nextPage());
    printInSerial();
    Serial.print("Minute : ");
    Serial.println(minutes);
    Serial.print("Pump speed : ");
    Serial.println(pumpspeed);

    if(bt_set){
      buttonState = 1;
      clearLCD();
      Serial.println("   ");
      u8g.firstPage();
      do{
        printTime();
      }while(u8g.nextPage());
      Serial.print("Time : ");
      Serial.print(minutes);
      Serial.println(" min ");
      delay(100);
      clearLCD();
      Serial.println("   ");
    }

    if(bt_in){
      startCountdown = 1;
      delay(100);
    }

    else if(bt_de){
      startCountdown = 0;
      delay(100);
      pumpspeed = 0;
      delay(100);
    }

    else if(bt_cancel){
      startCountdown = 0;
      minutes = 0;
      delay(100);
      pumpspeed = 0;
      delay(100);
    }
  break;
```

```
    case 1:
      u8g.firstPage();
      do{
        printTime();
      }while(u8g.nextPage());
      delay(100);
      Serial.print("Minute : ");
      Serial.print(minutes);
      Serial.println(" min ");

      if(bt_in){
        minutes++;
        delay(100);
        if(minutes > 60){
          minutes = 0;
        }
      }

      else if(bt_de){
        minutes--;
        delay(100);
        if(minutes < 0){
          minutes = 60;
        }
      }

      if(bt_set){
        buttonState = 0;
        delay(100);
        clearLCD();
        Serial.println("   ");
      }

      else if(bt_cancel){
        buttonState = 0;
        delay(100);
        clearLCD();
        Serial.println("   ");
        minutes = 0;
        pumpspeed = 0;
    }

    break;
  }

  //if bt_set = pressure, timer start countdown, minute = 1
  if(buttonState == 0 && startCountdown == 1 && minutes == 1){
    digitalWrite(buzzer, HIGH);
```

```
    delay(100);
    digitalWrite(buzzer, LOW);
    delay(100);
    digitalWrite(buzzer, HIGH);
    delay(100);
    digitalWrite(buzzer, LOW);
    delay(100);
    digitalWrite(buzzer, HIGH);
    delay(100);
    digitalWrite(buzzer, LOW);
    delay(100);
  }

  if(minutes == 0){
    digitalWrite(ledPin, HIGH);
  }
  else{
    digitalWrite(ledPin, LOW);
   }

   if(startCountdown == 1 && minutes>0){
    fuzzycontrol();
  }

}

void loading(void) {
  u8g.drawFrame(0, 20, 128, 20);//Frame
  u8g.drawBox(10, 25, 0, 10);//progress bar
  //delay(500);
  u8g.drawBox(10, 25, 108, 10);//progress bar
  u8g.drawStr(35, 55, "Loading...");//string
}
void opening(){
  u8g.drawStr(25, 10, " Welcome to ");//string
  u8g.drawStr(5, 40, "Auto Cupping System ");//string
}

//Clear the LCD
void clearLCD(){
    u8g.firstPage();
    do {
    } while( u8g.nextPage() );
}

//Display the pressure value from MPX5100DP
void setV(void) {
  u8g.setFont(u8g_font_tpssb);//u8g.setFont(u8g_font_8x13B);
```

```
  u8g.setColorIndex(1);
  //u8g.setFont(u8g_font_unifont);
  u8g.drawStr(0, 10,"Pressure = ");
  u8g.setPrintPos(75, 10);
  u8g.print(calibratedValue);
  u8g.drawStr(95, 10," kPa");
}

//Display time
void printTime(){
  u8g.setFont(u8g_font_tpssb);//u8g.setFont(u8g_font_8x13B);
  u8g.drawStr(0, 10,"Time = ");
  u8g.setPrintPos(49, 10);
  u8g.print(minutes);
  u8g.setPrintPos(65, 10);
  u8g.print(" min");
}

void printInSerial(){
  //Result print in Serial Monitor
  Serial.print("Pump speed = ");
  Serial.print(pumpspeed);
  Serial.print("\t \t");
  Serial.print("Pressure = ");
  Serial.print(calibratedValue);
  Serial.println(" kPa");
}

void fuzzycontrol(){
  //Mannual controller to prevent blister
  if(calibratedValue >= -25 ){
    pumpspeed = 255;
   }

  else if(-25 > calibratedValue && calibratedValue >= -35){
     pumpspeed = 200;
   }

  else if(-35 > calibratedValue && calibratedValue >= -40){
     pumpspeed = 115.001;
   }

  else if(calibratedValue < -40){
     pumpspeed = 0;
   }

  else{
    pumpspeed = 0;
```

```
  }
}
```

Appendix A (9): Programming for experiment on clear skin area with velocity = 115.001

```
const int enA = 10;
const int IN1_PIN = 8;
const int IN2_PIN = 9;
int pumpspeed = 115.001; // initialize speed

const int preSensor(A1);
int preValue= 0;
int calibratedValue;

void setup() {
  Serial.begin(9600);
  pinMode(10, OUTPUT);
  pinMode(8, OUTPUT);
  pinMode(9, OUTPUT);

  pinMode(preSensor, INPUT);

}

void loop() {

  digitalWrite(IN1_PIN, HIGH); // control motor A spins clockwise
  digitalWrite(IN2_PIN, LOW);  // control motor A spins clockwise

  analogWrite(enA, pumpspeed); // speed is a value from 0 to 255

  preValue = analogRead(A1);
  calibratedValue = -0.107*preValue + 3.5171;

  //Result print in Serial Monitor
  Serial.print("Digital value = ");
  Serial.print(preValue);
  Serial.print("\t \t");
  Serial.print("Pressure = ");
  Serial.print(calibratedValue);
  Serial.println(" kPa");

  delay(200);
```

```
  //Fuzzy Controller
  if(calibratedValue <= -40){
    pumpspeed = 0;
  }

  else if(calibratedValue >= -40){
     pumpspeed = 115.001;
  }

  else{
    pumpspeed = 115.001;
  }
}
```

Appendix A (10): Programming for experiment on clear skin area with velocity = 200

```
const int enA = 10;
const int IN1_PIN = 8;
const int IN2_PIN = 9;
int pumpspeed = 200; // initialize speed

const int preSensor(A1);
int preValue= 0;
int calibratedValue;

void setup() {
  Serial.begin(9600);
  pinMode(10, OUTPUT);
  pinMode(8, OUTPUT);
  pinMode(9, OUTPUT);

  pinMode(preSensor, INPUT);

}

void loop() {

  digitalWrite(IN1_PIN, HIGH); // control motor A spins clockwise
  digitalWrite(IN2_PIN, LOW);  // control motor A spins clockwise

  analogWrite(enA, pumpspeed); // speed is a value from 0 to 255

  preValue = analogRead(A1);
  calibratedValue = -0.107*preValue + 3.5171;
```

```
  //Result print in Serial Monitor
  Serial.print("Digital value = ");
  Serial.print(preValue);
  Serial.print("\t \t");
  Serial.print("Pressure = ");
  Serial.print(calibratedValue);
  Serial.println(" kPa");

  delay(200);

  //Fuzzy Controller
  if(calibratedValue <= -40){
    pumpspeed = 0;
  }

  else if(calibratedValue >= -40){
     pumpspeed = 200;
  }

  else{
    pumpspeed = 200;
  }
}
```

Appendix A (11): Programming for experiment on hairy skin area

```
#include "U8glib.h"
U8GLIB_ST7920_128X64 u8g(6,5,4,7);//En, Rw, Rs, Reset


const int enA = 10;
const int IN1_PIN = 8;
const int IN2_PIN = 9;
int pumpspeed = 255;//initialize speed

const int preSensor(A1);
int preValue= 0;
int calibratedValue;

void setup() {
  Serial.begin(9600);
  pinMode(10, OUTPUT);
```

```
  pinMode(8, OUTPUT);
  pinMode(9, OUTPUT);

  pinMode(preSensor, INPUT);

}

void loop() {

  digitalWrite(IN1_PIN, HIGH); // control motor A spins clockwise
  digitalWrite(IN2_PIN, LOW);  // control motor A spins clockwise

  analogWrite(enA, pumpspeed); // speed is a value from 0 to 255

  preValue = analogRead(A1);
  calibratedValue = -0.107*preValue + 3.5171;

  //Result print in Serial Monitor
  Serial.print("Digital value = ");
  Serial.print(preValue);
  Serial.print("\t \t");
  Serial.print("Pressure = ");
  Serial.print(calibratedValue);
  Serial.println(" kPa");

  delay(200);

  //Mannual controller to prevent blister
  if(calibratedValue >= -25 ){
    pumpspeed = 255;
  }

  else if(-25 > calibratedValue && calibratedValue >= -35){
     pumpspeed = 200;
  }

  else if(-35 > calibratedValue && calibratedValue >= -40){
     pumpspeed = 115.001;
  }

  else if(calibratedValue < -40){
     pumpspeed = 0;
  }

  else{
    pumpspeed = 0;
  }
```

```
  u8g.firstPage();
      do{
        setV();//Display pressure value in LCD

      }while(u8g.nextPage());
}

//Display the pressure value from MPX5100DP
void setV(void) {
  u8g.setFont(u8g_font_tpssb);//u8g.setFont(u8g_font_8x13B);
  u8g.setColorIndex(1);
  //u8g.setFont(u8g_font_unifont);
  u8g.drawStr(0, 10,"Pressure = ");
  u8g.setPrintPos(75, 10);
  u8g.print(calibratedValue);
  u8g.drawStr(95, 10," kPa");
}
```

APPENDIX B

Datasheet

Appendix B (1): Datasheet of Arduino Uno

Arduino Uno

Arduino Uno R3 Front

Arduino Uno R3 Back

Arduino Uno R2 Front

Arduino Uno SMD

Arduino Uno Front

Arduino Uno Back

Overview

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.
The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.
Revision 2 of the Uno board has a resistor pulling the 8U2 HWB line to ground, making it easier to put into DFU mode.
Revision 3 of the board has the following new features:

- 1.0 pinout: added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible both with the board that use the AVR, which operate with 5V and with the Arduino Due that operate with 3.3V. The second one is a not connected pin, that is reserved for future purposes.
- Stronger RESET circuit.
- Atmega 16U2 replace the 8U2.

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions, see the index of Arduino boards.

Summary

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V

Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

Schematic & Reference Design

EAGLE files: arduino-uno-Rev3-reference-design.zip (NOTE: works with Eagle 6.0 and newer)
Schematic: arduino-uno-Rev3-schematic.pdf
Note: The Arduino reference design can use an Atmega8, 168, or 328, Current models use an ATmega328, but an Atmega8 is shown in the schematic for reference. The pin configuration is identical on all three processors.

Power

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically.
External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.
The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.
The power pins are as follows:

- **VIN.** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- **5V.**This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage your board. We don't advise it.
- **3V3.** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **GND.** Ground pins.

Memory

The ATmega328 has 32 KB (with 0.5 KB used for the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).

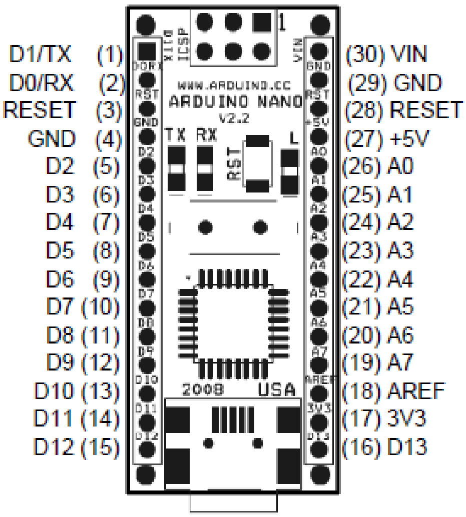
Input and Output

Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- **Serial: 0 (RX) and 1 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- **External Interrupts: 2 and 3.** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- **PWM: 3, 5, 6, 9, 10, and 11.** Provide 8-bit PWM output with the analogWrite() function.

Appendix B (2): Datasheet of Arduino Nano

Arduino Nano Pin Layout



Pin No.	Name	Type	Description
1-2, 5-16	D0-D13	I/O	Digital input/output port 0 to 13
3, 28	RESET	Input	Reset (active low)
4, 29	GND	PWR	Supply ground
17	3V3	Output	+3.3V output (from FTDI)
18	AREF	Input	ADC reference
19-26	A7-A0	Input	Analog input channel 0 to 7
27	+5V	Output or Input	+5V output (from on-board regulator) or +5V (input from external power supply)
30	VIN	PWR	Supply voltage

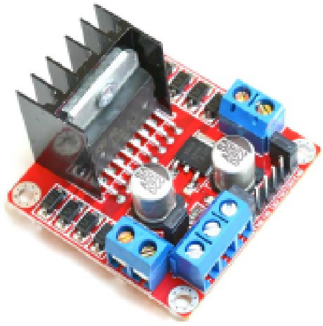
Appendix B (3): Datasheet of L298N Motor Driver

Handson Technology

User Guide

L298N Dual H-Bridge Motor Driver

This dual bidirectional motor driver, is based on the very popular L298 Dual H-Bridge Motor Driver Integrated Circuit. The circuit will allow you to easily and independently control two motors of up to 2A each in both directions.It is ideal for robotic applications and well suited for connection to a microcontroller requiring just a couple of control lines per motor. It can also be interfaced with simple manual switches, TTL logic gates, relays, etc. This board equipped with power LED indicators, on-board +5V regulator and protection diodes.

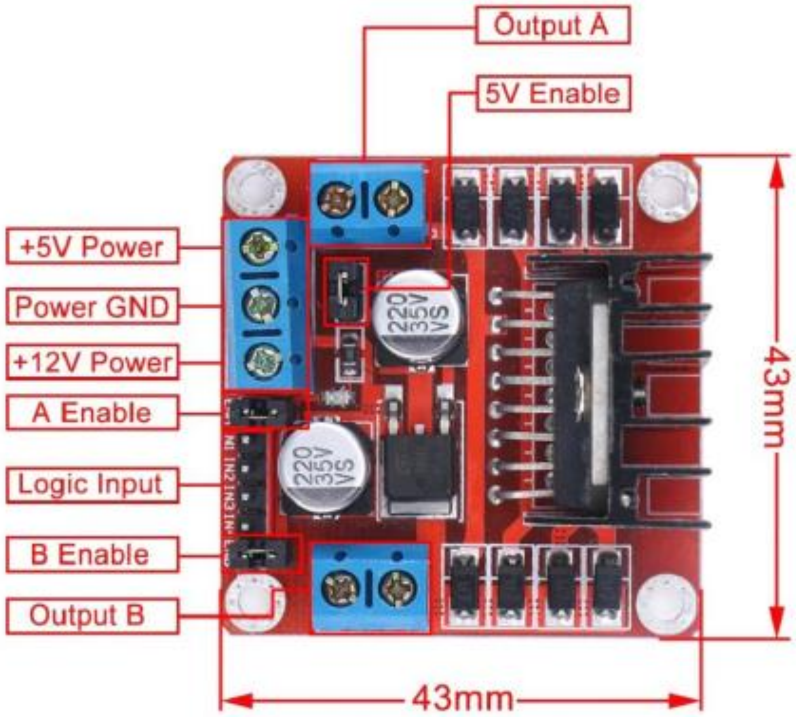


SKU: MDU-1049

Brief Data:

- Input Voltage: 3.2V~40Vdc.
- Driver: L298N Dual H Bridge DC Motor Driver
- Power Supply: DC 5 V - 35 V
- Peak current: 2 Amp
- Operating current range: 0 ~ 36mA
- Control signal input voltage range :
- Low: -0.3V ≤ Vin ≤ 1.5V.
- High: 2.3V ≤ Vin ≤ Vss.
- Enable signal input voltage range :
    - Low: -0.3 ≤ Vin ≤ 1.5V (control signal is invalid).
    - High: 2.3V ≤ Vin ≤ Vss (control signal active).
- Maximum power consumption: 20W (when the temperature T = 75 ℃).
- Storage temperature: -25 ℃ ~ +130 ℃.
- On-board +5V regulated Output supply (supply to controller board i.e. Arduino).
- Size: 3.4cm x 4.3cm x 2.7cm

Board Dimension & Pins Function:



Appendix B (4): Datasheet of MPX5100DP Pressure Sensor

Pressure

Freescale Semiconductor

MPX5100
Rev 13, 05/2010

Integrated Silicon Pressure Sensor On-Chip Signal Conditioned, Temperature Compensated and Calibrated

MPX5100
MPXV5100
Series

0 to 100 kPa (0 to 14.5 psi)
15 to 115 kPa (2.2 to 16.7 psi)
0.2 to 4.7 V Output

The MPX5100 series piezoresistive transducer is a state-of-the-art monolithic silicon pressure sensor designed for a wide range of applications, but particularly those employing a microcontroller or microprocessor with A/D inputs. This patented, single element transducer combines advanced micromachining techniques, thin-film metallization, and bipolar processing to provide an accurate, high level analog output signal that is proportional to the applied pressure.

Features

- 2.5% Maximum Error over 0° to 85°C
- Ideally suited for Microprocessor or Microcontroller-Based Systems
- Patented Silicon Shear Stress Strain Gauge
- Available in Absolute, Differential and Gauge Configuration
- Durable Epoxy Unibody Element
- Easy-to-Use Chip Carrier Option

Typical Applications

- Patient Monitoring
- Process Control
- Pump/Motor Control
- Pressure Switching

ORDERING INFORMATION

Device Name	Case No.	# of Ports			Pressure Type			Device Marking
		None	Single	Dual	Gauge	Differential	Absolute	
Unibody Package (MPX5100 Series)								
MPX5100A	867	•					•	MPX5100A
MPX5100AP	867B		•				•	MPX5100AP
MPX5100D	867	•				•		MPX5100D
MPX5100DP	867C			•		•		MPX5100DP
MPX5100GP	867B		•		•			MPX5100GP
Small Outline Package (MPXV5100 Series)								
MPXV5100GC6U	482A		•		•			MPXV5100G
MPXV5100GC7U	482C		•		•			MPXV5100G
MPXV5100DP	1351			•		•		MPXV5100DP
MPXV5100GP	1369		•		•			MPXV5100GP

freescale semiconductor

On-chip Temperature Compensation and Calibration

Figure 3 shows the sensor output signal relative to pressure input. Typical, minimum, and maximum output curves are shown for operation over a temperature range of 0° to 85°C using the decoupling circuit shown in Figure 5. The output will saturate outside of the specified pressure range.

Figure 4 illustrates both the Differential/Gauge and the Absolute Sensing Chip in the basic chip carrier (Case 867). A fluorosilicone gel isolates the die surface and wire bonds from the environment, while allowing the pressure signal to be transmitted to the sensor diaphragm.

The MPX5100 series pressure sensor operating characteristics, and internal reliability and qualification tests are based on use of dry air as the pressure media. Media, other than dry air, may have adverse effects on sensor performance and long-term reliability. Contact the factory for information regarding media compatibility in your application.

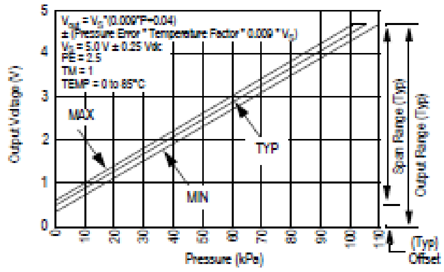


Figure 3. Output vs. Pressure Differential

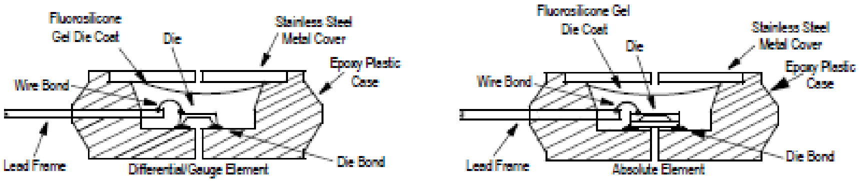


Figure 4. Cross Sectional Diagrams (not to scale)

Figure 5 shows the recommended decoupling circuit for interfacing the output of the integrated sensor to the A/D input of a microprocessor or microcontroller. Proper decoupling of the power supply is recommended.

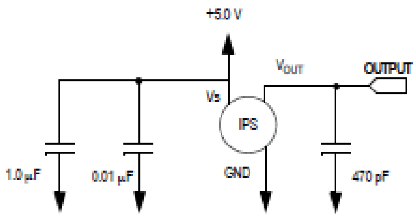
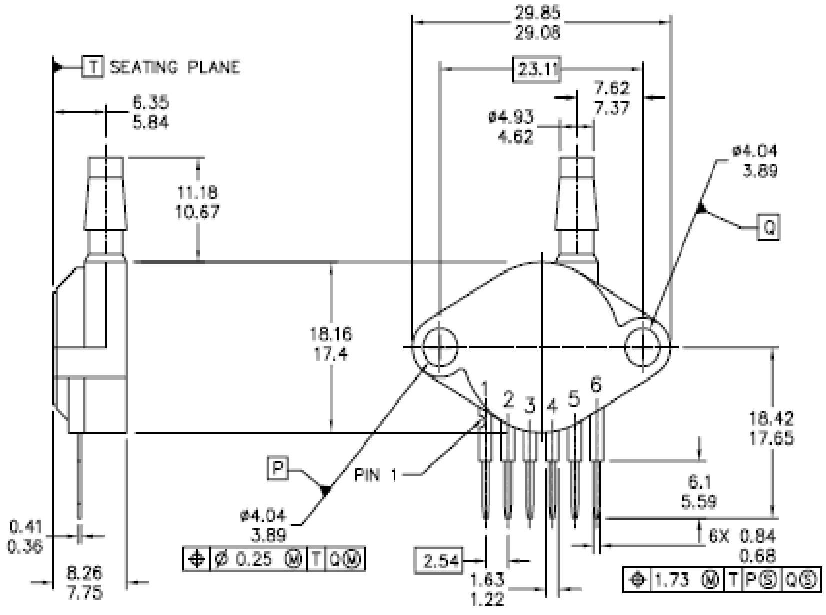


Figure 5. Recommended Power Supply Decoupling and Output Filtering
(For additional output filtering, please refer to Application Note AN1646.)

PACKAGE DIMENSIONS



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	CASE NUMBER: 867B-04	28 JUL 2005
	STANDARD: NON-JEDEC	

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PACKAGE DIMENSIONS

NOTES:

1. DIMENSIONS ARE IN MILLIMETERS.
2. DIMENSIONS AND TOLERANCES PER ASME Y14.5M-1994.
3. 867B-01 THRU -3 OBSOLETE, NEW STANDARD 867B-04.

STYLE 1:

PIN 1: V OUT
2: GROUND
3: VCC
4: V1
5: V2
6: V EX

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	STANDARD: NON-JEDEC	

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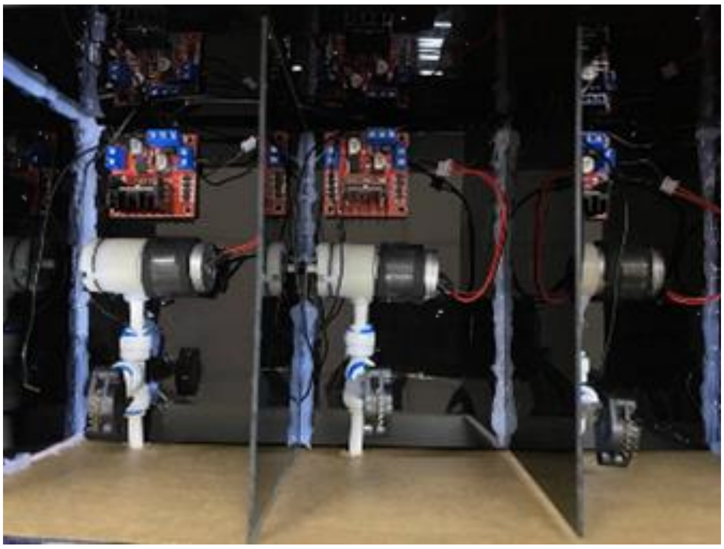
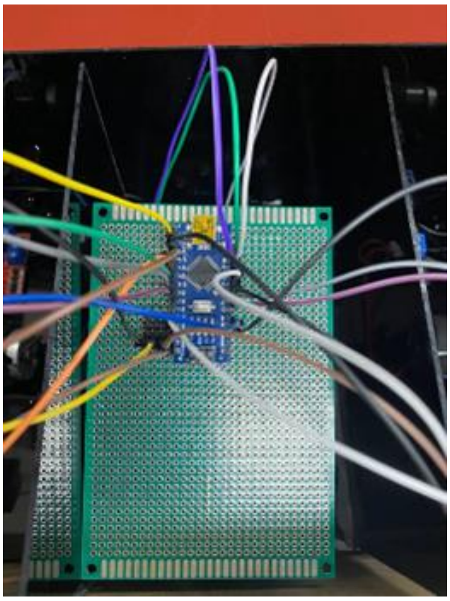
APPENDIX C

Automatic Cupping Suction Machine’s Picture

Appendix C: Picture of Automatic Cupping Suction Machine

Inner section





Outer Section